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SURVEYING

(#) Introduction :-

Earth - earth is an oblate spheroid.

Diameter = 12740 km (Average)

~~Average Radius = 6370 km~~

~~At equator~~ = 12756.75 km

At Poles = 12713.80 km

difference = 42.95 km

0.34 %

(#) Types of Surveying :

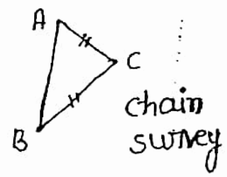
(1) Geodetic Survey : If earth curvature is considered for survey work.

(2) Plane survey : If earth curvature is not considered suitable for small distance.

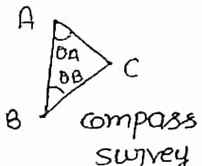


(#) Principle of surveying :-

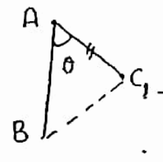
(1) Location of point is measured w.r.t. two reference point :



chain survey



compass survey



Traverse survey

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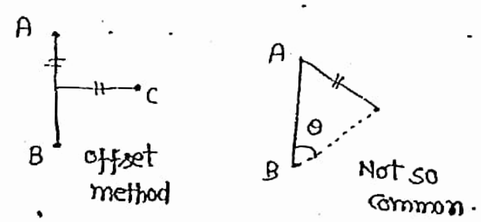
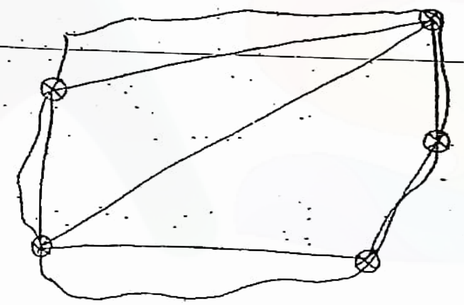


(2) Working Whole to part :-



→ Major control points are decided & measured accurately with high degree of precision. Minor details can be collected later to avoid the error to be accumulated.

LINEAR MEASOREMENTS

(#) (1) Scale :- Scale is a ratio of map distance to ground distance.

If on the drawing

Scale ⇒ 1cm = 100m

1 cm on paper = 100m on ground

Ratio : $\frac{1cm}{100m} = \frac{1cm}{10.000cm} = \frac{1}{10.000}$ (R.F.)

R.F = Representative fraction.

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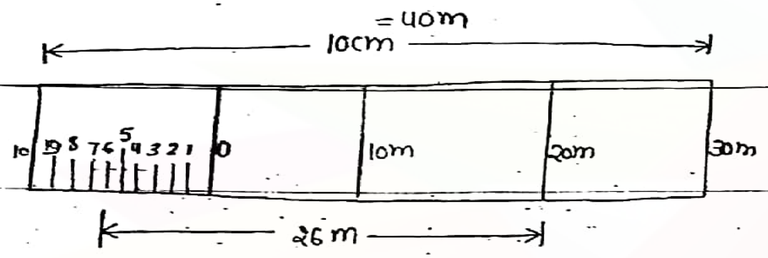
Types of Scale :-

(1) Plane Scale :- Plane scale measure only two dimension.

1cm = 4m

(#) How to make a scale 1cm = 4m —



Scale 1cm = 4m.

(1) Take a 10cm long line divide it in 4 equal parts. Each part is of 10m length.

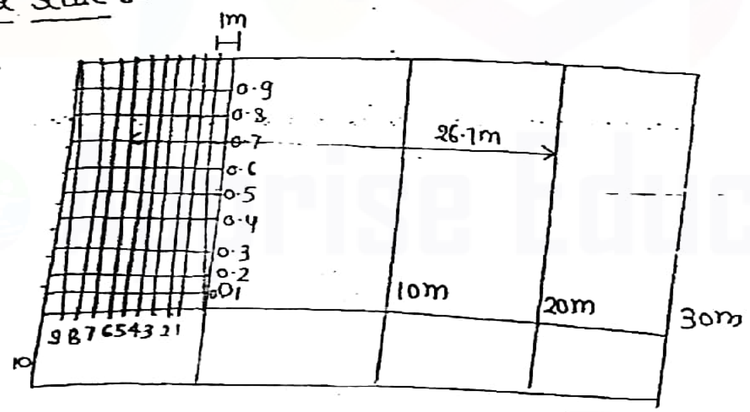
(2) Now divide 1st part in another 10 parts. This smaller divisions will show 1m.

Two dimension that can be read

① 10m (Decameter)

② 1m (meter)

(3) Diagonal Scale :- this scale can read upto three dimension



1cm = 4m

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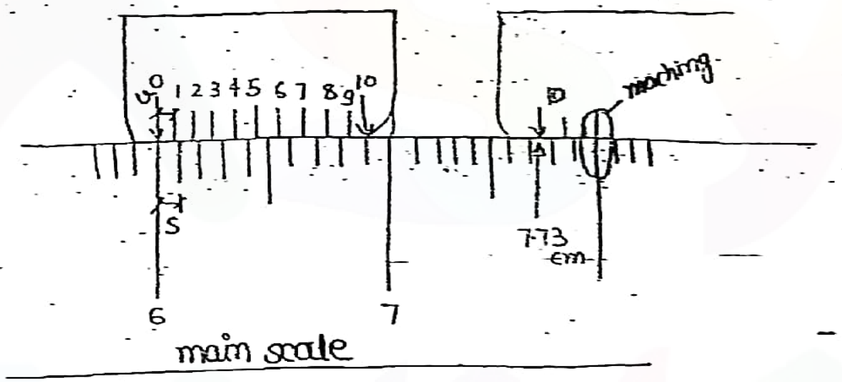
→ It works on the principle of similar triangle.

→ Three dimension | ① 10m → Decameter
② 1m → meter
③ 0·1m (10cm) → Decimeter.

3) Vernier Scale :-

(1) Direct Vernier :-



→ In case of direct vernier (n-1) division of main scale is divided into n divisions of vernier scale.

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

$$V = \frac{(n-1)}{n} \times S$$

(#) Least Count :- least count is the minimum dimension that can be read by a scale.

$$\text{Least count} = S - V$$

$$= S - \frac{(n-1)}{n} \times S$$

$$= \frac{Sn - nS + S}{n} = \boxed{\frac{S}{n}}$$

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For Example –

$S = 1m$

$n = 10$

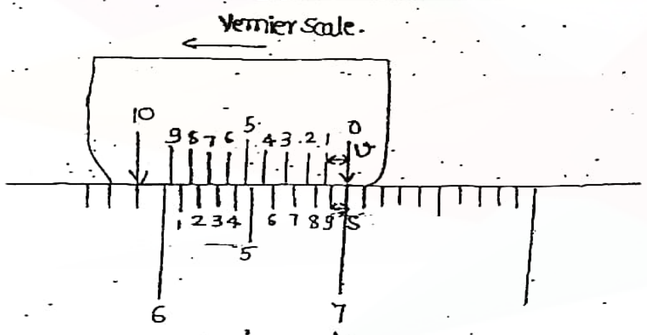
Least Count

$= \frac{S}{n} = \frac{1mm}{10} = 0.1mm.$

Reading of Vernier is taken by the line of vernier scale that will be exactly above of any one line of main scale.

In direct Virner → Vernier scale moves in the same dirⁿ of main scale.

(ii) Retrograde Vernier :-



→ In this Case

(n+1) division of main scale is divided into n division of Vernier scale.

$(n+1)S = n.v$

$v = \left(\frac{n+1}{n}\right)S$ — ①

Least Count →

$= V - S = \left(\frac{n+1}{n}\right)S - S = \frac{nS+S-nS}{S}$

$= \frac{S}{n}$

Example

$S = 1mm$

$n = 10mm$

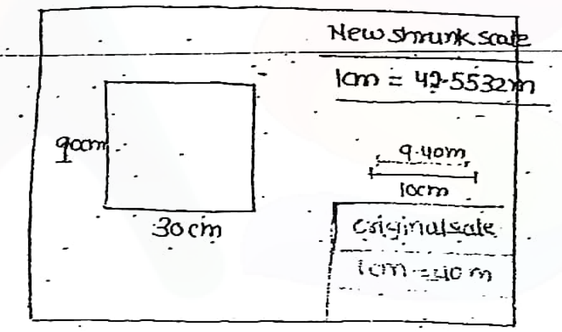
$LC = \frac{1}{10} = 0.1mm.$

→ In this scale, Vernier scale moves in opposite dirⁿ to the main scale.

(iii) Double Vernier :-

The direct vernier (or Retrograde Vernier), placed back to back with common zero value is called double vernier.

(4) Shrunk Scale :-



Present dimension Read : 30cm × 10cm

9.40 line was 10cm long –

$30cm \longrightarrow \frac{10}{9.40} \times 30\,cm$

$= 31.915\,cm.$

Ground length $= 31.915 \times 40$

$= 1276.60\,m.$

$10cm \longrightarrow \frac{10}{9.4} \times 10 = 10.638\,cm.$

$10.638 \times 40 = 425.53\,m.$

Actual area of plot

$L \times B = 1276.6 \times 425.53 = 543234.m^2.$

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Shrunk scale —

$$\boxed{\text{Shrinkage Factor} = \frac{\text{shrunk length}}{\text{original length}}}$$

Shrunk scale = shrinkage Factor × original scale.

Shrinkage Factor

$S.F. = \frac{9.40}{10.0} = 0.94$

original scale
1cm = 40 m
$= \frac{1}{4000}$

Shrunk scale $= 0.94 \times \frac{1}{4000}$

$= \frac{1}{4255.319}$

$\boxed{1cm = 42.5532m}$

Area of the plot $= (30 \times 42.5532) \times (10 \times 42.5532)$

$\boxed{A = 543232.23 m^2}$

Correction due to Incorrect length of chain/tape :-

If

L = Designated (True) length of a tape (should be) (say 30.0 m)

L' = Wrong length of Tape (say 30.25 m)

l' = wrong length of line measured.

l = True length of line.

True × True = wrong × wrong

$L \times l = L' \times l'$

$\boxed{l = \left(\frac{L'}{L}\right) \times l'}$ — (A)

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example (1) L = 30 m
L' = 30.25 m
l' = 6500 m.

$\therefore l = \left(\frac{L'}{L}\right) \times l'$

$= \frac{30.25}{30} \times 6500$

$\boxed{l = 6554.167 m}$

Ex:2 L = 30 m
L' = 29.70 m
l' = 6500 m

$\therefore l = \left(\frac{L'}{L}\right) \times l'$

$= \left(\frac{29.70}{30}\right) \times 6500$

$\boxed{l = 6435 m}$

Measured Value on ground	Noted down value	Error	Correction
30.25 m (more)	30 m (less)	(−)ve (−0.25)	(+) ve (+) 0.25 m
29.70 m (less)	30 (m) (more)	(+)ve (+0.3)	(−) ve (−) 0.30 m

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Tape Correction :-

(1) Correction due to standardization :-

If length of Tape/chain is not correct.

Correction per chain length :-

$$\boxed{C = (L' - L)}$$

[+ve → (+) correction
-ve → (-) Value.]

Total Correction required :-

$$C_{Total} = \left(\text{No. of chains}\right) \times C$$

$$\boxed{C_{Total} = \left(\frac{l'}{L}\right)(L' - L)}$$

case : (1)

$L = 30\,m$

$L' = 30.10\,m$

$l' = 7200\,m$

$l = \left(\frac{L'}{L}\right) \times l'$

$= \frac{30.10}{30} \times 7200$

$\boxed{l = 7224\,m}$

Correction per chain length

$C = (L' - L) = (30.10 - 30.0)$

$\boxed{C = 0.10\,m}$

No. of chains $= \frac{7200}{30} = 240$ chains.

Total correction $= 240 \times 0.10 = +24\,m$.

corrected length $= 7200 + 24 = 7224\,m$.

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This correction may be either '+ve' or '-ve'

In case of Area :-

$$\boxed{A = \left(\frac{L'}{L}\right)^2 \times A'} \quad \text{— (2)}$$

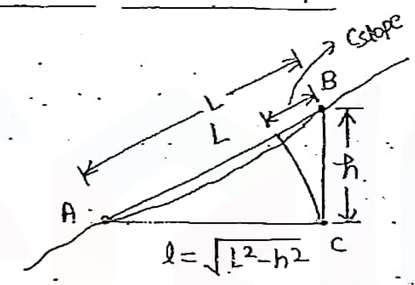
In case of Volume :-

$$\boxed{V = \left(\frac{L'}{L}\right)^3 \times V'} \quad \text{— (3)}$$

For length :

$$\boxed{l = \left(\frac{L'}{L}\right) \times l'} \quad \text{— (1)}$$

(2) Correction due to slope :-



correction : For slope

$$\boxed{C_{slope} = L - l = L - \sqrt{L^2 - h^2}} \rightarrow \text{exact difference.}$$

$$\boxed{C_{slope} = \frac{h^2}{2L}} \rightarrow \text{approximate formula.}$$

This correction is always (-)ve.

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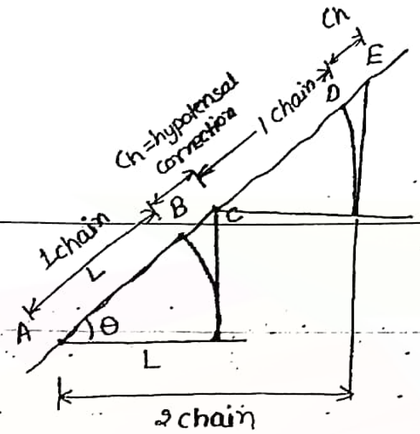
Hypotensal Correction



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

$= 100 \text{ links} \times \frac{\theta^2}{2}$

$= 50\ \theta^2 \text{ links}$

$AC = L\sec\theta$

$BC = AC - BA = L\sec\theta - L$

$C_h = L(\sec\theta - 1)$ → Hypotenussal Correction.

applied (added) after every chain length

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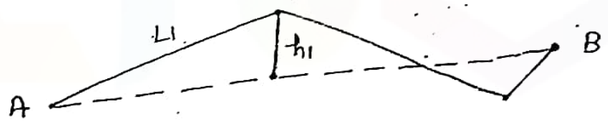
(3) Correction due to Alignment :-



Correction due to alignment –

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

$\boxed{Cal = \frac{h^2}{2L}}$ → This correction is also (–)ve. (always)

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(4) Correction due to temperature :-

Correction :

$$\boxed{C_T = (Tm - To) \cdot \alpha \cdot L}$$

Tm = Temp. at the time of measurement.

To = " " " Standard.

Tm > To	Length of Tape more	error (–)ve	Correction (+ve)
Tm < To	Tape length less	+ve	(–)ve.

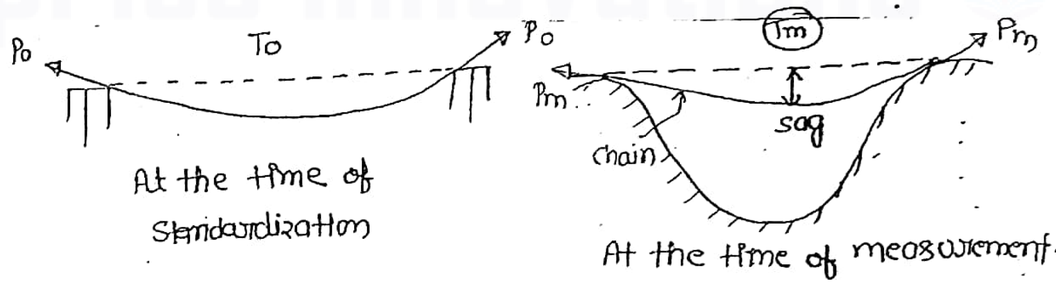
(5) Correction due to pull applied :-

$$\boxed{C_{pull} = \frac{(Pm - Po) \cdot l}{AE}}$$

Pm = Pull applied at the time of measurement.

Po = " " " " " Standardization.

Pm > Po	Error (–) ve	Correction (+)ve
Pm < Po	(+) ve	(–) ve



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(b) Due to Sag :-

$$C_{sag} = \frac{(W \cdot L)^2 \cdot L}{24\, P_m^2}$$

The correction is always (-ve)

W = wt. of tape / unit length.

Normal tension :

It is the value of pull (P_m) applied so that (+)ve pull correction is same as (-)ve sag correction, and they neutralize each other.

$$C_{pull} = C_{sag}$$

$$\frac{(P_m - P_o)\, L}{AE} = \frac{(WL)^2 \cdot L}{24\, P_m^2}$$

solve by trial & error

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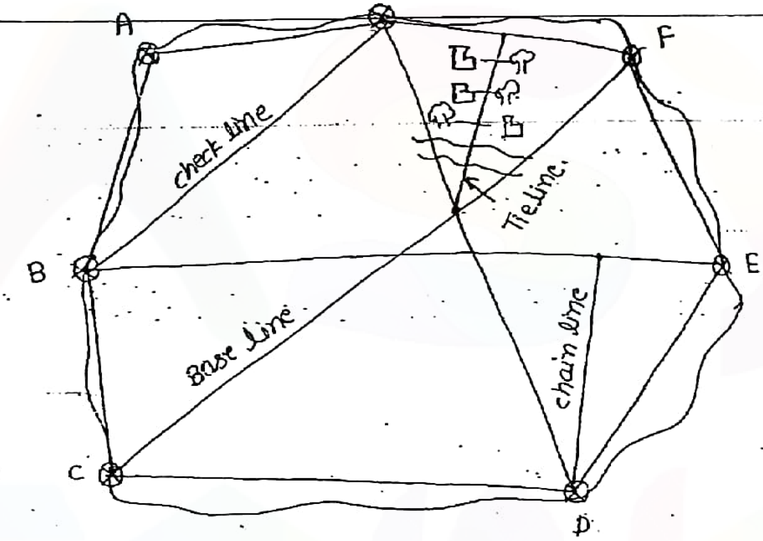
CHAIN SURVEY

Limiting length of offset :-

Important Points of chain survey :-



(1) Main stations :- Major control points to divide the area are called main stations.

(2) Main lines :- Lines joining main stations.

(3) Base lines : The longest line in the area that divide the total area almost in two parts.

(4) check line : Check lines are measured to check the accuracy of survey work done.

(5) Tie line : Any line drawn to collect more information about different objects in area (for collecting details.)

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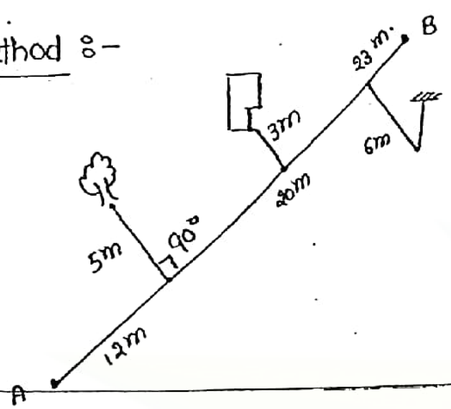
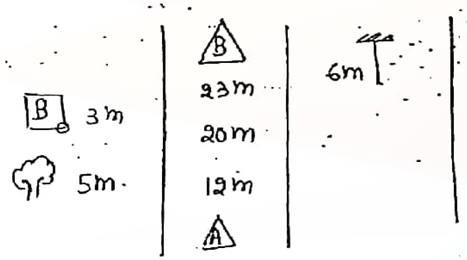
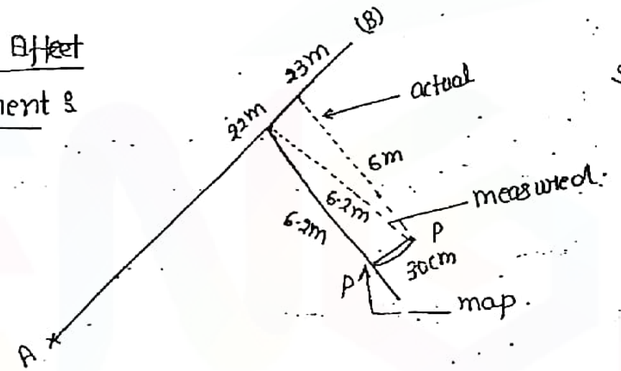
(#) Offset Method :-



Field Book



Error In Effect Measurement :



If error
$\ngtr$ 0.025 cm
$\ngtr$ 0.25 mm.

If scale 1cm = 20 m

$30\text{ cm} \Rightarrow \frac{30\text{m}}{20\text{m}} = 0.015\text{cm} = 0.15\text{ mm}$

If scale 1cm = 2m

$30\text{cm} \Rightarrow \frac{0.30}{2} = 0.15\text{cm} = 1.5\text{mm}.$

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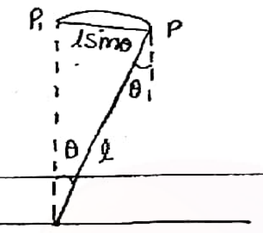
Limiting length of offset :-

Case (1) If the error is in laying dir^n only :



P = actual location of point on the ground.

P_1 = Plotted position of point on the drawing.

θ = error in laying direction.

Length of error on ground

$= l\sin\theta$ (meter)

if scale of drawing 1cm = Smeter.

Length of error on drawing :

$= \frac{l\sin\theta}{S}$ cm.

Max^m length of error allowed on the drawing = 0.25mm

= 0.025cm.

So, $\frac{l\sin\theta}{S}$ cm = 0.025 cm

$$\boxed{l = \frac{0.025S}{\sin\theta}}$$ limiting length of offset.

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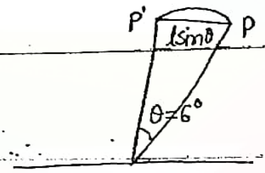
Ques: (1) If scale of drawing is

(i) 1cm = 60m

(ii) 1cm = 5m.

For above cases, find out the limiting length of offset, if max^m. error allowed in laying dir^n of the offset is 6°.

Solution:



max^m error in dir^n θ = 6°

If limiting length of offset = l m.

max^m error = lsinθ m.

Case (i) Scale ⇒ 1cm = 60m

Length of error on the drawing = $\frac{l\sin\theta}{60}$ cm ≯ 0.025cm

$$l = \frac{0.025 \times 60}{\sin 6^\circ} \text{ meter}$$

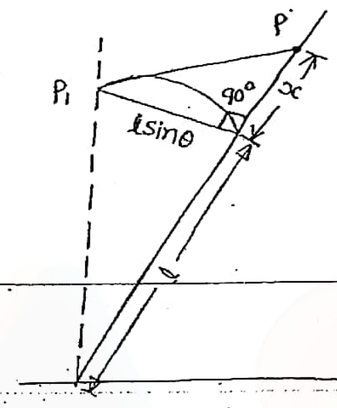
$$\boxed{l = 14.35\ m}$$

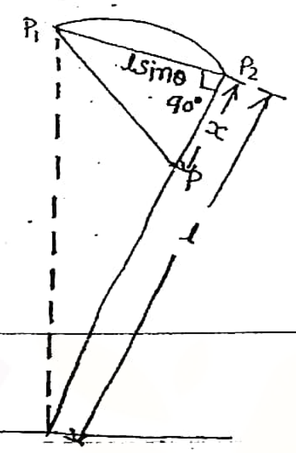
Case (ii) If scale ⇒ 1cm = 5m.

$$l = \frac{0.025 \times 5}{\sin 6^\circ} \text{ meter}$$

$$\boxed{l = 1.19m}$$

Case (2) When the error in laying dir^n as well as in length measurement also :-





P = Actual position of point on ground.

P_1 = Plotted position of point on drawing.

$PP_2 = x$ = Error in length measurement.

$P_1P_2 = l\sin\theta$ = Error due to wrong direction.

Total length of error on the ground

$$PP_1 = \sqrt{PP_2^2 + P_1P_2^2} = \sqrt{(l\sin\theta)^2 + x^2}$$

Length of error on the drawing (if scale is 1cm = 5meter)

$$= \sqrt{\frac{(l\sin\theta)^2 + x^2}{5}} \text{ cm} \quad \not> 0.025\text{cm}$$

$$\boxed{(l\sin\theta)^2 + x^2 = (0.0255)^2} \quad \text{— (A)}$$

Ques (2) If max^m length of an offset allowed is 20m & max^m error allowed in length measurement is 25cm, scale of drawing is 1cm = 50m. Find out max^m error that can be allowed in laying dir^n of offset. Max^m error on drawing = 0.025cm.

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Sol^n:

$x = 25cm$

$= 0.25m$

$\theta = ?$

$l = 20m$

Scale of drawing is $1cm = 50cm$

$(l\sin\theta)^2 + x^2 = (0.025s)^2$

$(20\sin\theta)^2 + (0.25)^2 = (0.025 \times 50)^2$

$\sin\theta = 0.061$

$\theta = 3.51$

$\therefore \boxed{\theta = 3°30'39''}$

If $\theta = 5°$

$l = ?$

$x = 25cm = 0.25m$

$\boxed{1cm = 50m}$ — scale.

$(l\sin 5°)^2 + (0.25)^2 = (0.025 \times 50)^2$

$\therefore \boxed{l = 14.05m}$

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COMPASS SURVEY

System of angle Measurement :-

(1) Most Commonly used :-

1 Circum = 360 degree

1 degree = 60 min.

1 min = 60 sec.

(2) Centesimal system :-

1 Circum = 400 grades

1 grade = 100 centigrade

1 centigrade = 100 centi-centigrade.

(3) Hour system :-

1 Circum = 24 hours

1 hour = 60 min.

1 min = 60 sec.

Relation :

24 hour = 360 degree

1 hour = 15° degree

60 minute = 15 X 60 minute

1 minute of time = 15 minute of angle

1 sec. of time = 15 sec. of angle.

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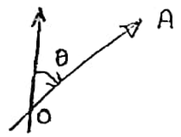
(2) Meridian :- A fixed line w.r.t. which bearing of line can be measured.

Bearing : Angle measured w.r.t. a fixed meridian.



(3) True Meridian :- The line joining true north & true south on earth surface is called true meridian.

⇒ Axis of rotation of earth meets earth surface at two points. these are true north and true south.

True Bearing : True Bearing is the bearing measured w.r.t. true meridian is called true bearing.

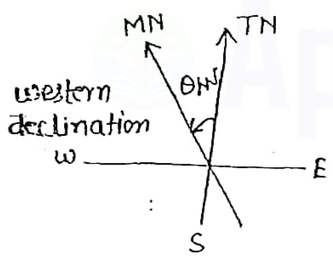
(4) Magnetic Meridian :-

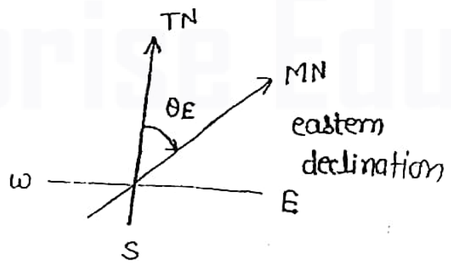
Dirⁿ of magnetic flux in the area show the magnetic meridian.

⇒ A magnetic will show the dirⁿ of magnetic north & south.

Magnetic Bearing : The bearing measured w.r.t. magnetic meridian.

(5) Declination : The difference of angle (horizontal angle) b/w true meridian & magnetic meridian is called declination.





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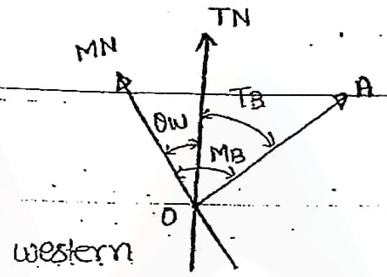
Declination may be —

(i) Western → If MM (magnetic meridian) is towards west from T.M.

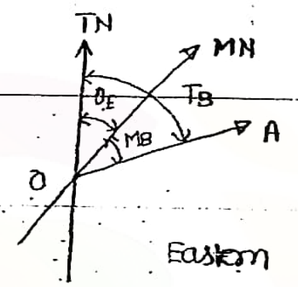
(ii) Eastern → " " " " " " east from T.M.



T.B. = MB - θW

↓

western declination



TB = MB + θE

↓

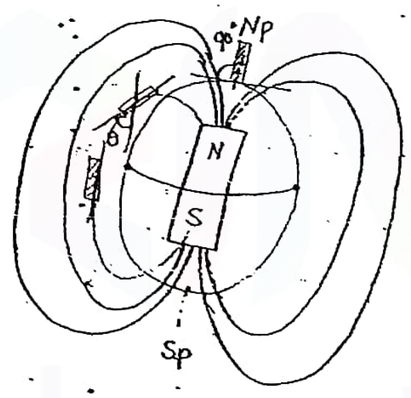
eastern declination.

(6) Angle of dip :-

Angle of dip —

at equator = 0

At poles = 90°



If a magnetic is hanged freely from its C.G it will align itself in the direction of magnetic flux. It will make some angle with horizontal. The vertical angle of magnetic flux direction w.r.t. horizontal at that area is called angle of dip.

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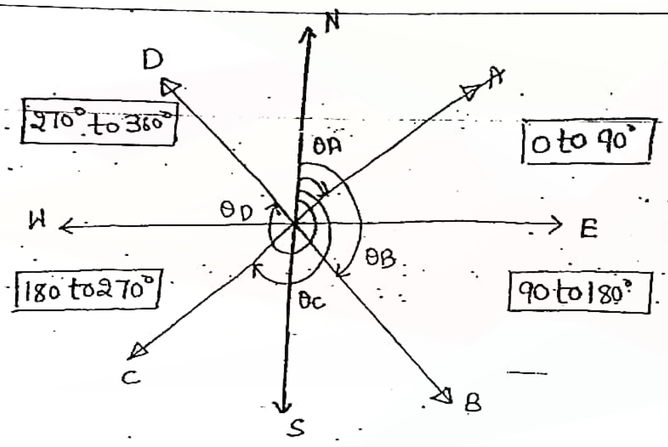
Note :- At equator = dip angle = 0

At pole = 90°

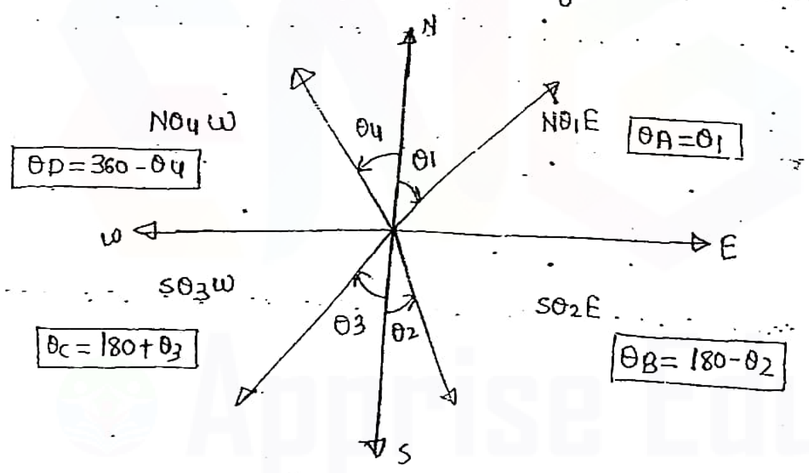
at other place = 0 to 90°.

System of Bearing Measurements:-

(1) WCB Method (Whole circle Bearing method)



(2) QSB Method (Quadrantal system of Bearing) Also called Reduced bearing.



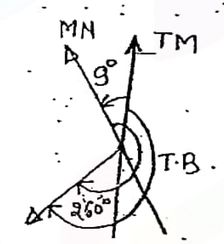
	WCB	QSB	
θ_A	0 to 90°	$N\theta_1 E$	$\theta_1 = \theta_A$
θ_B	90° to 180°	$S\theta_2 E$	$\theta_2 = \theta_B - 180°$
θ_C	180° to 270°	$S\theta_3 W$	$\theta_3 = \theta_C - 180°$
θ_D	270° to 360°	$N\theta_4 N$	$\theta_4 = \theta_D - 360°$

Ques: (1) If magnetic bearing of a line is 260° and declination is (i) 9° W (ii) 6° E calculate T.B. of the line -

T.B = MB ± θ

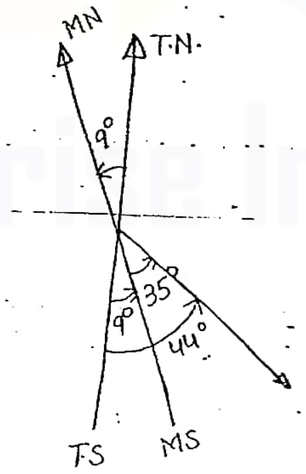
(i) 9° W ⇒ T.B = 260° − 9° = 251°

(ii) 6° W ⇒ T.B = 260° + 6° = 266°



Ques: (2) If magnetic bearing = S 35° E.

declination (i) 9° NW (ii) 5° E Calculate T.B.



W.C.B

180 − 35 = 145°

$\boxed{M.B = 145°}$

(i) 9° W

TB = 145° − 9° = 136°

S (180 − 136°) E

$\boxed{T.B. = S44E}$

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(ii) 5°E

T.B = 145° + 5°

= 150°

= S(180-150)E

= S 30° E

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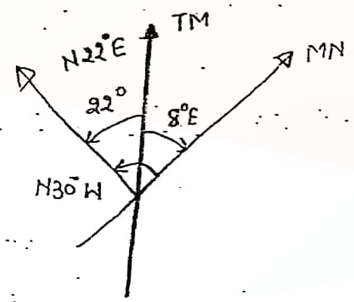
Ques 8(2) If magnetic bearing of a line is N 30° W, and declination is 8°E. Calculate the true bearing of line.



Mag. Bearing of line = N 30° W

= 360° - 30°

= 330° (WCB)

(ii) True Bearing of line

T.B = MB + DE

= 330° + 8°

= 338°

= N (360 - 338°) W

= N 22° W

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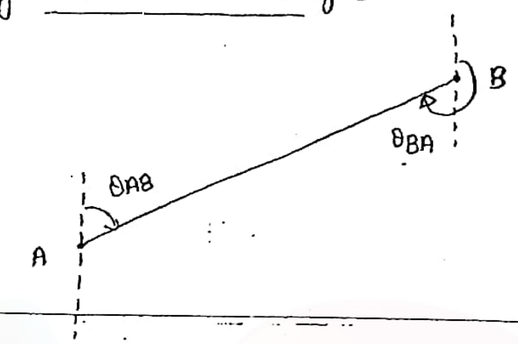
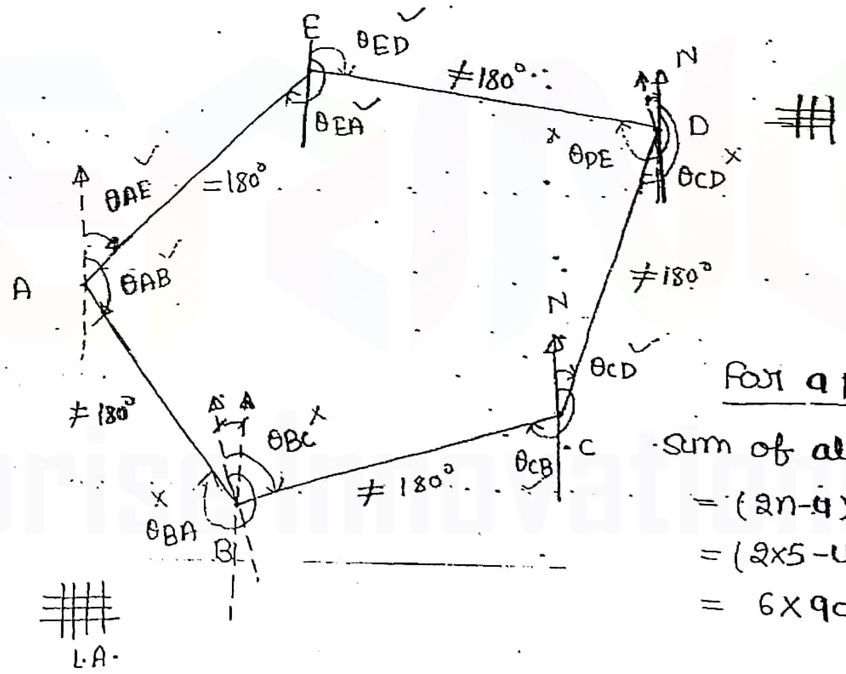
Fore Bearing and Back Bearing :-



For line AB	For line BA
F.B = θAB	F.B = θBA
BB = θBA	B.B = θAB

Local Attraction :-



For a pentagon

Sum of all angles

= (2n-4) × 90°

= (2×5-4) × 90°

= 6 × 90° = 540°

Important points :

1) If difference of F.B & B.B. is not equal to 180°, Any one station or both may be affected from local attraction.

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(2) If difference of a line

F.B − B.B = 180°

Both station are free from local attraction.

If AE correct Angle ⇒ AE − EA = 180°

Correct Angles :- All angles measured at A & E.

AE — ✓	AB — ✓
EA — ✓	ED — ✓

(3) If any station is affected from the local attraction, error and correction on all reading taken from that station will be same.

..... D is affect | Correction in DE = Correction in DE

If B is affected — Correction in BA − Correction in BC

(4) For a closed traverse :

sum of all internal angles $= (2n-4) \times 90°$

Ques: (1) following bearing were taken for a closed traverse

Line	FB	B.B	difference
AB	75° 5'	254° 20'	x
BC	115° 20'	296° 35' ✓	x
CD	165° 35' ✓	345° 35' ✓	180°
DE	224° 50' ✓	44° 5'	x
EA	304° 50'	125° 5'	x

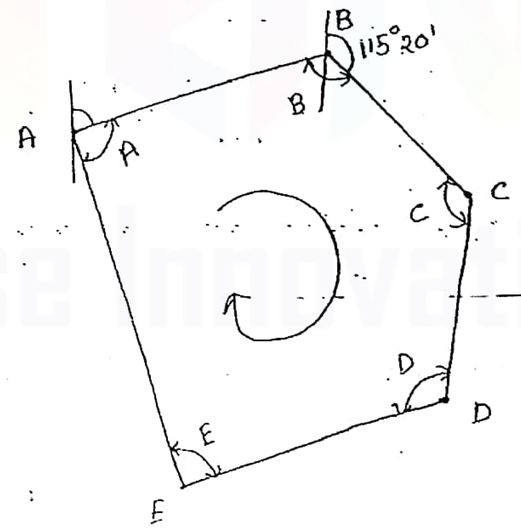
1. Find out the correct bearing of lines which station are free from local attraction

(#) C & D are free from local Attraction.

Line	Bearing	Correction	Correct Bearing	Calculation
AB	75°5'	+0°30'	75°35'	
BA	254°20'	+1°15' ←	255°35' ←	75°35'+180°
BC	115°20'	1°15' →	116°35'	
CB	296°35'	0°	296°35'	116°35'+180°
CD	165°35'	0°	165°35'	
DC	345°35'	0°	345°35'	
DE	224°50'	0°	224°50'	
ED	44°5'	+0°45' ←	44°50' ←	224°50'−180°
EA	304°50'	+0°45' →	305°35'	
AE	125°5'	+0°30' ←	125°35' ←	305°35'−180°

** Method for Calculation of Internal angle for a closed traverse:

Step (1) Draw the traverse



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Step:2 Draw a clockwise circle inside the traverse.

Step:3

Internal Angle.

$\angle A$ =	AE −	AB
$\angle B$ =	BA −	BC
$\angle C$ =	CB −	CD
$\angle D$ =	DC −	DE
$\angle E$ =	ED −	EA

Step(4) If any angle is (-)ve then add 360°.

Step:(5) If any angle becomes more than 360°, then deduct 360°.

Ques: Following are the bearing of a closed traverse −

Line	F.B	B.C	diff.
AB	142°30'	322°30'	180°
BC	223°15'	44°15'	×
CD	287°	107°45'	×
DE	12°45'	193°15'	×
EA	60°	239°	×

Solution:

	Bearing	Correction	Corrected Bearing	Calculation
AB	142°30'	0	142°30'	
BA	322°30'	0	322°30'	
BC	223°15'	0	223°15'	223°15'−180
CB	44°15'	−1°0'	43°15'	
CD	287°	−1°	286°	286°−180
DC	107°45'	−1°45'	106°	
DE	12°45'	−1°45'	11°0'	11°+180
ED	193°15'	−2°15'	191°	
EA	60°	−2°15'	57°45'	57°45'+180°
AE	239°	0	237°45'	

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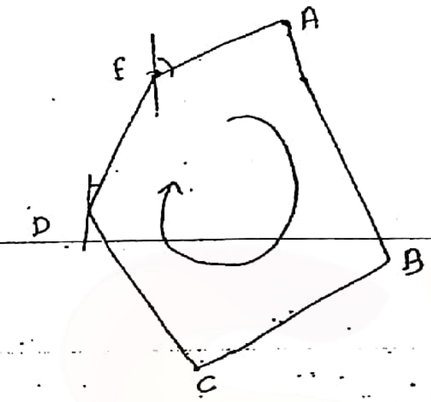
We have to apply internal angle Method



$\angle A$ = AE − AB = 239° − 142°30' = 96°30'
$\angle B$ = BA − BC = 322°30' − 223°15' = 99°15'
$\angle C$ = CB − CD = 44°15' − 287° + 360° = 117°15'
$\angle D$ = DC − DE = 107°45' − 12°45' = 95°
$\angle E$ = ED − EA = 193°15' − 60° = 133°15'

541°15'

Sum of all internal angle = $(2n-4)\times 90 = 540°$

Total error = (+) 1°15'

Total correction = (−) 1°15'

Correction per angle = $\frac{(-)\ 1°15'}{5} = (-)\ 0°15'$

Corrected Internal Angles −

$\angle A$ = 96°15'
$\angle B$ = 99°
$\angle C$ = 117°
$\angle D$ = 94°45'
$\angle E$ = 133°

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$AB = 142°30'$
$+ \angle A = 96°15'$
$AE = 238°45'$
$-180°$

$AE = \angle A + AB$

$EA = 58°45'$
$\angle E = +133°$
$ED = 191°45'$
$-180°$

$ED = \angle E + EA$

$DE = 11°45'$
$\angle D = +94°45'$
$DC = 106°30'$
$+180°$

$DC = \angle D + DE$

$CD = 286°30'$
$\angle C = +117°$
$403°30'$
$-360°$
$CB = 43°30'$
$+180°$
$BC = 223°30'$

$CB = \angle C + CD$ .....

$\angle B = +99°$
$BA = 322°30'$
$-180°$
$AB = 142°30'$

$BA = BC + \angle B$

It is better to solve A 2 feel the one common some so that it is correct.

Ques: (3) Work out the correct bearing of a closed traverse.

	FB	B.B.		
AB	191°30' ✓	13° ✓	178°30'	(1°30') (less error
BC	69°30'	246°30'	-177°	(3°)
CD	32°15'	210°30'	178°15'	(1°45')
DE	262°45'	80°45'	182°	(2°)
EA	230°15'	53°	177°15'	2°45'

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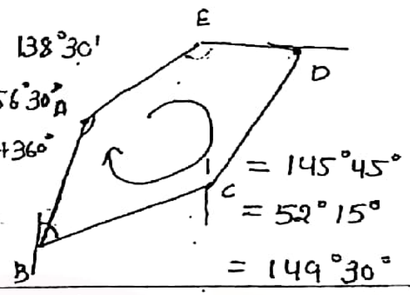
Soln: Internal Angle Method:

$\angle A = AB - AE = 191°30' - 53° = 138°30'$
$\angle B = BC - BA = 69°30' - 13° = 56°30'$
$\angle C = CD - CB = 32°15' - 246°30' + 360°$
$\angle D = DE - DC = 262°45' - 210°30'$
$\angle E = EA - ED = 230°15' - 80°45'$



$= 145°45'$
$= 52°15'$
$= 149°30'$

$= 542°30'$

Total error $= +2°30'$

Correction $= (-)\,2°30'$

Correction per angle $= (-)\,0°30'$

Corrected Angle -

$\angle A = 138°$
$\angle B = 56°$
$\angle C = 145°15'$
$\angle D = 51°45'$
$\angle E = 149°$
$540°$

$\frac{1°30'}{2} = 0°45'$

AB has least error — (where only two elements are there)

$AB = 191°30' + 0°45' = 192°15'$
$BA = 13° - 0°45' = 12°15'$
} diff $= 180°$

$AB = 192°15'$
$-\angle A = 138°$
$AE = 53°45'$
$+180°$
$EA = 234°15'$

$AE = AB - \angle A$

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$EA = 234°15'$
$-\angle E = -149°$
$ED = 85°15°$
$+180°$

$ED = EA - \angle E$

$DE = 265°15°$
$\angle D = -51°45'$
$DC = 213°30'$
$= -180°$

$DC = DE - \angle D$

$CD = 33°30'$
$\angle C = (-)145°15'$
$= -111°45°$
$+360°$
$CB = 248°15°$
$-180°$

$CB = CD - \angle C$
$+36°$

$BC = 68°15'$
$\angle B = -56°$
$BA = 12°15'$
$+180°$
$AB = 192°15'$

$BA = BC - \angle B$

Same value of AB [illegible]

Correct.

Ques: (4)
ES-2002
2(c) 10 marks

Ques: (5)
ES-2005
8(c)

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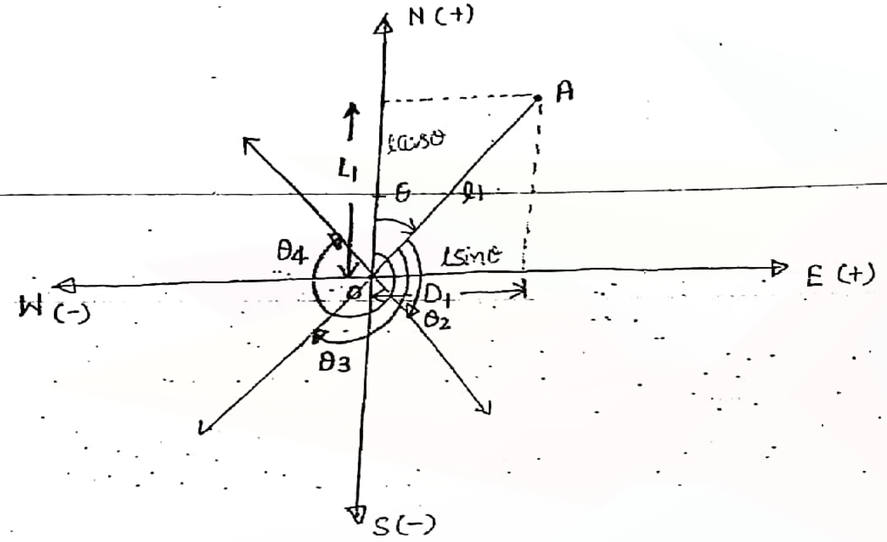
TRAVERSE SURVEY

⊕ Lattitude and Departure :-



Lattitude of a line is the projection on N-S line.

$$\boxed{L = l\cos\theta}$$

Departure : projection on E-W line.

$$\boxed{D = l\sin\theta}$$

WCB	QSB	Lattitude	Departure
0 to 90°	N θ1 E	(+) lCosθ	(+) lsinθ
90 to 180°	S θ2 E	(-) lCosθ	(+) lsinθ
180° to 270°	S θ3 W	(-) lCosθ	(-) lsinθ
270° to 360°	N θ4 W	(+) lCosθ	(-) lsinθ

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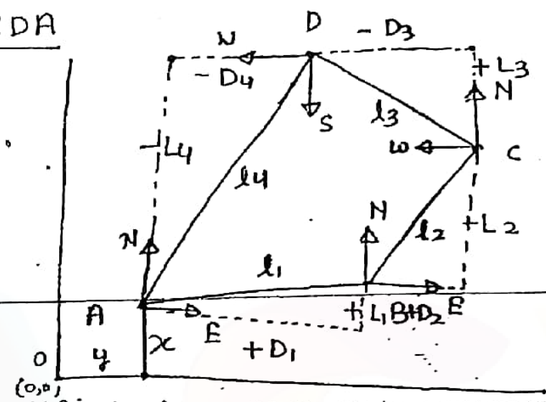
⊕ For a closed traverse :-

For ABCDA



Dependent Lattitude / Departure = The value of latt. / Dep. of each line seperately.

For DA

$$Lat = -L_4 = -l_4\cos\theta_4$$

$$Dep = -D_4 = -l_4\sin\theta_4$$

Independent Co-ordinate :-

→ Co-ordinate of different points w.r.t. one fixed origin.

Point	Lat.	Dep
A	x	y
B	x+L1	y+D1
C	x+L1+L2	y+D1+D2
D	x+L1+L2+L3	y+D1+D2-D3

For a closed Traverse :

$$\Sigma Lat = 0$$

$$\Sigma Dep = 0$$

$$l_1\cos\theta_1 + l_2\cos\theta_2 + \text{---} = 0 \quad —(i)$$

$$l_1\sin\theta_1 + l_2\sin\theta_2 + \text{---} = 0 \quad —(ii)$$

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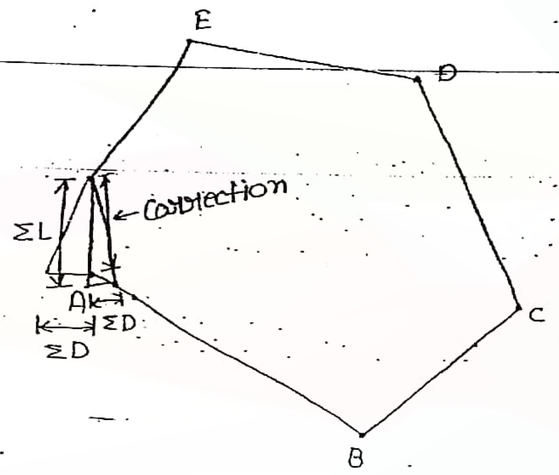
Closing Error :-

If $\Sigma Lat \neq 0$

$\Sigma Dep \neq 0$

Then there are some errors in measurements.



⇒ The traverse drawn on the paper will not close at end.

Methods for correcting a closing error :-

(1) Bowditch Method.

(2) Transit Method.

(3) Graphical method.

(4) Axis method.

(i) Bowditch Method :- This method is used when linear and angular both measurements have been taken with equal degree of precision.

→ The corrections are based on length of different lines.

ΣL = Total error in lattitude. (Adding all lat. with +/-)

ΣD = Total error in departure. (using +/- sign)

Correction in lattitude of a line

$$\boxed{C_L = \frac{l_1}{\Sigma l} \times \Sigma L}$$

$(\Sigma l = l_1 + l_2 + l_3 + \text{----} l_n)$

Correction in departure -

$$\boxed{C_D = \frac{l_1}{\Sigma l} \times \Sigma D}$$

29/12/2015

2) Transit Method :

→ This method is used when angular measurement are more accurate than linear Measurement.

If,

ΣL = Total error in lattitude (Adding with +/- sign)

ΣD = Total error in departure (Adding with +/- sign)

L_T = Total sum of lattitude (without sign. consider all +ve)

D_T = Total sum of departure (without sign, consider all +ve)

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Line	Length	Bearing	Latt.	Dep.	Correction in Lat.	Correctn in Dep.	Corrected Lat	Corrected Dep.
AB	160	46°	111.15	115.09	(+) 5.76	(-) 3.59	116.91 (111.15+5.76)	111.50
BC	190	130°	-122.13	145.54	(+) 6.85	(-) 4.26	-115.28	141.28
CD	200	220°	-153.21	-128.56	(+) 7.29	(-) 4.49	-146.0	-133.05
DA	180	320°	137.89	-115.70	(+) 6.48	(-) 4.02	144.37	-119.74
	$\Sigma L = 730$			$\Sigma L = -26.30$	$\Sigma D = 16.38$		0	0

ΣL, ΣD

closing error $= \sqrt{(26.30)^2 + (16.38)^2}$

$= 30.98$ m

$\frac{l}{\Sigma l} \times \Sigma L$ =

Es. (2013)

$c_L = \frac{l_1}{L_T} \times \Sigma L$

$c_D = \frac{D_1}{D_T} \times \Sigma D$

For Transit Error →

$L_T = 524.38$ (w/o sign)

$L_D = 504.89$ (w/o sign)

$\frac{26.30}{524.38} \times l_1$

Corrn in Lat	Corrn in dep	Corrected Lat	Corr. Dep.
(+) 5.276	(-) 3.74	116.72	111.36
(+) 6.126	(-) 4.72		
(+) 7.68	(-) 4.17		
(+) 6.92	(-) 3.75		
26.30	16.38		

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Correction in Latitude of a line :

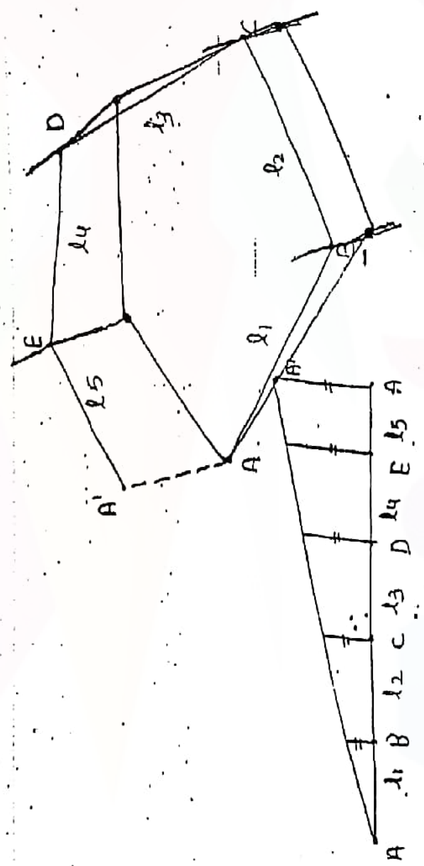
$c_L = \frac{l_1}{L_T} \times \Sigma L$

Correction in Departure of line :

$c_D = \frac{D_1}{D_T} \times \Sigma D$

(3) Graphical Method :

→ It is based on bowditch method.



Ques: ① A closed traverse has following length and bearing. Find out the closing error and correct the traverse for closing error by - (a) Bowditch Method (b) Transit method.

Line	Length	Bearing
AB	160	46°
BC	190	130°
CD	200	220°
DA	180	320°

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Ques (2) A closed traverse has following length and bearing Calculate missing Values —

Line	Length	Bearing	$l\cos\theta$ Lat	Dep.
PQ	x	35°	$0.819x$	$0.57x$
QR	280	80°	48.62	275.75
RS	350	165°	-338.07	90.59
ST	y	238°	$-0.53y$	$-0.85y$
TP	275	310°	176.76	-210.66

$\Sigma Lat = 0$

$0.819x - 0.53y - 112.69 = 0$ — (I)

$\Sigma Dep = 0$

$0.57x - 0.85 + 155.68 = 0$ — (II)

$\boxed{x = -452.47}$ m

$\boxed{y = -486.57}$ m.

Ques : (3) A closed traverse has following length & bearing —

Line	length	Bearing	Lat.	Dep.
AB	240 m	86°	16.74	239.42
BC	x	43°	$0.73x$	$0.68x$
CD	140m	310°	89.99	-107.25
DE	225m	300°	112.5	-194.86
EF	160 m	θ	$160\cos\theta$	$160\sin\theta$
FA	200	165°	-193.185	51.76

$26.045 + 0.73x - 10.93 + 160\sin\theta + 0.68x + 160\cos\theta = 0$

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$\Sigma Lat = 0$

$0.73x + 160\cos\theta + 26.04 = 0$ — (I)

$\Sigma Dep = 0$

$0.68x + 160\sin\theta - 10.93 = 0$ — (II)

$160\cos\theta = -(26.04 + 0.73x)$

$160\sin\theta = (10.93 - 0.68x)$

$\because \sin^2\theta + \cos^2\theta = 1$

$\therefore (160\cos^2\theta) + (160\sin^2\theta) = (0.73x + 26.04)^2 + (0.68x - 10.93)^2$

$160^2 = 0.99x^2 + 797.546 + 23.153x$

$\approx x^2$

$\boxed{x = 79.77, -310.92}$

$\boxed{x = 146.31}$

$\cos\theta = \dfrac{-0.73x - 26.04}{160}$

$= -0.830289.$

$\sin\theta = \dfrac{-0.68x + 10.93}{160}$

$= (-)\ 0.55369.$

$\tan\theta = \dfrac{0.55369}{0.830289} = 0.666847$

$\boxed{\theta = 33°41'52''}$

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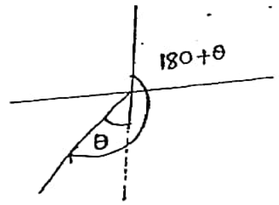
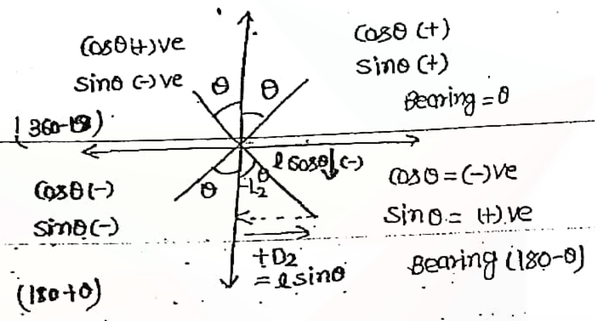
Bearing of line

$= 180 + \theta$

$= 180 + 33°41'53''$

$= 213°41'53''$





Ques 1(c) A closed traverse as following length & bearings — ES-2000

Line	Length	Bearing	Lat. CosΘ	Dep. SinΘ
AB	200	θ	$200\cos\theta$	$200\sin\theta$
BC	98	178°	−97.94	3.42
CD	x	270°	0	−x
DA	86.4	1°	86.38	1.51

$\Sigma Lat = 0$ $\qquad$ $\Sigma Dep = 0$

$200\cos\theta - 11.56 = 0$ $\qquad$ $200\sin\theta - x + 4.93 = 0$

$\cos\theta = \frac{11.56}{200}$ $\qquad$ $200\sin\theta = x - 4.93$

$\cos\theta = 0.0578$

$(200\sin\theta)^2 + (200\cos\theta)^2 = (x - 4.93)^2 + (11.56)^2$

$(200)^2 = x^2 + 24.301 - 9.86x + 133.634$

$x^2 - 9.86x - 39842.065 = 0$

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LEVELLING

$\boxed{x_1 = 204.6\,m}$

$200\sin\theta = x - 4.93$

$\sin\theta = \frac{199.67}{200}$

$\sin\theta = 0.9986$

$\cos\theta = 0.0578$

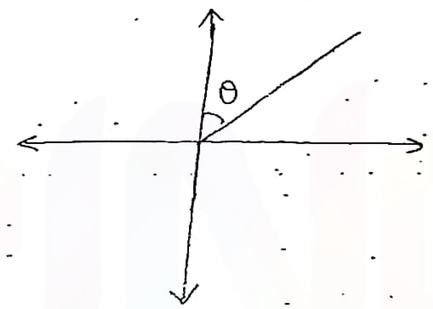
$\tan\theta = \frac{0.9986}{0.0578} = 17.276$

$\theta = 86.68°$

$\boxed{\theta = 86°41'13''}$ — both angle (+ve)

Bearing $= \theta$

$= 86°41'13''$



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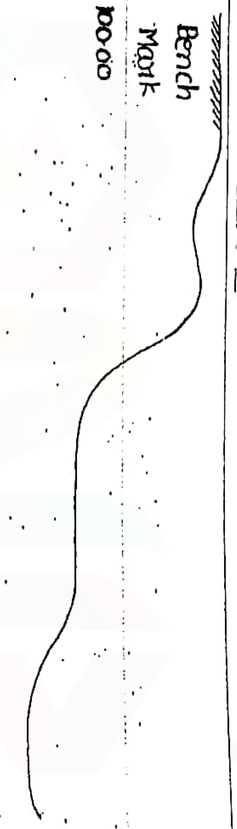

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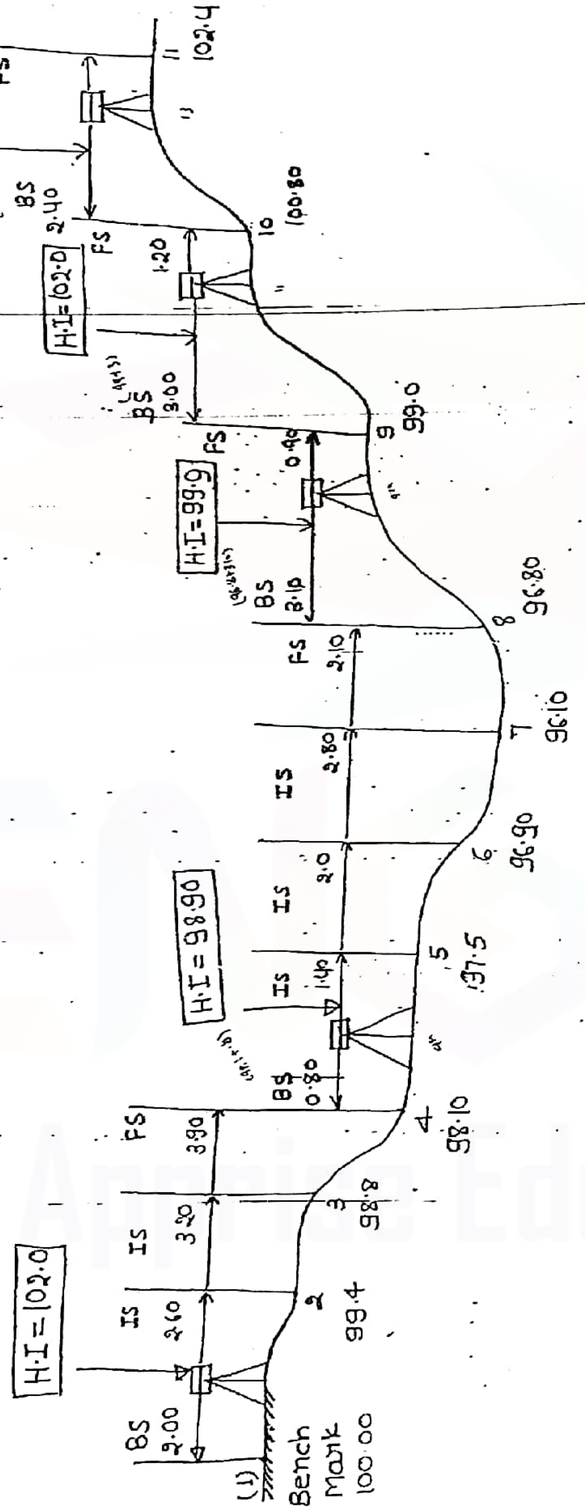
LEVELLING



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Important definition :-

(1) Bench Mark :- A fixed location on ground of known R.L., from where levelling work can be started.

(2) Reduced Level (RL) :- Height of any point w.r.t. either mean sea level or w.r.t. any bench mark of known R.L is called Reduced level.

(3) Back Sight :- First reading taken after setting up the instrument at any station.

(4) ForeSight : Last reading taken from any istrument location.

(5) Intermediate Sight :- All other reading than BS/FS are called IS.

(6) Height of Instrument Method :-

$$H.I = \left(\begin{array}{l}\text{R.L. of Bench Mark} \\ \text{or previous station}\end{array} + \text{B.S.}\right)$$

$$\text{R.L. of Next point} = H.I - I.S/F.S$$

(7) Rise & Fall Method :

$$\text{Rise / Fall of this point} = \left(\begin{array}{l}\text{Previous} \\ \text{reading}\end{array}\right) - \left(\begin{array}{l}\text{Next} \\ \text{Reading}\end{array}\right)$$

(+)ve → Rise.

(-)ve → Fall.

$$= \left(\begin{array}{l}\text{Staff reading} \\ \text{of previous point}\end{array}\right) - \left(\begin{array}{l}\text{Staff reading} \\ \text{at this point}\end{array}\right)$$

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R.L. of this point = R.L. of previous point + Rise (or) − Fall

Ques 8 (1) Following reading were taken in a fly levelling using a staff of 4.0 m length.

BS 2.00, IS 2.60, IS 3.20, FS 3.90 / BS 0.80, IS 1.40, IS 2.0, IS 2.80, FS 2.10 / BS 3.10, FS 0.90 / BS 3.00, FS 1.20 / BS 2.40, FS 0.80

Instrument was shifted after 4th, 9th, 11th & 13th reading. Ist reading was taken on a B.M. of R.L − 100.00 m. Fill the level book and calculate R.L of different points.

Point	BS	I.S	FB.S	H.I	R.L	Rise	Fall	R.L
1	2.00	2.60		102.00	100.00	x	x	100.00
2		2.60			99.4		0.6	99.4
3		3.20	3.90		98.8		0.6	98.8
4	0.80		3.90	98.9	98.1		0.70	98.1
5		1.40			97.5		0.60	97.5
6		2.0			96.9		0.6	96.9
7		2.80			96.1		0.8	96.1
8	3.10		2.10	99.9	96.80	0.7		96.8
9	3.00		0.90	102.0	99.0	2.20		99.0
10	2.40		1.20	103.2	100.8	1.80		100.8
11			0.80		102.40	1.60		102.40
	11.3	2	8.9		2.4 m	6.3	3.9	

diff = 2.4

Rise | fall

(only for IS)

(#) Arithmetic check

= ΣBS − ΣFS = 11.30 − 8.90 = 2.40

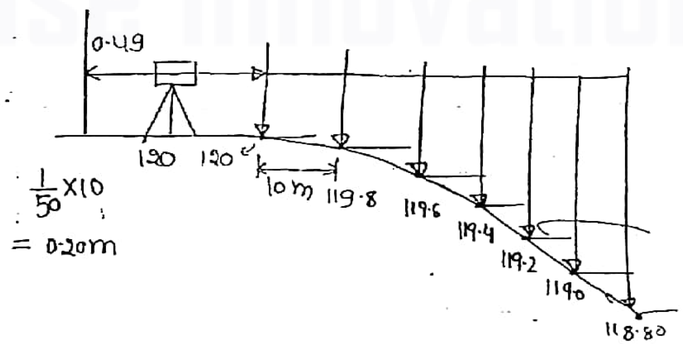
= (Last R.L) − (Ist R.L) = 102.4 − 100.00 = 2.4 | 2.4

= ΣRise − Σfall = 6.3 − 3.9 = 2.4

Ques: 7(b) In running fly level from a bench mark, of R.L 120.75 m. Following readings were taken —
ES-2008

B.S	0.85	1.285	1.182	0.965	0.49
F.S	0.555	1.150	1.945	1.755	—

From the last position of insument seven pegs at 10 m interval are to be set out on a uniform falling gradient of 1 in 50. R.L of Ist peg is 120.0 m. work out the staff reading for top of the pegs. fill level book and apply arithmetic check.



$\frac{1}{50} \times 10$
= 0.20 m

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Point	BS	I.S	F.S	H.I	R.L	Rise	Fall	R.L
1	0.85				120.75	x	x	
2	1.285		0.555		121.045	0.295		
3	1.185		1.150		121.180	0.135		
4	0.965		1.945		120.417		0.763	
5	0.49		1.755		119.627		0.790	
6		0.117			120.00	0.373		
7		0.317			119.8		0.20	
8		0.517			119.6		0.20	
9		0.717			119.4		0.20	
10		0.917			119.2		0.20	
11		1.117			119.0		0.20	
12			1.317		118.8		0.20	
	ΣBS = 4.772		ΣFS = 6.722			0.803	2.753	

Rise / Fall for point No-6

$= 120.00 - 119.627$

$= 0.373$

$0.49 - x = 0.373$

$x = 0.49 - 0.373$

$\boxed{x = 0.117}$

check:-

ΣBS − ΣFS

$= 4.772 - 6.722$

$= (-)1.95$

Last RL − 1st RL

$= 118.8 - 120.75$

$= (-)1.95$

ΣRise − Σfall $= 0.803 - 2.753$

$= (-)1.95$

(o.k)

Ques: (2) Find out missing values in a level book as shown below -

Points	BS	IS	FS	R.L	Rise	fall
① B.M	2.40			120.00		
2)	① 5.65		2.20	② 121.2	1.20	⑤
3)		2.85		124.00	2.80	⑥
4)		③ 1.65		125.20	~~3.00~~ 1.2	⑦
5)	④ 3.55		1.80	125.05		⑧ 0.15
6)			2.60	126.00	0.95	⑨

Missing Value :-

⑤ $2.40 - 1.20 = 1.20$ (Rise)

⑥ $12.4 - 121.2 = 2.80$ (Rise)

⑦ $127 - 124 = 3$ (Rise)

⑧ $126.8 - 127.0 = (-)0.2$ (fall)

⑨ $125.0 - 126.8 = -(1.8)$ (fall)

③ $\boxed{2.85 - 1.2}$ ⑦

(1) $= 2.80 + 2.85 = 5.65$ ✓

(2) $120.0 + 1.20 = 121.20$ m ✓

~~(3) 1.80 = 0.20 (3) 1.80 − 0.20 = 1.6~~

(3) $2.85 - 1.2 = 1.65$

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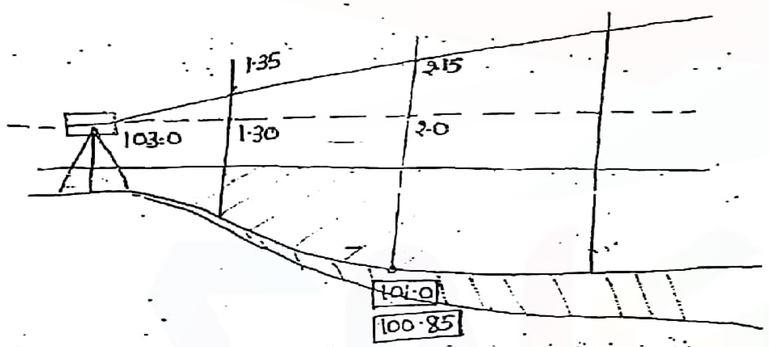
Receprocal Levelling :-

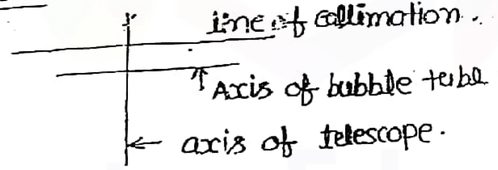
→ Receprocal levelling is used to find out any error in the levelling instrument and to eliminate the effect of such error and other error like due to earth curvature & refraction.

→ If line of sight is not horizontal when bubble is showing in centre. The instrument is faulty. In this case all the readings taken will be wrong.



Adjustments :

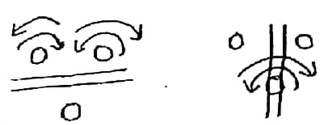
→ (1) Permanent Adjustment :-



→ (2) Temporary Adjustment :-

(i) centreing

(ii) Levelling →



(iii) Removal of parallax – crosshair (disturbance)
(focusing of crosshair.)



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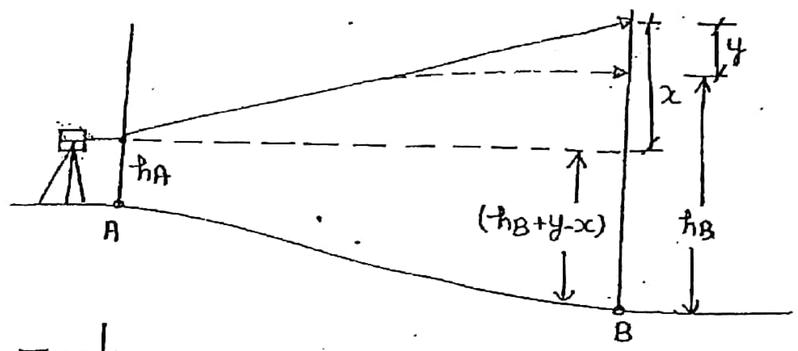

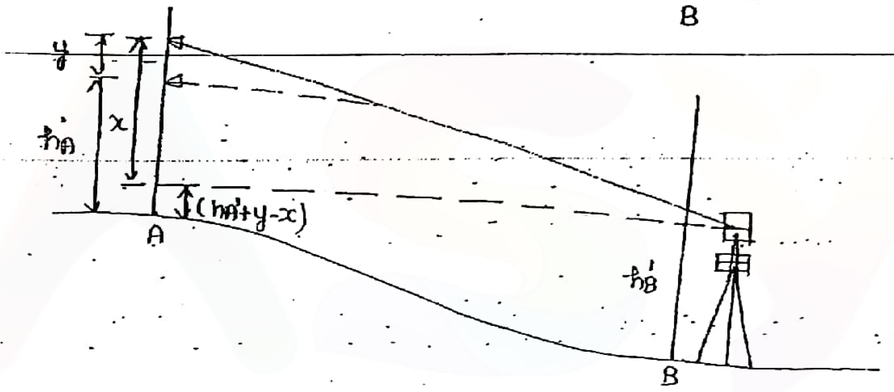

Two point 'A' & 'B' are selected at some distance, and staff readings are noated keeping the instrument Ist near A & then near B.

	Staff reading at 'A'	Staff reading at B.
Instru. A	h_A ✓	h_B
Instru. B	h_A'	h_B' ✓

(#) When the Instrument is at A

correct reading at A $= h_A$

" " " B should be $= (h_B+y-x)$

exact difference of level b/w A & B

$$H = (h_B + y - x) - h_A \quad \text{—①}$$

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(ii) When instrument is at B –

Correct reading at A should be = $(h_A' + y - x)$

" " " B = h_B' " =

exact difference of level

$$H = h_B' - (h_A' + y - x)$$

$$H = (h_B' - h_A' - y + x) \quad \text{—②}$$

Add ① & ②

$$2H = h_B + y - x - h_A + h_B' - h_A' - y + x$$

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

Ques: (1) For a reciprocal levelling, following readings were taken —

	staff reading at (A)	staff reading at (B)	difference
Instrument (A)	1.82 h_A	2.72 (2.785) (h_B Error = 0.065)	0.90
Instrument (B)	0.92 0.985 (h_A' error = 0.065)	1.95 h_B'	1.03

0.965 (Avg) exact difference

R.L B = 199.035

If R.L of point A is 200.00 m and distance b/w (A) & (B) is 260 m. Calculate the exact R.L of point B & angular error in the instrument. Neglect the effect of curvature and refraction.

Sol: Exact difference of level b/w A & B.

$$H = \frac{(h_B - h_A) + (h_B' - h_A')}{2} = \frac{(2.72 - 1.82) + (1.95 - .92)}{2}$$

$$\boxed{H = 0.965}$$

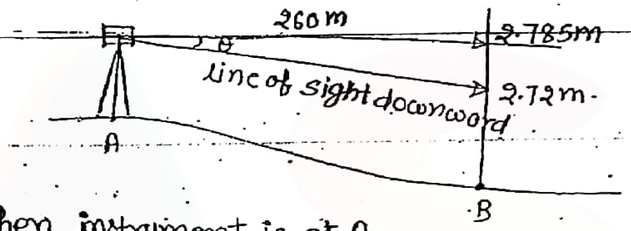
R.L of A = 200.00 m.

∴ R.L of B = 200.00 (R.L of A) – difference of level

(B is below A) = 200.00 – 0.965

= 199.035 m.

Error in Instrument :



when instrument is at A –

Correct Reading at A = 1.82

exact Reading diff of level = 0.965

exact Reading at B should be = 1.82 + 0.965

= 2.785m

Reading taken at B = 2.72 < 2.785m.

line of sight

error in inclination :–

$$= \frac{\text{difference of Reading}}{\text{distance}} = \frac{2.785 - 2.72}{260}$$

$$= \frac{1}{4000} \text{ Ans}$$

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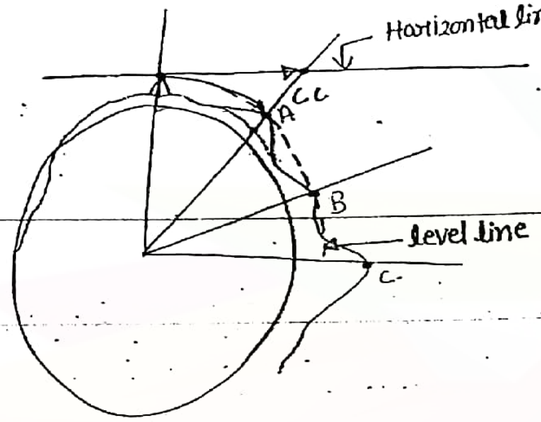
⊕ Correction due to earth curvature and refraction :-

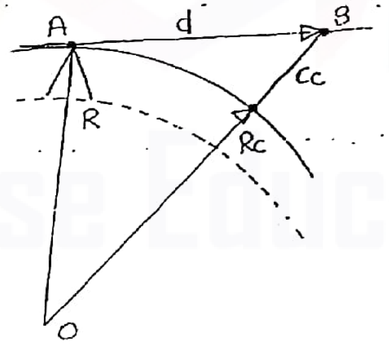
(1) Due to earth curvature :-



(⊕) Horizontal line :- A line tangent to any point on earth surface · line of sight setup by an instrument will show a horizontal line.

(⊕) Level line :- A line ⊥el to earth surface - The R·L of different points should be measured w·r·t level line.

(⊕) Correction due to curvature :- is the difference b/w horizontal line and level line for any point.



$R + R_c$

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

$R^2 + C_c^2 + 2 \cdot R \cdot C_c = R^2 + d^2$

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

$$\boxed{C_c = \frac{d^2}{2R}}$$

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Correction due to curvature $= \frac{d^2}{2R}$

$$C_c = \frac{d^2}{2 \times 6370} \text{ km} = \frac{d^2}{2 \times 6370} \times 1000 \text{ meter}$$

$$\boxed{C_c = (-)\ 0.0785 d^2}$$

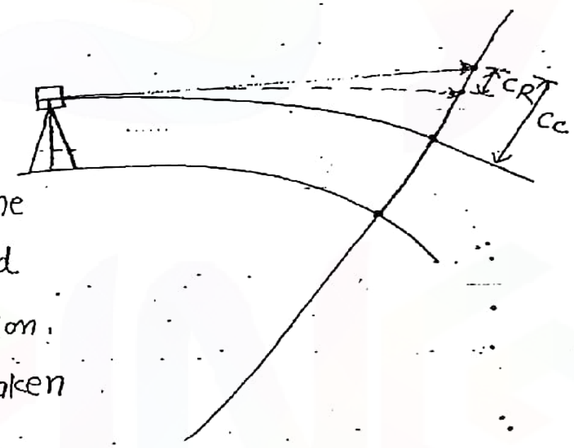
This correction is always (−)ve for staff reading.

$R \cdot L = HI - (h_1 - C_c)$

$R \cdot L = H \cdot I - h_1 + C_c$

This correctⁿ. will become (+)ve for R·L.

(2) Correction due to Refraction :-



Due to refraction, line of sight get deflected in downward direction, thus the reading taken is less.

This correction shall be (+)ve for staff reading.

$$C_R = (+)\frac{1}{7} \times \frac{d^2}{2R} = \frac{1}{7} \times C_c$$

$$\boxed{C_R = \frac{1}{7} C_c}$$

$$C_R = (+)\ \frac{1}{7} \times 0.0785\ d^2$$

$$\boxed{C_R = (+)\ 0.0112 d^2} \quad -(2)$$

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(3) Combined Correction due to Curvature & Refraction :

$$C = C_c + C_R$$

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

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

$$= -\frac{6}{7} \times 0.0785 d^2$$

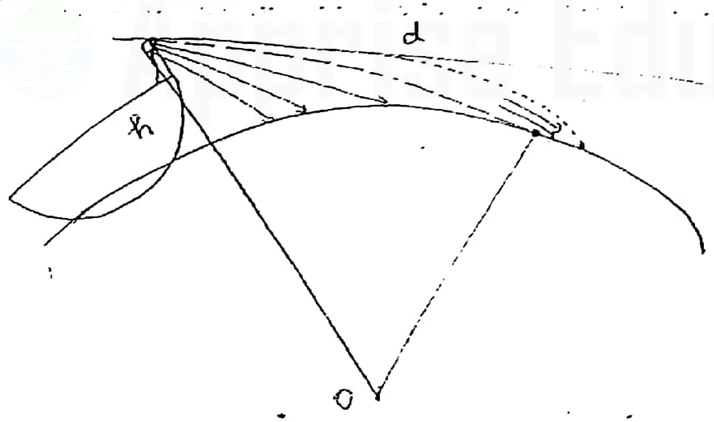
$$\boxed{C = (-)\ 0.0673 d^2} \quad \text{—— (3)}$$

Example :- Calculate C_c, C_R & C due to curvature & Refraction.

For (i) 120 m (ii) 1500 m.

	For 120 m	For 1500 m.
d in km	0.12 km	1.5 km
$C_c = 0.0785 d^2$	$= 1.13 \times 10^{-3}$ m. $= (-)\ 0.113$ cm	$= 0.1766$ m $= (-)\ 17.66$ cm
$C_R = \frac{1}{7} C_c$	+ 0.016 cm	(+) 2.52 cm
Combined	(−) 0.096 cm	(−) 15.14 cm.

(#) Distance of Visible horizon :-



⇒ Distance of visible horizon is max^m distance up to which A person can see on the surface of earth.

(#) If only earth curvature is considered —

$$h_{(m)} = C_c = \frac{d^2}{2R} = 0.0785\, d^2 \ (\text{km})$$

$$d = \sqrt{\frac{h}{0.0785}}$$

$$d = 3.57\sqrt{h}$$

$$\boxed{d = 3.57\sqrt{h}}$$ d → in km, h → in m.

(#) If combined effect of earth curvature & refraction is considered.

The person will be able to see some more distance.

$$h = \frac{6}{7}\cdot\frac{d^2}{2R} = 0.0673 d^2$$

$$d = \sqrt{\frac{h}{0.0673}} = 3.855\sqrt{h}$$

$$\boxed{d = 3.855\sqrt{h}}$$ ← Distance of visible horizon.

h — in m

d — in km.

ES-98

Que (b): An observer standing on the deck of a ship just sees a light house. The top of light house is at 79 m above sea level and the ht. of observer's eye is 9 m above sea level. Find the distance of observer from light house.

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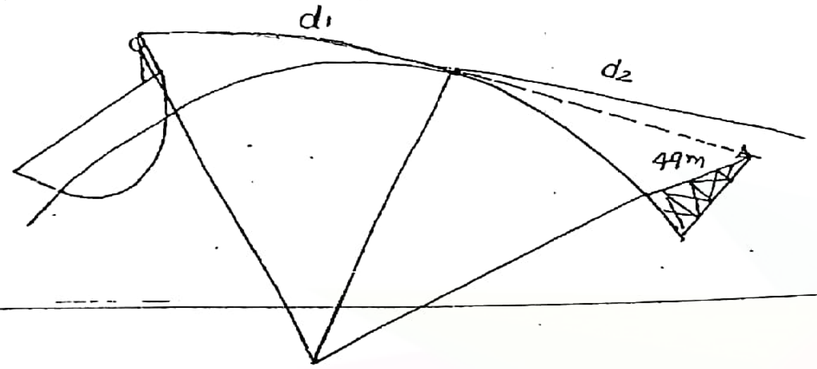


Total distance

$= d_1 + d_2$

$= 3.855\sqrt{h_1} + 3.855\sqrt{h_2}$

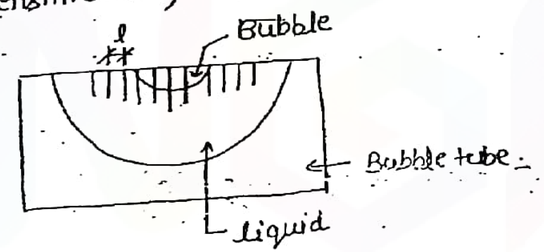
$= 3.855(\sqrt{49} + \sqrt{9}) = 3.855(7+3)$

$= \underline{38.55\ km}$

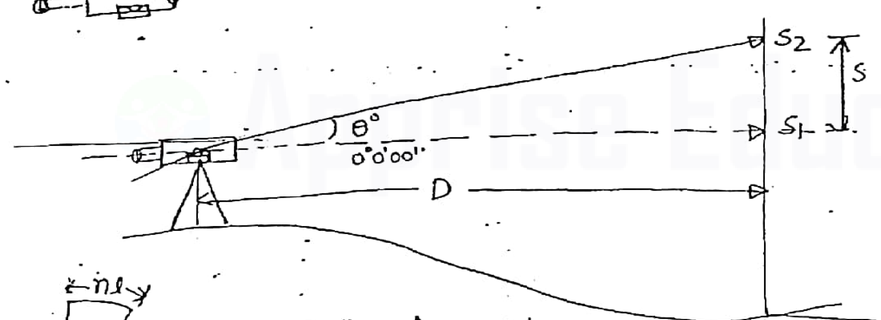
31/12/13

Sensitivity of a Bubble tube :

(Also called Sensitiveness)









R = Radius of curvature of bubble tube.

If a staff reading S_1 is taken from an istrument when bubble is just in centre. Now, if the telescope is rotated by θ angle so that the staff reading changes to S_2. Distance of staff = D from instrument.

In this case the bubble has moved by n divisions.

If l = length of one division —

$$\boxed{\theta = \frac{S}{D} = \frac{nl}{R}} \quad \text{— ① Angle of rotation.}$$

Sensitivity or sensitiveness of bubble tube is the angle of movement due to one division movement of bubble (say α angle).

Sensitiveness —

$$\boxed{\alpha = \frac{\theta}{n} = \frac{S}{nD} = \frac{l}{R}} \quad \text{— ②}$$

Ques: (1) The staff reading taken from an instrument when bubble was at centre on a staff kept at 250 m distance was 1.62 m. The bubble was then moved by 6 division & staff reading changed to 1.95 m. If length of on division of bubble tube is 2.50 mm calculate —

(i) Sensitiveness of a bubble tube.

(ii) Radius of curvature of bubble tube.

Ln:

$l = 2.5\ mm$ (length of one division)

$n = 6$ (no. of division moved).

$D = 250\ m$

S = staff intercept $= S_2 - S_1$

$= 1.95 - 1.62 = 0.33\ m$

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(i) Sensitiveness of bubble tube

$$\alpha = \frac{S}{nD} = \frac{0.33}{6 \times 250} = \frac{11}{50000} = 2.2 \times 10^{-4} \text{ rad}.$$

$$= (2.2 \times 10^{-4}) \left(\frac{180}{\pi} \times 60 \times 60\right) \text{ sec}.$$

$$= 45''.38$$

(ii) Radius of curvature -

$$R \Rightarrow \alpha = \frac{l}{R} = 2.2 \times 10^{-4}$$

$$R = \frac{l}{\alpha} = \frac{2.5 \text{ mm}}{2.2 \times 10^{-4}} = 11363.64 \text{ mm}$$

$$= 11.364 \text{ m}.$$

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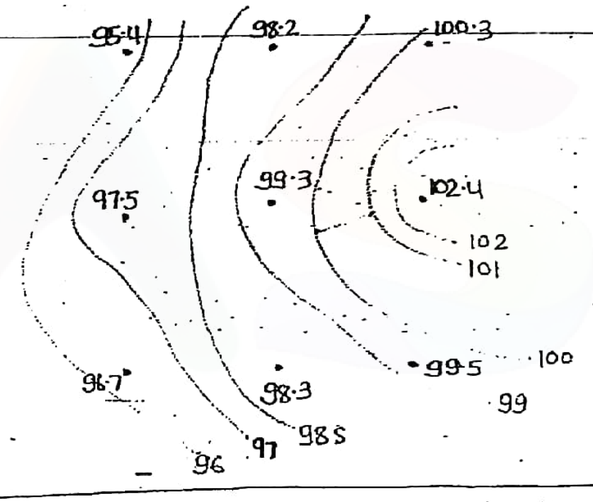
CONTOURS

Contours are the locus of equal elevation points on ground surface.



On a particular contour R.L of all points will be same

Important Terms :-

(1) Contour Intervals :- Difference of R.L. b/w two consecutive contour for a drawing is called contour interval. For one drawing contour interval should be kept same at all location.

For ex: In fig - C.I. = 1m

2) Horizontal Equivalent :- It is the horizontal distance b/w any 2 point on two consecutive contour.

3) Properties :-

(a) Two contour does not cross each other/does not meet at any point.

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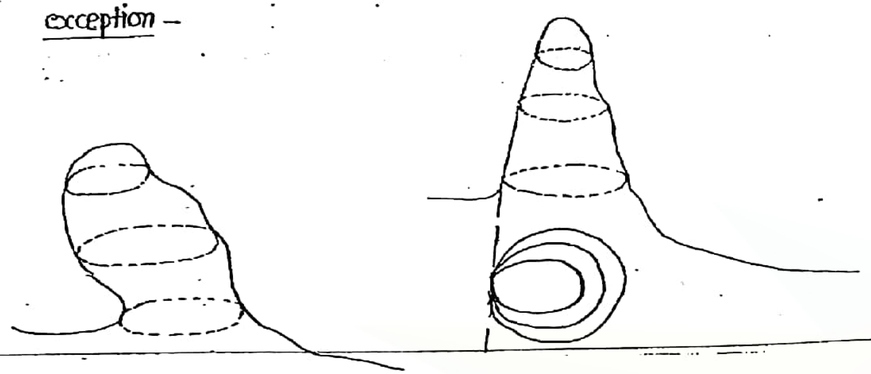
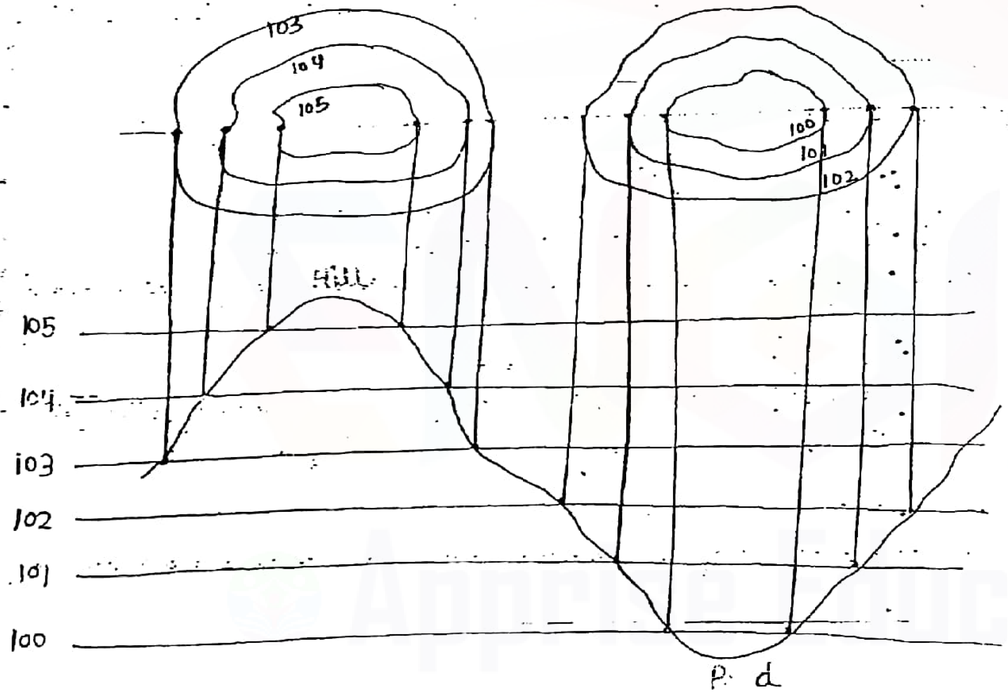
exception –



(b) closed contours show either a hill or a pond.



(c) Ridge line / valley line :

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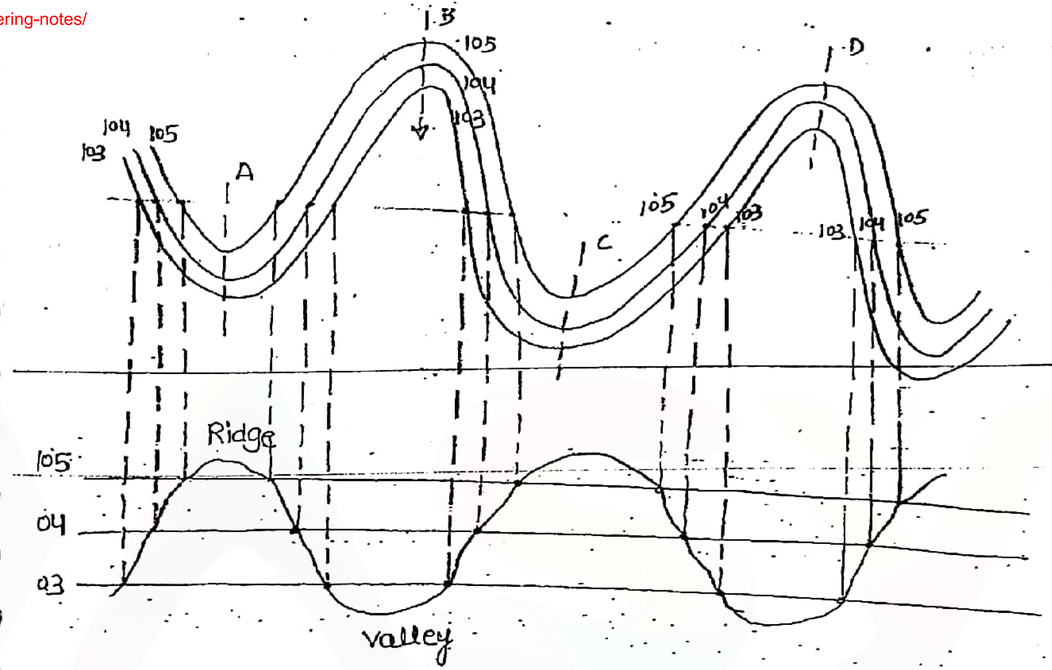
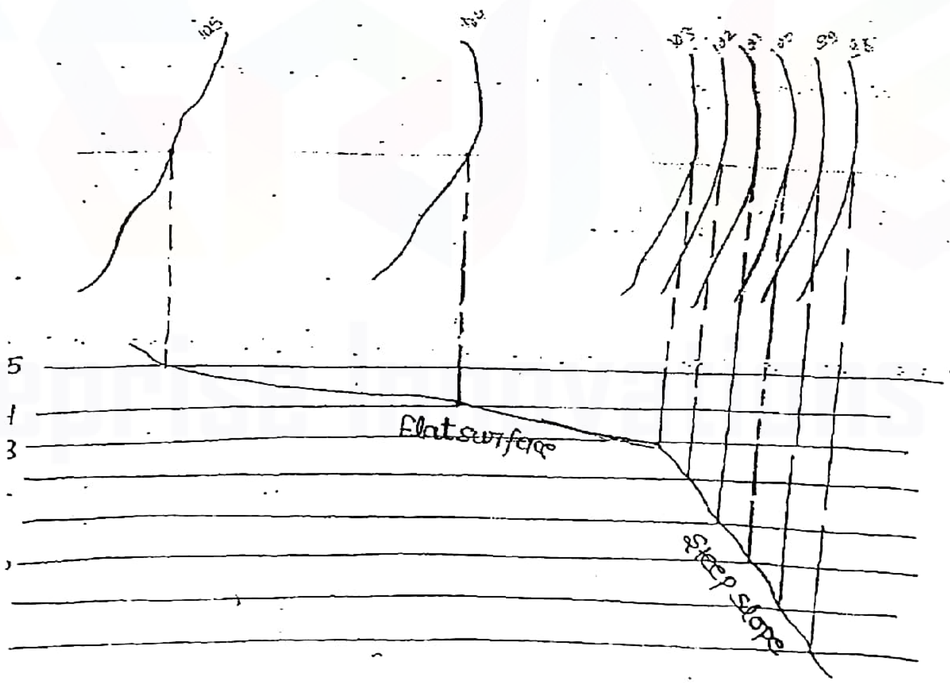


(d) Distant contours — Flat surface

Close contours — steep slope.



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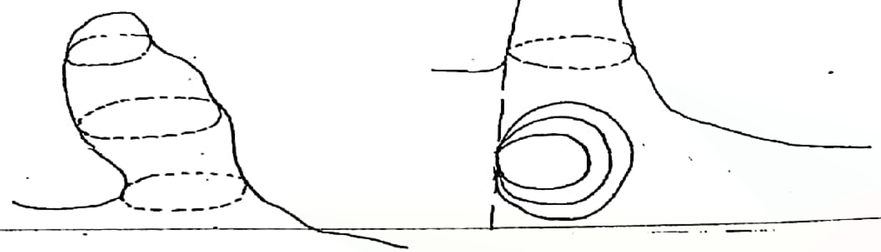
exception –





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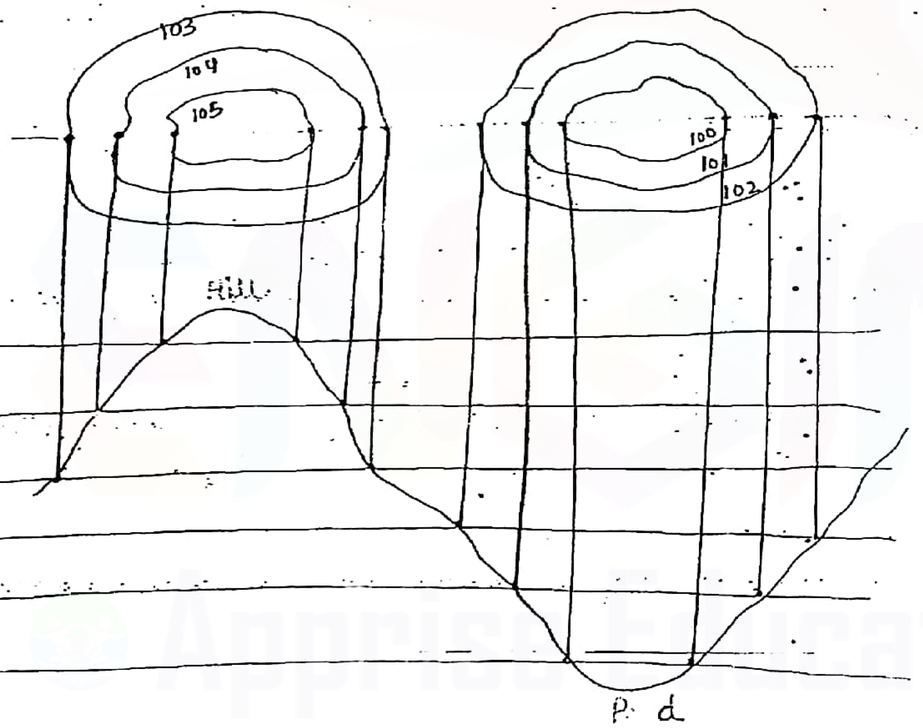
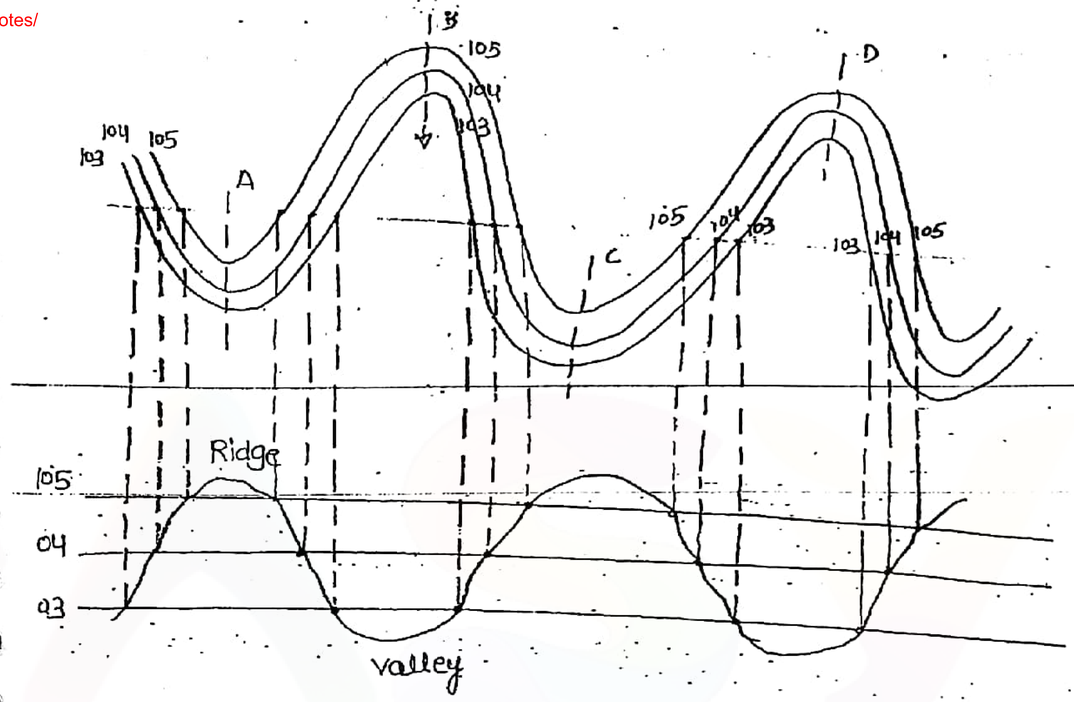
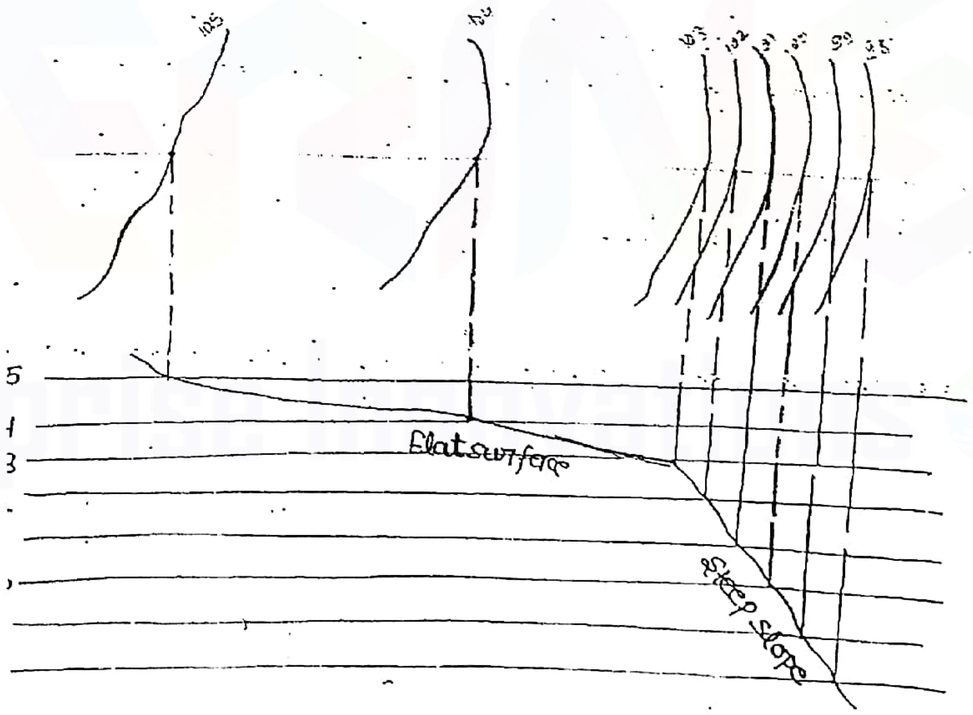


(c) Ridge line / Valley line:



(d) Distant contours — Flat surface

Close contours — steep slope.



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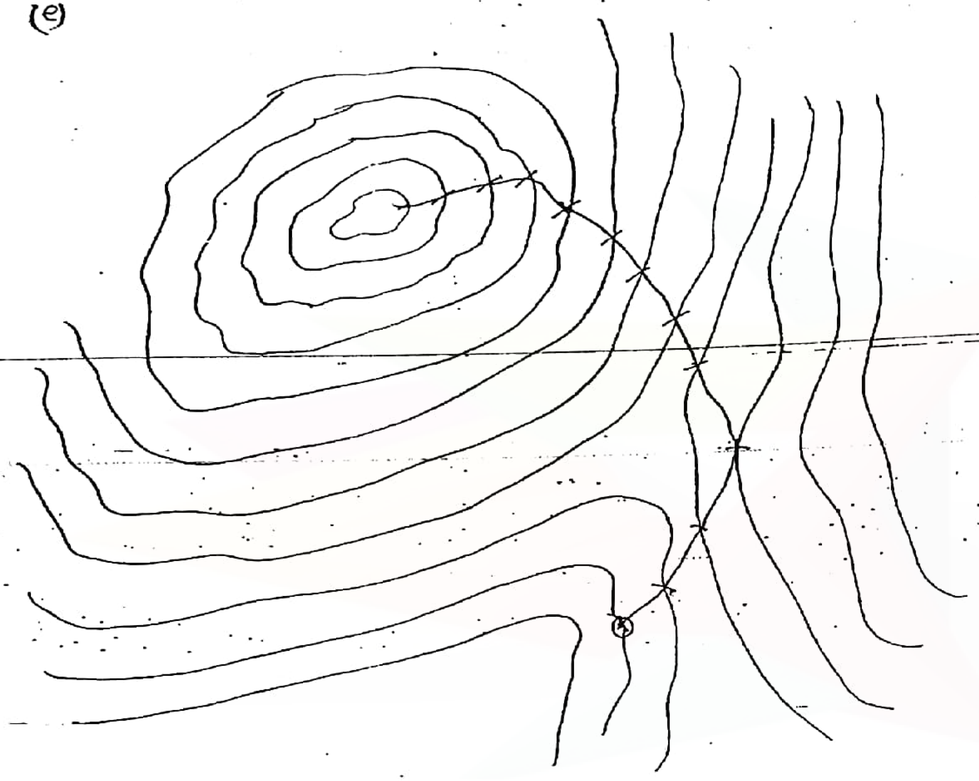
(e)



How to set alignment of a road in hilly area using a contour plan.

on a uniform gradient

Ex. gradient = 1 in 30.

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AREA / VOLUME

(1) Area: —

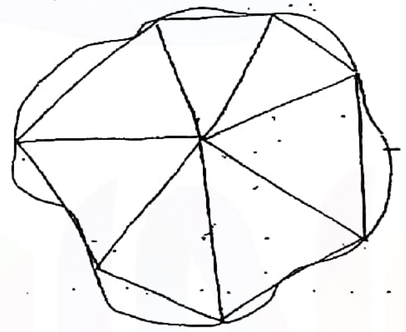
(A) By dividing into a no. of triangles.

Area of triangle —

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

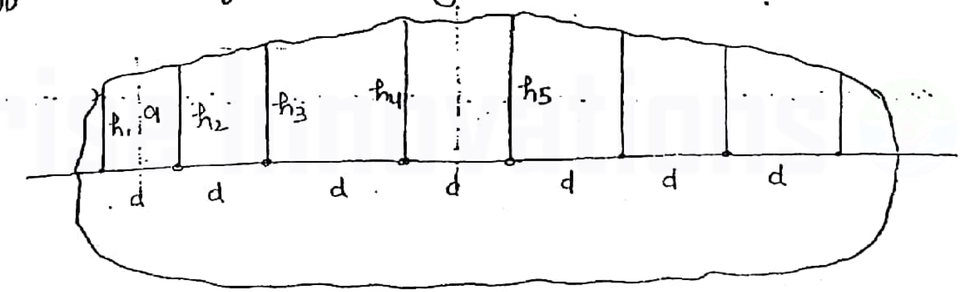
$$s = \frac{a+b+c}{2}$$

$$A = \frac{1}{2}ab\sin C = \frac{1}{2}bc\sin A = \frac{1}{2}ac\sin B.$$



(B) offset Method:

offset taken from a single line at equal interval.



(i) Average ordinate Rule

$$A = \left(\frac{h_1+h_2+h_3+\cdots h_n}{n}\right) \times (n-1)d$$

This is a rough meth

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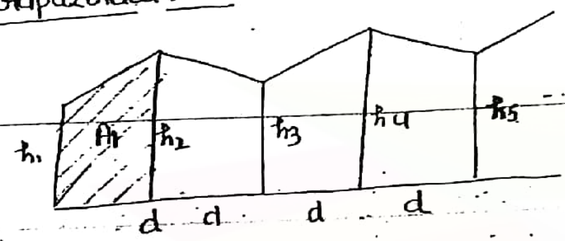
(ii) Mid ordinate Rule :- If mid ordinates O_1, O_2, O_3 ... measured.

$$A = d \times (O_1 + O_2 + O_3 + O_4 + \dots O_n)$$

(iii) Trapazoidal Rule :-



Area of one block

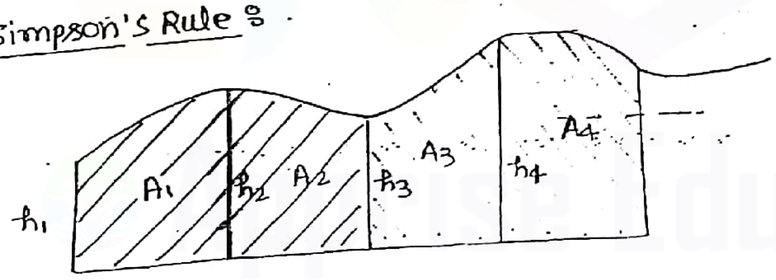
$$A_1 = d \times \left(\frac{h_1 + h_2}{2}\right)$$

$$A_2 = d \times \left(\frac{h_2 + h_3}{2}\right)$$

Total area —

$$A = d\left[\frac{h_1 + h_n}{2} + h_2 + h_3 + \dots h_{n-1}\right]$$

(iv) Simpson's Rule :-



Area of two block -

$$A_1 + A_2 = \frac{d}{3}(h_1 + 4h_2 + h_3)$$

$$A_3 + A_4 = \frac{d}{3}(h_3 + 4h_4 + h_5)$$

Total area —

$$A = \frac{d}{3}\left[(h_1 + h_n) + 4(h_2 + h_4 + h_6 + \dots) + 2(h_3 + h_5 + h_7 + \dots)\right]$$

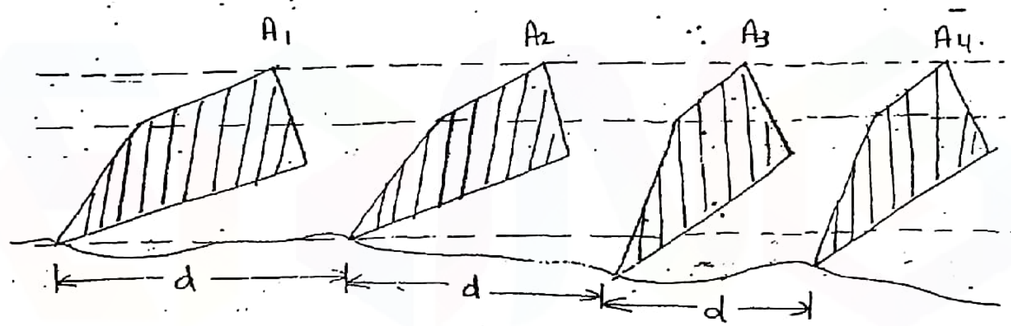
⇒ We need add no. of offsets in simpson's rule.

⇒ If there are even no. of offsets.

Calculate one area (1st or last) by trapazoidal rule and add in total area calculated for other offset by simpson's rule.

2) Volume :-

(A) Trapazoidal Rule :-



Volume

$$V = d \times \left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \dots A_{n-1}\right]$$

Simpson's Rule

Volume :

$$V = \frac{d}{3}\left[(A_1 + A_n) + 4(A_2 + A_4 + A_6 + \dots) + 2(A_3 + A_5 + A_7 + \dots)\right]$$

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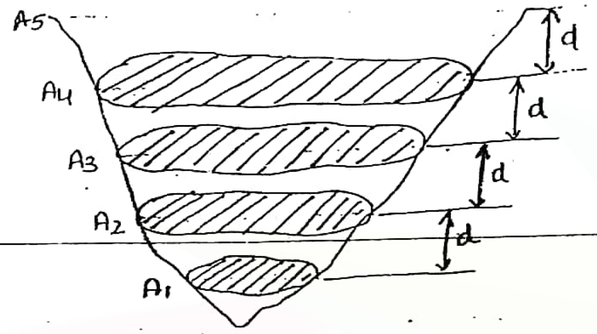
Another Example –

Volume of water in a reservoir –



Ques: 6(a) In a proposed reservoir. The area contouring within the contours are. ES-2006.

Contours (in m)	100	95	90	85	80	75	70	65
Area (in ha)	32	26	24	18	15	13	7	2

1 hect. $= 10^4 m^2$ (100m x 100m)

Using the method of end areas calculate –

(1) capacity of reservoir when it is full at 100m level.

(2) Elevation of water level when it is 60% full. Ignore the volume below 65 m level.

Soln's End Area Method is trapazoidal Rule –

(1) Volume of water when water is full up to 100m.

$$V = E\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \text{---}\right]$$

$$= 5\left[\frac{32+2}{2} + 26 + 24 + 18 + 15 + 13 + 7\right]$$

$$= 600 \text{ Ha-m}.$$

(2) When the reservoir is 60% full.

$$V = 0.6 \times 600$$

$$\boxed{V = 360 \text{ Ha-m}}$$

Contour	Area	Average Area	Volume	Total Volume
100	32	29	145	600
95	26	25	125	455 ▽ 360 Ha-m
90	24	21	105	330
85	18	16.5	82.5	225
80	15	14.0	70.0	142.5
75	13	10	50.0	72.5
70	7	4.5	22.5	22.5
65	2	0		

Neglect

For 330 Ha-m ⟶ W.T = 90m

For 455 Ha-m ⟶ W.T = 95m

For 360 Ha-m ⟶ ?

$$W.T = 90 + \frac{(95-90)}{(455-330)}(360-330)$$

$$\boxed{W.T = 91.2 \text{ m}}$$

Ques: 6(b) A railway embankment is 16m wide with side slope 2:1 assume the ground to be level in the dirn. transverse to the centre line. Calculate the volume contain contained in a length of 100m, the centre ht. at 20

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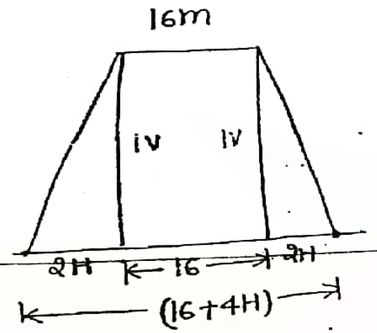
Interval being in meter —

2.0, 4.5, 4.0, 3.5, 2.5, 1.5

∋ Area

$A = \frac{(B+B_1)}{2} \times H$



Distance	height	Top width	Bottom width (16+4H)	Area
0m	2.0	16	24	40 m²
20 m	4.5	16	34	112.5
40m	4.0	16	32	96
60 m	3.5	16	30	80.5
80 m	2.5	16	26	52.5
100m	1.5	16	22	28.5

$A = \frac{16+24}{2} \times 2.0$

Volume —

$V = d \times \left[\frac{A_1 + A_n}{2} + A_3 + A_2 + A_4 + A_5 + -- \right]$

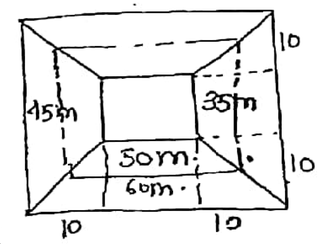
$= 20 \times \left[\frac{40+28.5}{2} + 112.5 + 96 + 80.5 + 52.5 \right]$

$V = 7512\ m3$

Ques:(3) An excavation has been made as shown in figure. Calculate the quantity of earth excavated.

Use:- (i) Trapazoidal Rule.

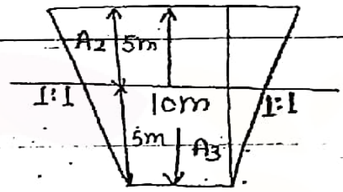
(ii) Simpson's Rule.



(i) Trapazoidal Rule:

$\therefore V =$ $A_1 = 70 \times 55 = 3850\ m^2$

$A_2 = 50 \times 35 = 1750\ m^2.$



$V = d\left(\frac{A_1+A_2}{2}\right)$

$= 10\left(\frac{3850+1750}{2}\right)$

$V = 28000\ m^3.$

(ii) Simpson's Rule:

$A_1 = 70 \times 55 = 3850\ m^2$

$A_2 = 60 \times 45 = 2700 m^2$

$A_3 = 50 \times 35 = 1750 m^2$

$V = \frac{d}{3}\left[A_1 + 4A_2 + A_3\right]$

$= \frac{5}{3}\left\{3850 + 4 \times 2700 + 1750\right\}$

$= 27383.33\ m^3$

(iii) Trapazoidal Rule

$V = d \times \left\{\frac{A_1+A_3}{2} + A_2\right\}$

$= 5 \times \left\{\frac{3850+1750}{2} + 2700\right\}$

$= 27500 m^3$

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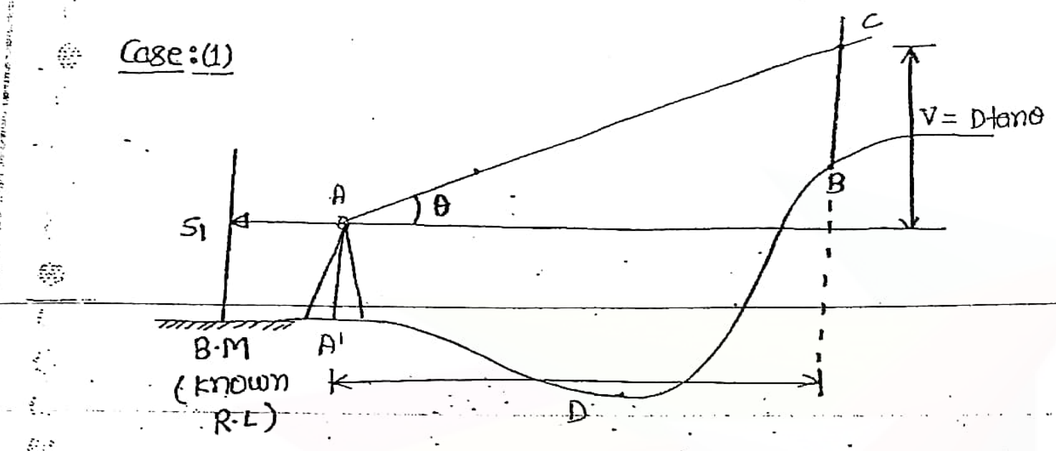
TRIGONOMETRICAL LEVELLING

Case: (1)



Vertical height ⇒

$$V = D \tan\theta$$

known values :-

(i) R.L of B.M.
(ii) Staff Reading B.M = S_1
(iii) Angle = θ
(iv) Distance = D

Find out R.L of C -

R.L of C :-

$$\boxed{\text{R.L of C} = \text{R.L of B.M} + S_1 + V + C}$$

$$\boxed{C = 0.0673 d^2}$$ correction due to curvature and refraction.

Case: (2) :- If distance 'D' cannot be measured :

known values

(i) R.L of B.M.
(ii) Staff reading at BM = S_1
(iii) Angle θ_1 & θ_2
(iv) Distance B.

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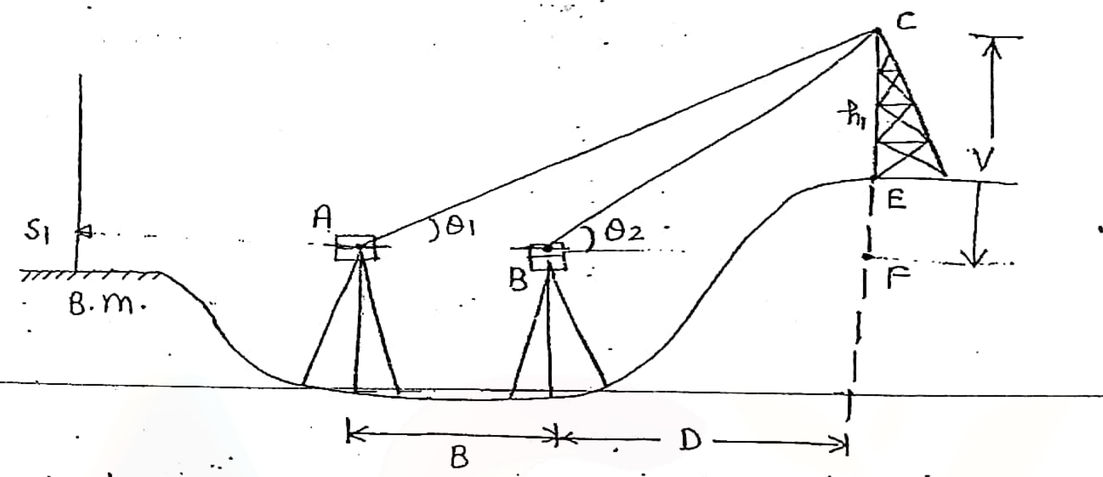

find out :

(1) Distance 'D'
(2) V
(3) R.L of C/E point

In Δ ACF

$$\tan\theta_1 = \frac{V}{B+D}$$

$$V = (B+D)\tan\theta_1 \quad \text{—— (1)}$$

In Δ BCF

$$\tan\theta_2 = \frac{V}{D}$$

$$V = D\tan\theta_2 \quad \text{—— (2)}$$

Put (2) in (1)

$$D\tan\theta_2 = (B+D)\tan\theta_1$$

$$D(\tan\theta_2 - \tan\theta_1) = B\tan\theta_1$$

$$D = \frac{B\tan\theta_1}{(\tan\theta_2 - \tan\theta_1)} \quad \text{—(A)}$$

$$V = D\tan\theta_2$$

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$$V = \frac{B\tan\theta_1 \cdot \tan\theta_2}{(\tan\theta_2 - \tan\theta_1)} \quad \text{— (B)}$$

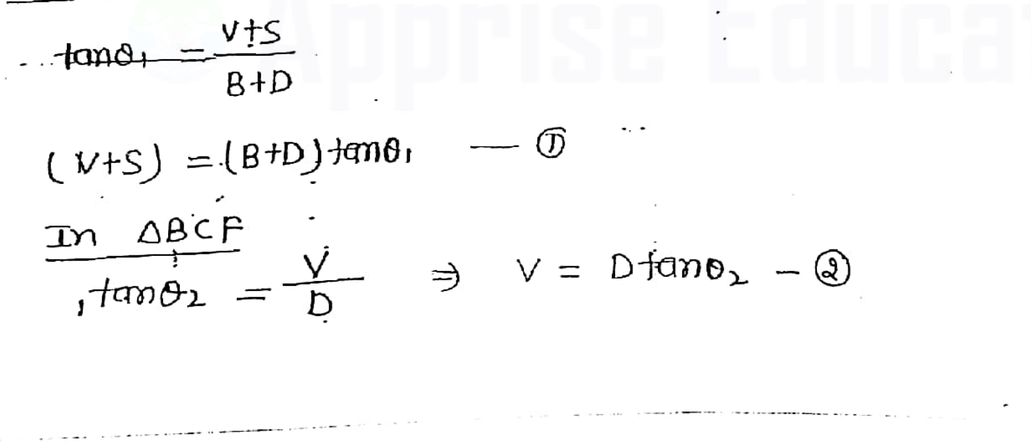
R.L of point C

= R.L of Bm + S_1 + V + C

R.L of E

= R.L of C − h_1

Case: (3) If distance 'D' cannot be measured →



Known Value

① R.L of B.m.
② Staff Reading at Bm = S_1/S_2
③ Angle θ_1 & θ_2
④ Distance 'B'

Find out

① Distance 'D'
② 'V'
③ R.L of C/E point

In Δ ACG

$$\tan\theta_1 = \frac{V+S}{B+D}$$

$$(V+S) = (B+D)\tan\theta_1 \quad \text{— ①}$$

In ΔBCF

$$\tan\theta_2 = \frac{V}{D} \Rightarrow V = D\tan\theta_2 \quad \text{— ②}$$

Put ② in ①

$$D\tan\theta_2 + S = (B+D)\tan\theta_1$$

$$D(\tan\theta_2 - \tan\theta_1) = B\tan\theta_1 - S$$

$$D = \frac{B\tan\theta_1 - S}{(\tan\theta_2 - \tan\theta_1)}$$

$$V = \frac{D}{B}\tan\theta_2$$

$$= \frac{(B\cdot\tan\theta_1 - S)\cdot\tan\theta_2}{(\tan\theta_2 - \tan\theta_1)} \quad \text{— (B')}$$

R.L of point C

= R.L of B.m + S_1 + S + V + C

R.L of E

= R.L of C − h_1

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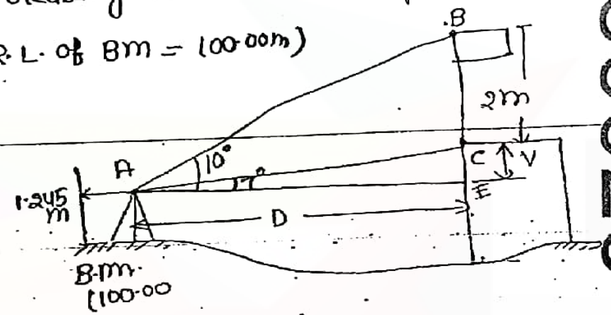
ES-2005 3(a)

Ques: ① A flag post of ht. 2m ~~away~~ was erected on top of a building. Find the R.L of top of flag post. if the vertical angle to bottom and top of it were measured as 7° and 10° resp. from a point. Staff reading on a B.M from the same pt. at 0°0'0" was 1.245 m (R.L. of Bm = 100.00m)



$\tan 7° = \frac{V}{D}$

$\therefore V = D \tan 7°$ — ①

$\tan 10° = \frac{V+2}{D}$

$V+2 = D\tan 10°$ — ②

$D\tan 7° + 2 = D\tan 10°$

$\boxed{D = 37.35\ m}$

$V = D\tan 7°$

$V = 37.35 \tan 7°$

$\boxed{V = 4.59\ m}$

R.L. of top of the flag :-

$= RL \text{ of } Bm + S_1 + V + 2$

$= 100 + 1.245 + 4.59 + 2.0$

$= 107.83m.$

Ques: (ES-2001) In order to determine the elevation of top Q of 6(b)) a signal on a hill observations ~~wh~~ were made from 2 points P & R. All three points are in same vertical plane.

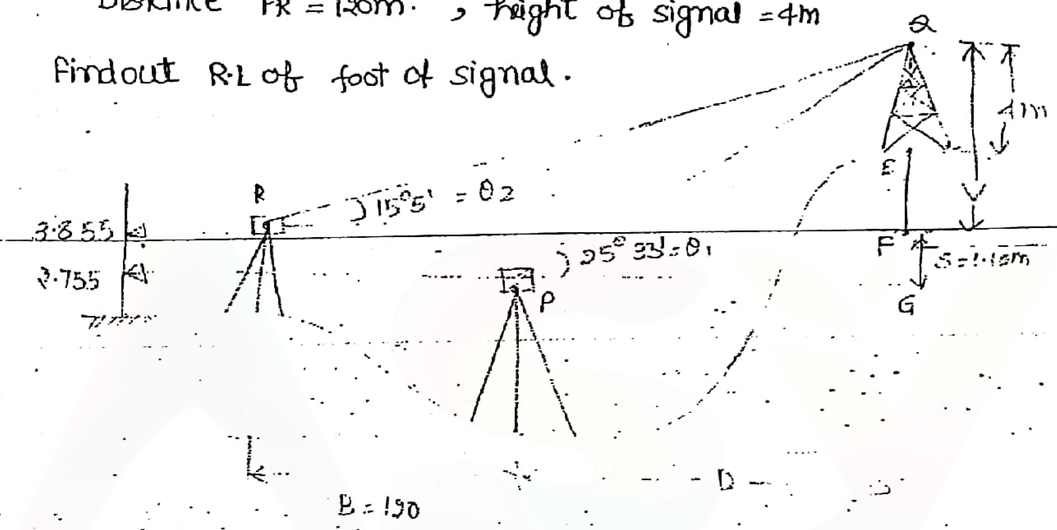
Angle of elevation to Q | from P = 25°35'
R = 15°5'

Staff reading at B.M | from P = 2.755m
from R = 3.855 m.

R.L = 105.42m.

Distance PR = 120m. , height of signal = 4m

Find out R.L of foot of signal.



$\tan\theta_1 = \frac{V+S}{D}$

$V+S = D\tan\theta_1$ — ①

$\tan\theta_2 = \frac{V}{B+D}$

$V = (B+D)\tan\theta_2$ — ②

Put in 1.

$(B+D)\tan\theta_2 + S = D\tan\theta_1$

$D = \frac{B\tan\theta_2 + S}{\tan\theta_1 - \tan\theta_2}$

$= \frac{120\tan 15°5' + 1.10}{\tan 25°35' - \tan 15°5'}$

$\boxed{D = 159.81m}$

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∴ in eqn (2)

$V = (B+D)\tan\theta_2$

$= (120 + 159.8)\tan 15°51'$

$\boxed{V = 75.41m}$

R.L of foot of signal –

$= R.L \text{ of } B.M + S_2 + V - 4.0$

$= 105.42m + 3.855 + 75.41 - 4.0$

$= 180.68m$

ES-1992
Que (5(b)) Determine the R.L of a church spire at C from the following observations taken from two stations. A & B 50 m apart. $\angle BAC = 60°$, $\angle ABC = 50°$

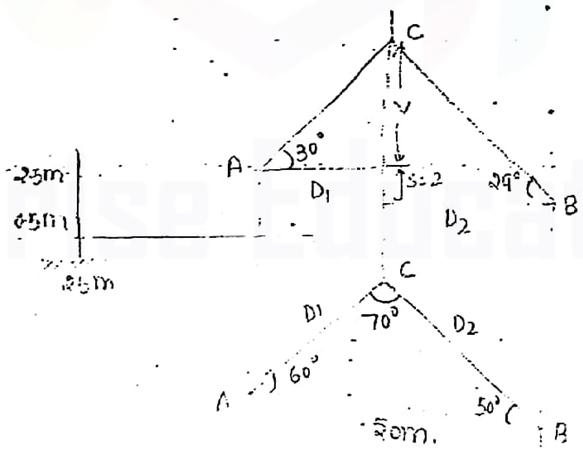
Angle of elevation to top of spire from A = 30°
" B = 29°

Staff reading on a B.M. of R.L = 25.0m from A = 2.5m
from B = 0.50m.

In plan:-

In ΔABC

$\frac{D_1}{\sin 50°} = \frac{D_2}{\sin 60°} = \frac{50}{\sin 70°}$



$\boxed{D_1 = 40.76m}$

$\boxed{D_2 = 46.08m}$

$V = D_1 \tan 30°$

$= 40.76 \tan 30°$

$\boxed{V = 23.53m}$

R.L. of C = R.L of BM + 2.5 + V

$= 25 + 2.5 + 23.53$

$\boxed{R.L. \text{ of } C = 51.03m}$

$V + S = D_2 \tan 29°$

$V = 46.08 \tan 29° - 2.0$

$\boxed{V = 23.54m}$

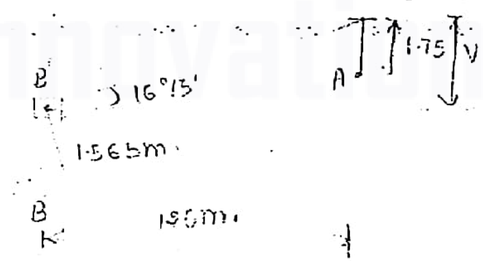
R.L. of C = 25.0 + 2.50 + 23.54

$\boxed{R.L. \text{ of } C = 51.04m}$

Ques 8(c) ES-2004 :- The top of a stack was sighted from 2 stations A & B. 125m apart & are in same vertical plan with top of the stack – Angle of the elevation of top of stack – from A = 35°20'
from B = 22°28'

The angle of elevation from B to a vane 1.75m above the foot of staff held at station A was 16°15' If instrument height at A = 1.856m & at B = 1.565m.

R.L. of Station B = 100.00m. Find out R.L. of top of the stack.



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$V = D\tan 16°15'$

$V = 125\tan 16°15'$

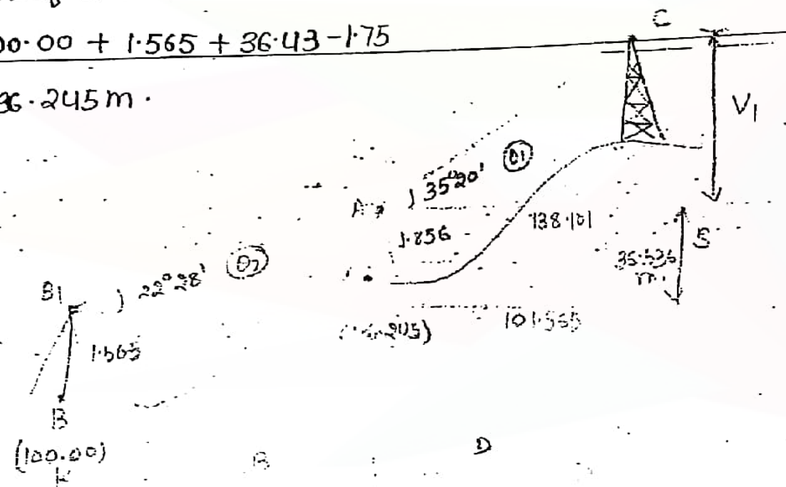
$\boxed{V = 36.43m}$

R.L. of A →

$= \text{R.L of } B + 1.565 + V - 1.75$

$= 100.00 + 1.565 + 36.43 - 1.75$

$= 136.245m.$



(ii) R.L. of A $= 136.245\ m$

H.I. of A $= 136.245 + 1.856$

$= 138.101\ m$

(iii) R.L. of B $= 100.00$

H.I. of B $= 100.00 + 1.565$

$= 101.565\ m$

$S = \text{H.I. of } A - \text{H.I of } B$

$= 138.101 - 101.565$

$\boxed{S = 36.536m}$

$\tan\theta_1 = \frac{V_1}{D}$

$\boxed{V_1 = D\tan\theta_1}$ —— (1)

$\tan\theta_2 = \frac{V+S}{B+D}$

$V+S = (B+D)\tan\theta_2$

$D\tan\theta_1 + S = B\tan\theta_2 + D\tan\theta_2$

$D = \frac{B\tan\theta_2 - S}{\tan\theta_1 - \tan\theta_2}$

$= \frac{125\tan 22°28' - 36.536}{\tan 35°20' - \tan 22°38'}$

$\boxed{D = 51.31m}$

$\therefore V_1 = D\tan\theta_1$

$= 51.31 \times \tan 35°20'$

$\boxed{V_1 = 36.37m}$

R.L. of C

$= \text{R.L. of } A + 1.856 + V_1$

$= 136.245 + 1.856 + 36.37$

$= 174.47m.$

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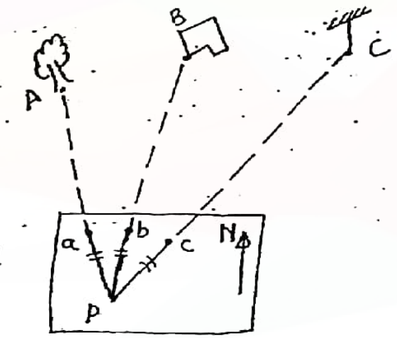
PLANE TABLE SURVEYING

There are 4 methods :-

(1) Radiation } used for locating the position of objects
(2) Intersection } on the drawing.

(3) Traversing } used for locating the position of instrument
(4) Resection } station on the drawing.



(1) Radiation :-

(i) Fix the table over the station. Make the table in a suitable dirn.

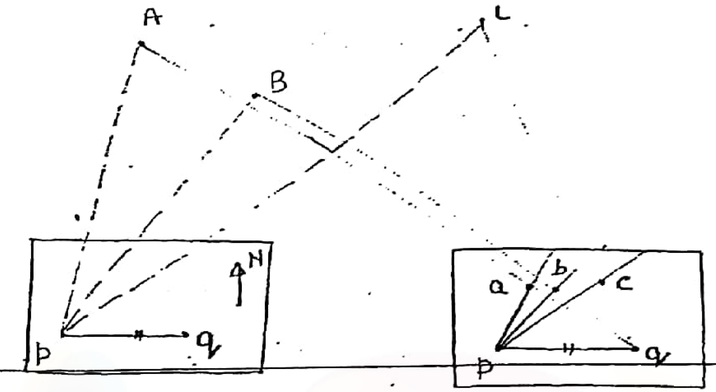
(ii) Draw orientation line in North dirn.

(iii) Locate the position of instrument station 'P' on drawing as p using U-fork.

(iv) Now draw lines from p towards different objects A, B & C

(v) Measure the distance on ground PA, PB and PC (of objects) from P point and mark the distance on the lines using a suitable scale.

(2) Intersection :-



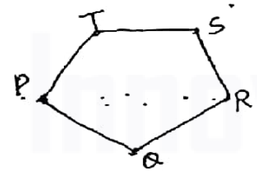
(i) Fix the table at one station say 'P'. Draw orientation line in North direction. Mark the location of P on the drawing as point 'p'.

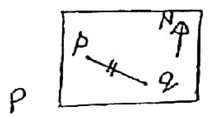
(ii) Now Draw lines towards different objects say A, B & C. Draw a line towards another selected station 'Q'. Measure and mark the distance PQ and get the location of q.

(iii) Now shift the table to Q. Correct the orientation of table by compass or by back orientation towards P.

(iv) Now again draw lines towards different objects. Intersection points will be the location of objects on the drawing.

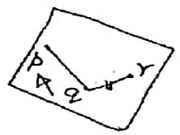
(3) Traversing :-





P

R



Q

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(i) same as above.

(ii) Draw a line towards another selected station Q. Measure and mark the distance PQ and get the location of q.

(iii) same as above.

(iv) Now draw the line towards next station & mark the distance.

(v) This process is repeated till the traverse get closed.

(4) *** Resection :-

tmp.

⇒ Resection is the method of locating the position of instrument station on the drawing. with the help of already marked position of some objects on the drawing after correcting the orientation of the table.

Methods :-

(1) By Compass.
(2) By back orientation.
(3) Three point problem.
(4) Two point problem.

(#) Three point Problem :-

(1) Tracing paper method.
(2) Bessel's graphical method.
(3) Lehman's method.

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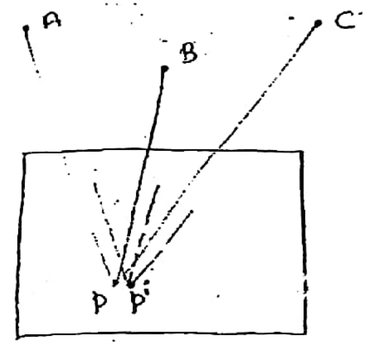
(1) Tracing Paper Method :-



⇒ ① Put a tracing paper on the drawing.

② From any tentative location of point P, say P' on tracing paper. Draw 3 lines towards station A, B & C.

③ Now rotate the tracing paper on the drawing such that all the 3 points A, B & C come exactly over 3 lines draw on tracing paper.

④ Transfer location of P' on the drawings that is the correct location of instrument station P(say P)

⑤ Now rotate the table such that line Pa is towards A This is the correct orientation of the table.

⑥ In this position all the lines drawn Aa, Bb & Cc will meet at the single pt P.

02/01/2015

(2) Bessel's Graphical Method :-

(i) ab → B

(ii) b'a → A

(iii) Intersection = P'

rotate P'c → C

Correct orientation.

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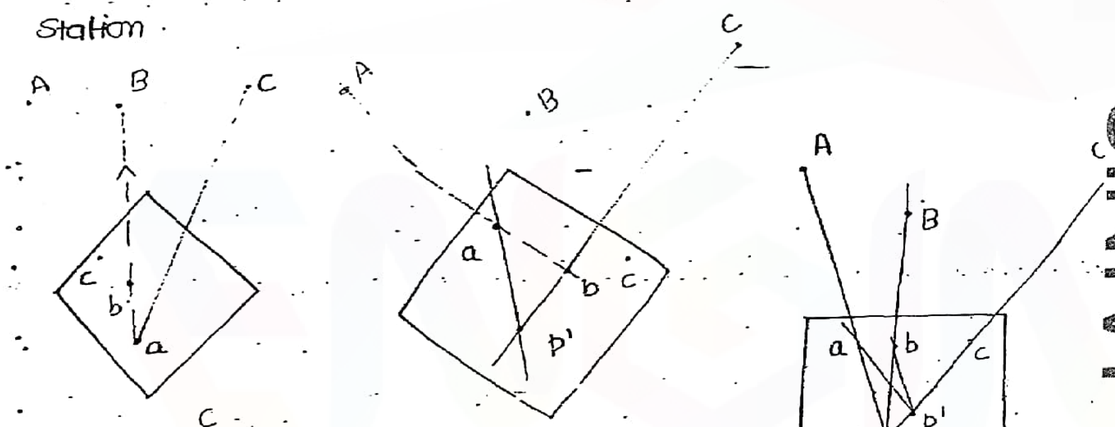
(IV) Join Aa, Bb, Cc at P point.

→ Rotate the table so that line ab is towards B and in this position draw a line from a toward c.

→ Now again rotate the table so that line ba is toward A again draw a line from b towards c.

→ ~~Intersection point of above two lines draw is p' point. Now~~ rotate the table so that p'c is towards c. This is the correct orientation of the table.

→ In this position draw lines Aa, Bb, & Cc they will get at a single point P that is the location of instrument station.



Step 1 ⇒ $\overset{c}{\cancel{a}}b \rightarrow B$

Step-2 $\overset{c}{\cancel{b}}a \rightarrow A$

Step 3 & 4.

(3) Lehman's Method :-

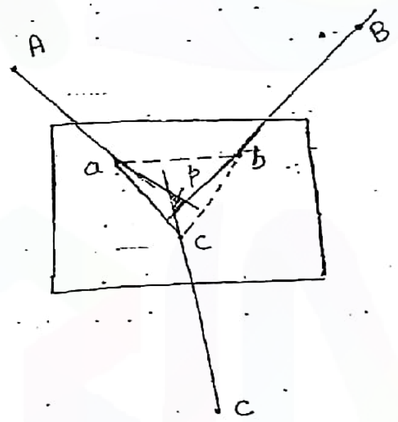
⇒ If orientation of the table is not correct, the lines drawn from 3 points a, b & c will not meet at a single point they will from a triangle called "triangle of error".

⇒ Lehman's method is eliminating this triangle of error by selecting another suitable location of Instrument station by following some rules called lehman's rules so that this triangle of error can be reduce to a point by taking diffrent trials.

⇒ This is also called trial & error method.

(4) Lehman's Rules :-

① If the an triangle of error is within major triangle abc. The possible ~~error~~ point shall be within the triangle.



2) If the Δ of error is outside the major Δ, the possible point shall be outside the Δ of error.

3) The possible point should be taken opposite to the Δ. (opposite to the side of a Δ).

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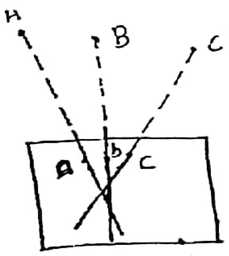
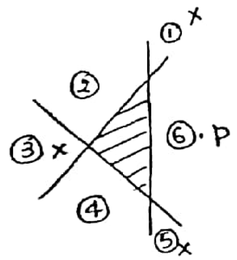
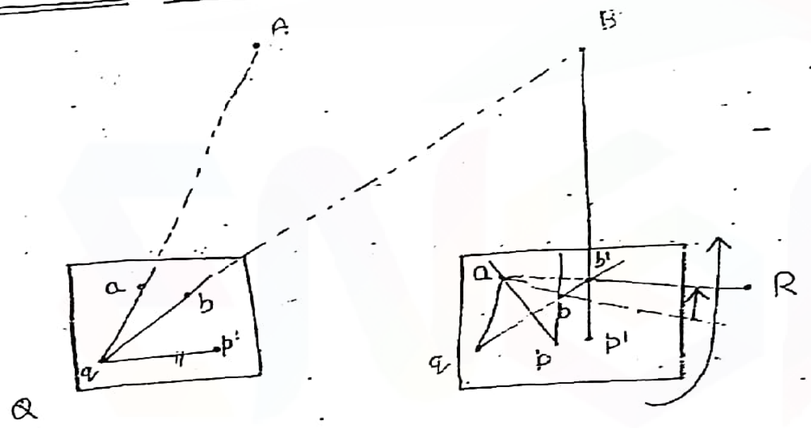




④ The possible point should be taken on the same side of all the 3 lines drawn.

⑤ The point p should be selected such that distance pa, pb and pc are proportional to ground distance PA, PB & PC.

Two Point Problem :-



① A & B are the two objects, for which position on the drawing are a & b.

② Fix the table at another station Q.

③ keeping approx orientation draw line Aa & Bb to meet at q.

③ Draw a line from q towards p, measure and mark distance QP on the drawing to get point P.

④ Now shift the table to P. draw a line P'B to meet line qb at b' ∠b'ab is the error in orientation.

⑤ Now fix a flag in the dirn of ab' at R now rotate the table such that line ab comes in the dirn of R. This is the correct orientation of the table.

⑥ Now draw line Aa & Bb to meet at p that is the correct location of instrument station P.

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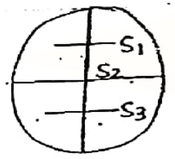
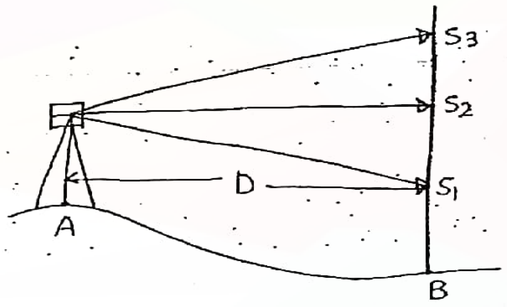
TACHEOMETER SURVEYING

→ Using a tacheometer staff reading can be read to calculate the R.L of a point as well as the distance of the staff location from the instrument.

→ Three staff readings are taken.



Cross-hair



S_2 = Used for R.L

$S_3 | S_1$ = Used for Distance.

Staff Intercept

$$s = (S_3 - S_1)$$

Distance of staff from Instrument –

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

where

k = multiplying constant (generally – 100)

C = Additive constant (generally-zero)

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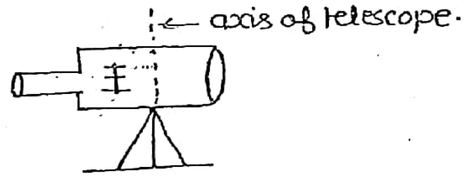
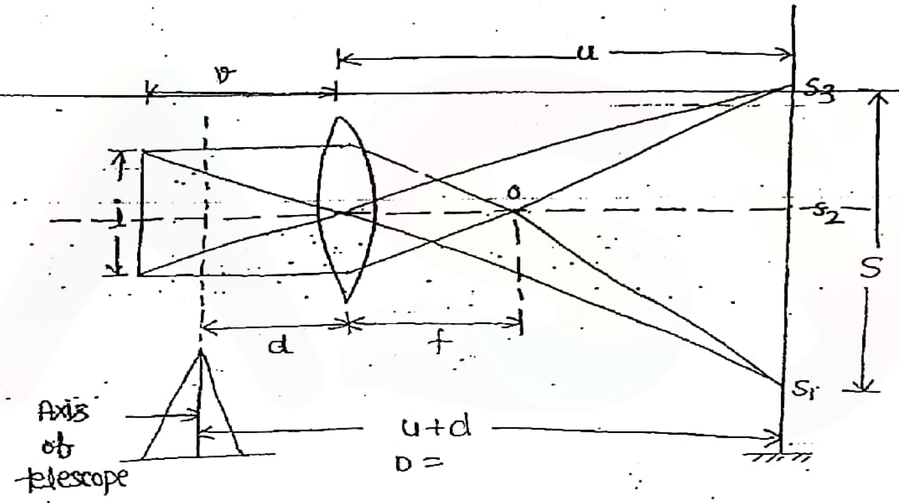
Principle of Tacheometer :-





(#) For the object piece

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \quad \text{—— (1)}$$

Ratio $\quad \frac{s}{i} = \frac{u}{v} \quad \Big\| \quad v = \frac{ui}{s} \quad \text{—— (2)}$

Put in (1)

$$\frac{1}{f} = \frac{1 \cdot s}{u \cdot i} + \frac{1}{u} = \frac{1}{u}\left(\frac{s}{i} + 1\right)$$

$$u = f\left(\frac{s}{i} + 1\right) = \left(\frac{f}{i} \cdot s + f\right) \quad \text{—— (3)}$$

Total distance D

from instrument (axis of telescope) to staff

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$$D = U + d$$

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

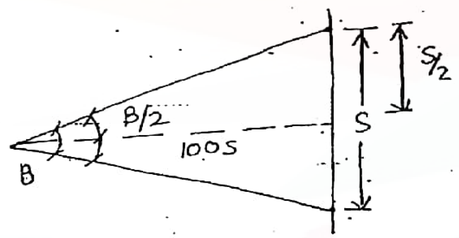
$$D = \left(\frac{f}{i}\right) s + (f + d)$$

$$\boxed{D = ks + c}$$

Multiplying constant $k = (f/i)$ = generally = 100

Additive constant $c = (f+d)$ = generally = 0

When $k = 100$, $c = 0$ | The telescope is called Anallactic telescope.



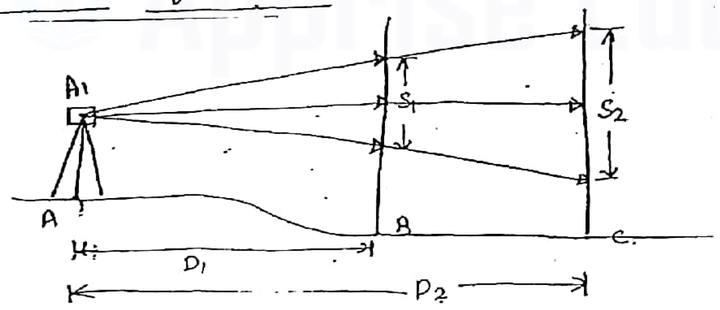
$$\tan B/2 = \frac{S/2}{100S} = \frac{1}{200}$$

$$B/2 = \tan^{-1}\left(\frac{1}{200}\right) = 0°17'11.32"$$

$$\beta = 2 \times 0° \times 17' 11.32" = 0°34'22.63"$$

For anallactic telescope.

Determination of k and c :-



The staff readings are taken at 2 location of known distances from instrument say D_1 & D_2.

S_1 & staff Intercept —

at B = S_1

at C = S_2

$$D_1 = k \cdot S_1 + C \quad \text{—— (I)}$$

$$D_2 = k \cdot S_2 + C \quad \text{—— (II)}$$

Solve for k & c

(II) - (I)

$$k = \frac{(D_2 - D_1)}{(S_2 - S_1)} \quad \text{— (A)}$$

$$C = D_1 - kS_1$$

$$C = D_1 - \frac{(D_2 - D_1)}{(S_2 - S_1)} \times S_1$$

$$= \frac{D_1 S_2 - D_1 S_1 - D_2 S_1 + D_1 S_1}{S_2 - S_1}$$

$$\boxed{C = \frac{D_1 S_2 - D_2 S_1}{S_2 - S_1}} \quad \text{— (B)}$$

Ques: ① S_1 & staff readings taken on B & C are —

	Distance	Stadia Readings		
B	120	1.23	1.81	2.39
C	200	0.95	1.93	2.91

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⇒ Calculate K & C :

$D_1 = 120\,m$

$S_1 = 2.39 - 1.23$

$\boxed{S_1 = 1.16}$

$D_1 = K \times S_1 + C$

$120 = K \cdot 1.16 + C$ —— ①

$D_2 = 200\,m$

$S_2 = 2.91 - 0.95$

$\boxed{S_2 = 1.96}$

$D_2 = K \cdot S_2 + C$

$200 = K \times 1.96 + C$ — ②

② − ①

$200 - 120 = K(1.96 - 1.16)$

$K = \frac{80}{0.80} = 100$

$C = 120 - K \cdot S_1$

$C = 120 - 100 \times 1.16$

$\boxed{C = 4}$

Staff Readings :- 1 on angle of elevation or angle of depression.

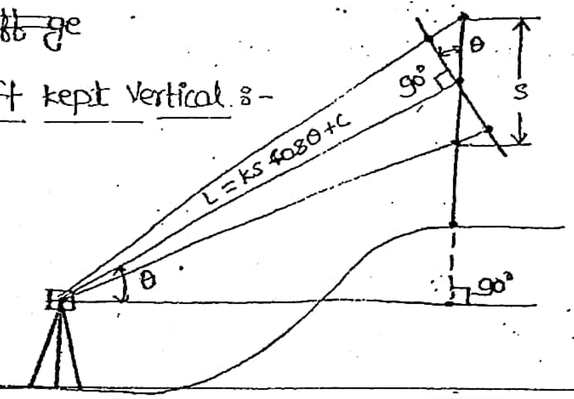
Vertical staff

staff kept Normal

(⊥cular to line of sight)

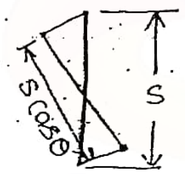
~~(1) Staff ge~~

(1) Staff kept Vertical :-



Inclined length

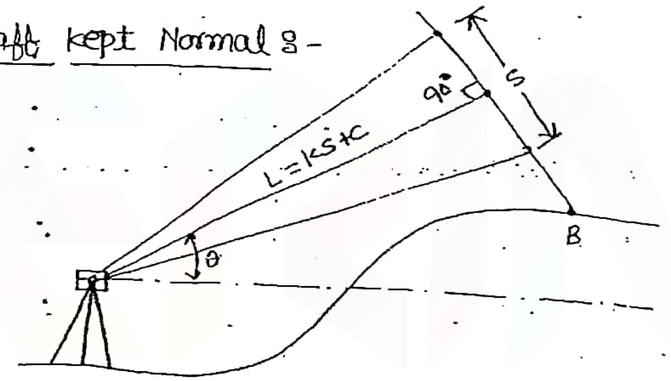
$L = KS\cos\theta + C$



Staff intercept ⊥cular to line of sight = $S\cos\theta$

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

(2) Staff kept Normal :-



In this case the staff is kept inclined (⊥cular to line of sight) The inclined distance from instrument to central reading of staff.

$\boxed{L = KS + C}$

S = staff intercept.

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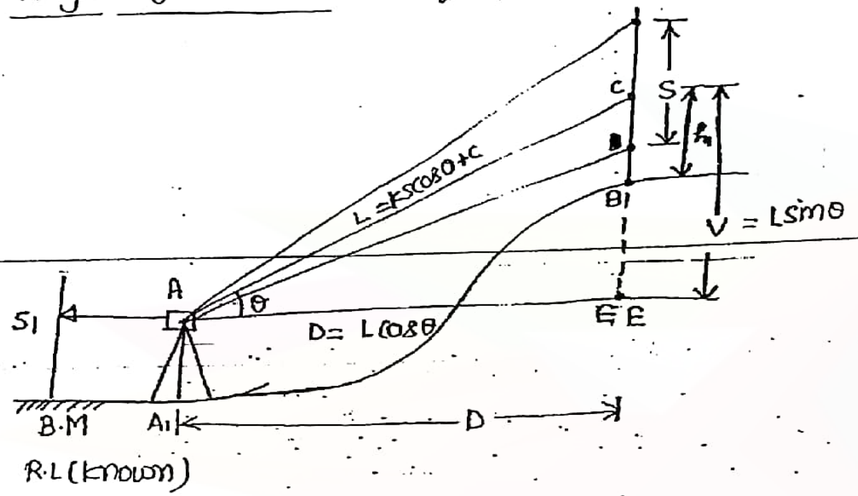
There are four cases :

(1) Angle of Elevation (staff kept vertical)



Staff Intercept = S

Inclined length . $L = KS\cos\theta + C$

(i) For Horizontal distance ,

$$D = L\cos\theta$$

$$= (KS\cos\theta + C)\cdot\cos\theta$$

$$\therefore \boxed{D = K\cdot S\cos^2\theta + C\cos\theta} \text{ — (A)}$$

(ii) Vertical Height :-

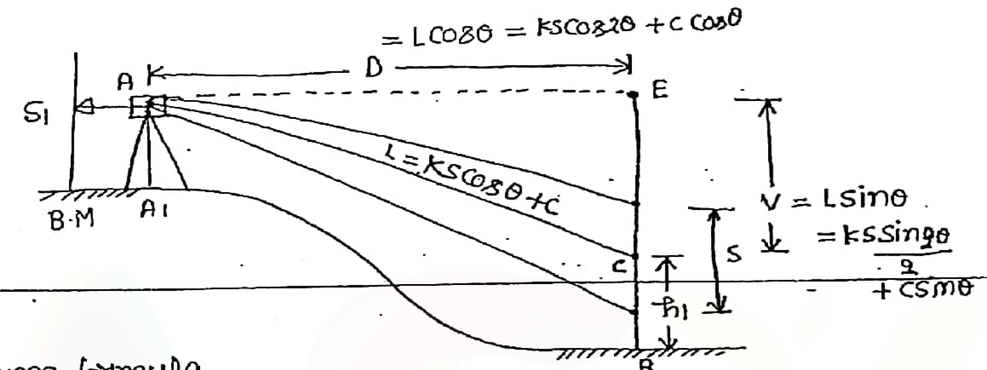
$$V = L\sin\theta = (KS\cos\theta + C)\sin\theta$$

$$= \frac{KS\sin 2\theta}{2} + C\sin\theta$$

$$\boxed{V = KS\frac{\sin 2\theta}{2} + C\sin\theta} \text{ — (B)}$$

R.L. of B_1 = R.L of B.M + S_1 + V − h_1 + $C_{combined}$

(2) Angle of Depression : (Staff is kept vertical).



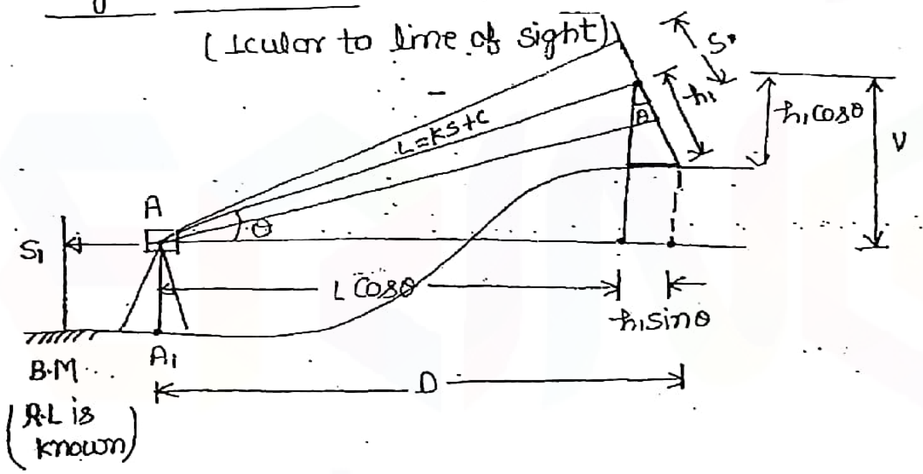
⇒ Same formula.

⇒ R.L. of B ⇒

= R.L. of B.M + S_1 − V − h_1 + $C_{combined}$.

3) Angle of Elevation :- (Staff kept Normal)

(⊥cular to line of sight)



Staff Intercept = S

Inclined length

$$L = KS + C$$

(i) Horizontal Distance -

$$D = L\cos\theta + h_1\sin\theta$$

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$$\boxed{D = (KS+C)\cos\theta + h_i \sin\theta} \quad -(A)$$

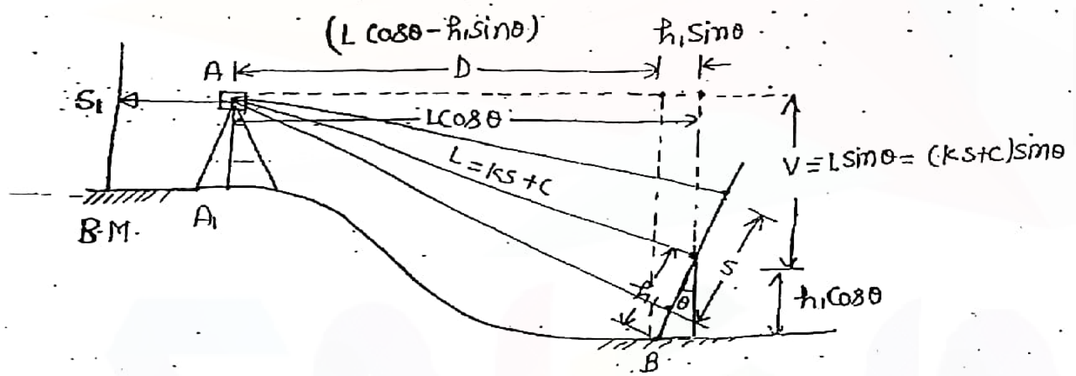
(2) Vertical Ht. :-

$$V = L\sin\theta$$

$$\boxed{V = (KS+C)\sin\theta} \quad -(B)$$

(3) R.L. of B = R.L. of B.M + S_1 + V − $h_i\cos\theta$ + Combined

(4) Angle of depression (staff is kept Normal)



Staff Intercept = S

Inclined length

$$L = KS + C$$

(i) Horizontal distance:

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

$$\boxed{D = (KS+C)\cos\theta - h_i \sin\theta}$$

(ii) Vertical height:

$$V = L\sin\theta$$

$$\boxed{V = (KS+C)\sin\theta}$$

R.L. of B = R.L. of BM + S_1 − V_1 − $h_i\cos\theta$ + Combined.

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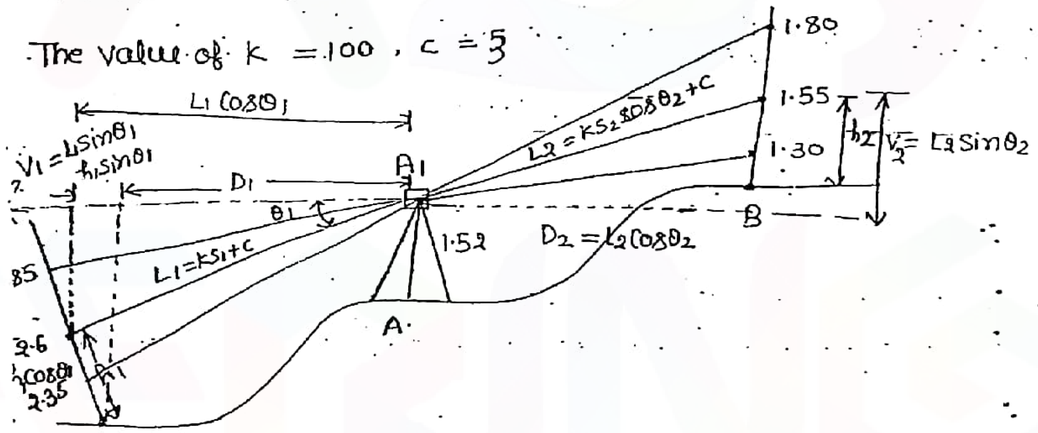
Ques (1) From a tacheometer set up at station 'A' readings were taken on a B.M. M, and another station B.

Reading from	Staff Reading at	Staff Position	Angle	Stadia Reading
(A)	BM (M)	Inclined (normal to L.O.S)	−15°	2.35, 2.6, 2.85
	B	Vertical	+20°	1.30, 1.55, 1.80

If R.L. of B.M (M = 200.00 m. Find out the R.L. of A & B and distance of BM and B from A H.I. at A = 1.52m.

The value of K = 100, C = 5



Staff intercept = S_1 = 0.5

⇒ from A to B.M

Inclined length (staff is normal to L.O.S)

$$L_1 = KS_1 + C$$

$$S_1 = 0.5$$

$$\therefore L = 100 \times 0.5 + 5$$

$$\boxed{L = 55\text{m}}$$

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Horizontal distance :-

$\Rightarrow D_1 = L_1 \cos\theta_1 - h_1 \sin\theta_1$

$D_1 = 53 \cos 15° - 2.60 \times \sin 15°$

$\boxed{D_1 = 50.52 m}$

Vertical ht :-

$V_1 = L_1 \sin\theta_1$

$= 53 \sin 15°$

$\boxed{V_1 = 15.72 m}$

R.L of A

$= R.L \text{ of } B.M + h_1 \cos\theta_1 + V_1 - 1.52$

$= 200 + 2.6 \cos 15° + 13.72 - 1.52$

$= 214.71 m$

From A to B :-

Staff intercept $S_2 = 1.8 - 1.3$

$= 0.5 m$.

Inclined length :-

$L_2 = k \cdot S_2 \cos\theta_2 + C$

$= 100 \times 0.5 \times \cos 20 + 3$

$\boxed{L_2 = 49.98 m}$

Vertical ht :

$V_2 = L_2 \sin\theta_2$

$= 49.98 \cdot \sin 20°$

$\boxed{V_2 = 17.10 m}$

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horizontal distance :-

$D_2 = A \text{ to } B = L_2 \cos\theta_2$

$= 49.98 \times \cos 20$

$\boxed{D_2 = 46.97 m}$

R.L of B

$= R.L \text{ of } A + 1.52 + V_2 - h_2$

$= 214.71 + 1.52 + 17.10 - 1.55$

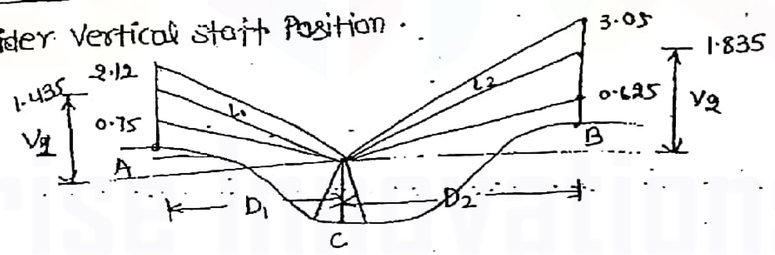
$= 231.78 m$.

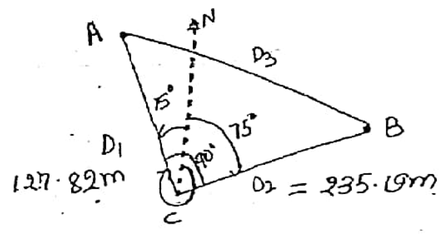
Ques:(2) 2(d) ES-2012 Determine the gradient from A to B from the following observations made with a fixed hair tacheometer fitted with anallactic lense of $k = 100$

Reading	Bearing	Reading on stadia hair		Reading on axial hair	Vertical angle
to A	345°	0.75	2.12	1.435	+15°
to B	75°	0.625	3.05	1.835	+10°

Consider Vertical staff Position.

Soln :-





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① From C to A

Staff intercept

$S_1 = 2.12 - 0.75 = 1.37\,m$

inclined length

$L_1 = K \cdot S_1 \cos\theta_1 + C$

$= 100 \times 1.37 \times \cos 15° + 0$

$= 132.33\,m$

Horizontal Distance :

$D_1 = L_1 \cos\theta_1 = 132.33 \cos 15°$

$D_1 = 127.82\,m$

Vertical Height :

$V_1 = L_1 \sin\theta_1 = 132.33 \times \sin 15°$

$V_1 = 34.25\,m$

∴ R.L. of C = x

H.I of C = y

R.L of A

$= x + y + V_1 - h_1$

$= x + y + 34.25 - 1.435$

$= x + y + 32.815$

② From C to B

Staff intercept

$S_2 = 3.05 - 0.625$

$= 2.425\,m$

Inclined length

$L_2 = K \cdot S_2 \cos\theta_2 + C$

$= 100 \times 2.425 \cos 10° + 0$

$L_2 = 238.82\,m$

Horizontal distance

$D_2 = L_2 \cos\theta_2$

$= 238.82 \cos 10°$

$D_2 = 235.19\,m$

Vertical Ht :

$V_2 = L_2 \sin\theta_2$

$= 238.82 \times \sin 10$

$V_2 = 41.47\,m$

R.L of B $= x + y + V_2 - h_2$

$= x + y + 41.47 - 1.835$

$= x + y + 39.635\,m$

③ Difference of R.L from A to B

$= R.L.\ B - R.L.\ A$

$= x + y + 39.635 - x - y - 32.815$

$= 6.82\,m$ (B is higher)

In Horizontal angle ΔABC

$\angle C = 75° + (360 - 345°)$

$= 90°$

$D_3 = \sqrt{D_1^2 + D_2^2} = \sqrt{(127.82)^2 + (235.19)^2}$

$D_3 = 267.68\,m$

gradient from A to B

$= \frac{\text{difference of R.L}}{\text{Horizontal distane}} = \frac{6.82}{267.68} = \frac{1}{39.25}$ (upward)



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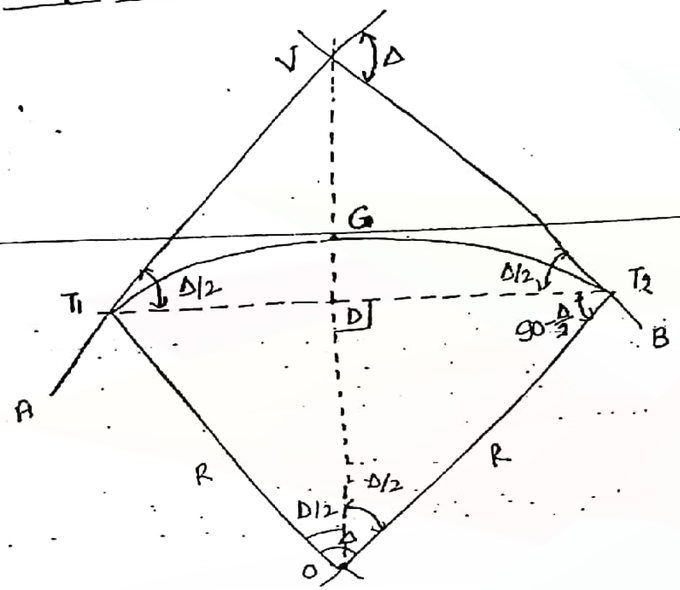
CURVE

(1) Simple Curve :-



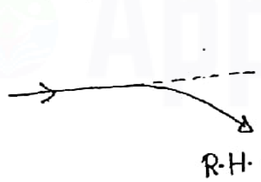
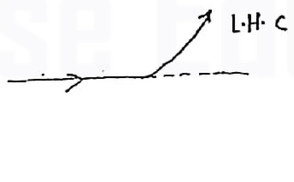
Important terms :-

(1) Point of Intersection (V point)

(2) Total deflection Angle (Δ)

(3) Point of curve (T_1) P.C.
Point of tangency (T_2) P.T

(4)

Right hand curve	Left-Hand Curve
	

(5) Forward tangent (T_2B)
Backward tangent (T_1A) | for curve from A to B.

(6) Tangent length

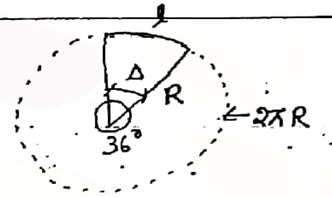
$VT_1 = VT_2 = R \cdot \tan\frac{\Delta}{2}$ | In ΔOT_1V, $\tan\frac{\Delta}{2} = \frac{VT_1}{R}$

(7) Length of curve (curve length T_1CT_2)

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

$$\boxed{l = \frac{2\pi R}{360} \times \Delta^\circ}$$

∴ length of curve.



(8) Apex Distance (VC)

$VC = OV - OG$

$\left[\cos\frac{\Delta}{2} = \frac{R}{OV} \;||\; OV = \frac{R}{\cos\Delta/2} = R\cdot\sec\frac{\Delta}{2}\right]$

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

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

(9) Midordinate (CD)

$CD = OC - OD$

$= R - R\cdot\cos\frac{\Delta}{2}$

$CD = R\left(1 - \cos\frac{\Delta}{2}\right)$

(10) Long chord (T_1DT_2) :-

$= 2T_1D$

$= 2\cdot R\cdot\sin\frac{\Delta}{2}$

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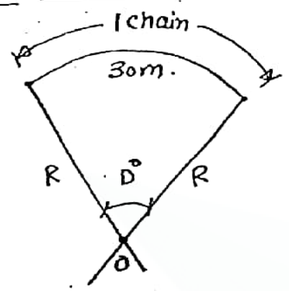
(ii) Degree of curve (D°) and Radius of curve (R) :-

Angle made by one chain length of curve at centre is called degree of curve.



(i) For a 30m chain length

$$\frac{30m}{D^\circ} = \frac{2\pi R}{360^\circ}$$

$$D^\circ = \frac{360 \times 30}{2\pi R} = \frac{1718.9}{R}$$

$$\boxed{D^\circ \simeq \frac{1720}{R}}$$

Radius of curve

$$\boxed{R = \frac{1720}{D^\circ}}$$

(ii) For a 20m chain

$$\frac{20m}{D^\circ} = \frac{2\pi R}{360}$$

$$R = \frac{360 \times 20}{2\pi D^\circ} = \frac{1146}{D^\circ}$$

$$\boxed{D^\circ = \frac{1146}{R}} \quad \text{or} \quad \boxed{\frac{1146}{D^\circ} = R}$$

Radius of curve :-

D°	1°	2°	3°	4°	5°
30m	1720m	860 m	573m	430 m	344 m
20m	1146m	573 m	382 m	287 m	230 m.

(12) Chainage of different Points :-

If chainage of V = given

(i) chainage of T_1 = Chainage of V − VT_1

where $(VT_1 = R \cdot \tan\frac{\Delta}{2})$

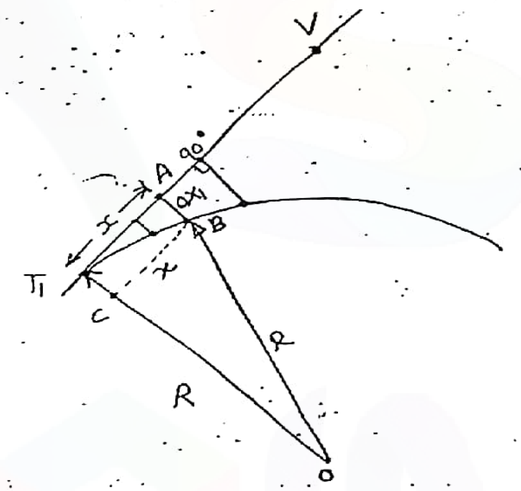
(ii) chainage of T_2 = chainage of $T_1 + l$

where $\left(l = \frac{2\pi R}{360^\circ} \times \Delta^\circ\right)$

(13) Setting out of a simple Curve :-

(A) offset Method

(1) Perpendicular offset from the tangent :-



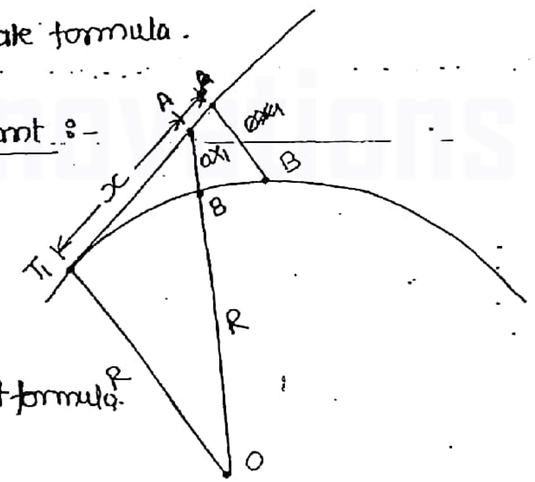
$ox_1 = AB = TC$

$= OT_1 - OC$

$$\boxed{ox_1 = R - \sqrt{R^2 - x^2}} \rightarrow \text{exact formula.}$$

$$\boxed{ox_1 = \frac{x^2}{2R}} \quad \text{Approximate formula.}$$

(2) Radial offset from the tangent :-



Radial at x distance from T_1

$ox_1 = AB$

$= OA - OB$

$$\boxed{ox_1 = \sqrt{R^2 + x^2} - R} \quad \text{exact formula.}$$

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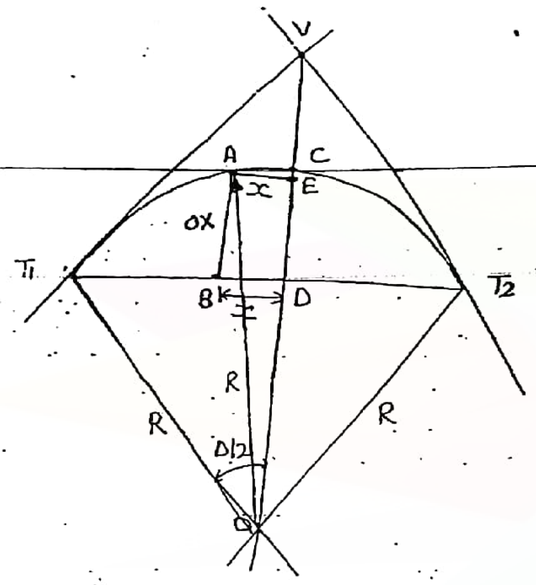
$\boxed{OX_1 = \frac{x^2}{2R}}$ — approximate formula.

(3) offset from long chord :-



At distance x from D point

$OX = AB$

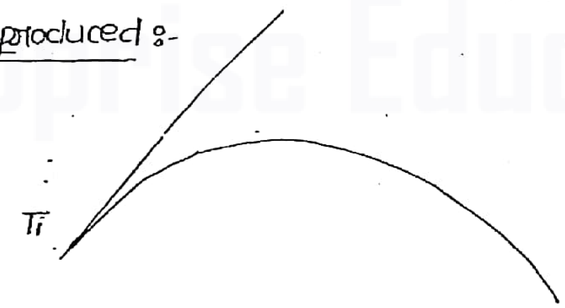
$= ED$

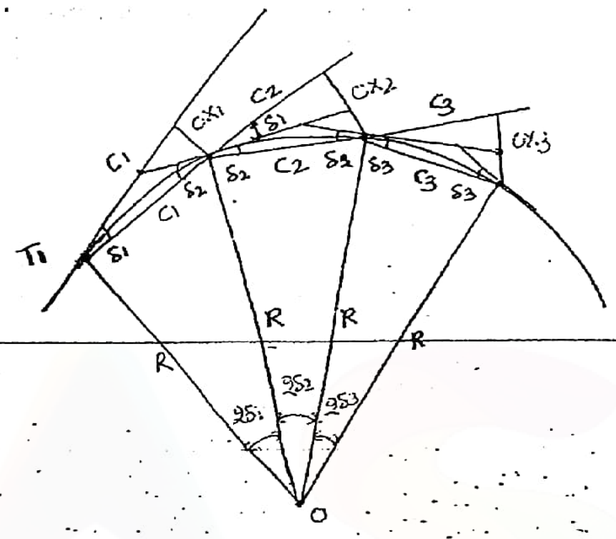
$= OE - OD$

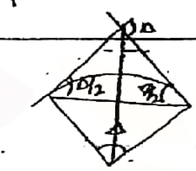
$= \sqrt{R^2 - x^2} - R\cos\frac{\Delta}{2}$

$$\boxed{OX = \sqrt{R^2 - x^2} - R\cos\frac{\Delta}{2}} \quad \text{— (A)}$$

(B) offset from chord produced :-







$\frac{C_1}{2\pi R} = \frac{2\delta_1}{360^\circ}$



$2\delta_1 = \frac{C_1 \times 360^\circ}{2\pi R} = \frac{C_1}{R} \times \frac{180}{\pi}$ degree.

$\boxed{2\delta_1 = \frac{C_1}{R}}$ Rad.

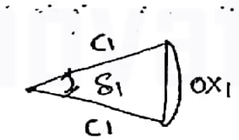
$\delta_1 = \frac{C_1}{2R}$

$\delta_2 = \frac{C_2}{2R}$

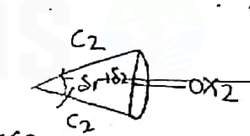
- - - -

$\delta_n = \frac{C_n}{2R}$

$OX_1 = C_1 \cdot \delta_1$



$$\boxed{OX_1 = C_1 \cdot \frac{C_1}{2R} = \frac{C_1^2}{2R}}$$



$OX_2 = C_2 \times (\delta_1 + \delta_2)$

$= C_2\left(\frac{C_1}{2R} + \frac{C_2}{2R}\right)$

$$\boxed{OX_2 = \frac{C_2(C_1 + C_2)}{2R}}$$

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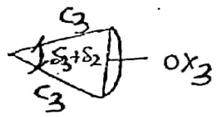
$$OX_3 = C_3(\delta_2+\delta_3)$$

$$\boxed{OX_3 = \frac{C_3(C_2+C_3)}{2R}}$$



$$\therefore \quad \boxed{OXn = \frac{Cn(Cn-1+Cn)}{2R}}$$

⇒ Generally, Ist and last chord will be of different length

C_1 & C_n are different

⇒ All other chord are of same length = 1 chain

$$\boxed{C_2 = C_3 = C_4 \text{ ---- } C_{n-1} = C = 1 \text{ chain}}$$

Final offset :

$$OX_1 = \frac{C_1^2}{2R}$$

$$OX_2 = \frac{C_2(C_2+C_1)}{2R} = \frac{C(C+C_1)}{2R}$$

$$OX_3 = OX_4 \text{ ------ } OX_{n-1}$$

$$= \frac{C_r(C_{r+1}+C_r)}{2R} = \frac{(C+C)C}{2R}$$

$$= \frac{2C^2}{2R} = \frac{C^2}{R}$$

$$OXn = \frac{Cn(Cn-1+Cn)}{R}$$

$$\boxed{OXn = \frac{Cn(C+Cn)}{2R}}$$

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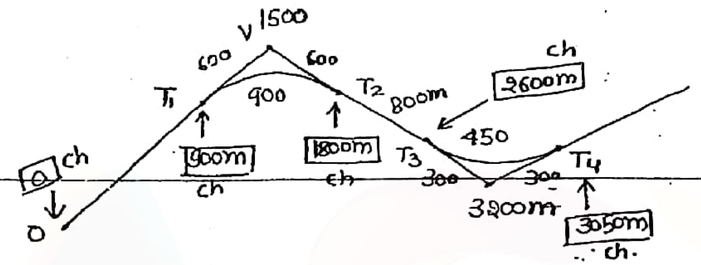
⑪ chainage of different points :-

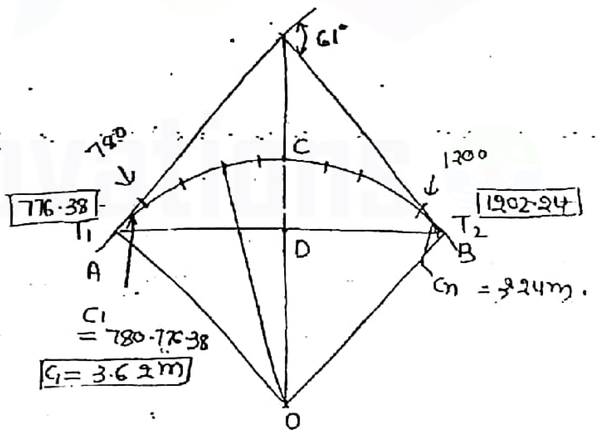


⇒ chainage is the distance measured along the route followed.

Ques:(1) Two tangents intersect at a chainage 50·60 (50 chains + 60 links), the deflection angle being 61°. Calculate he necessary data to set out a circular highway curve of 20 chain radius to connect the two tangent by the method of offset from chords. Take 20m. chain length (100 links)

radius of curve = 20 chain
= 20×20
= 400m.

chainage of V
= 50·60 chain
= 50 chains + 60 link
= 50×20 + 60×20/100
= 1012m.



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tangant length:

$VT_1 = VT_2 = R \cdot \tan\frac{\Delta}{2}$

$= 400 \times \tan\frac{61}{2}$

$= 235.62\,m$

Length of curve :

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

$= \frac{2 \times \pi \times 400}{360} \times 61^\circ$

$\boxed{l = 425.80\,m}$

chainage of T_1 :-

$= ch.\ V - VT_1$

$= 1012 - 235.62$

$= 776.38\,m$

chainage of T_2 :-

= chainage of T_1 + l

$= 776.38 + 425.80$

$= 1202.24\,m$

Exact Multiple of 20m just after $T_1 = 780m$

I^{st} chord $= C_1 = 780 - Ch.\ of\ T_1$

$= 780 - 776.38$

$= 3.62\,m$

Exact Multiple of 20m just before $T_2 = 1200\,m$

last chord $C_n = Ch.\ T_2 - 1206$

$= 2.24\,m$

All other chords

$C_3 = C_3 = \text{------} C_{n-1} = C = 20m$

$= 1\,chain$

offsets :-

$OX_1 = \frac{C_1^2}{2R} = \frac{3.62^2}{2 \times 400} = 0.016\,m$

$OX_2 = \frac{C(C_1+C)}{2R} = \frac{20(3.62+20)}{2 \times 400} = 0.59\,m$

OX_3 ------ OX_{n-1}

$= \frac{C^2}{R} = \frac{20^2}{400} = 1m$

$OX_n = \frac{C_n(C_n+C)}{2R}$

$= \frac{2.24 \times (20+2.24)}{800}$

$= 0.06\,m$

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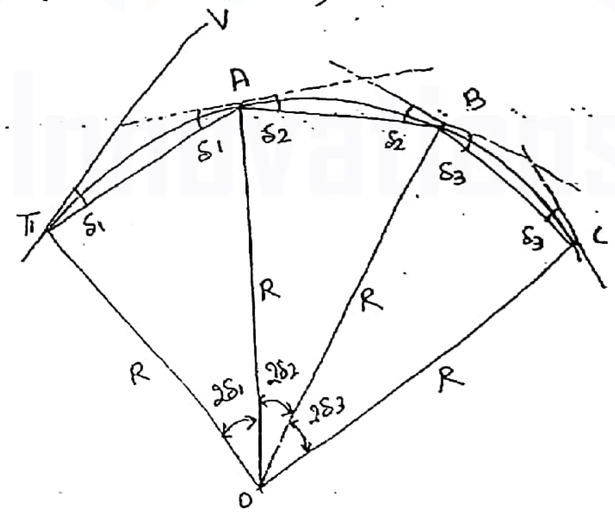
Setting out of Simple Curve :-

c) Deflection Method (Rankine Method)



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$$\frac{C_1}{2\pi R} = \frac{2\delta_1}{360^\circ}$$

$$\delta_1 = \frac{360\, C_1}{4\pi R} = \frac{90\, C_1}{\pi R} \quad \text{—①}$$

Similary,

$$\delta_2 = \frac{90\, C_2}{\pi R}$$

$$\delta_3 = \frac{90\, C_3}{\pi R}$$

- - - - - - -

$$\delta_n = \frac{90\, C_n}{\pi R}$$

Total deflection angle for different point.

— Total deflection angle is the angle b/w I^{st} tangent and the line joining T_1 point to the point.

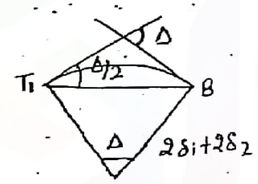
for A $\Rightarrow$ $\Delta_1 = \delta_1$

for B $\Rightarrow$ $\Delta_2 = \delta_1 + \delta_2 = \Delta_1 + \delta_2$

for C $\Rightarrow$ $\Delta_3 = \delta_1 + \delta_2 + \delta_3 = \Delta_2 + \delta_3$

- - - - -

- - - - -



for any point $\Delta = \Delta_{n-1} + \delta_n$

There are two methods:-

1) One theodalite Method.

2) Two theodalite Method.

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Ques: 6(b) ES-1990 Two tangent intersect at chainage 1200 m, the deflection angle being 40°. Compute the data to set out a simple curve of radius 400m by defl^n angle & offsets. take 30 m chord length in the general bridge. (one theodolite).

Solution: $R = 400m$.

$\Delta = 40^\circ$

chainage $= 1200m = V$

tangent length —

$$VT_1 = VT_2 = R\tan\frac{\Delta}{2}$$

$$= 400 \times \tan\frac{40}{2}$$

$$= 145.58m.$$

Length of curve —

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

$$l = 279.25m$$

chainage of T_1:

ch. of $V - VT_1$

$= 1200 - 145.59$

$= 1054.41$ m

chainage of T_2

ch. of $T_1 + l$

$= 1054.41 + 279.25$

$= 1333.66$ m.

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C_1 chainage T_1 = 1054.41 m

Just after T_1 exact multiple of 30 = 1080 m

$C_1 = 1080 - 1054.41$

$\boxed{C_1 = 25.59\ m}$

C_n chainage T_2 = 1333.66 m

Just before T_2 exact multiple of 30 m = 1320 m.

$C_n = 1333.66 - 1320$

$= 13.66\ m$

deflection angle →

$$\delta_1 = \frac{90 C_1}{\pi R} = \frac{90 \times 25.59}{\pi \times 400}$$

$$= 1^\circ 49' 58''$$

$$\delta_2 = \delta_3 = \delta_4 \text{ ------ } \delta_{n-1}$$

$$= \frac{90 \times C}{\pi R} = \frac{90 \times 30}{\pi \times 400}$$

$$= 2^\circ 8' 55''$$

$$\delta_n = \frac{90 \times C_n}{\pi \times R} = \frac{90 \times 13.66}{\pi \times 400} = 0^\circ 58' 42''$$

Points	δ	Δ	
1	1°49'58'	1° 49'58"	
2	2°8'55'	3° 58'53"	
3	2°8'55'	6° 7' 48"	
4	---	8° 16' 43"	
5	---	10° 25' 38"	
6	---	12° 34' 33"	
7	---	14° 43' 28"	
8	---	16° 52' 23"	20°0'0"
9	---	19°1' 18"	
10	---		
11	0°58'42"		

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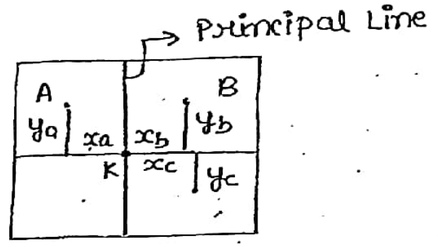
PHOTOGRAMMETRY



Photograph :-

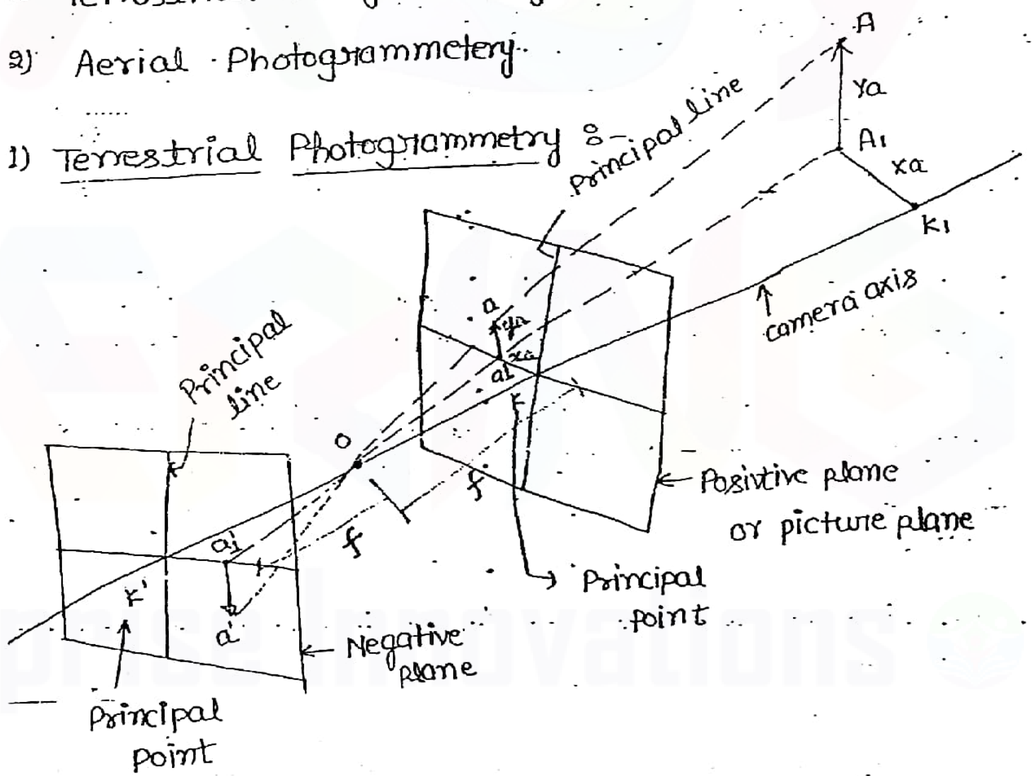
K = Principal point

Types :-

1) Terrestrial Photogrammetry

2) Aerial Photogrammetery

1) Terrestrial Photogrammetry :-



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Imp definitions :-

(A) Camera Axis : Line joining the principal points and focal point is called camera axis.

(B) Picture Plane : Positive photograph on which image are in same dir^n as of objects.

(C) Negative Plate : When the image is inverted.

(D) Focal length (f) Distance from focal point 'o' to principal point.

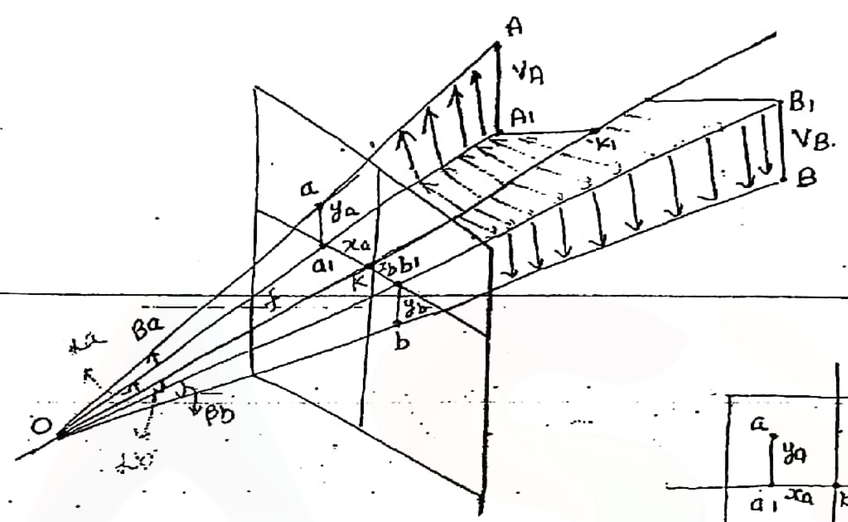
$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

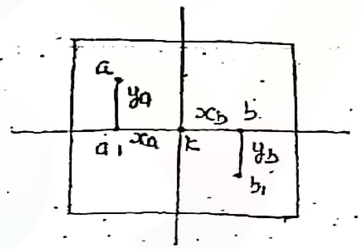
(E) Principal Points : Intersection of 2 axis drawn on the photograph. Intersection of camera axis and principal line.

(F) Principal Line : The vertical line passing from k of photograph.

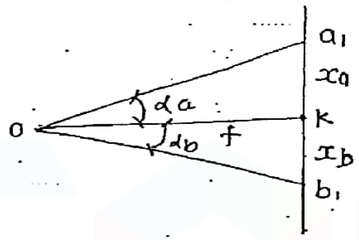
(G) Principal Plane : The line plane containing camera axis and principal line.

Horizontal and Vertical Angles from a Horizontal photograph :





In Horizontal triangle



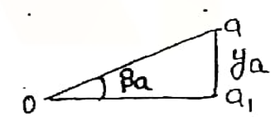
$$\tan \alpha_a = \frac{x_a}{f} \quad \text{—(I)}$$

$$\tan \alpha_b = \frac{x_b}{f} \quad \text{—(II)}$$

$$oa_1 = \sqrt{f^2 + x_a^2} = \frac{f}{\cos\alpha_a} = f\sec\alpha_a$$

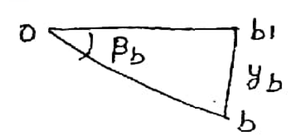
$$ob_1 = \sqrt{f^2 + x_b^2} = \frac{f}{\cos\alpha_b} = f\sec\alpha_b$$

In Vertical Triangle :



$$\tan\beta_a = \frac{y_a}{oa_1} = \frac{y_a}{\sqrt{f^2+x_a^2}} = \frac{y_a}{f\sec\alpha_a}$$

$$\tan\beta_b = \frac{y_b}{ob_1} = \frac{y_b}{\sqrt{f^2+x_b^2}} = \frac{y_b}{f\sec\alpha_b}$$



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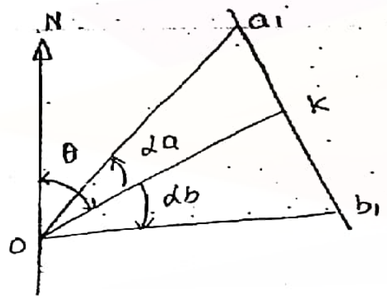
Height of ... of similarity

$$\frac{V_A}{y_a} = \frac{D_A}{oa_1}$$

$$\boxed{V_A = \frac{D_A y_a}{f \cdot \sec\alpha_a}}$$

Similarly

$$\boxed{V_B = \frac{D_B y_b}{f \cdot \sec\alpha_b}}$$



Bearing of Different lines

→ If bearing of $OK = \theta$

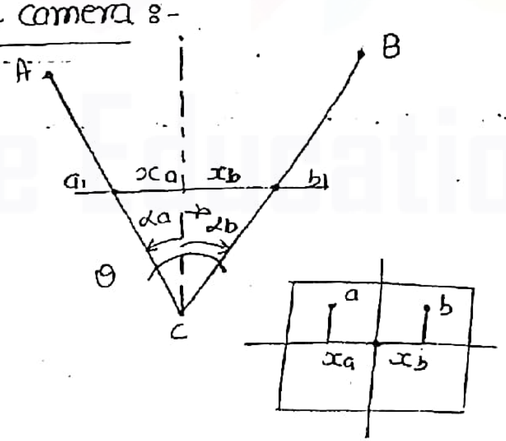
→ bearing of $OA = \theta - \alpha_a$

→ bearing of $OB = \theta + \alpha_b$

⊕ Determination of Focal Length of camera :-

→ Take a point on the ground. Measure total horizontal angle b/w A & B at a third point C.

→ Setup the camera at C and take photograph of A or B



→ measure x_a & x_b on the photograph.

$$\tan\alpha_a = \frac{x_a}{f}$$

$$\tan\alpha_b = \frac{x_b}{f}$$

$$\tan\theta = \tan(\alpha_a + \alpha_b)$$

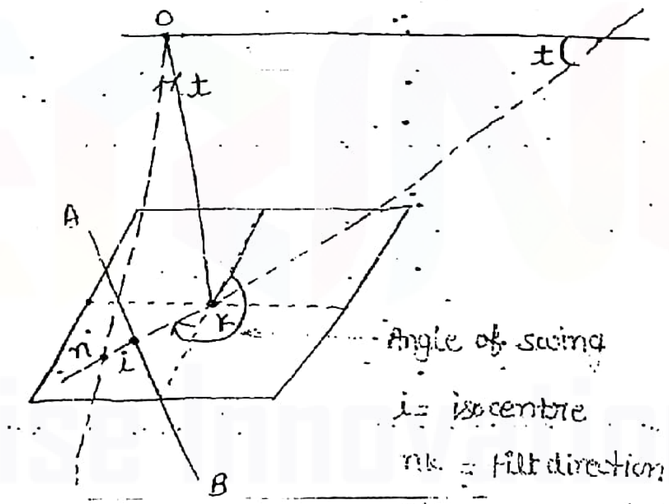
$$= \frac{\tan\alpha_a + \tan\alpha_b}{1 - \tan\alpha_a \cdot \tan\alpha_b}$$

$$= \frac{x_a/f + x_b/f}{1 - x_a/f \times x_b/f}$$

$$\boxed{\tan\theta = \frac{f(x_a + x_b)}{f^2 - x_a \cdot x_b}}$$

solve ⓕ.

(2) Aerial Photogrammetry :-



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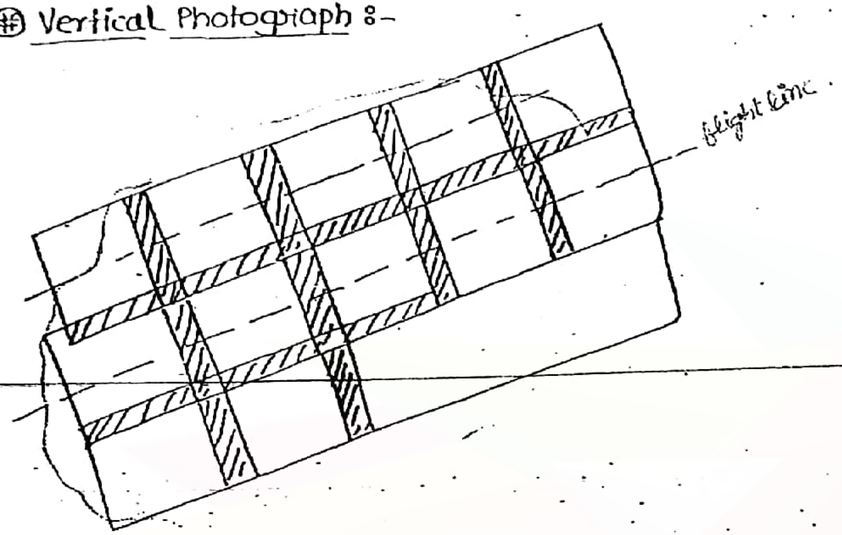
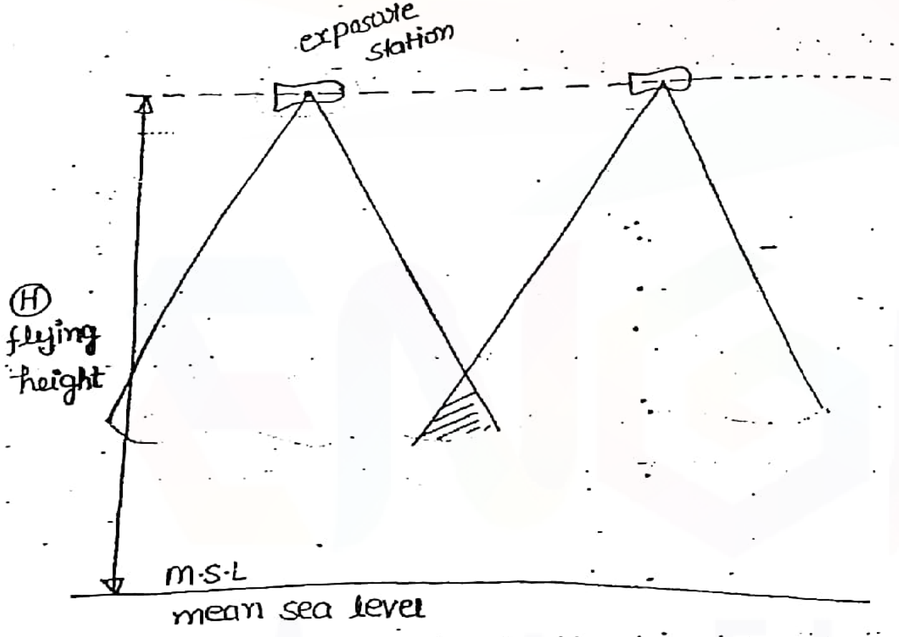
Vertical Photograph :-





Imp definition :-

(1) **Vertical photograph :** If camera axis is vertical.

(2) **Tilted photograph :** camera axis at an inclination.

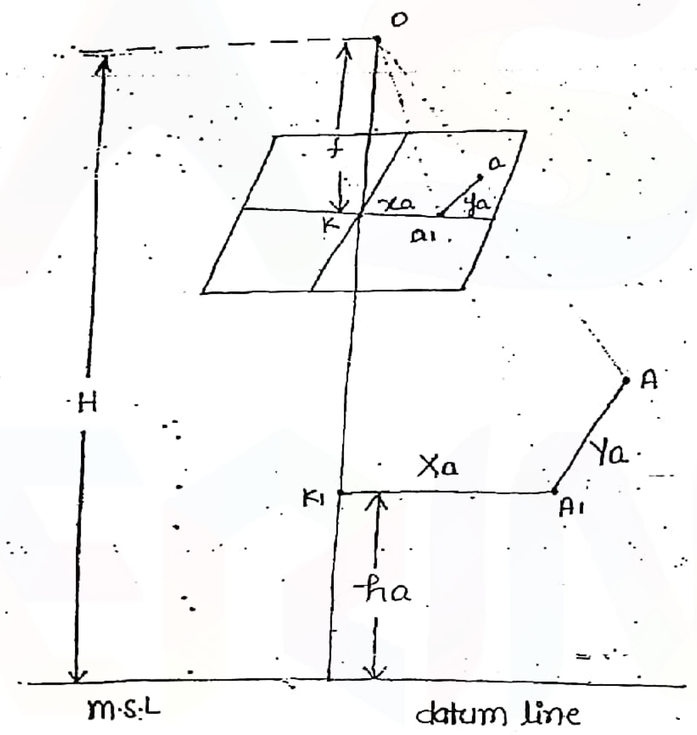
Terrestrial	High oblique :	If sky is visible in photograph.
	Low oblique :	If sky is not visible. (Horizon is not visible)

(3) **Exposure station :-** From where, the photograph have been taken.

(4) **Flying Height :** Ht. of camera from M.S.L

(5) **flight line :** Along which airplane will be flying.

scale of a Vertical Photograph :-



scale of photograph :

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

$$= \frac{xa}{Xa} = \frac{ya}{Ya}$$

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$OKa_1 \simeq OK_1A_1$

$$\frac{f}{H-h_a} = \frac{x_a}{X_a} = \frac{Oa_1}{OA_1}$$

In Δle :-

$Oa_1a \simeq OA_1A$

$$\frac{Oa_1}{OA_1} = \frac{y_a}{Y_a}$$

scale of photograph

$$= \frac{f}{H-h_a} = \frac{x_a}{X_a} = \frac{y_a}{Y_a}$$

Ground Distances

$$X_a = \left(\frac{H-h_a}{f}\right) x_a$$

$$Y_a = \left(\frac{H-h_a}{f}\right) y_a$$

Datum scale : $h_a = 0$

$$\boxed{\text{scale} = \frac{f}{H}}$$

Average scale : For an average ht $= h_{av}$

$$\boxed{\text{scale} = \frac{f}{H-h_{av}}}$$

Horizontal Distance b/w two points on the ground :

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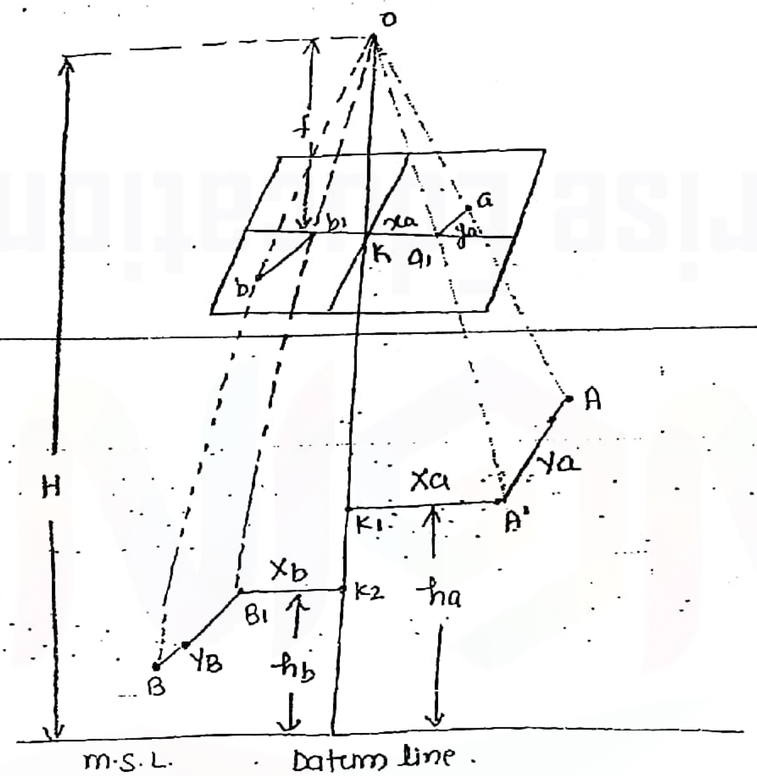

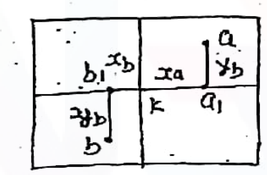

for point A

$$\frac{x_a}{X_a} = \frac{y_a}{Y_a} = \frac{f}{H-h_a}$$

for Point B

$$\frac{x_b}{X_b} = \frac{y_b}{Y_b} = \frac{f}{H-h_b}$$

Ground distances :

$$\boxed{X_a = \left(\frac{H-h_a}{f}\right) x_a \qquad Y_a = \left(\frac{H-h_a}{f}\right) y_a}$$

$$\boxed{X_b = \left(\frac{H-h_b}{f}\right) x_b \qquad Y_b = \left(\frac{H-h_b}{f}\right) y_b}$$

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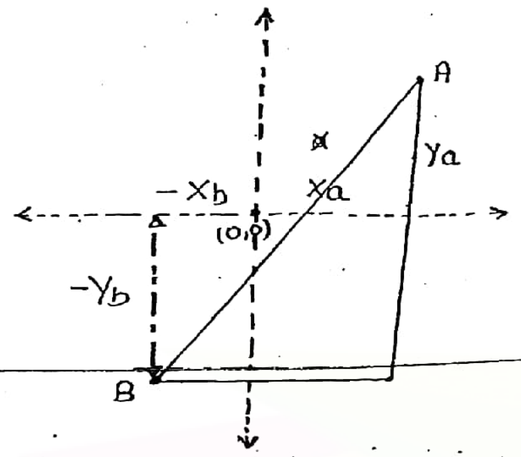
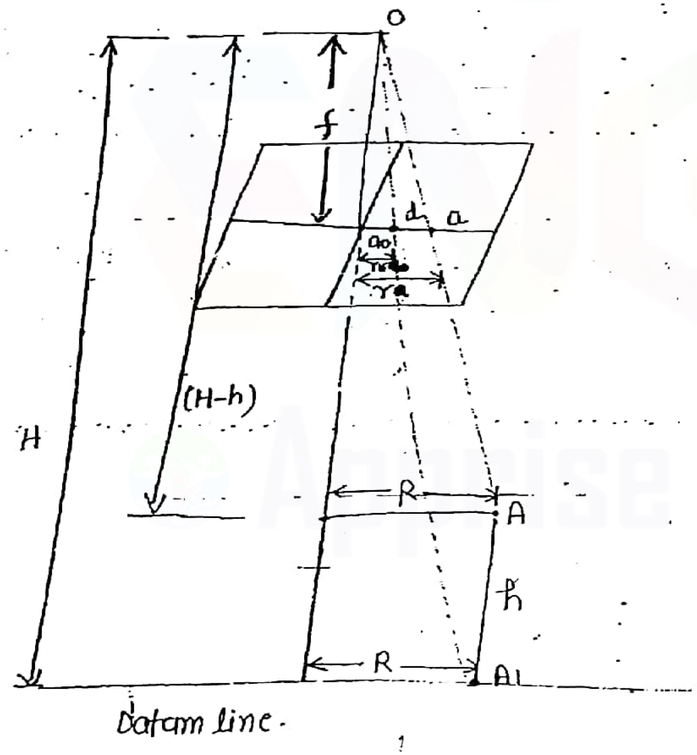


General Formula for Horizontal distance AB

$$AB = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2}$$

⑪ Relief Displacement :-



$a a_0 = d$

= Releif Displacement

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

$$r_0 = \frac{f \cdot R}{H} \quad \text{——} \quad (1)$$

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

$$r = \frac{R f}{(H-h)} \quad \text{——} \quad (2)$$

Relief Displacement

$$d = r - r_0$$

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

$$d = f \cdot R \left[\frac{H - H + h}{(H-h)H}\right] = f \cdot R \left[\frac{h}{(H-h)H}\right] = \frac{r \cdot h}{H}$$

$$\boxed{d = \frac{r \cdot h}{H}}$$ Relief Displacement

Ques ① A vertical photograph was taken from a ht of 1600 m above m.s.l. determine the scale of photograph for an area at average elevation of 250 m above m.s.l. Focal length of camera (f) is 15cm.

$H = 1600\ m$

$h_{av} = 250\ m$

$f = 15\ cm$

$= 0.15\ m$

Scale : $\frac{f}{H - h_{ave}} = \frac{0.15\ m}{1600 - 250} = \frac{1}{9000}$ scale of P.g.

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Ques: (2) A camera of focal length 20cm is used for a vertical photograph the average elevation of a terrain is 1800m. At what ht the aircraft should fly so that a scale of $\frac{1}{10000}$ can be obtained on the photograph.

$f = 0.2m$.

$h_{av} = 1800m$.

$H = ?$

$$\text{Scale} = \frac{1}{10,000} = \frac{f}{H - h_{av}}$$

$$H - h_{av} = f \times 10,000$$

$$= 0.2 \times 10,000$$

$$H = h_{av} + 2000$$

$$\boxed{H = 3800m}$$ Ans.

2(c)

Ques: (3) A section line AB 300m long on a flat terrain measures 102.4 mm on a vertical photograph a radio tower also appear on the photograph. The distance of bottom & top image of the radio tower from principal point is 7cm & 8cm respe. Average elevation of terrain is 553m. Determine the Ht. of tower. Focal length of camera (f) is 152.4mm.

ES: 2001

Solution: $f = 152.4mm$

Scale:

$$\frac{ab}{AB} = \frac{102.4mm}{300 \times 10^3 mm} = \frac{f}{H - h_{av}} = \frac{152.4 \times mm}{(H-553) \times 1000 mm}$$

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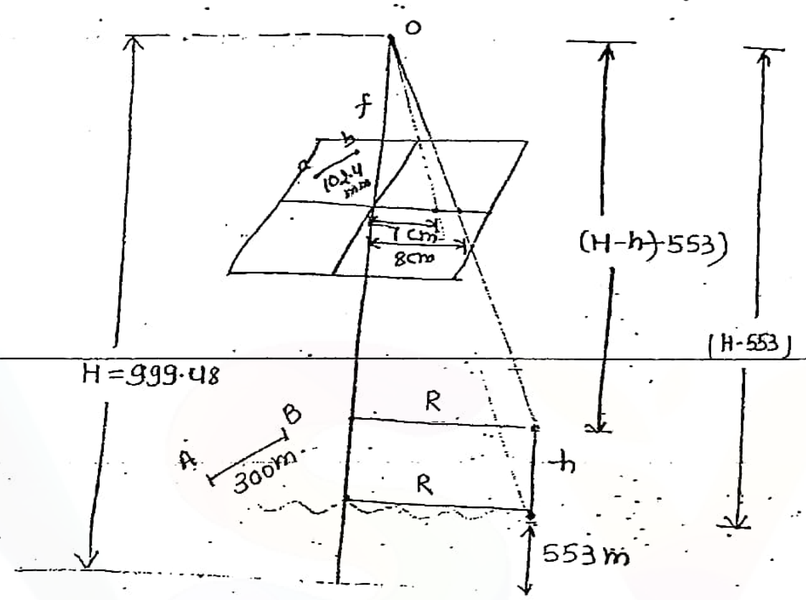

$$H = 553 + \frac{152.4}{102.4} \times 300$$

$$\boxed{H = 999.48m}$$

In Δgle :-

$$\frac{7cm}{R} = \frac{f}{(H-553)} \quad \text{— (i)}$$

$$\frac{8cm}{R} = \frac{f}{(H-553-h)} \quad \text{— (ii)}$$

$$7 \times (H-553) = 8\,(H-553-h)$$

$$7 \times (999.48 - 553) = 8(999.48 - 553 - h)$$

$$\boxed{h = 55.81m}$$

(OR)

$$d = \frac{rh}{(H-h_{av})} \Rightarrow h = \frac{d\,(H-h_{av})}{r} = \frac{1cm\,(999.48-553)}{8cm}$$

$$= \underline{55.81m}$$

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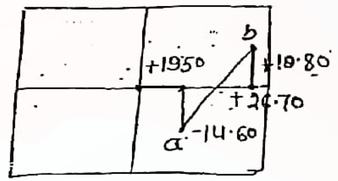
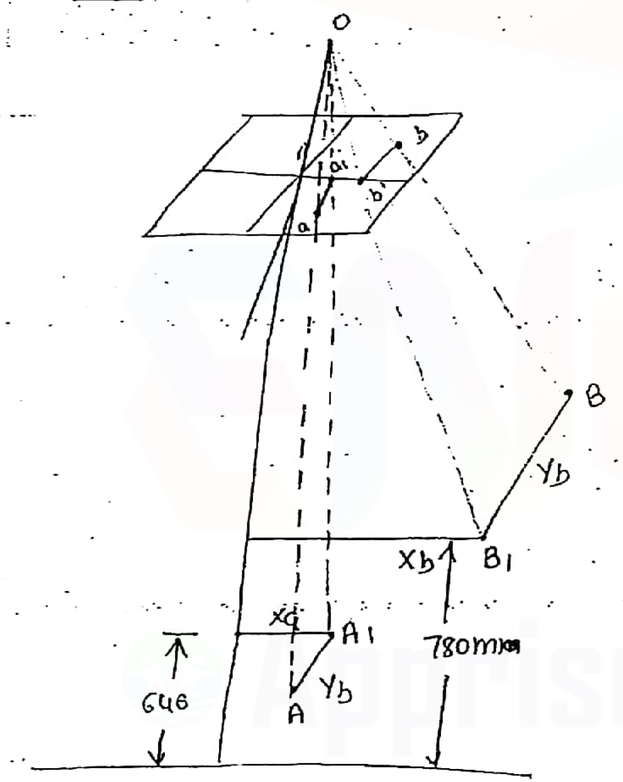
Ques 2(b) (ES: 1997) A vertical photograph was taken from a ht of 3200 m above m.s.l with a camera of focal length 120 mm. It contain 2 pt a & b corresponding to ground pt A & B.

Photo points	Elevation (m) above msl	Photo Co-ordinates x	y
a	640	+19.50	-14.60
b	780	+26.70	+10.80

Find out Horizontal length AB.

Soln:





Scale for Point A

$$x_a/X_a = \frac{y_a}{Y_a} = \frac{f}{H-h_a}$$

Scale for Point B

$$\frac{x_b}{X_b} = \frac{y_b}{Y_b} = \frac{f}{H-h_b}$$

$$X_a = \frac{H-h_a}{f} \times x_a = \frac{(3200-640)}{120} \times (+19.50) = (+)\,416.0$$

$$Y_a = \frac{H-h_a}{f} \times y_a = \frac{(3200-640)}{120} \times (-14.60) = (-)\,311.46$$

$$X_b = \frac{H-h_b}{f} \times x_b = \frac{(3200-780)}{120} \times (26.70) = (+)\,538.45$$

$$Y_b = \frac{H-h_b}{f} \cdot y_b = \left(\frac{3200-780}{120}\right) \times (+10.80) = (+)\,217.8$$

Horizontal Distance:

$$AB = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2}$$

$$= \sqrt{(416 - 538.45)^2 + (-311.46 - 217.8)^2}$$

$$AB = 543.24\text{m}.$$ Ans

Ques (5) 3 points A, B, & C where photograph on a horizontal photograph.

Point	x	y
A	-36.50	+25.50
B	+10.50	-20.20
C	+56.80	+30.10

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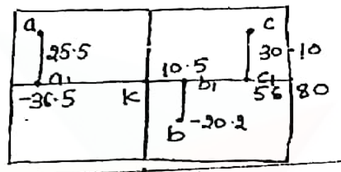
Focal length of camera is 125 mm. If bearing of line OA is 340° and hor. Distance of A from O is 216 m. Calculate the bearing of other lines and ht. of point A.

Solⁿ:-

$\tan\alpha_a = \frac{x_a}{f} = \frac{36.50}{125}$

$\boxed{\alpha_a = 16.27° = 16°16'40''}$

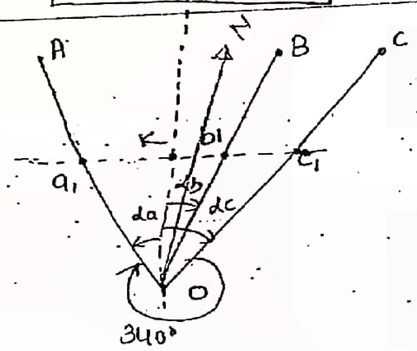


$\tan\alpha_b = \frac{x_b}{f} = \frac{10.50}{125}$

$\boxed{\alpha_b = 4°48'5''}$

$\tan\alpha_c = \frac{x_c}{f} = \frac{56.86}{125}$

$\boxed{\alpha_c = 24°26'13.37''}$



Bearing of OA = 340°

$+\ \alpha_a = 16°16'40''$

Bearing of OK = 356°16'40''

Bearing of OB

= Bearing of OK + α_b

= 356°16'40'' + 4°48'5'' − 360

= 1°4'45''

Bearing of OC

= Bearing of OK + α_c

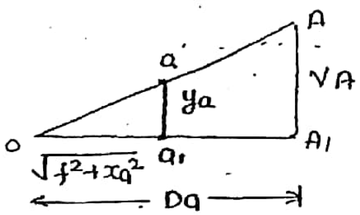
= 356°16'40'' + 24°26'13.37'' − 360°

= 20°42'53.37''

$V_A = \frac{y_a}{\sqrt{f^2+x_a^2}} \times 216\ m$

$= \frac{25.50}{\sqrt{125^2+36.5^2}} \times 216$

$\boxed{V_A = 42.30m}$



Ques:(6) The size of 1 vertical photograph is 30 cm × 20 cm.

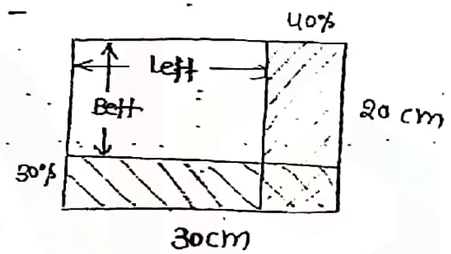
If longitudinal lap = 40%

side lap = 30%

Scale of photograph is 1 cm = 200 m.

Findout total no. of photograph required to cover a total area of 1200 km² on ground.

Solⁿ:



$L_{eff} = L \times \left(1 - \frac{W_L}{100}\right) = 30 \times \left(1 - \frac{40}{100}\right)$

$= 30 \times 0.6$

$L_{eff} = 18cm.$

$B_{eff} = B \times \left(1 - \frac{W_S}{100}\right) = 20\left(1 - \frac{30}{100}\right)$

$= 20 \times .70$

$B_{eff} = 14cm.$

Actual effective area covered on ground.

$= (18 \times 200) \times (14 \times 200)\ m^2$

$= 10080000/10^6\ km^2 = 10.08\ km^2$

Total N

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Total No required -

$= \frac{1200}{10.08} = 119.05$. (say 120 photography)

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ACCURACY & ERRORS

Important terms :-

(1) Precision : Degree of accuracy used in a measurement is called precision.

By using precision precise instrument, reading the values correctly, skilled manpower.

(2) Accuracy : Degree of accuracy obtained By

The measurement is more nearer to the correct value. It is called more accurate.

(3) True Value :- The exact correct value of a quantity.

(4) True error : The difference b/w exact correct value (True value) and measured value is called true error.

(5) Most probable Value :

The value that have more chances of being the correct value of a quantity is called MPV.

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(#) Sources of errors :-

(1) Instrumental : Due to faulty Instrument.

(2) Personal Error : Human error in reading or writing the measurement.

(3) Natural Error : Due to temp. difference, Humidity wind, local attraction, declination etc.

Types of Error :-

(1) Mistakes :- Mainly due to human error.

(+ve)/(-)ve . Value is not constant.

(2) Accumulative Error : same value and sign are repeated in this case. Always (+ve) or Always (-)ve.

Total error → Very large.

3) Compensating Error (Random Error) :

sign → (+)/(-) any.

Value → any value.

In case of Random Errors :-

Rule of probability is applicable.

It follows 2 rules —

1) small error are more frequent than large errors

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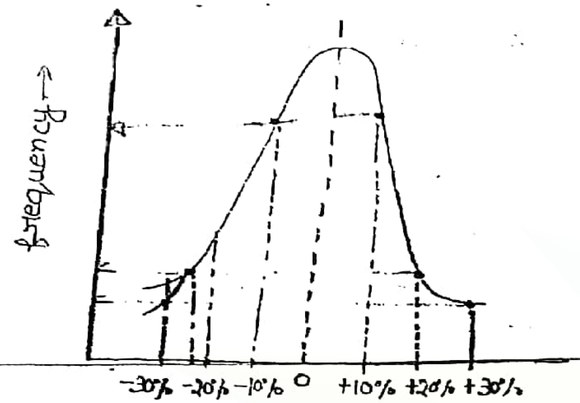

(2) (+ve) & (-ve) errors of same quantity have equal frequency.

Most Probable Value :

(#) Most Probable value can be found by using the principle of least squre.

→ The MPV is that value for which sum of squre of error is least.

Case(1). If all measurement have equal unit weight

$x_1, x_2, x_3 \text{ --- } x_n$.

are the measurement a quantity.

If x = Most probable value.

Error : $(x-x_1), (x-x_2), (x-x_3)$ - - - - - - .

Sum of squre of Errors :-

$$y = (x-x_1)^2 + (x-x_2)^2 + \text{-----} + (x-x_n)^2$$

$$\frac{dy}{dx} = 2(x-x_1) + 2(x-x_2) + \text{ - - - } 2(x-x_n).$$

$$nx - (x_1+x_2+x_3+\text{ - - - }) = 0$$

$$\boxed{x = \frac{x_1+x_2+x_3+\text{ - - - }x_n}{n} = \text{Mean} = \text{MPV}}$$

Case:2 :- When the measurements have different wts :-

Measurement	weight	MPV	Errors	Squre of error
x_1	w_1		$(x-x_1)$	$(x-x_1)^2$
x_2	w_2		$(x-x_2)$	$(x-x_2)^2$
x_3	w_3	(x)	$(x-x_3)$	$(x-x_3)^2$
⋮	⋮		⋮	⋮
x_n	w_n		$(x-x_n)$	$(x-x_n)^2$

sum of squre of Error
$w_1(x-x_1)^2$
$w_2(x-x_2)^2$
$w_3(x-x_3)^2$
⋮
$w_n(x-x_n)^2$

$$y = w_1(x-x_1)^2 + w_2(x-x_2)^2 \text{ - - - } w_n(x-x_n)^2$$

= least.

$$\frac{dy}{dx} = 2w_1(x-x_1) + 2w_2(x-x_2) + \text{ - - - } 2w_n(x-x_n)$$

$= 0$

$$x = \frac{w_1x_1 + w_2x_2 + \text{ - - - } w_nx_n}{(w_1+w_2+\text{ - - - }w_n)}.$$

x = weighted average value

x = MPV (most probable value)

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Theory of Weights :-

weight of a measurement show the probable accuracy of the measurement.

Ex: (1) if $x_1 - w_1$, $x_2 - w_2$, ..., $x_n \Rightarrow w_n$ | weight of mean | weighted average mean $= \Sigma w$

(2) A & B are two measurements.

$A - w_1$, $B - w_2$ | weight of $(A+B) = \dfrac{1}{\left(\frac{1}{w_1} + \frac{1}{w_2}\right)}$

Ex
(A) $6.15 \Rightarrow 12$
(B) $6.18 \Rightarrow 8$ | $\Rightarrow$ weight of $(A+B) = \dfrac{1}{\frac{1}{12}+\frac{1}{8}} = 4.8$

(3) weight of $(A-B) = \dfrac{1}{\frac{1}{w_1}+\frac{1}{w_2}}$

Ex: (A) $4.0 \Rightarrow \overset{x+\delta x}{4.03}$
(B) $2.0 \Rightarrow \underset{y-\delta y}{1.96}$ $\Rightarrow A-B = 4.03 - 1.96 = 2.07$

Ex: $4.03 - 4$, $1.96 - \underset{2.07}{3}$ || $A-B = \dfrac{1}{\frac{1}{4}+\frac{1}{3}} = \boxed{1.714}$ ↓ weight

(4) If a measurement (A) is multiplied by a constant k.

weight of $k \cdot A = \dfrac{w_1}{k^2}$

weight of $A = w_1$

(5) If a measurement $A \rightarrow w_1$

wt of $\dfrac{A}{k} \Rightarrow k =$ Constant.

$= w_1 \times k^2 = w_1 \times k^2$

For a Set of Measurement :- of the same Quantity :-

(A) If weight of different measurements are 1.

(all measurements are unit weight)

(1) Probable Error in a single measurement :-

$$\boxed{E_s = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{(n-1)}}}$$

Where
v = Error in diff. measurement $= (x - x_1)$

(2) Probable error in Mean value (MPV) :

$$\boxed{E_m = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{n(n-1)}}} \boxed{= \frac{E_s}{\sqrt{n}}}$$

(3) Probable error in a single measurement of wt. w_1 :-

$$\boxed{E_{sw} = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{w_1(n-1)}} = \frac{E_s}{\sqrt{w_1}}}$$

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(B) If different measurement have unequal weight

(1) P.E in a Single Measurement :-

$$E_S = \pm 0.6745 \sqrt{\frac{\Sigma(wv^2)}{(n-1)}}$$

(2) P.E of weighted average mean :-

$$E_m = \pm 0.6745 \sqrt{\frac{\Sigma(w \cdot v^2)}{(\Sigma w)(n-1)}} = \pm \frac{E_S}{\sqrt{\Sigma w}}$$

(3) P.E of a single measurement of weight w

$$E_{sw} = \pm 0.6745 \sqrt{\frac{\Sigma(w \cdot v^2)}{w_1 (n-1)}}$$

$$= \frac{E_S}{\sqrt{w_1}}$$

Ques: Following measurement were taken for road of certain fixed length b/w 2 points.

2354 m, 2359 m, 2362 m, 2357 m, 2351 m.

Find out –

(1) Probable Error of Single measurement

(2) P.E of mean.

(3) P.E. of a single measurement of weight (4).

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Solution :

(1) Mean of the series $= \frac{2354 + 2359 + 2362 + 2357 + 2351}{5}$

$= 2356.6$ m.

x_1	$\bar{x}$	v	v^2
2354		-2.6	6.76
2359		+2.4	5.76
2362	2356.6	+5.4	29.16
2357		+0.4	0.16
2357		-5.6	31.36

$\Sigma v^2 = 73.20$

(2) P.E of a Single measurement :

$$E_S = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{n-1}}$$

$$= \pm 0.6745 \sqrt{\frac{73.20}{5-1}}$$

$$E_S = \pm 2.89 m$$

(3) P.E of a mean :

$$E_m = \pm 0.6745 \sqrt{\frac{\Sigma v^2}{n(n-1)}} = \frac{E_S}{\sqrt{n}}$$

$$= \frac{2.89}{\sqrt{5}} = \pm 1.29.$$

$$E_m = \pm 1.29 m.$$

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$$= \pm 0.6745 \sqrt{\frac{\Sigma v^2}{\omega_1 (n-1)}}$$

$$= \frac{E_s}{\sqrt{\omega_1}} = \pm \frac{2.89}{\sqrt{4}} = \pm 1.44$$

$$\boxed{E_{s\omega} = \pm 1.44m}$$

Ques: (2) If following measurement have weight as shown below for a quantity —

cm	wts.
25.4	8
25.9	3
25.3	4
25.5	12
25.7	9

: Calculate:

(1) P.E of single measurement

(2) P.E of weighted av. mean

(3) P.E of single mean of weight 5

Solution:-

mm	weight	$\bar{x}$	v	v^2	ωv^2
254	8	255.4	-1.4	1.96	15.68
259	3		+3.6	12.96	38.88
253	4		-2.4	5.76	23.04
255	12		-0.4	0.16	1.92
257	9		+1.6	2.56	23.04
	$\Sigma\omega = 36$				$\Sigma\omega v^2 = 102.56$

$$\Rightarrow \text{mean weighted mean} = \frac{254\times8 + 259\times3 + 253\times4 + 255\times12 + 257\times9}{8+3+4+12+9}$$

$$= 255.39m = 255.4m$$

(1) P.E of Single measurement:

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma\omega v^2}{(n-1)}}$$

$$= \pm 0.6745 \sqrt{\frac{102.56}{5-1}}$$

$$\boxed{E_s = 3.42mm}$$

(2) P.E of weighted av. mean:

$$E_m = \pm 0.6745 \sqrt{\frac{\Sigma\omega v^2}{\Sigma\omega(n-1)}}$$

$$= \frac{E_s}{\sqrt{\Sigma\omega}} = \frac{3.42}{\sqrt{36}}$$

$$\boxed{E_m = 0.57mm}$$

(3) P.E of Single measurement of weight (5)

$$E_{s\omega} = \frac{E_s}{\sqrt{n}} = \pm \frac{3.42}{\sqrt{5}}$$

$$\boxed{E_{s\omega} = \pm 1.53\,mm}$$

Ques: 7(d) The following are the observed values of an angle and their weightage:- ES 2009

Angle	weightage
30°24' 20"	2
30° 20' 18"	2
30° 24' 19"	3.

Calculate:

(1) P.E of S.M

(2) P.E of WAM

(3) P.E of S.M. of $\omega = 3$.

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Solution: weighted av. mean $= 30°24'19''$

$$= \frac{30°24'20'' \times 2 + 30°24'18'' \times 2 + 30°24'19'' \times 3}{2+2+3}$$

$$= 30°24'19''$$

	weight	$\bar{x}$	v	v^2	wv^2
30°24'20"	2		1"	1	2
30°24'18"	2	30°24'19"	1"	1	2
30°24'19"	3		0	0	0

$\Sigma w = 7$ $\qquad$ $\Sigma wv^2 = 4$

(1) P.E of S.M :

$$E_s = \pm 0.6745 \sqrt{\frac{4}{3-1}} = 0.95$$

(2) P.E of WAM :

$$= \frac{E_s}{\sqrt{\Sigma w}} = \frac{0.95}{\sqrt{7}} = 0.36$$

(3) P.E of S.M. of $w = 3$:

$$= \frac{0.95}{\sqrt{3}} = 0.55$$

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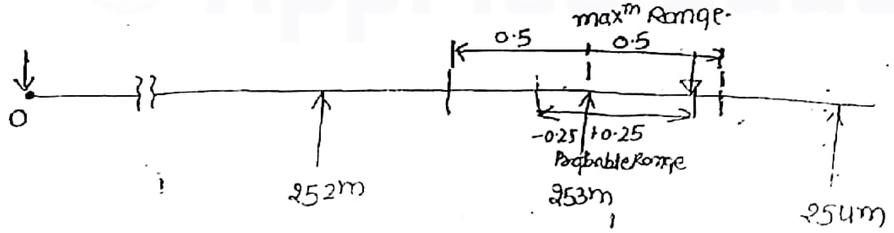
Significant figure of a single measurement :-

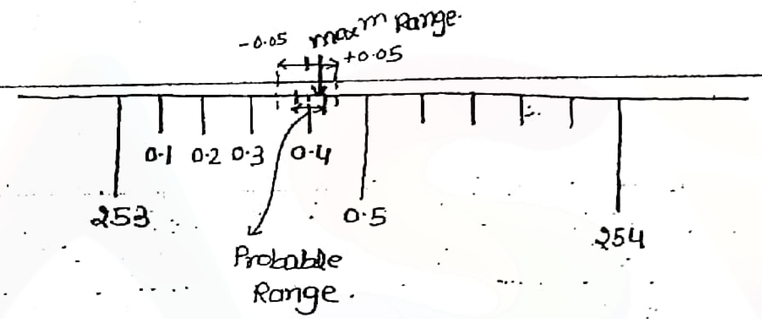
(#) If a measurement taken is 253 m



There may be a max^m error $= \pm 0.5$ m.

Probable error $= \pm 0.25$ m.

(#) If measurement is 253.4 m.



Max^m error $= \pm 0.05$ m

Probable error $= \pm 0.025$ m.

(#) (1) Accumulation of errors of known sign :

$$e_t = \pm(e_1 + e_2 + e_3 + \cdots)$$

$\Rightarrow$ max^m errors are added as above.

(#) (2) Accumulation of Random errors :-

$$e_t = \sqrt{e_1^2 + e_2^2 + e_3^3 + \cdots}$$

$\Rightarrow$ These are probable errors are added like this.

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(#) "A measurement have 'n' number of digits :-

1st (n-1) digits are called certain digits.

Last nth digit is called uncertain digits.

Error may be there in last digit as discussed above.

(#) Errors in computed Results :-

(1) Sum : $S = x + y$ — (1)

	Max	Probable
$x \rightarrow$	δx	e_x
$y \rightarrow$	δy	e_y

$ds = dx + dy$ — (2)

(i) Maxm error in S :-

$ds = \pm(\delta x + \delta y)$ — (i)

(ii) Probable error in S :-

$e_s = \pm\sqrt{e_x^2 + e_y^2}$ — (ii)

(iii) Maxm Range of S :-

$= S + \delta S$

to $S - \delta S$

(iv) Probable Range of S

$= S + e_s$

to $S - e_s$

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Ques : (1) $S = x + y$
$= 4.5 + 21$

Calculate maxm & Probable error and range of (S).

$x = 4.5 \rightarrow \delta x = 0.05 \rightarrow e_x = 0.025$

$y = 21 \rightarrow \delta y = 0.5 \rightarrow e_y = 0.25$

(i) Maxm error :-

$\delta S = \delta x + \delta y = 0.05 + 0.5 = \pm 0.55$

maxm Range of S :-

$S + \delta S = 25.5 + 0.55 = 26.05$

to $S - \delta S = 25.5 - 0.55 = 24.95$ //

(ii) Probable error :

$e_s = \pm\sqrt{e_x^2 + e_y^2}$

$= \pm\sqrt{(0.025)^2 + (.25)^2}$

$= \pm 0.2512$

Probable Range of S

$S + e_s = 25.5 + 0.2512 = 25.7512$

to $S - e_s = 25.5 - 0.2512 = 25.2488$.

i) Deduction :-

$S = x - y$

$ds = dx - dy$.

(i) maxm error → $\delta S \pm (\delta x + \delta y)$

(ii) Probable error $e_s = \sqrt{e_x^2 + e_y^2}$

(iii) maxm Range of S same as above

(iv) same as above

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$S = x \times y$

$dS = x\,dy + y\,dx$

(i) for $S \rightarrow$ max^m errors $\quad x \rightarrow y \cdot \delta x$, $\quad y \rightarrow x \cdot \delta y$

Total max^m error in S

$\delta S = x\,\delta y + y\,\delta x$ — (1)

(ii) Probable error

For $S \Rightarrow$ P.E in $x = y \cdot e_x$

P.E in $y = x \cdot e_y$

$\therefore e_S = \sqrt{(y \cdot e_x)^2 + (x \cdot e_y)^2}$

$\frac{e_S}{S} = \frac{1}{S}\sqrt{(y e_x)^2 + (x \cdot e_y)^2}$

$= \sqrt{\left(\frac{y \cdot e_x}{xy}\right)^2 + \left(\frac{x \cdot e_y}{xy}\right)^2}$

$$\boxed{\frac{e_S}{S} = \pm\sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}}$$

(iii) Probable Range :

$= S + e_S$ to $S - e_S$

(4) division :

$S = \frac{x}{y}$

$dS = \frac{y\,dx - x\,dy}{y^2} = \left(\frac{1}{y}\right)dx - \left(\frac{x}{y^2}\right)dy$

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(1) max^m error

$$\boxed{\delta S = \pm\left(\frac{1}{y}\cdot\delta x + \frac{x}{y^2}\delta y\right)} \text{ — (A)}$$

max^m Range :

$S + \delta S$ to $S - \delta S$.

(2) Probable Range

$e_S = \sqrt{\left(\frac{1}{y}e_x\right)^2 + \left(\frac{x}{y^2}e_y\right)^2}$

$\frac{e_S}{S} = \frac{y}{x}$ " "

$\frac{e_S}{S} = \sqrt{\left(\frac{y}{x}\cdot\frac{1}{y}\cdot e_x\right)^2 + \left(\frac{y}{x}\times\frac{x}{y^2}e_y\right)^2}$

$$\boxed{\frac{e_S}{S} = \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}} \text{ — (B)}$$

$\delta S = \frac{1}{y}(+\delta x) - \left(\frac{x}{y^2}\right)(-\delta y)$

$= +\left(\frac{1}{y}\delta x + \frac{x}{y^2}\delta y\right)$

$\delta S = \frac{1}{y}(-\delta x) - \left(\frac{x}{y^2}\right)(+\delta y)$

$= -\frac{1}{y}(\delta x) - \frac{x}{y^2}\delta y$.

$= -\left(\frac{1}{y}\delta x + \frac{x\delta y}{y^2}\right)$

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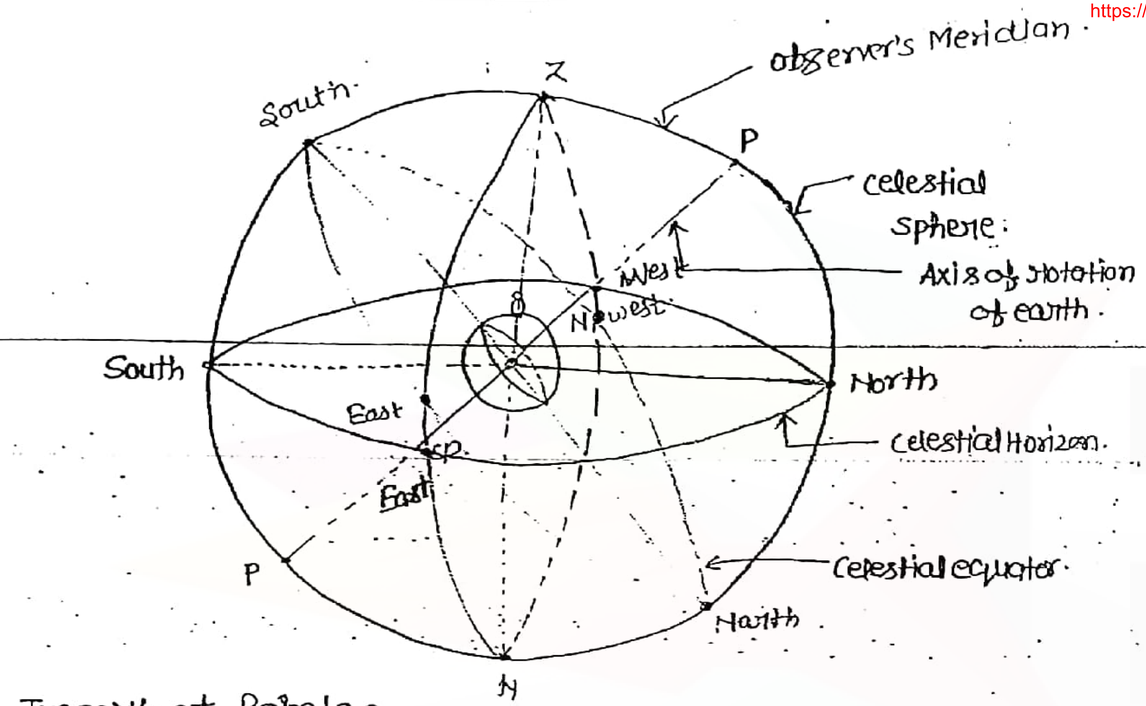


Important Points :

(1) Celestial Sphere :-

An imaginary sphere on which all stars, planets, sun, moon are assumed to be projected is called Celestial sphere.

(2) Zenith :

A point exactly above the observers position on celestial sphere is called zenith (Z).

(3) Nadir :

The point on celestial sphere exactly below the observer is called Nadir Point.

(4) Zenith Nadir line : Line joining zenith & Nadir point. This line will also pan from observer and centre of earth.

(5) Poles : Axis of rotation of earth meets the celestial sphere at two points, these points are called poles.

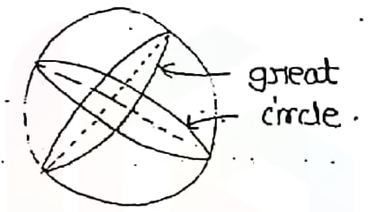
6) Celestial Horizon (Horizon) :

A great circle on celestial sphere that is ⊥cular to zenith Nadir line is called Horizon.

Great Circle :

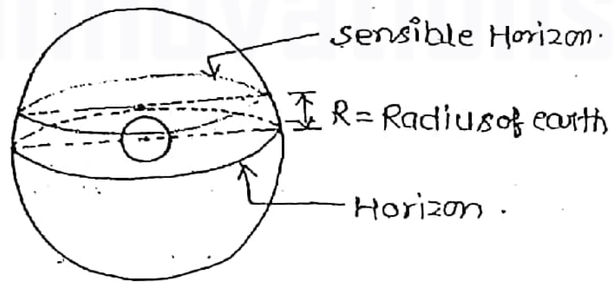
All those circles that have centre same as centre of sphere are called great circle.

Radius of great circle = Radius of sphere



1) Sensible Horizon :

A circle ||el to the horizon that has centre as observer position is called sensible Horizon.



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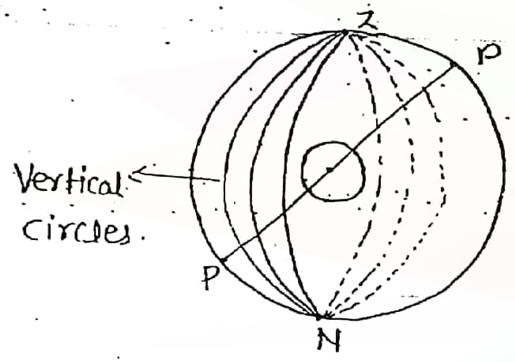
axis of rotation of earth (line joining poles) is called equator.

(9) Vertical Circle :

All those great circles that passes from zenith and nadir are called vertical circle.



(10) Observer's Meridian :

A vertical circle passing from zenith, Nadir & Poles point is called observer is meridian.

(11) Prime Vertical :

A vertical circle ⊥ular to observer's meridian is called prime vertical.

(12) Directions :-

(a) North & South point :-

Intersection of observer's meridian with horizon or equator are north & south Points.

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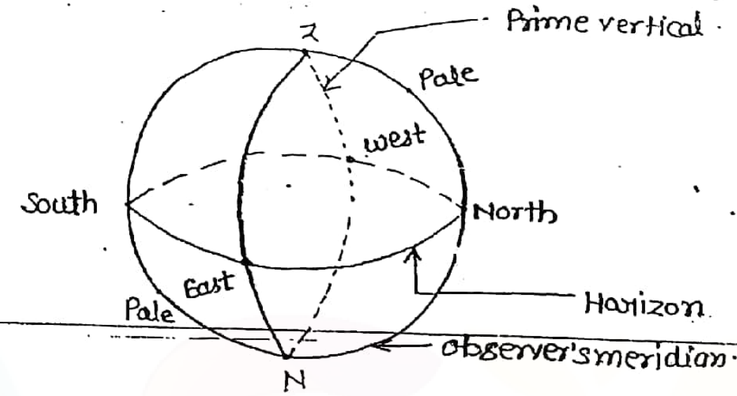
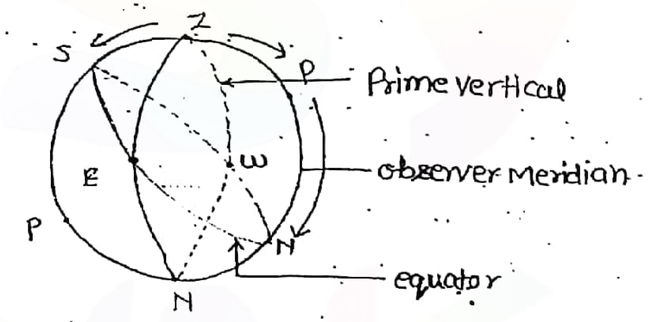


(with Horizon)



b) East & west Point :

The intersection of prime vertical with equator or Horizon are called east & west point.

3) Ecliptic :

Ecliptic is the ~~per~~ relative path of sun, projected on celestial sphere w.r.t earth position is called Ecliptic.

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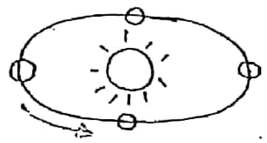
(i) Rotation

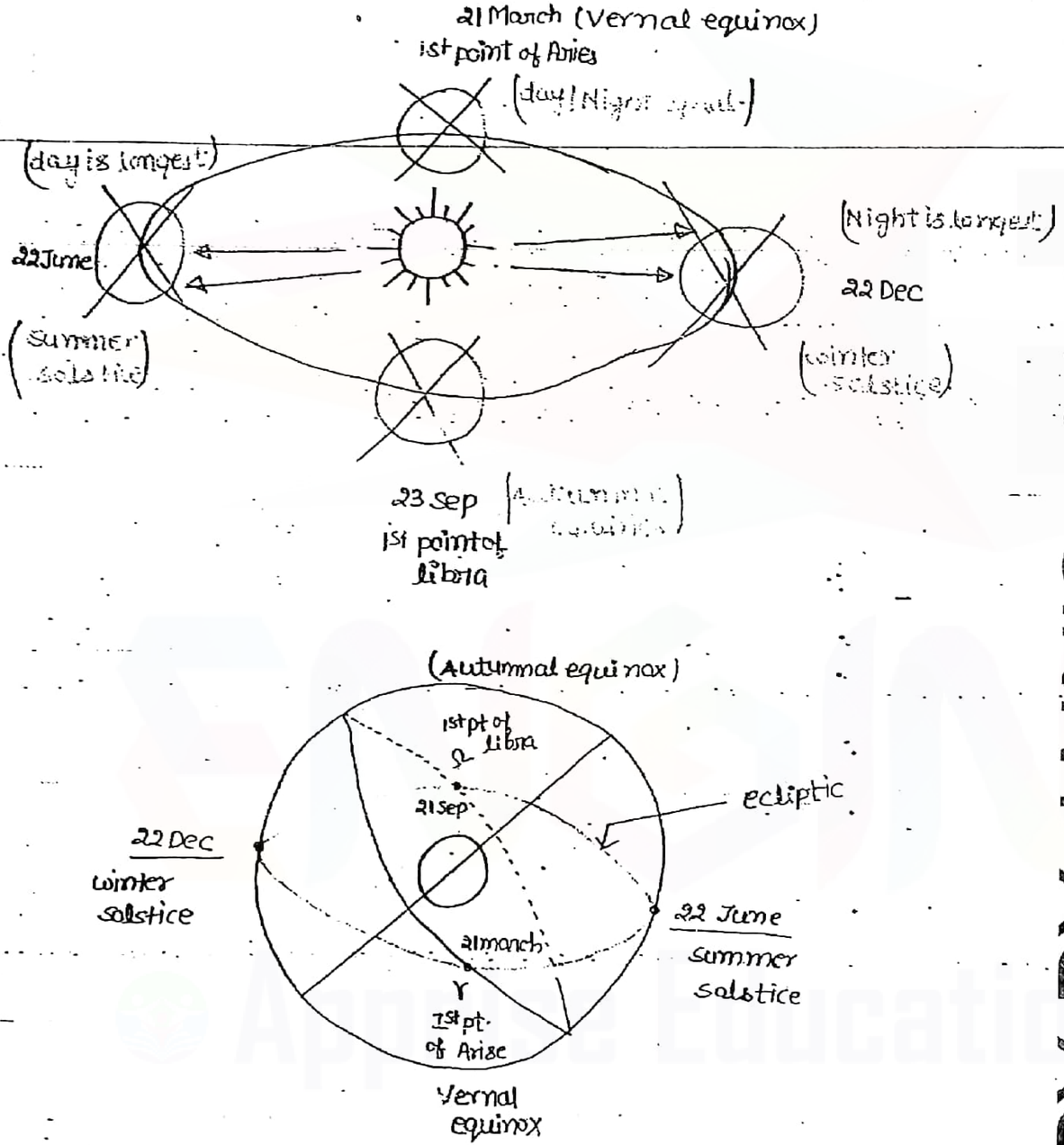
Daily Rotation.



(ii) Revolution

yearly.





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(iii) Co-ordinate System :-

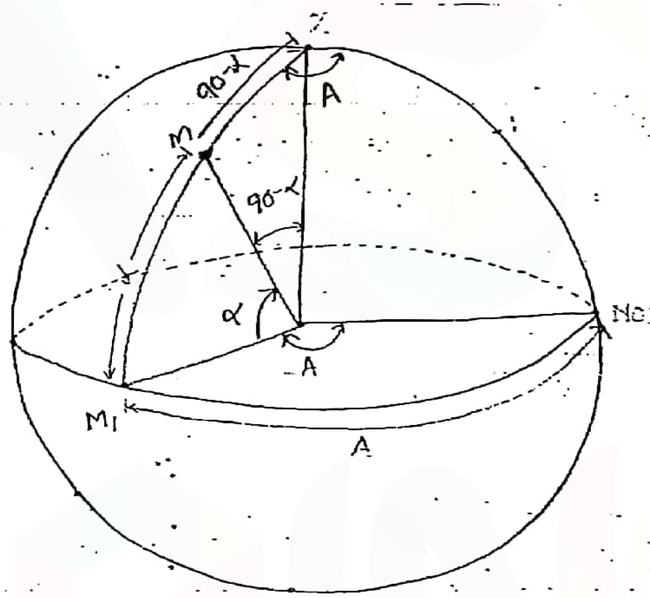
(1) Horizon System :-

(Altitude & Azimuth system)

Reference points / circles :-

(1) Zenith (2) Horizon (3) observer's meridion.

Angles :-



a) Altitude (α) : Angle above or below horizon measured towards zenith / Nadir upto star Position is called altitude (α).

b) Co-altitude (90-α) : / also called ~~Zenith distance~~

Angular distance from zenith to star is called zenith distance. (90-α).

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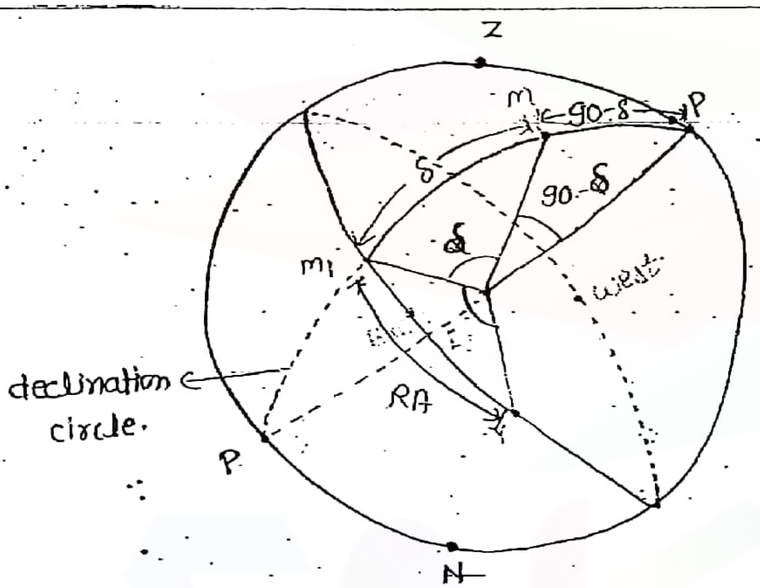
from observer's meridian (North point) is called Azimuth.

2) Independent equatorial system:
(Right ascension and declination)



Reference Points / circles:

(1) Poles (2) Equator (3) 1st point of Aries.

i) Declination (δ)

The angle measured declination circle (circle joining the star and poles) above or below equator is called declination.

i) Co-declination / Polar distance:

PM = (90-δ) → angular.
distance from pole to star position.

(ii) Right ascension:

The angles:-

(1) measured along equator.
(2) Starting from 1st point to Aries.
(3) Going toward east is called right ascension

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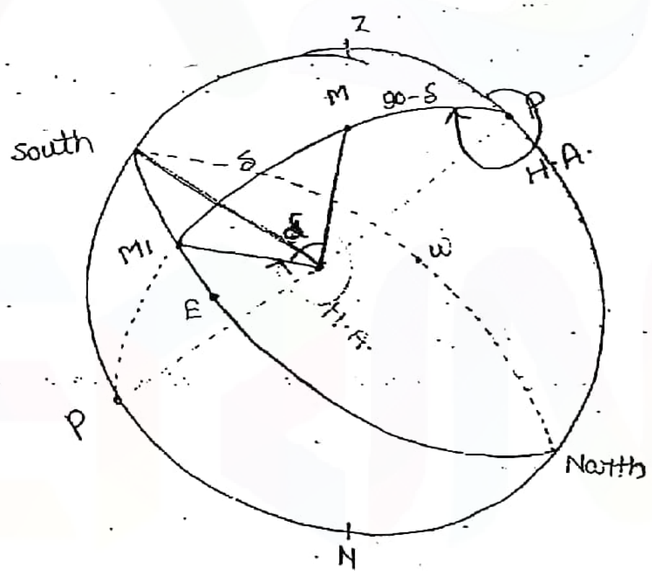
(3) Dependent Equatorial System:-

(Declination and hour angle system)



Reference Point and circle:-

(1) Pole (2) Equator (3) South Point

Angles:

i) Declination: (δ) same as previous = mm,

ii) Co-declination (90-δ) & Polar distance = PM.

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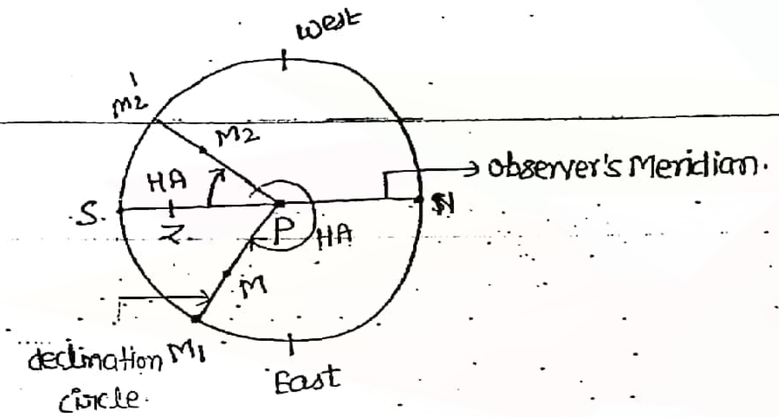
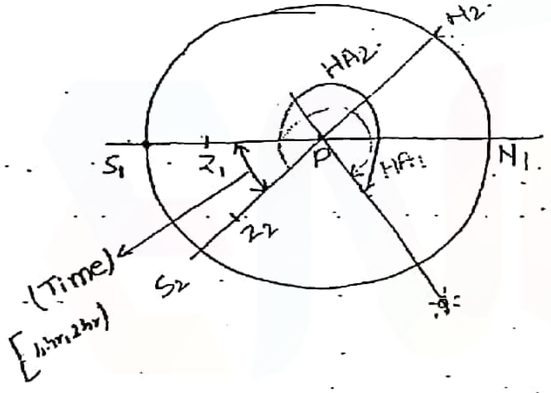
(iii) Hour angle : Hour angle of a star is –

(1) measured along equator.

(2) starting from south point.

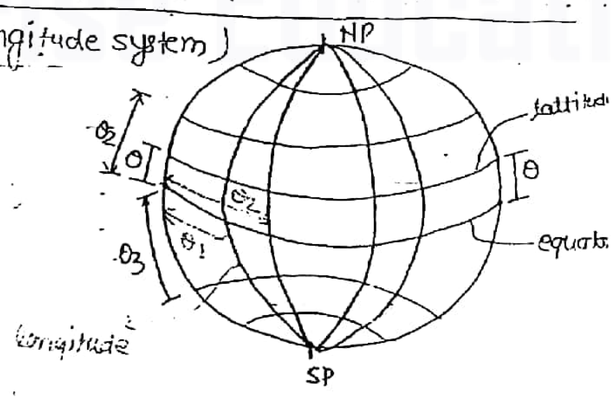
(3) Going towards west.





(4) Celestial latitude & longitude system :-

(Terrestrial latitude and longitude system)



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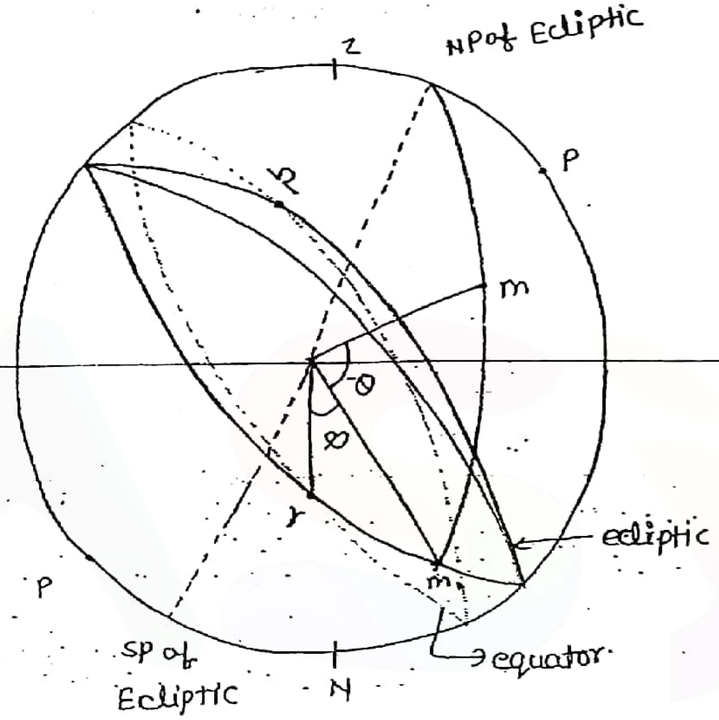

References :

1) North pole of Ecliptic : A point ⊥ular to ecliptic on celestial sphere.

2) Ecliptic

3) 1st point of aries

4) Celestial latitude :

Angle above or below the ecliptic upto star position is called celestial latitude.

5) Longitude : Angle measured along ecliptic starting from 1st point of aries & measured upto star position is called Celestial longitude (ϕ).

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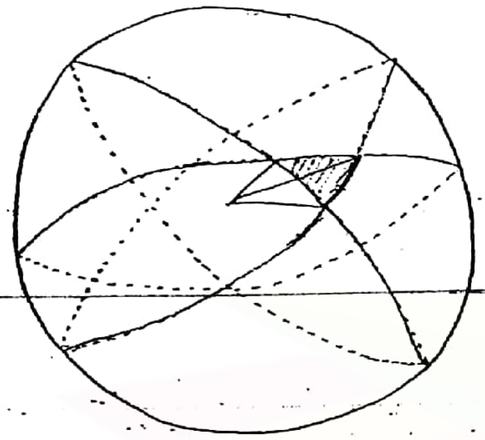

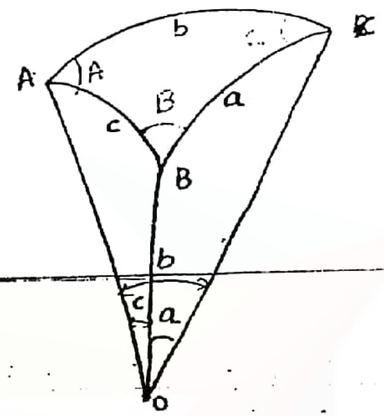

A spherical triangle is formed by intersection of 3 great circle on the surface of sphere.

A spherical triangle has three angles & three sides.

Angle: Angle B/w any 2 plane.

Sides: Angle B/w any 2 edge is called sides.

Properties of spherical triangle:-

(1) $180 < A+B+C < 540^\circ$

(2) spherical excess:

$$E_s = (A+B+C) - 180^\circ$$

Area of spherical triangle

$$A = \frac{\pi R^2}{180^\circ} \times E_s$$

(3) if $a+b = 180^\circ$

$A+B = 180^\circ$

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(4) Any Angle $< 180^\circ$

(5) sum of any two side > third side.

$a+b > c$

$b+c > a$

$c+a > b$

Formula:-

(1) $$\frac{\sin a}{\sin A} = \frac{\sin b}{\sin B} = \frac{\sin c}{\sin C}$$

(2) Cos formula:-

$$\cos a = \frac{\cos A + \cos B \cdot \cos C}{\sin B \cdot \sin C}$$

$$\cos A = \frac{\cos a - \cos b \cdot \cos c}{\sin b \cdot \sin c}$$

Napier Rule:

It is applicable for a right angle spherical triangle when any one angle $= 90^\circ$. (not side)

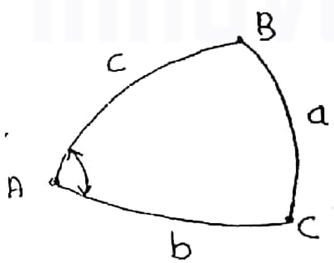
(#) If any side $= 90^\circ$.

then this Rule is not applicable.

If angle $A = 90^\circ$

Step-1: write all angle in sequence.

b, {C, a, B} c



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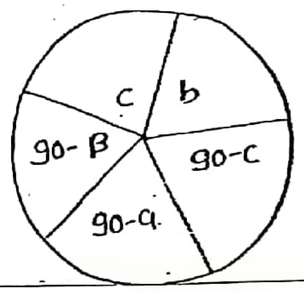
Step-2 b, | 90-C ; 90-a ; 90-B, | c



Step-3: Take a circle and divide it in five parts. Write down all angle in any direction but in sequence.

Key formula:

(1) Sin (any angle) = tan (Adj 1) x tan (adj 2)

(2) Sin (any angle) = Cos (opp 1) x Cos (opp 2).

(#) Different Formula (10 formula can be formed)

(1) $\sin b = \tan c \times \tan(90-C)$

$$\boxed{\sin b = \tan c \cdot \cot C} \quad \text{—①}$$

(2) $\sin b = \cos(90-B) \times \cos(90-a)$

$$\boxed{\sin b = \sin B \times \sin a} \quad \text{—②}$$

(3) $\sin(90-a) = \tan(90-B) \cdot \tan(90-C)$

$$\boxed{\cos a = \cot B \cdot \cot C} \quad \text{—③}$$

(4) $\sin(90-a) = \cos c \cdot \cos b$.

$$\boxed{\cos a = \cos c \cdot \cos b} \quad \text{—④}$$

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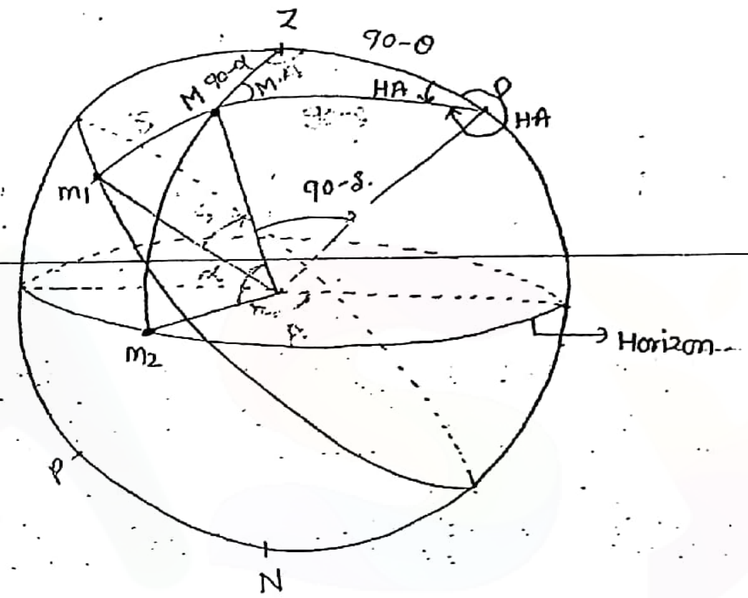
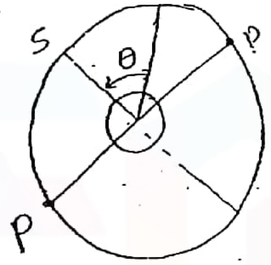
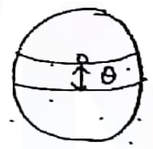
ASTRONOMICAL TRIANGLE



latitude → θ

90-θ = Co-latitude.





⇒ The ΔZPM is called - Astronomical triangle.

⇒ This is a spherical triangle that has -

(1) Three Sides:

(a) 90-δ = PM = Co-declination (Polar distance)

(b) 90-α = ZM = Co-altitude (zenith distance)

(c) 90-θ = PZ = Colatitude.

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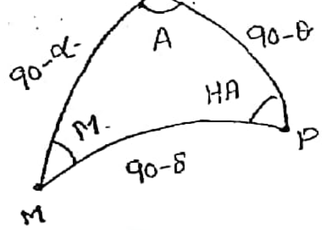
(b) $\angle Z$ = Azimuth (A)

(c) $\angle M$ = Star angle



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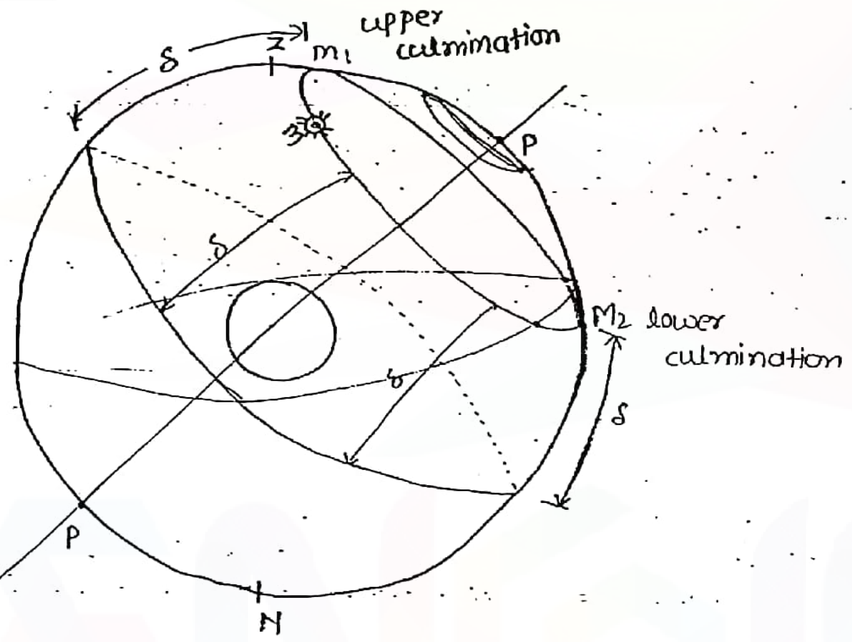
#) Different position of star according to daily rotation of earth:



(1) Star at upper/lower transit
upper/lower culmination

→ when star is crossing observer's meridian near zenith it is called at upper culmination/transit.

→ When the star is crossing near Nadir point, the observer's meridian, it is called at lower transit position.

→ Declination of star is always same at any position.

(2) when star at Horizon:

when star is at Horizon,

the co-altitude = 90°

altitude = 0°

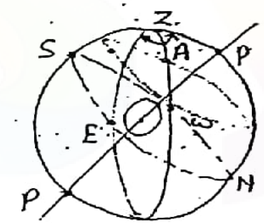
Sun at sun rise and sunset position is at Horizon.

(3) Star at Prime Vertical:

When a star is at prime vertical.

Azimuth = 90°

Napier Rule can be applied.

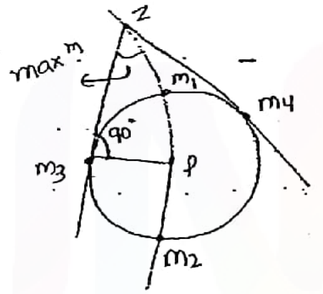


(4) Star at elongation:

when a star is at elongation its azimuth measured Z w.r.to observer's meridian is max^m. In this position, star angle

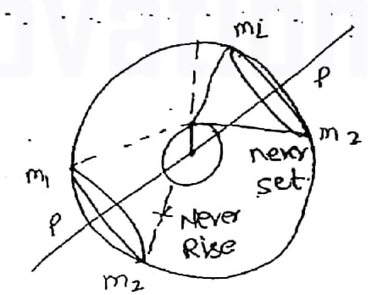
at $M_3 = 90°$ (Napier Rule can be applied)

$M_4 = 90°$



(5) Circumpolar Star:

The star that never rise or never set for a particular observer is called circumpolar star.



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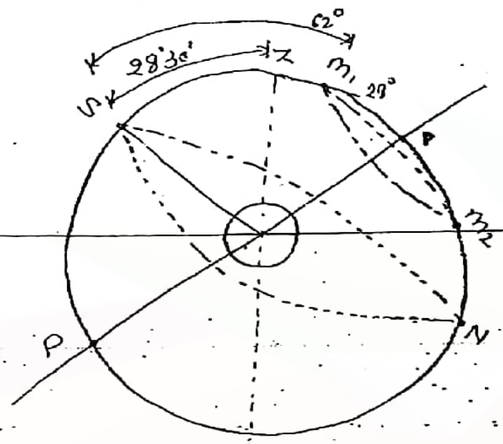
of a star is 62°N, calculate the zenith distance of the star when it is at upper & lower culmination points.

Soln:



PM_1 = Co-declination

$= 90 - \delta$

$= 90 - 62°$

$= 28°$

at upper culmination

$Zm_1 = \delta - \theta$

$= 62° - 28°30'$

$= 33°30'$

at lower culmination

$Zm_2 = Zm_1 + 28° + 28°$

$= 33°30' + 56°$

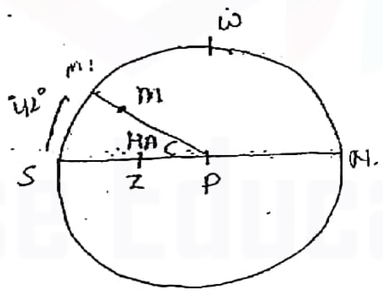
$= 89°30'$

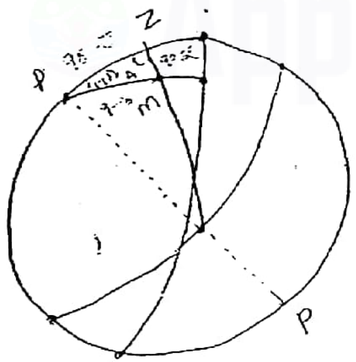
Que:(2) Determine the altitude and Azimuth of a star that have

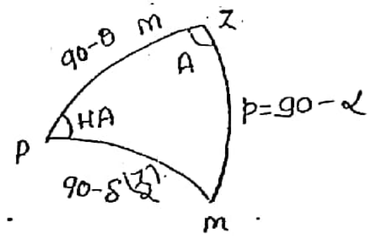
(1) declination = 25°N

(2) Hour Angle = 42°

(3) Latitude of observer = 52°N.







$Z = 90 - \delta = 90° - 25°$

$= 65°$

$m = 90 - \theta = 90 - 52°$

$= 38°$

$P = HA = 42°$

(1) $\cos P = \dfrac{\cos p - \cos m \cdot \cos Z}{\sin m \cdot \sin Z}$

$\cos 42° = \dfrac{\cos p - \cos 38° \cdot \cos 65°}{\sin 38° \cdot \sin 65°}$

$\cos p = 0.747$

$p = 41°36'34.58''$

$p = 90 - \alpha$

altitude $= 90 - p = 90 - 41°36'34.58''$

$= 48°23'25.42''$

(2) $\cos Z = \dfrac{\cos Z - \cos m \cdot \cos p}{\sin m \cdot \sin p}$

$\cos Z = \dfrac{\cos 65° - \cos 38° \cdot \cos 41°36'34.58''}{\sin 38° \cdot \sin 41°36'34.58''}$

$Z = 114°2'34.89''$ (Azimuth)

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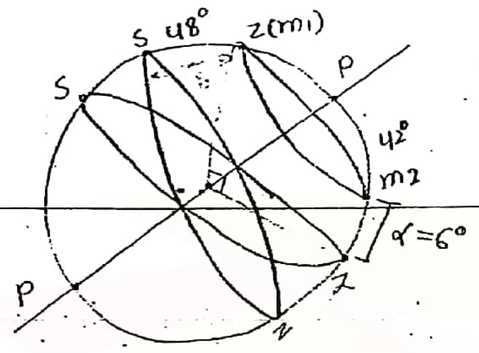
at zeinth pt. Calculate the altitude of star at its lower transit position.



At zeinth :-

declination = 48°

latitude of place is also 48°

$ZP = 90 - 48° = 42°$

Altitude at lower transit

$= 90° - 48° - 42° = 6°$

Qu:(4) Calculate the Sun's azimuth and Hour angle at sunset position, at a place of latitude 42°. when declination of sun is 23°.

α = 0°

Altitude

$zm = 90° - \phi$

$\delta = Z = 90 - \delta$

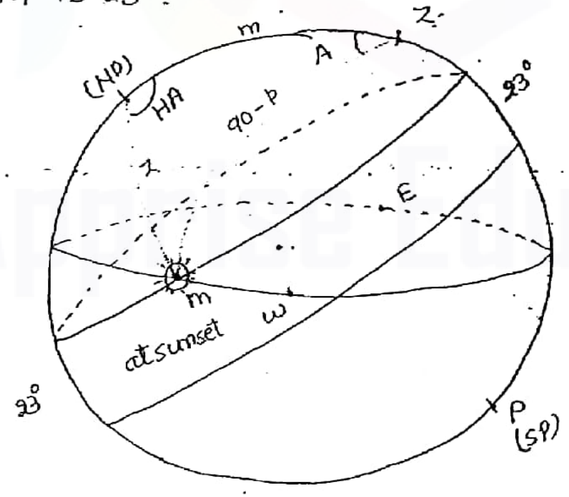
$= 90 - 23°$

$= 67°$

$m = 90 - 0$

$= 90 - 42°$

$= 48°$



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(#) (1) $\cos P = \dfrac{\cos\phi - \cos m \cdot \cos z}{\sin m \cdot \sin z}$

$= \dfrac{\cos 90° - \cos 48° \cdot \cos 67°}{\sin 48° \cdot \sin 67°}$

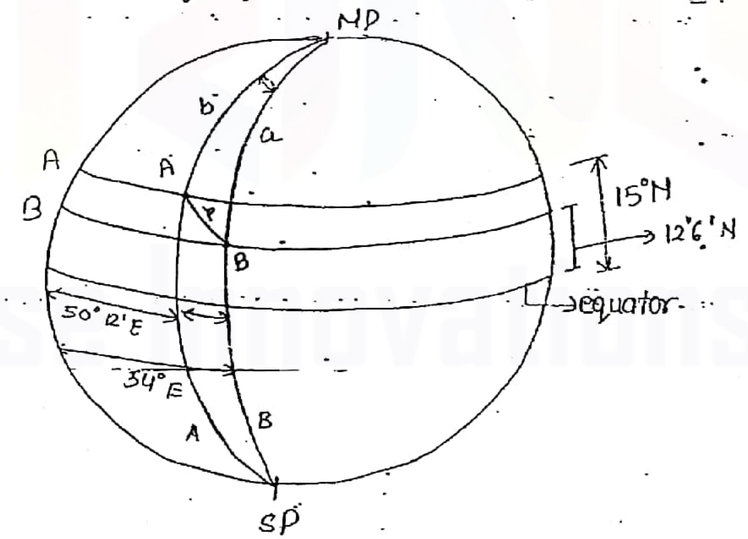
$P = 112°28'11.82''$

(2) $\cos Z = \dfrac{\cos z - \cos m \cdot \cos\phi}{\sin m \cdot \sin z}$

$= \dfrac{\cos 67° - \cos 48° \cdot \cos 9°}{\sin 48° \cdot \sin 90°}$

$Z = 58°16'45.09''$

Ques-ES-1994 find the shortest distance b/w two places A & B, given that latitude of A & B are 15°N & 12°6'N & their longitudes are 50°12'E & 54°0 E.



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$a = 90° - 12°6' = 77°54'$

$b = 90° - 15° = 75°$

$p = ?$

$P = 54° - 50°12'$

$= 3°48'$

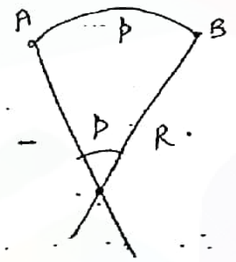
$$\cos P = \frac{\cos p - \cos a \cos b}{\sin a \cdot \sin b}$$

$$\cos 3°48' = \frac{\cos p - \cos 77°54' \cdot \cos 75°}{\sin 77°54' \cdot \sin 75°}$$

$\cos p = 0.9964$

$\boxed{p = \cancel{0°30'28.62'}}$

$\boxed{p = 4°41'46.07''}$



Length AB

$$= \frac{2\pi R}{360°} \times p$$

$$= \frac{2\pi \times 6370\,km}{360°} \times 4°41'46.07''$$

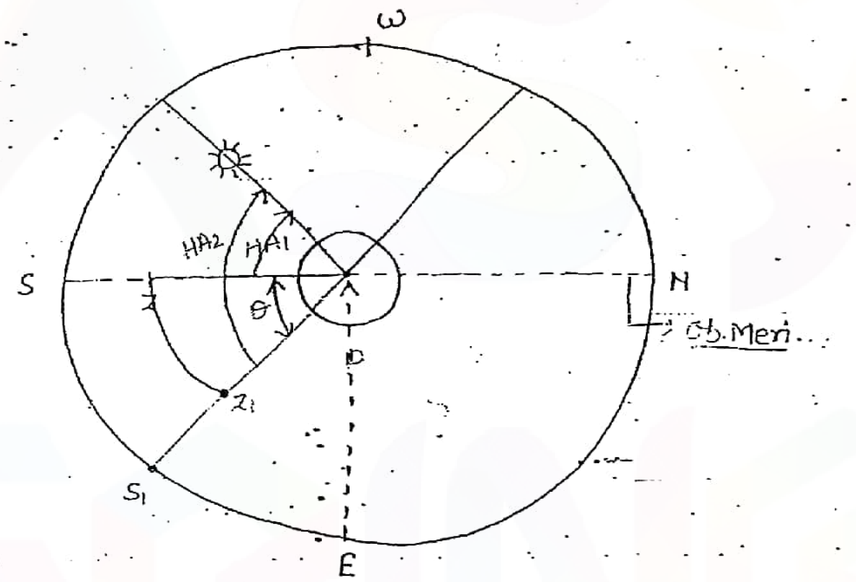
$= 522.104\,km$

28/02/2015

TIME

→ Time is called the rotation of earth measured from a particular instant of time.

→ The change in hour angle of any fixed point in universe (first pt. of Aries, Sun) is called time.



Time $\theta = HA_2 - HA_1$

#) (1) sideral time : Time measured w.r.to Ist point of Aries is called sideral time.

change in hour angle of Ist point of Aries is called sideral time.

Local sideral time : when time is started counting when Ist point of Aries is at lower transit position from a

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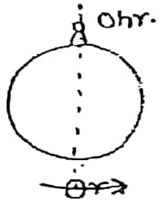
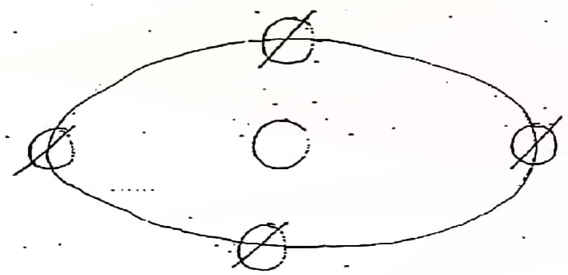
time.



(#)(2) Salar time : Time counter as per position of sun.

(i) Apparent Solar time : Acc. to actual movement of sun around earth.



Actual rotation and revolution of earth around sun.

(#) The one day is actually not equal to 24 hrs.

(#) ever all days are not of same duration.

Mean solartime :

To calculate/read time we assume a fictious sun (imaginary sun) moving at a constant speed, according to which the time measured is called mean solar time. As per mean solar time 1day = 24 hrs.

(3) Equation of time :-

That is, difference b/w apparent solar time and mean solar time at any istant is called equation of time.

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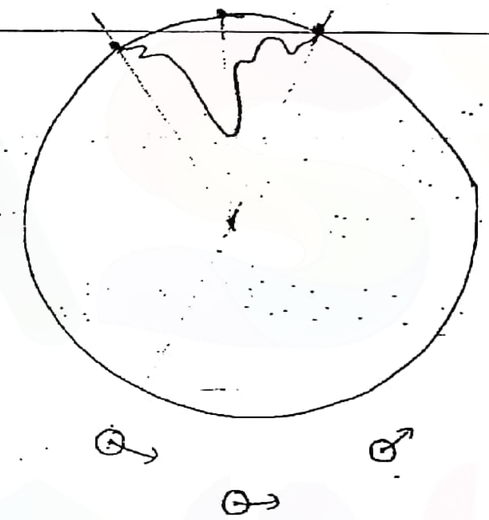
(4) Local mean solar time :-

When time is started counting when the fictious sun crosses the observer's meridian at lower transit position for a particular location, time counted is called local mean solar time.



(5) Standard time : different places in a country will have difference local mean solar time. To keep uniformity of time throughout the country, only one time is followed for all places, that will be the local mean solar time of a particular place (say Allahabad for India).

This one time followed by all for one country is called standard time.

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1 hour = $\frac{360}{24}$ = 15° degree

1 hr = 15 degree

60 minutes = 15×60 minute

1 minutes = 15 minute
of time of angle.

60 sec = 15×60 sec.

1 sec = 15 sec
of time of angle

(1) Convert :-

78°49'36" → into time

$78^\circ = \frac{78}{15}$ = 5 hr 12 min 0 sec

$49' = \frac{49}{15}$ = 0 hr 3 min 16 sec.

$36'' = \frac{36}{15}$ = 0 hr 0 min 2.4 sec

5 hr 15 min 18.4 sec.

(2) Convert :-

9 hr 49 min 32 sec. — into angle.

9 hr = 9×15 = 135° 0' 0"

49 min = 49×15 = 12° 15' 0"

32 sec = 32×15 = 0° 8' 0"

147° 23' 0"

Que If the difference of longitude b/w 2 place is 82°45'30" what will be the time difference b/w two place.

$\frac{82^\circ 45' 30''}{15}$ = 5 hr. 31' 2" Ans

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