SURVEY NOTES

CHAPTER 1

Definition :-

* It is the science of determining the relative positions of various points above, on, or below the earth surface by direct or indirect measurement of distance, direction & elevation.

* Objectives of surveying :-

-> To take measurements to determine the relative positions of the existing features on or near the ground.

-> To mark the positions of the proposed structure on the ground.

-> To determine areas, volume & other related quantities.

* Principles of surveying :-

There are two major principles of surveying:

(i). Location of a point by measurement from two points of reference.

(ii). Working from whole to part

* Surveying

Plane Surveying	Geodetic Surveying
• earth's curvature is not considered.	• earth's curvature is considered
• accuracy is low	• accurate
• Small area is surveyed	• Large area is surveyed
• The direction of the plumb bob lines at various point is considered parallel	• The direction of the plumb bob lines at various points is not parallel.
• earth surface is considered flat	• earth surface is considered curved.

* Instrumental Surveying:-

It is the type of survey with in which the surveying type is classified based on Instrument used. Some of those are:-

(i) chain surveying:- using chains only linear measurement

(ii). compass surveying:- using compass measuring horizontal angles

(iii). Plane Table surveying:- Map is prepared of the traverse.

(iv) Theodolite sur. → using theodolite measures horizontal & verticle angles

(v). Levelling → determines the Relative level of various points, etc.

(vi).

* Precision of measurements:-

It denotes its closeness to another measurement of the same quantity. Quantity is measured several times & the values obtained are very close to one another, the precision is high.

Accuracy of measurements:-

It denotes the closeness of a measurement to its true value. If the measured value is very close to its true value, it is very accurate. It is degree of perfection achieved in measurement.

* Instruments used for measuring distances:-

The different instruments used are

1. Chains :-

(a). Gunter's Chain

Contains 66 feets = 100 links = 20.12 m.

(b). Engineer's chain

Contains 100 feets = 100 links = 30.48 m

(c) Revenue chain

Contains 33 feets = 16 links = 10.06 m.

Besides as per IS 1492 - 1970 the surveying chains are of four different lengths:

(a). 5 m (25 Links)
(b). 10 m (50 links)
(c). 20 m (100 links)
(d). 30 m (150 links)

2. Tapes :-

(a). Linen / cloth Tapes.
(b). Glass fibre Tapes
(c) Metallic Tapes
(d) Steel Tapes
(e) Invar Tapes :- alloy of steel & Nickel.

3. EDM :- It is an electronic optical measurement instrument used to measure distances.

* Errors & mistakes in linear Measurement :-

1. Natural errors :-
due to temperature, refraction, declination, etc.

2. Instrumental errors :-
due to imperfect construction & adjustment of the instruments.

3. Cumulative errors / systematic :-
errors which accumulate systematically due to different reasons. These errors can be corrected :-

(i) error in length of chain/Tape (+ve/-ve)
(ii) Variation in temperature (+ve/-ve)
(iii). Pull correction (+ve/-ve)
(iv). Miss alignment (+ve)
(v). Sag correction (+ve), etc.

4. Compensating errors :-
These errors occure due to
(i) incorrect holding / marking of arrows
(ii). Incorrect setting chain angles
(iii) chain is not calibrated uniformly, etc.
These errors cannot be corrected.

5. Mistakes / Accidental errors :-
due to displacement of arrows, misreading, miscounting chain lengths, etc.

* Corrections :-

(a). Correction due to incorrect length :-

$$c = l' - l$$

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

where,

l = nominal length of tape
l' = actual length of tape
L = Measured length
C_a = Correction.
= +ve when ($l' > l$)
-ve ($l' < l$)

(b). Correction for temperature :- (+ve/-ve)

$$C_t = \alpha(T_m - T_0)L$$

where,
α = co-efficient of linear expansion.
T_m = mean temperature
T_0 = Standared temperature.

(c). Correction for pull :- (+ve / -ve)

$$C_P = \frac{(P - P_0) L}{AE}$$

where,

P = Pull applied during measurement (N)

P_0 = Standard pull (N)

L = measured length

A = Cross sectional area of tape

E = Young's modulus.

(d). Correction for sag :- (always -ve)

$$C_{sg} = \frac{l (wl)^2}{24 P^2}$$

where,

l = length of tape

P = applied pull

w = weight of tape per unit length.

Problem 7 A 20-m steel tape was standardised on flat ground, at a temperature of 20°C and under a pull of 15 kg. The tape was used in catenary at a temperature of 30°C and under a pull of P_c kg. The cross-sectional area of the tape is 0.22 cm^2, and its total weight is 400 g. The Young's modulus and coefficient of linear expansion of steel are 2.1×10^6 kg/cm^2 and 11×10^{-6} per °C respectively. Find the correct horizontal distance if P is equal to 10 kg. (WBSC 1988)

Solution Given data:

$L = 20$ m	$A = 0.02\ cm^2$
$T_0 = 20°C$	$\alpha = 11 \times 10^{-6}$ per °C
$P_0 = 15$ kg	$E = 2.1 \times 10^{-6}\ kg/cm^2$
$T_m = 30°C$	$W = 400$ g $= 0.4$ kg
$P = 10$ kg	$n = 1$

Here, applied pull $P = 10$ kg.

(a) Temperature correction, $C_t = \alpha(T_m - T_0)\,L$

$$= 11 \times 10^{-6}\,(30 - 20)\,20$$

$$= 11 \times 10^{-6} \times 10 \times 20$$

$$= 0.00220 \text{ m } (+\text{ve})$$

(b) Pull correction, $C_p = \dfrac{(P - P_0)\,L}{A \times E}$

$$= \frac{(10 - 15)\,20}{0.02 \times 2.1 \times 10^6}$$

$$= -\frac{5 \times 20}{0.02 \times 2.1 \times 10^6}$$

$$= -0.00238 \text{ m } (-\text{ve})$$

(c) Sag correction, $C_s = \dfrac{LW^2}{24 n^2 P^2}$ $(n = 1)$

$$= \frac{20 \times (0.4)^2}{24 \times (10)^2} = 0.00133 \text{ m } (-\text{ve})$$

Total correction $= +0.00220 - 0.00238 - 0.00133 = -0.00151$ m

Correct horizontal distance $= 20 - 0.00151 = 19.99849$ m

2 CHAINING AND CHAIN SURVEYING

* Instruments used for chaining :-

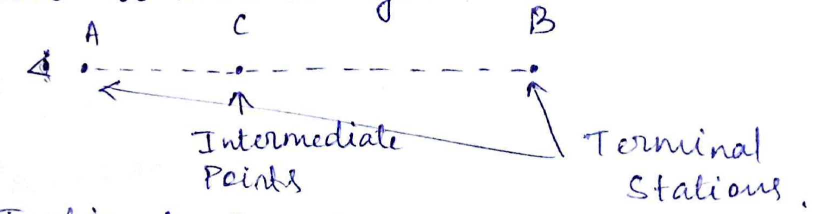
(i). Arrows
(ii). Pegs
(iii). Ranging Rods
(iv). Offset Rod.
(v). Plaster's laths
(vi). Plumb Bob.
(vii). clinometer

* Ranging :-

It is the process of establishment of intermediate points on line with survey line. If the chain length is less than the line to be measured, than some intermediate points will be established in line with the two terminal points before chaining. There are two methods of ranging.

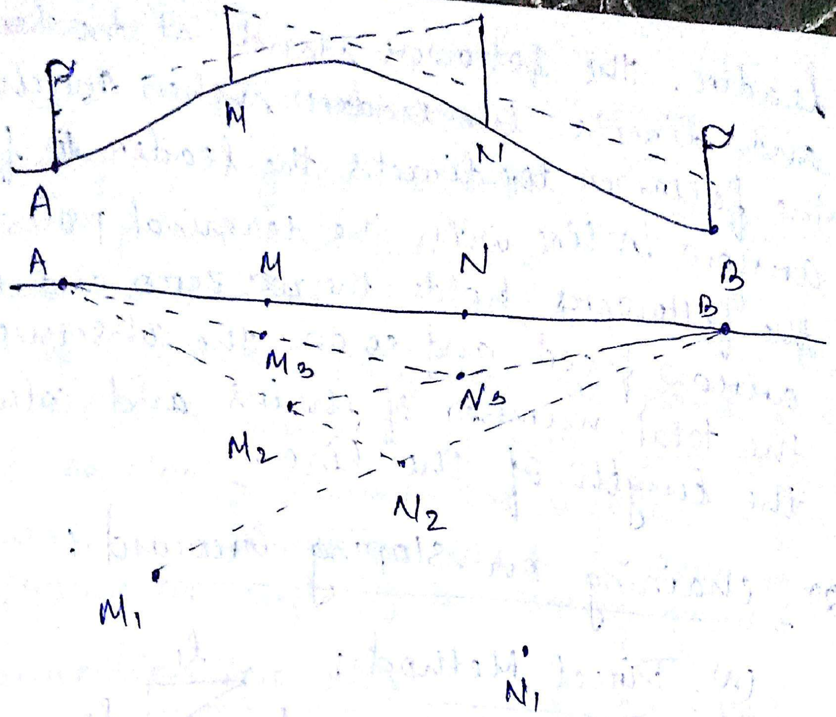
(i). Direct Ranging:

It is done when the end stations are intervisible. The direct ranging can be done by eye or with an instrument called a line ranger.



(ii). Indirect Ranging :-

It is adopted when end points are not intervisible. Such a condition occurs where there is high intervening ground between the end points. This type of ranging is also called as Reciprocal Ranging.



* Ranging By Line Ranger :

It consists of either two plane mirrors or two right angled isosceles prisms placed one above the other, among which one of mirror or prism is made adjustable. The prism / mirror shows the reflection of the Ranging rods at the terminal stations. When the surveyor observes the images of ranging rods, if they appear to be in same verticle line then they are said to be perfectly aligned. If not then the observer moves the instrument sideways till the two images are in the same verticle line.

→ error due to incorrect ranging is an compensating ~~non~~ error.

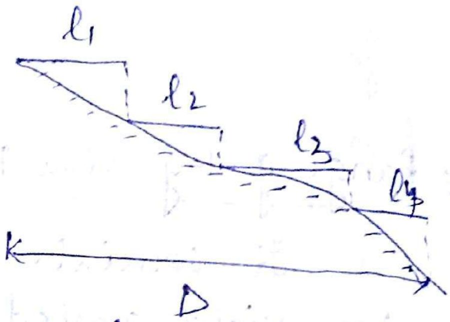
* Method of chaining :

(1) chaining on flat ground :

Two chainmen are required for measuring the length of a line greater than a chain length. The chainmen holding the zero / rear end of chain is called follower, The chainmen holding forward handle is called leader. The follower stands at the terminal and directs the leader, when one chain away the follower directs the leader to fix an arrow in line with the terminal poles. Then the followers holds the zero end on the arrow fixed and so on. The observer counts the total number of chains and calculates the length of the line.

(2). Chaining on sloping Ground:

(a). Direct Method:



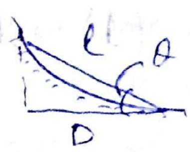
It is also called as method of stepping, here the distance is measured in small horizontal streaches or steps. In this method the follower holds zero end of tape while leader selects any suitable length and pulls the tape tight so that it is horizontal and transfers the point to the ground by a plumb bob and moves forward. Thus total length

$$D = l_1 + l_2 + l_3 + l_4$$

(b). Indirect Method:

In this method sloping distance say 'l' is measured and the horizontal distance 'D' is calculated. For this the angle of slope or difference in elevation between two points is also to be measured.

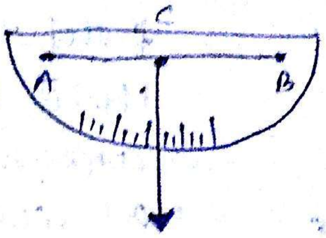
so, $D = l \cos \theta$



CODE OF SIGNALS FOR RANGING

S.No.	Signal by the Surveyor	Action by the Assistant
1	Rapid sweep with right hand	Move considerably to the right
2	Slow sweep with right hand	Move slowly to the right
3	Right arm extended	Continue to move to the right
4	Right arm up and moved to the right	Plumb the rod to the right
5	Rapid sweep with left hand	Move considerably to the left
6	Slow sweep with left hand	Move slowly to the left
7	Left arm extended	Continue to move to the left
8	Left arm up and moved to the left	Plumb the rod to the left
9	Both hands above head and then brought down	Correct
10	Both arms extended forward horizontally and the hands depressed briskly	Fix the rod

* **Clinometer :-**



It is a simple instrument consisting of a graduated arc a light plumb bob with long thread suspended at the centre. When the line of sight AB is horizontal the plumb bob intersects the zero mark. When the line of sight is titled (i.e. on sloping ground) the angular difference between the plumb bob line & the zero mark represents the angle of the sloping ground.

* **Correction for slope :-** (always −ve)

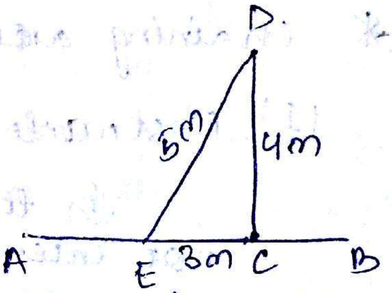
$$C_v = L(1-\cos\theta)$$

where, L = Inclined length measured
θ = angle of slope.

* **Setting perpendicular with chain & Tape :**

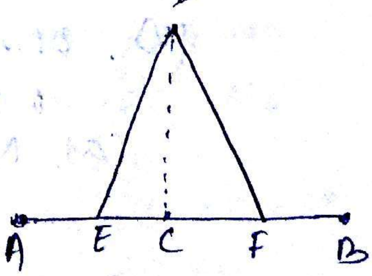
(1). to a chain line from a point on it :

(a). The 3-4-5 method :

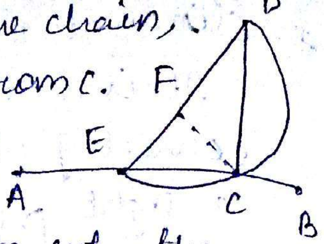


To set a perpendicular at C, mark a point E at 3m distance from C. Hold the zero end at E and mark a point at 5m, aligned to the point C. Join the points C & D.

(b). Select EF equidistance from C. Hold the zero end of the tape at E & 10m end at F. Pick up 5m mark, stretch the tape tight & establish D. Join DC.

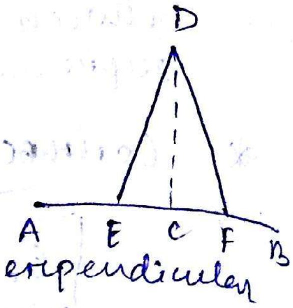


(3). Select any point F outside the chain, Preferably at 5m distance from C. Hold the 5m mark at F & Zero mark at C, & with F as centre draw an arc to cut the line at E. Join EF & produce it to D such that EF = FD = 5m.

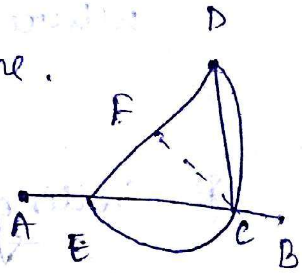


(2). To a chain line from a point outside it:

(a). Select any point E on the line With D as centre & DE as radius, draw an arc to cut the chain line in F. Bisect EF at C. CD will be perpendicular to AB.



(b). Select any point E on the line. Join ED & bisect it at F. With F as centre & EF or FD as radius, draw an arc to cut the chain line in C. CD will be perpendicular to the chain line.



* Chaining across different types of obstacles:

(1). Obstracle to ranging but not chaining:-

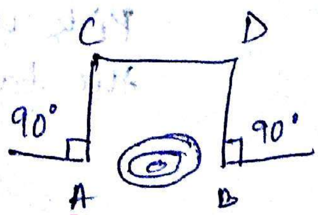
In this type of obstracle, the ends are not intervisible, is quite common obstrucle. The method of reciprocal ranging may be used.

(2). Obstacle to chaining but not ranging:-

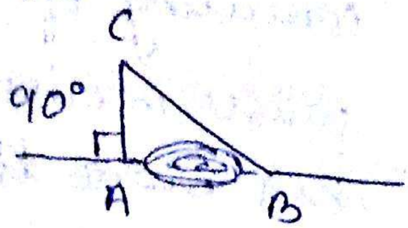
Occurs in case of any ponds, rivers, etc.

(a). Method 1:- (In case of Ponds)

Select two points A & B on either side. Set out equal perpendiculars AC & BD. Measure CD, then CD = AB.

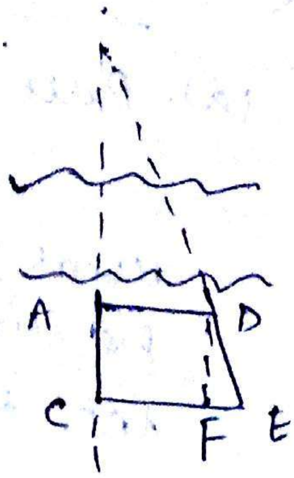


(b). <u>Method 2</u> :- (In case of ponds)



Set out AC perpendicular to the chain line. Measure AC & BC. The length AB is calculated from the relation $AB = \sqrt{BC^2 - AC^2}$

(c) <u>Method 3</u> :- (In case of river)



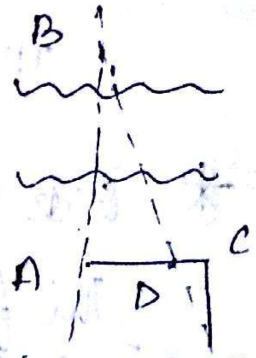
Select point B on one side & A & C on the other side. Erect AD & CE as perpendiculars to AB & range B, D & E in one line. Measure AC, AD and CE. If a line DF is drawn parallel to AB, cutting CE in F perpendicularly, then triangles ABD & FDE will be similar.

So, $\frac{AB}{AD} = \frac{DF}{FE}$ $\left[\because FE = CE - CF = CE - AD \right]$

$\Rightarrow \frac{AB}{AD} = \frac{AC}{CE - AD}$

$AB = \frac{AC \times AD}{CE - AD}$

(b). <u>Method 4</u> :- (In case of river)



Erect a perpendicular AC & bisect it at D. Erect perpendicular CE at C & range E in line with BD. Measure CE. Then AB = CE

1.23 PROBLEMS ON OBSTACLES IN CHAINING

Problem 1 A survey line CD intersects a building. To overcome the obstacle a perpendicular DE, 87 m long, is set out at D. From E, two lines EF and EG are set out at angles 50° and 65° respectively with ED. Find the lengths EF and EG such that points F and G fall on the prolongation of CD. Also find the obstructed distance DF. (WBSC 1989)

Solution

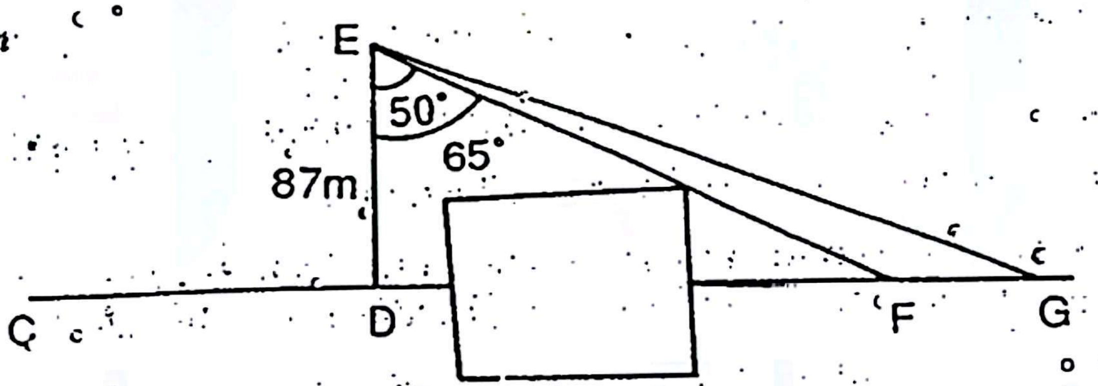


Fig. P.1.1

From Δ DEF,

$$\frac{DE}{EF} = \cos 50°$$

$$EF = \frac{DE}{\cos 50°} = \frac{87}{0.6428} = 135.345 \text{ m}$$

and

$$\frac{DF}{DE} = \tan 50°$$

$$DF = DE \tan 50° = 87 \times 1.1918 = 103.68 \text{ m}$$

From Δ DEG,

$$\frac{DE}{EG} = \cos 65°$$

$$EG = \frac{DE}{\cos 65°} = \frac{87}{0.4226} = 205.9 \text{ m}$$

* Chain Surveying :-

It is the method of land surveying in which only linear measurements are made. No angular measurements are taken. Chain surveying is used for areas of small extent on open ground having few simple details.

* Principle of surveying :-

The Basic principle of chain surveying is Triangulation. In chain surveying the area to be surveyed is divided into a fram work consisting of well conditioned triangle (i.e., a triangle whose interior angles are not less than 30° & not more than 120°) is called Triangulation.

* Basic Definitions :-

(a). Base line :-

It is the long survey line which runs through the area of the land to be surveyed such that it divides the area into two equal parts.

(b). Tie line :-

If the distance of the point of details from the chain line is very large, long offsets are to be taken. These are the lines run to locate the details of the long offsets.

(c). check line :-

These lines run through the area to check the accuracy of the work.

* Selection of survey stations :-

The following points should be considered while selecting survey stations :-

- It should be visible from at least two or more stations
- As far as possible main lines should run on level ground.
- All triangles should be well conditioned
- Main network should have as few lines as possible.
- obstacles to ranging & chaining should be avoided.

sk ugmit

* Offsets :-

Lateral measurements to chain lines for locating ground features are known as offsets. For this purpose perpendicular / oblique offsets may be taken.

(a). Perpendicular Offsets:-

Offsets which are perpendicular to the chain line are termed as perpendicular offsets. These can be taken using 3-4-5 rule, Cross staff or optical square, etc.

(b). Oblique offset:-

It is always greater than perpendicular distance. All the offsets which are not taken at the right angle to chain line are known as oblique offsets.

* Instruments for setting offset :-

(a). Cross Staff :

It is an instrument used to set out angles. There are three types cross staff :

(i). open cross staff :

It is used to set two lines at right angles to each other.

(ii). French cross staff :

It is used to set lines at 45° or 90°

(iii). Adjustable cross staff :

It is used to set any angle by adjusting the mirror or prism.

(b). Optical squares :

More convenient & accurate than cross staff for setting out right angles.

Consists of two mirrors making an angle of 40° with each other one mirror totally silvered another top silvered bottom unsilvered.

* Errors in chain surveying :-

Compensating errors	Cumulative errors
• These errors cannot be corrected as their nature is not known clearly. Some of them are : → Incorrect holding. → " marking of arrows → " Plumbing. → " setting of chain angles with cross staff.	• These errors can be corrected. → If chain is too long. (Measured distance will be less so (+ve correction) → If chain is too short. measured distance will be more so (-ve correction) • Besides these others errors due to temperature, pull, etc can also occur & corrected.

*

* Correction for chain length if too long or too short :-

$$l = l'\left[\frac{L'}{L}\right]$$

where,

L = True length of chain
l' = measured length of line
l = True " "
L = incorrect length of chain

*

(3). ANGULAR MEASUREMENT & COMPASS SURVEY :-

* COMPASS :-

It is a branch of surveying in which directions of survey lines are determined with a compass & the lengths are measured with a tape or a chain. The major type of compass generally used are prismatic & surveyor's compass.

* Adjustment of Prismatic & surveyor compass;

Prismatic

(a). ~~Gent~~ Temporary Adjustment:

(i) Centering: adjusting tripod

(ii). Levelling: leveling tripod ~~with bubble~~ ~~device~~.

(iii). Focusing the prism.

(b). Permanent Adjustment:

- Similar to surveyor's
- only done when the relation bet^n parts of the instrument are disturbed.

Surveyor

(a). Temporary Adjustment: similar to Prismatic

(b). Permanent Adjustment

(i). Adjustment of level (to make the level Perpendicular to the verticle axis)

(ii). Adjustment of Sight Vane (Bring sight vane into verticle Plane)

(iii). Adjustment of needles (Sensitivity, Horizontal, etc)

(iv). Adjustment of Pivot (Bring pivot point exactly to the Centre of the graduating circle)

The difference between surveyor's and prismatic compass is given in Table 5.3.

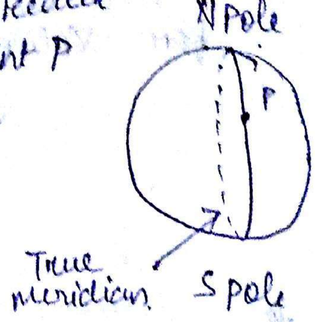
TABLES 5.3. DIFFERENCE BETWEEN SURVEYOR'S AND PRISMATIC COMPASS

Item	*Prismatic Compass*	*Surveyor's Compass*
(1) *Magnetic Needle*	The needle is of 'broad needle' type. The needle does not act as index.	The needle is of ' edge bar ' type. The needle acts as the index also.
(2) *Graduated Card*	(*i*) The graduated card ring is attached with the needle. The ring does not rotate along with the line of sight. (*ii*) The graduations are in W.C.B. system, having 0° at South end, 90° at West, 180° at North and 270° at East. (*iii*) The graduations are engraved inverted.	(*i*) The graduated card is attached to the box and not to the needle. The card rotates along with the line of sight. (*ii*) The graduations are in Q.B. system, having 0° at N and S and 90° at East and West. East and West are interchanged. (*iii*) The graduations are engraved erect.
(3) *Sighting Vanes*	(*i*) The object vane consists of metal vane with a vertical hair. (*ii*) The eye vane consists of a small metal vane with slit.	(*i*) The object vane consists of a metal vane with a vertical hair. (*ii*) The eye vane consists of a metal vane with a fine slit.
(4) *Reading*	(*i*) The reading is taken with the help of a prism provided at the eye slit. (*ii*) Sighting and reading taking can be done simultane-ously from one position of the observer.	(*i*) The reading is taken by directly seeing through the top of the glass. (*ii*) Sighting and reading taking cannot be done simultaneously from one position of the observer.
(5) *Tripod*	Tripod may or may not be provided. The instrument can be used even by holding suitably in hand.	The instrument cannot be used without a tripod.

* Meridian :-

(i) True Meridian

T.M. is at a point P is the greater circle passing through the point P & the geographical North & South Poles of earth



(ii). Magnetic Meridian

Magnetic meridian at a point is the direction indicated by a freely suspended, balanced magnetic needle at the point.

(iii). Arbitrary Meridian

It is the meridian which is taken in any convenient, arbitrary direction. Any reference line may be taken as arbitrary meridian.

* Bearing :-

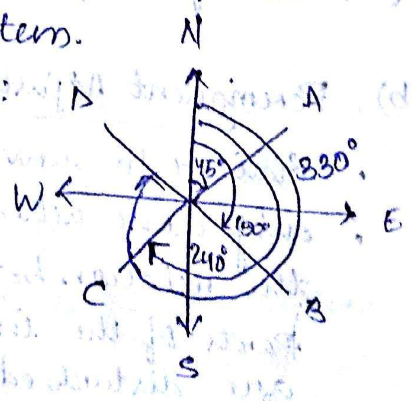
It is the direction of the line with respect to the meridian. In surveying the bearings are generally taken as follows:

(i) Whole circle Bearing (WCB):

In this system, the bearing of a line is measured clockwise from the north end of the reference meridian. Also called as Azimuthal system.

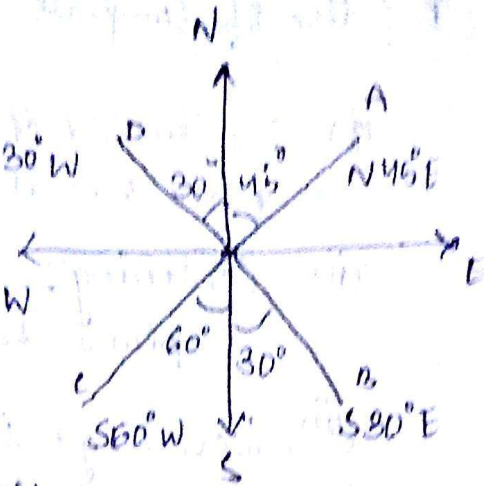
Conversion of Quadrant Bearing to WCB:

Line	Quadrant	Q. Bearing	WCB.
OA	I	N θ_1 E	θ_1
OB	II	S θ_2 E	$180° - \theta_2$
OC	III	S θ_3 W	$180° + \theta_3$
OD	IV	N θ_4 W	$360° - \theta_4$



(ii). Quadrantal Bearing (QB)

This bearing of a line is the acute angle which the line makes with the meridian.



Thus the QB is measured from the North point or south point. The QB of a line cannot be greater than 90°. It is also called as Reduced Bearing system (RB).

Conversion of whole Circle Bearing to QB

line	Quadrant	WCB	QB
OA	I	θ = 0° to 90°	N θ E
OB	II	θ = 90° to 180°	S (180° − θ) E
OC	III	θ = 180° to 270°	S (θ − 180°) W
OD	IV	θ = 270° to 360°	N (360° − θ) W.

1). Convert the following WCBs to QBs

(a). WCB

line	WCB	sol^n	QB
AB	45° 30'		N 45° 30' E
BC	125° 45'	180° − 125° 45'	S 54° 15' E
CD	222° 15'	222° 15' − 180°	S 42° 15' W
DE	320° 30'	360° − 320° 30'	N 39° 30' W

2). Convert the following QBs to WCBs.

line	QBs	sol^n	WCB
AB	S 36° 30' W	180° + 36° 30'	216° 30'
BC	S 43° 30' E	180° − 43° 30'	136° 30'
CD	N 26° 45' E	I^st quadrant	26° 45'
DE	N 40° 15' W	360° − 40° 15'	319° 45'

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① N.W. | N.E

IV 270-360	I 0 to 90'
III	II 90 to 180'

SW | SE

② RB → WCB

360 - RB	WCB = RB.
180 + RB	WCB = 180 - RB.

③ WCB → RB.

W(360-W)W	W(WCB)E
S[WCB-180]W	S(180-WCB)E

④ FB → BB.

θ < 180' add 180'

θ > 180' Sub 180'

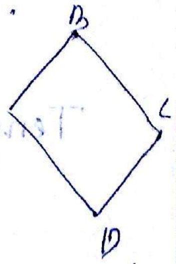
⑤ FB → BB.

N20E → S20W

N → S E → W

S → N W → E

⑥ ∠A = B. of PL - B. of NL.

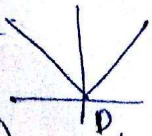


Permanent adjustment of compass

= B. of AD - B. of AB.

Special case

∠D : ?



⑦ TB = MB + D (East).

TB = MB - D (West)

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* Use of Compass :-

(i). The tripod stand is placed & the compass is fixed over the tripod.

(ii). Centering: it is done with the help of a plumb bob.

(iii). Levelling: is done with the help of a ball and socket arrangement provided on top of the tripod stand.

(iv). The prism is moved & adjusted accordingly

(v). The brake pin is pressed and the rotating ring is bought to rest. & after checking the horizontality of the compass, the readings of the are taken from the graduated ring (i.e. Magnetic Bearing).

* Fore Bearing:

The bearing of a line in the direction of the progress of survey is called the fore bearing (F.B.)

* Back. Bearing:

The bearing of the line in the direction opposite to the direction of the progress of survey is called the back bearing (B.B.)

Problem 6 The following are the fore and back bearings of the sides of a closed traverse:

Side	FB	BB
AB	150°15′	330°15′
BC	20°30′	200°30′
CD	295°45′	115°45′
DE	218°0′	38°0′
EA	120°30′	300°30′

Calculate the interior angles of the traverse.

Solution

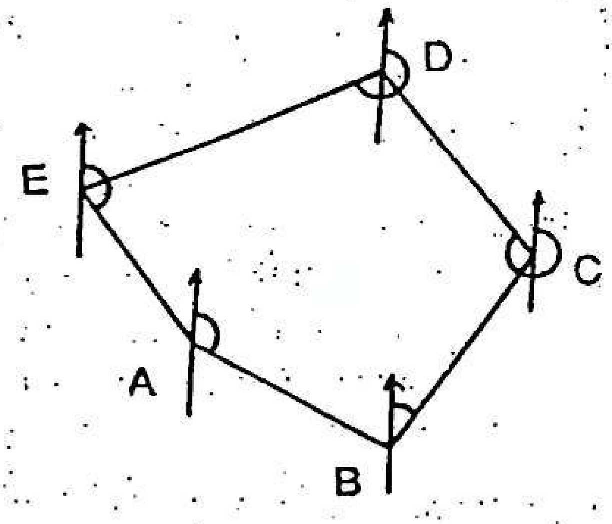


Fig. P-3.9

Exterior ∠A = BB of EA – FB of AB
= 300°30′ – 150°15′ = 150°15′

(a) Interior ∠A = 360°0′ – 150°15′ = 209°45′

Exterior ∠B = BB of AB – FB of BC
= 330°15′ – 20°30′ = 309°45′

(b) Interior ∠B = 360°0′ – 309°45′ = 50°15′

(c) Interior ∠C = FB of CD – BB of BC
= 295°45′ – 200°30′ = 95°15′

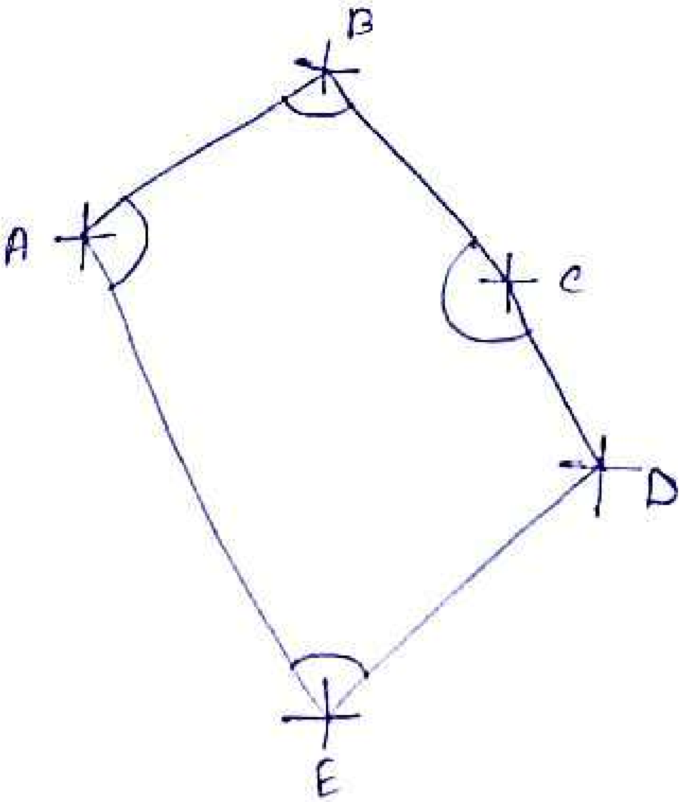
(d) Interior ∠D = FB of DE – BB of CD
= 218°0′ – 115°45′ = 102°15′

(e) Interior ∠E = FB of EA – BB of DE
= 120°30′ – 38°0′ = 82°30′

Check The sum of the interior angles should be equal to $(2N-4) \times 90°$. In this case,

$$(2N - 4) \times 90 = 540° \qquad (N = 5)$$

	FB	BB
AB	80°10'	259°0'
BC	120°20'	301°50'
CD	170° 50'	350° 50'
DE	230°10'	49°30'
EA	310° 20'	130°15'



(a) calculation of included angles.

$\angle A$ = BB of EA − FB of AB

$= 130^\circ 15' - 80^\circ 10'$

$\angle A = 50^\circ 5'$

$\angle B$ = BB of AB − FB of BC

$= 259^\circ 0' - 120^\circ 20'$

$\angle B = 138^\circ 40'$

$\angle C$ = BB of BC − FB of CD

$= 301°50' - 170°50'$

$= 131°0'$

$\angle D$ = BB of CD − FB of DE

$= 350°50' - 230°10'$

$= 120°40'$

$\angle E$ = 360° − (FB of EA − BB of DE)

$= 360° - (310°20' - 49°30')$

$= 99°10'$

Sum of Internal angles $= (2n-4) \times 90°$

$= (2 \times 5 - 4) \times 90°$

$= 540°$

$\angle A + \angle B + \angle C + \angle D + \angle E$

$= 50°5' + 138°40' + 131°0' + 120°40' + 99°10'$

$= 539°35'$

error $= 540° - 539°35' = 25'$

Distribution of error $= +5'$

Now angles are

$\angle A = 50°5' + 5' = 50°10'$

$\angle B = 138°40' + 5' = 138°45'$

$\angle C = 131°0' + 5' = 131°5'$

$\angle D = 120°40' + 5' = 120°45'$

$\angle E = 99°10' + 5' = 99°15'$

(b) $259^\circ 0' - 80^\circ 10' = 178^\circ 50'$

$301^\circ 50' - 120^\circ 20' = 181^\circ 30'$

$350^\circ 50' - 170^\circ 50' = 180^\circ 0'$

$49^\circ 30' - 230^\circ 10' = -180^\circ 40'$

$130^\circ 15' - 310^\circ 20' = -180^\circ 5'$

end

e

rom

On ~~verifyi~~ verifying the observed bearings The difference of FB and BB of the line CD is exactly 180°. So C and D are free from local attraction.

(ii) FB of DE

$\angle D$ = BB of CD − FB of DE

FB of DE = BB of CD − $\angle D$

$= 350^\circ 50' - 120^\circ 45'$

$= 230^\circ 5'$

BB of DE

$230^\circ 5' - 180^\circ = 50^\circ 5'$

FB of EA

$\angle E = 360^\circ$ − (FB of EA − BB of DE)

$\angle E = 360^\circ$ − FB of EA + BB of DE

FB of EA = 360° + BB of DE − $\angle E$

$= 360^\circ + 50^\circ 5' - 99^\circ 15'$

$= 310^\circ 50'$

BB of EA $= 310^\circ 50' - 180^\circ = 130^\circ 50'$

FB of AB

$\angle A =$ BB of EA − FB of AB

FB of AB = BB of EA − $\angle A$

$= 130^\circ 50' - 50^\circ 10'$

FB of AB $= 80^\circ 40'$

BB of AB $= 80^\circ 40' + 180^\circ 0' = 260^\circ 40'$

FB of BC

$\angle B =$ BB of AB − FB of BC

FB of BC = BB of AB − $\angle B$

$= 260^\circ 40' - 138^\circ 45'$

FB of BC $= 121^\circ 55'$

BB of BC

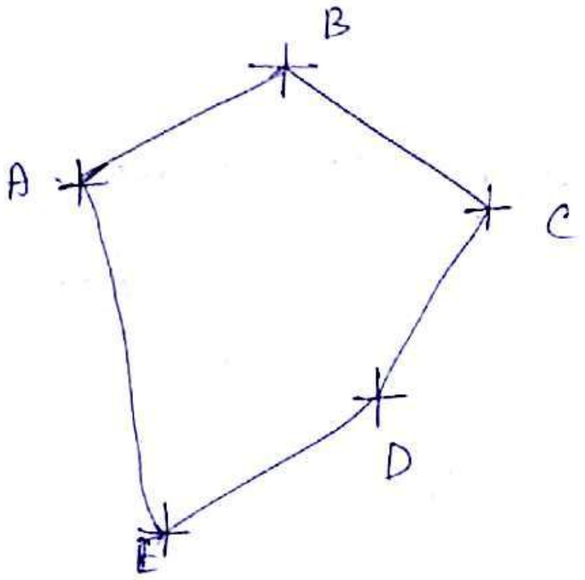
$180^\circ + 121^\circ 55' = 301^\circ 55'$

Corrected bearings

Line	FB	BB	
AB	$80^\circ 40'$	$260^\circ 40'$	
BC	$121^\circ 55'$	$301^\circ 55'$	
CD	$170^\circ 50'$	$350^\circ 50'$	C & D free from local attraction
DE	$230^\circ 5'$	$50^\circ 5'$	
EA	$310^\circ 50'$	$130^\circ 50'$	

(2)

	FB	BB
AB	$59^\circ 0'$	$239^\circ 0'$
BC	$139^\circ 30'$	$317^\circ 0'$
CD	$215^\circ 15'$	$36^\circ 30'$
DE	$208^\circ 0'$	$29^\circ 0'$
EA	$318^\circ 30'$	$138^\circ 45'$



$\angle A$ = BB of EA − FB of AB

$= 138^\circ 45' - 59^\circ 0'$

$= 79^\circ 45'$

$\angle B$ = BB of AB − FB of BC

$= 239^\circ 0' - 139^\circ 30'$

$= 99^\circ 30'$

$\angle C$ = BB of BC − FB of CD

$= 317^\circ 0' - 215^\circ 15'$

$= 101^\circ 45'$

$\angle D = 360^\circ - ($ FB of DE $-$ BB of CD $)$

$= 360^\circ - (208^\circ 0' - 36^\circ 30')$

$= 188^\circ 30'$

$\angle E = 360^\circ - ($ FB of EA $-$ BB of DE $)$

$= 360^\circ - (318^\circ 30' - 29^\circ$

$= 70^\circ 30'$

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

$= (2 \times 5 - 4) \times 90^\circ$

$= 540^\circ$

$\angle A + \angle B + \angle C + \angle D + \angle E$

$= 79^\circ 45' + 99^\circ 30' + 101^\circ 45' + 188^\circ 30' + 70^\circ 30'$

$= 540^\circ$

(ii)

$239^\circ 0' - 59^\circ 0' = 180^\circ 0'$

$317^\circ 0' - 139^\circ 30' = 177^\circ 30'$

$215^\circ 15' - 36^\circ 30' = 178^\circ 45'$

$208^\circ 0' - 29^\circ 0' = 179^\circ 0'$

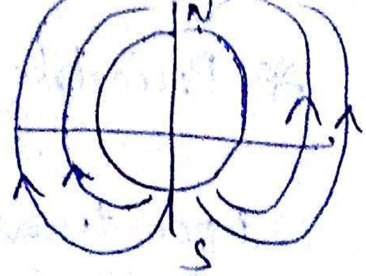
$318^\circ 30' - 138^\circ 45' = 179^\circ 45'$

A and B are free from local attraction.

Corrected bearing

	Correction	FB	BB	Remarks
AB	+0°	59° 0'	239° 0'	Station A and B are free from local attraction.
BC	+0°	139° 30'	319° 30'	
CD	+2° 30'	217° 45'	37° 45'	
DE	+1° 15'	209° 15'	29° 15'	
EA	+0° 15'	318° 45'	138° 45'	

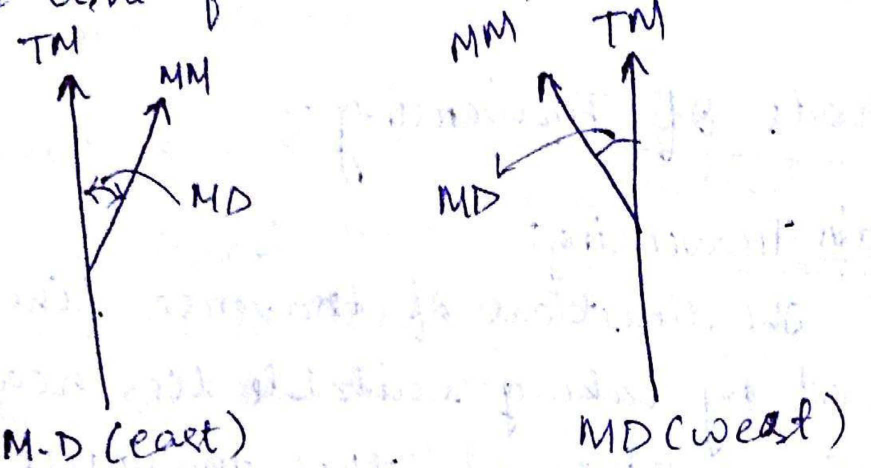
* Magnetic dip:



The angle which the lines of force made with the angle surface of the earth is called angle of the dip or dip of the needle.

* Magnetic declination:

Magnetic declination at a place is the horizontal angle betn true meridian & magnetic meridian shown by the needle at the time of observation.



If the declination is towards east

TB = MB + Declination

If declination is towards west

TB = MB - Declination.

* Variation in Declination:

The value of declination at a place never remains constant but changes from time to time. Some of the types of variation in declination are:

(i). Diurnal Variation (varies daily)

(ii). Annual variation (varies annually)

(iii). Irregular " (causes due to magnetic storms like earthquakes, etc)

3.12 PROBLEMS ON MAGNETIC DECLINATION

Remember the following:

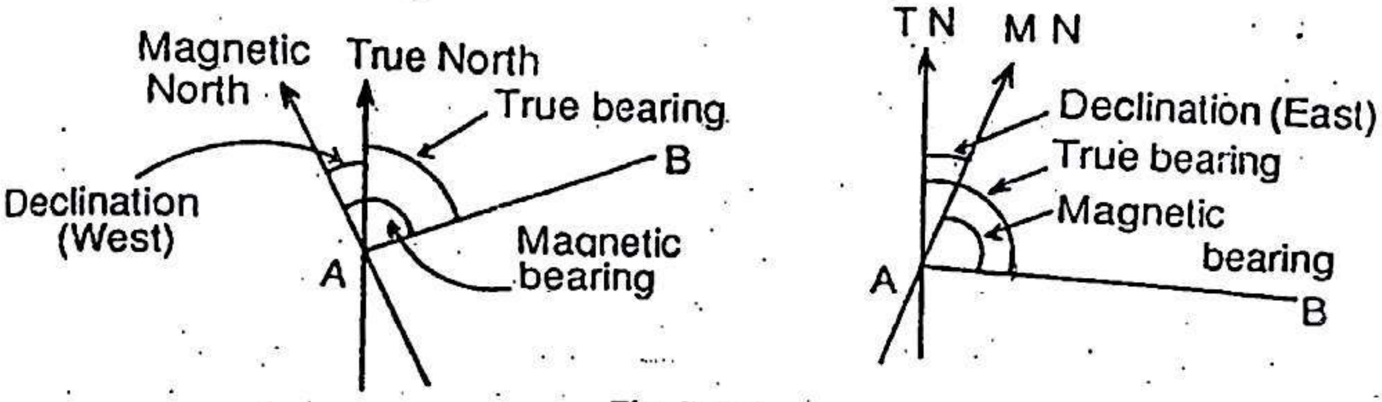


Fig. P-3.1

Determination of true bearing and magnetic bearing:

(a) True bearing = magnetic bearing ± declination

Note [use the positive sign when declination east, and the negative sign when declination west]

(b) Magnetic bearing = true bearing ± declination

Note [Use the positive sign when declination west, and the negative sign when declination east.]

Problem 1 (a) The magnetic bearing of a line AB is 135°30′. What will be the true bearing, if the declination is 5°15′ W.

(b) The true bearing of a line CD is 210°45′. What will be its magnetic bearing, if the declination is 8°15′ W.

Solution

(a) True bearing of AB = magnetic bearing − declination

$= 135°30' - 5°15' = 130°15'$

(b) Magnetic bearing = true bearing + declination

$= 210°45' + 8°15' = 219°0'$

Problem 2 The magnetic bearing of a line CD is S 30°15′ W. Find its true bearing, if the declination is 10°15′ E.

Solution First convert the RB to WCB, and then follow the usual procedure to find the true bearing in WCB. Finally, convert the true bearing to RB.

RB of CD = S 30°15′ W

WCB of CD = $180°0' + 30°15' = 210°15'$

Now TB = MB + declination (east)

$= 210°15' + 10°15' = 220°30'$

Required true bearing = $220°30' - 180°$ = S 40°30′ W

* Errors in compass:
(1). Personal Errors.
(2) Instrumental Errors.
(3). Natural Errors.

1). Personal Errors :→

(a). Inaccurate leveling.
(b). " centering.
(c) " Bisection of signals.
(d) Carelessness in reading & recording.

2). Instrumental Errors :→

(a). Pivot being bent
(b). sluggish needle.
(c). Pivot being blunt.
(d). Improper blancing weight.
(e). Line of sight (not passing through centre of the sight)
(f). Plane of sight (not verticle)

4). Natural Errors :→.

(a). Variation in declination.
(b). Local attraction.
(c). Magnetic changes in the atm.
(d). Irregular Variation due to magnetic

* Principle of Traversing :-

Open traversing:

It starts from one station & closes at another station whose location is neither known nor established.

Closed traversing.

It starts from one traverse station & closed either on the same or another station whose location is already known.

* Methods of Traversing :-

Chain Traversing:

The directions of traverse lines are fixed by taking suitable ties near the traverse stations. This traverse is not very accurate & is rarely used in Practice

Compass Traversing :

The directions of the traverse lines are determined with a magnetic compass.

Plane Table Traverse :

It can be ~~plotted~~ used to plot a traverse directly in the field.

Stadia Traverse :

In this traverse the length of the traverse lines, the angles betⁿ the traverse lines & the elevation of stations are measured with Tacheometer.

Theodolite Traverse :

The angles are measured with theodolite.

* Local Attraction :

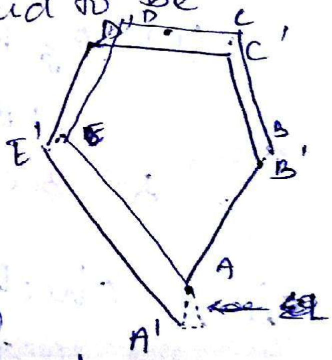
It is due to the influence of magnetic materials like heavy steel or nickel objects, electric poles, transmission lines, etc.

If the difference in FB & BB of a line is not 180° the stations represented by that line are affected due to Local attraction.

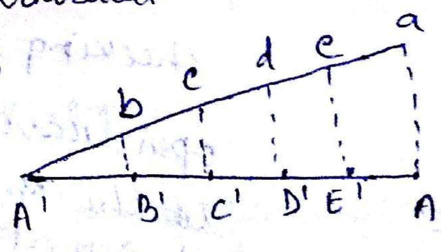
Problems
[illegible]

* Adjustment of closing error :

When a closed traverse is plotted, if the finishing & starting points does not coincide, then the distance by which the traverse fails to close is said to be the closing error. The method for correction of the error adopted is Bowditch Rule.



Thus AB'C'D'E'A' is an unbalanced polygon with closing error equal to AA'. Thus the error is distributed linearly among all the stations as per the proportional to the length by a graphical (i.e. triangle) construction. Where in aA represents the error (AA') & the corresponding coordinates bB', cC', dD', eE'. represents the distribution at the respective stations. Parallel to the closing error.



* Check for traverse :->

(i). closed Traverse :-

(a). traverse by angle :-

- The sum of measured interior angles should be equal to $(2N-4) \times 90°$.
- The sum of measured exterior angles shall be equal to $(2N+4) \times 90°$

where,

N = Number of sides of the traverse

(b). By deflection angle :-

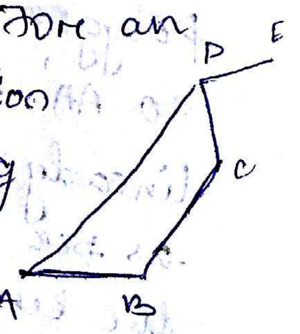
The sum of the deflection angles should be equal to 360°.

(c). By Bearing :-

FB of the last line should be equal to Back bearing ± 180°.

(ii). Checks in Open Traverse :-

There is no such direct method for checking the open traverse. For an open traverse ABCDE. In addition to the observation of bearing of AB at station A. Bearing of AD can also be measured. Similarly at D bearing of DA can be measured & check is applied. If the two bearings differ by 180°, the work may be accepted.



Gales Table :-

The traverse computations are done in a tabular form, a more common form being Gales Traverse Table. The following steps are necessary:

(i). adjust the interior angles to satisfy the sum of interior angles

(ii). Starting with bearings of one line calculate the bearings of all other lines.

(iii). calculate the latitudes & Departures & also (ΣL & ΣD)

(iv). apply necessary corrections to satisfy $\Sigma L = 0$ & $\Sigma D = 0$ equations.

(v). using the corrected values calculate the independent co-ordinates.

×

[5]. PLANE TABLE SURVEYING:

* **Objectives of Plane table surveying:**
  - The topographical features to be mapped are in full view.
  - To plot small scale maps.
  - To plot the field observations by using a graphical method.

* **Principle of Plane Table surveying:**

The principle of plane Table surveying is parallelism. i.e. "All the rays drawn through various details should pass through the survey stations."

The rays drawn from stations to objects on the paper are Parallel to the lines from the stations to the objects on the ground.

* Accessories used fore Plane Table Surveys:

(a). Board
(b). Tripod (provided to fix the drawing board)
(c). Alidade (used to establishing a line of sight. There are two type of allidady simple & telescopic allidate).
(d). Trough Compass (It is used to plot the magnetic meridian & to facilitate the orientation of Plane table in the magnetic meridian).
(e). Spirit level (used to level the plane table)
(f). Plumbing Fork (used to transfere the ground points on to the sheet)
(g).

* Methods of Plane table Surveying:

(i). Radiation:-

In this method the instrument is setup at a station & rays are drawn to various stations which are to be plotted. The distances are cut to a suitable scale after actual measurements. This method is suitable only when the area to be surveyed is small & all the stations are visible & accessible from the instrument station.

(ii) Intersection :-

In this method two stations are so selected that all the other stations to be plotted are visible from these. The line joining these two stations is called base line. The length of this line is measured very accurately. This method is suitable when the distance between the stations is too large, or the stations are inaccessible or the ground is undulating.

(iii). Traversing :-

This method is similar to compass or theodolite traversing. The table is set at each of the stations in succession. A foresight is taken to the next station & the distance is cut to a suitably chosen scale. This method is most suitable when a narrow strip of terrain is to be surveyed. eg. roads, railways, etc.

(iv). Resection :-

It is a method of orientation employed when the table occupies a position not yet located on the drawing sheet. It is defined as the process of locating the instrument station occupied by the plane table by drawing rays from the stations whose positions have already been plotted on the drawing sheet. The position of such a station is fixed on the drawing sheet by resection.

(i). Resection after orientation by compass
(ii). Resection after orientation by back sighting.
(iii). " " " by two point problem
(iv). " " " by three point Problem

* Two point Problem :-

In this problem two well defined points whose position have already been plotted on the plan.

(a). P & Q are well defined points whose positions are already plotted on map as p & q. A new station at A shall be plotted perfectly bisecting P & Q.

(b). A random station B shall be selected, & table is set up & adjusted & clamped.

(c). With alidade at p & q the P, Q stations are bisected & the rays are drawn, & intersect at b.

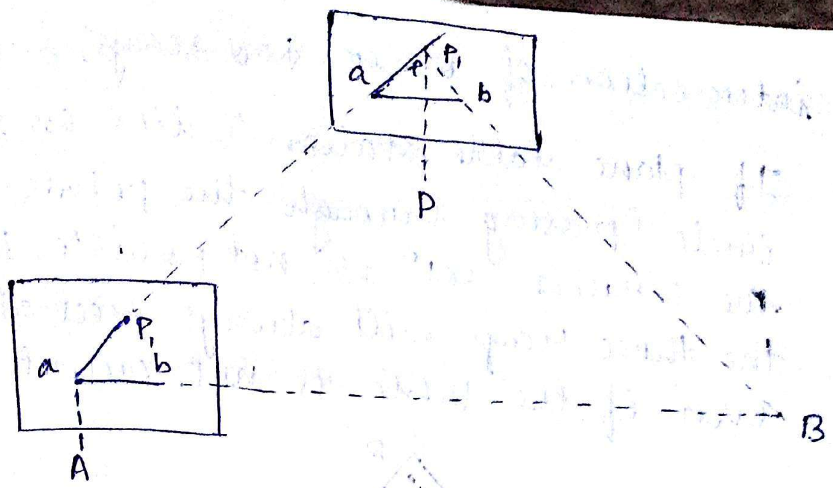
(d) With alidade centred at b, the ranging rod at A is bisected & a ray is drawn. & a point a_1 is marked.

(e). The table is shifted & centred on A with a_1 on A, and checked by backsighting. With alidade touching P, the point P is bisected & rays are drawn.

(f). With alidade centred at a_1 the point Q is bisected & a ray is drawn. If this ray intersects the ray bq at a point q_1. The triangle pqq_1 is called triangle of error.

(g). The alidade is placed along the line pq_1 & a ranging rod R is fixed at some distance from the table. The alidade is placed along the line pq & the table is turned to bisect R.

(h). Finally the alidade is centred on p & q, the points P & Q are bisected & rays are drawn. If the intersect at a. This would represent the exact position of the required station A.



* Three point Problem :-

The three point Problem can be done in three different methods :-

(i). Tracing paper method.

(ii). Graphical Method

(iii). Lehman's method.

Lehman's method :

In this method three well defined points are selected where position have already been plotted on the map.

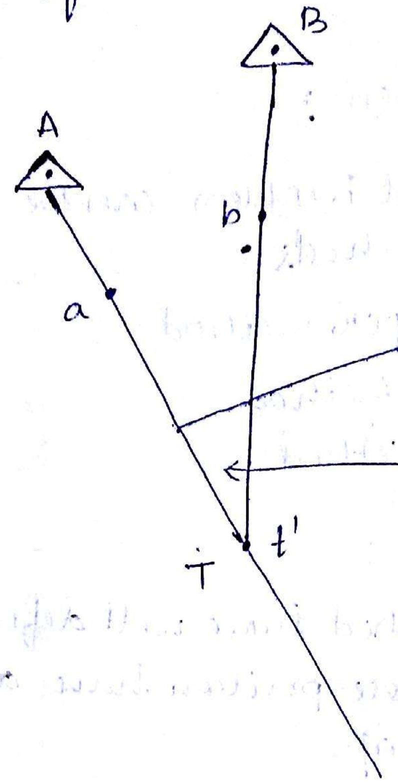
(a). The distane of the point "t" to be fixed from each of the rays aA, bB & cC is proportional to the respective distances of the stations A, B, & C from the station T.

(b). while looking towards the stations the point "t" to be fixed, will either be to the left or to the right of each of the rays.

(c). when T is outside the great circle ABC, t' is always on the same side of the ray drawn to the most distant station as the intersection of the other two rays.

(d). when T falls within any of the three segments of the great circle ABC, formed by the sides of the triangle ABC, the ray towards the middle station lies between 't' & the intersection of other two rays.

(e). If plane table station T lies on the great circle (passing through the points A, B & C) the correct sol^n is not possible, because the three rays will always meet at a point even if the table is not oriented.



* Errors in plane table surveying :-

(i) Instrumental errors :-

→ The surface of drawing board is not plane

→ The edge of alidade is not straight

→ The object vane & sight vane are not perpendicular to the alidade.

→ The edge of alidade is not parallel to the line of sight.

→ The fixing clamp is not proper.

(ii). manipulation & sighting errors :-

→ Defective leveling.

→ Defective sighting.

→ Defective Orientation

→ " Centering.

(iii) Plotting Error :-

-> Defective scale of map
-> Wrong intersection of the rays.

Precautions :

-> centring should be perfect
-> levelling " " "
-> Orientation " " "
-> Alidade should be centred on the same side of the station pin until the work is completed
-> while shifting the plane table from one station to another, the tripod stand should be kept vertical.
-> Several accessories have to be carried so care should be taken that nothing shall be missed.

(6). THEODOLITE SURVEYING AND TRAVERSING:

* Theodolite Surveying:-

It is an intricate instrument used mainly for accurate measurement of horizontal & vertical angles up to 10" to 20", depending upon the least count of the instrument. The basic purpose of theodolite surveying are as follows:

-> measuring horizontal angles
-> measuring vertical angles
-> measuring deflection angles
-> measuring magnetic bearings
-> measuring the horizontal distances.
-> ,, the verticle height, etc.

*. Theodolite are two types.

(a). Transit Theodolite

(b). Non-Transit Theodolite.

* Features of Transit Theodolite :-

(a). Centering :-

The process of setting up the instrument exactly over the station mark. For which the plumb bob is used.

(b). Vertical Axis :-

Also called as Azimuth axis. It is axis about which the instrument rotates in the horizontal plane

(c) Horizontal Axis :-

Also called as Trunion axis. It is axis about which the telescope & vertical circle rotate in vertical plane.

(d). Line of collimation :-

It is the line passing through the intersection of horizontal & vertical cross hairs & optical centre of object glass & its continution.

(e). Transiting :-

The process of turning the telescope in vertical plane through 180° about the trunion axis. It is also called reversing.

(f). Bubble line :-

A straight line tangential to the longitudinal curve of the level tube at its centre when the bubble is at centre it is said to be horizontal.

(g). Swinging :-

Process of turning the telescope in Horizontal plane.

(h). Changing Face :-

Operation of bringing the face of the telescope from left to right & vice versa. It is done by transitting.

* Essential parts of Transit Theodolite :-

1. Tribrach :- ~~It is a~~

It is triangular plate carrying three foot screws.

2. Foot screws :-

These are used for levelling the instrument.

3. Trivet :

It is a circular plate having a central, hole for fixing the theodolite on the tripod stand by a nut.

4. Levelling head :

The foot screws, trivet & tribrach is combinedly called as levelling head.

5. Lower Plate :

It is also known as scale plate. It is bevelled & the scale is graduated from 0° to 360° in a clockwise direction. It is provided with a clamp screw & the tangent screw. when clamp screw is tightened then the lower plate is fixed.

6. Upper plate :

It consists the vernier scales A & B. Its motion is controlled by the upper screw & the upper tangent screw.

7. Plate bubble :

Two plate bubbles are mounted at right angles to each other on the upper surface of the vernier plate. used to level the instrument while horizontal measurements.

8. Telescope:

It is pivoted between the standards at right angles to the horizontal axis. It can be rotated about horizontal axis in a vertical plane.

9. Verticle Circle:

It is rigidly fixed with the telescope & moves with it. It consists of foure quadrants, each graduated from 0° to 90°.

10. Altitude Bubble:

A bubble tube is provided on the top of index bar. This bubble tube is used during the measurement of vertical angles.

11. Compass:

An adjustable trough compass can be fitted with a screw to the standard, to measure the magnetic bearing of a line.

* Reading the verenier Theodolite:

It concist of a main scale & a verenier scale. The main scale shows the reading in degrees & the verenier scale shows in minutes. Thus if the arrow shows the direct readings of the verenier.

* Temporary adjustments of theodolite :-

(a) **Setting :**

To fix theodolite to the tripod.

(b). **Centering :**

To place the vertical axis exactly over the station mark.

(c). **Levelling up :**

It is done using leveling screws of foot screws. To make the vertical axis of instrument truly vertical.

(d). **Elimination of Parallax :**

Parallax is a condition arising when the image formed by the objective is not in the plane of cross hairs. It can be eliminated by the following way:

(i). Focusing the eye piece (i.e. the cross hair)

(ii). Focusing the objective (i.e. the image)

(e). **Adjustment of plate level :**

To make the axis of plate bubble perpendicular to the vertical axis when the bubble is central.

(f). **Adjustment of line of sight :**

The line of sight should coincide with optical axis of the telescope.

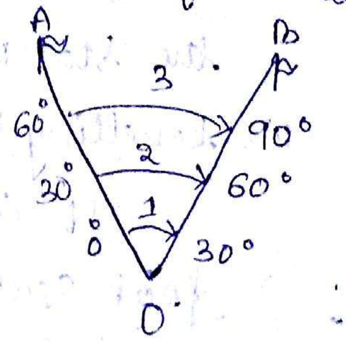
(g). **Adjustment of horizontal axis :**

Horizontal axis should be perpendicular to the vertical axis.

* Measurement of Horizontal angles :

(a). Method of Repetition :

Used to measure a horizontal angle to a finer degree of accuracy than obtainable with the least count of vernier.



→ Suppose the angle ∠AOB is to be measured by the repetition process

→ Initially by turning the telescope the ranging ~~road~~ rod at 'A' is bisected & upper clamp is loosened & the telescope is turned clockwise & the ranging rod at B is bisected. & 1st reading is taken

→ Fixing the upper clamp & loosening the lower the rod at 'A' is bisected & similarly as above the 2nd reading is taken by bisecting rod at B.

→ similarly another reading is taken for better accuracy.

$$\text{so, } \angle AOB = \frac{\text{accumulated angle}}{\text{no. of readings}}$$

$$= \frac{90^\circ}{3} = 30^\circ \text{ (in this example)}$$

* Measurement of Verticle angles :-

Vertical angle is the one between the horizontal line & the inclined line of sight.

→ The telescope is located at O and adjusted properly & the telescope is clamped.

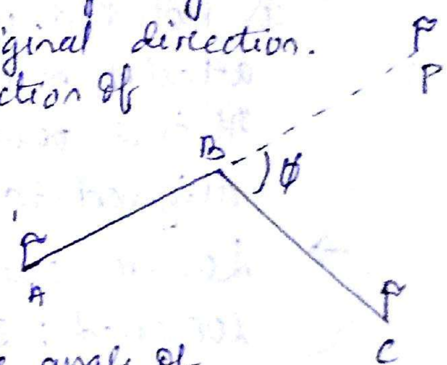
→ The altitude bubble is bought to the centre ensuring the horizontallity of the telescope (line of collimation),

→ Thus in order to measure the angle of elevation (∠AOC) the point A of the rod is bisected and then face of the telescope is changed & the readings are again taken. The average of the two reading is taken.

→ Similar process is adopted for measuring the angle of depression (i.e. ∠COB)

* Measurement of Deflection Angle :

Deflection angle is the angle by which a line is deflected from its original direction. Let AB be the general direction of survey. Suppose it is deflected in the direction BC. The line AB is extended up to P. Then ∠PBC (ϕ) is known as the angle of deflection & has to be measured by the following steps :



→ The theodolite is set up at B, centred & levelled properly. The upper clamp is tightened & the lower one loosened, The telescope is is turned & the ranging rod at A is bisected then the lower clamp is fixed.

→ The telescope is transited & ranging rod at P is bisected. Now the upper clamp is loosened, by turning the telescope clockwise the ranging rod at C is bisected & the readings are noted & upper clamp is fixed.

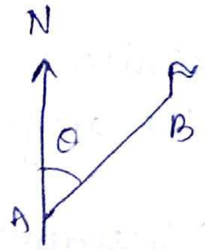
→ The lower clamp is loosened & by turning the telescope clockwise ranging rod at A is bisected. The lower clamp is fixed.

→ By transiting the telescope rod P is bisected and upper clamp is loosened and a similar proce is adopted & the readings are taken.

→ Thus the deflection angle is doubled & average of the two readings are taken.

* Measurement of Magnetic Bearing:

If the magnetic bearing of the line AB is to be measured:



→ The theodolite is set up at A, centred & leveled & upper clamp is fixed.

→ By loosening the lower clamp, the telescope is rotated untile the trough compass (attached to the theodolite) shows the north. At this point it is ~~attached to the mac~~ aligned to the magnetic meridian

→ Lower clamp is fixed & upper clamp is loosened; The ranging rod at 'B' is bisected by turning the telescope clockwise & reading is taken.

→ The face of the instrument is changed and the reading is taken again. The mean value of these two readings is taken as the magnetic bearing of AB.

* Prolongating a straight line with theodolite:

→ Theodolite is set up at B, centred & levelled

→ The ranging rod at A is bisected & the upper & lower clamp is fixed.

→ The telescope is transited & through it a ranging rod is fixed at C along the line AB.

→ Now the theodolite is shifted & set up at C, then a backsight reading is taken on B. The upper & lower clamps are fixed.

→ The telescope is transited & the next point D is fixed on the line by a ranging rod.

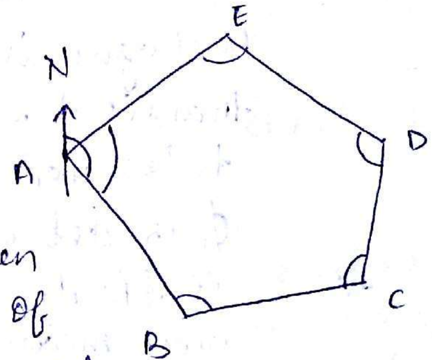
→ similarly other points are fixed.

* Methods of traversing :-

The following are the different methods of traversing:

(1) Included angle method :

This method is most suitable for closed traverse. In this method the bearing of the initial line is taken.



→ The theodolite is set up at A. The telescope is oriented along the magnetic meridian then the magnetic bearing of the line AB is measured.

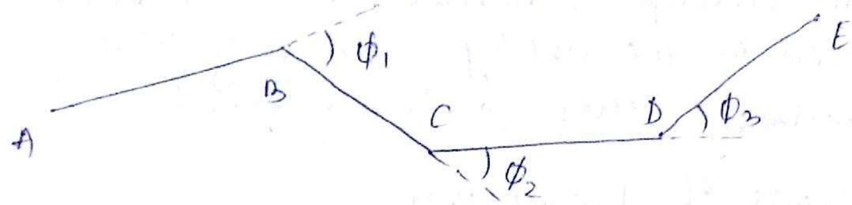
→ Again vernier A is set to 0° & ~~lower~~ upper clamp is fixed.

→ lower clamp is loosened & the ranging rod at E is bisected. Fixing the ~~upp~~ lower clamp the upper clamp is loosened. By turning the telescope the ranging rod at B is bisected. The readings on the vernier is noted & ∠A is obtained in this fashion. The face is changed & ∠A is measured again. The mean of the two observations ~~are~~ is taken as ∠A.

→ similarly the other angles are measured with theodolite centred at B, C, D & E. The check is applied & the error is distributed.

(2). Deflection Angle Method:

Method is most suitable for open traverse



The above shown open traverse starts from A.

→ The theodolite is set up at A, after this the bearing of the line AB is measured.

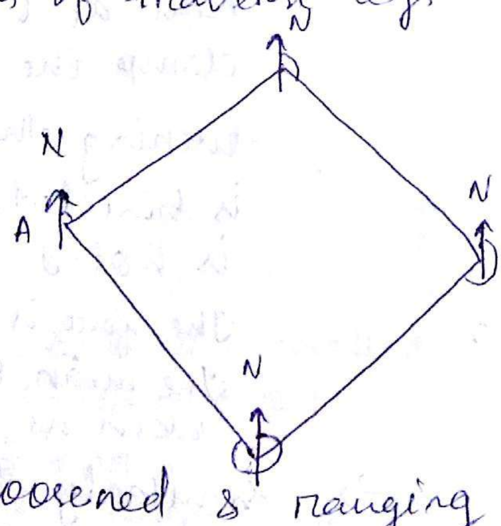
→ The theodolite is shifted to B. Then a backsight is taken on A. The telescope is transited & by turning it clockwise the ~~telus~~ rod at C is bisected. & the angle ϕ_1 is determined.

→ Similarly the other deflection angles ϕ_2 & ϕ_3 are measured.

(3). Fast Needle Method:

Also called as magnetic bearing method. This method is used to measure the magnetic bearings & the lengths of traverse legs.

→ The theodolite is set up at A. ~~Jree~~ & aligned along the magnetic meridian & the lower clamp is fixed.



→ The upper clamp is loosened & ranging rod at B is bisected. The readings on vernier A gives the fore bearing of AB. The B.B of line DA is also measured. Now the upper clamp is fixed & traverse is conducted in clockwise direction.

→ The instrument is set up at B. & the lower clamp is loosened & ranging rod at A is bisected. The telescope is transited & upper clamp is released & ranging rod at C is bisected.

→ Again instrument is shifted to C & same process is repeated to find the bearings of the remaining sides

* Check in closed Traverse :-

→ Sum of measured interior angles should be equal to $(2N - 4) \times 90°$

→ Sum of measured exterior angles should be equal to $(2N + 4) \times 90°$

→ Algebric sum of deflection angles should be equal to 360° (right hand deflection +ve
left " " -ve)

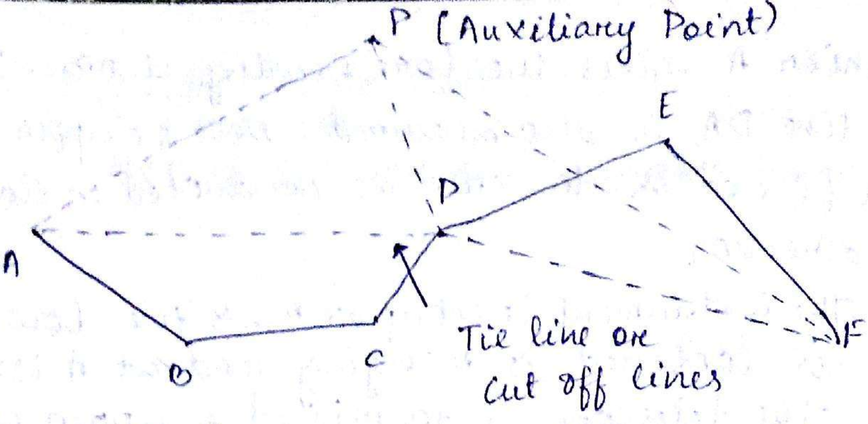
→ FB & BB of the last line should differ by 180°

→ chaining of each line should be done twice in both directions.

* Check in Open Traverse :-

(1). Tie line or cut off line:

Suppose ABCDEF is an open traverse. The cut-off lines AD & DF are suitably taken. The FB & BB of lines AD & DF are measured & so are distances AD & DF. After plotting the traverse the distances, FB & BB of the cut-off lines tally with the field measurements, then the traverse is said to be correct.



(2). Auxiliary Point :

It is a point selected on one side of the traverse. The magnetic bearings of this point are taken from A, D & F. If the traverse is done properly then all these bearings must meet at P when plotted from stations.

* Errors in theodolite :

(1). Instrumental Errors:

(i) Non adjustment of plate bubble
(ii). Line of collimation not being perpendicular
(iii). Horizontal axis not being perpendicular to Vertical axis
(iv). Graduations not being uniform
(V). Verniers being eccentric, etc.

(2). Personal Errors:

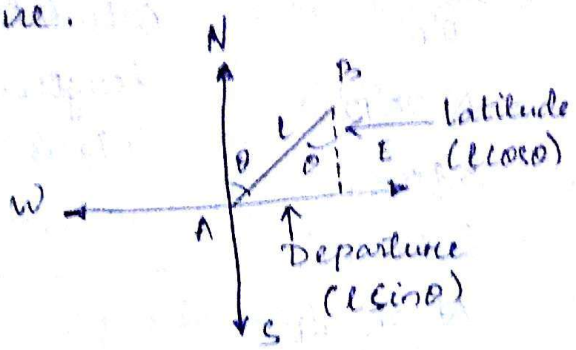
→ improper centering.
→ inaccurate levelling
→ clamping is not perfectly done
→ If parallax error is not perfectly removed.
→ inaccurate bisecting of ranging rod.
→ Oversighting of readings.

(3). Natural Errors :

→ Refraction caused due to high temperatures
→ High speed winds induces vibrations in the instrument.

* Computation of Latitude & Departure :

Latitude of a line is the distance measured parallel to the North - South line & the departure of a line is measured parallel to the East-west line.



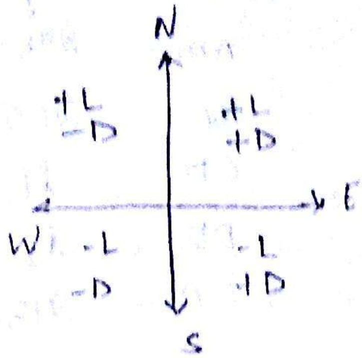


Table for computing latitude & departure

Line	Length (L)	Reduced bearings	Latitude	Departure
AB	L	NθE	+L cosθ	+L sinθ
BC	L	SθE	-L cosθ	+L sinθ
CD	L	SθW	-L cosθ	-L sinθ
DA	L	NθW	+L cosθ	-L sinθ

Note
sum of latitude must be equal to zero
Sum of Departure must be equal to zero.

Line	Consecutive co-ordinates			
	Northing(+)	southing(-)	Easting(+)	westing(-)
AB	L cosθ		L sinθ	
BC		-L cosθ	L sinθ	
CD		L cosθ		L sinθ
DA	L cosθ			L sinθ

Note
Sum of Northings = Sum of Southings
sum of Eastings = sum of westings.

Q. The measured lengths & bearings of the sides of a closed traverse ABCDEA run in an anticlockwise direction and are tabulated below:

Line	length(m)	Bearings.
AB.	298.7	0°0'
BC	205.7	N 25°12' W
CD	l_1	S 75°6' W
DE	l_2	S 56°24' E
EA	213.4	N 35°36' E

Calculate the lengths of CD & DE.

Soln

line	length	Bearing	(L cosθ) Latitude	(L sinθ) Departure
AB	298.7	0°0'	+298.7	0
BC	205.7	N 25°12' W	+186.12	−87.58
CD	l_1	S 75°6' W	$-0.26 l_1$	$-0.97 l_1$
DE	l_2	S 56°24' E	$-0.55 l_2$	$+0.83 l_2$
EA	213.4	N 35°36' E	+173.52	+124.23

as we know

$\Sigma L = 0$ & $\Sigma D = 0$

So,

$\Sigma L = 0$

$\Rightarrow 298.7 + 186.12 - 0.26 l_1 - 0.55 l_2 + 173.52 = 0$

$\Rightarrow 658.34 = 0.26 l_1 + 0.55 l_2$

$\Rightarrow 0.26 l_1 + 0.55 l_2 = 658.34$ —— (1)

$\Sigma D = 0$

$\Rightarrow 0 - 87.58 - 0.97 l_1 + 0.83 l_2 + 124.23 = 0$

$\Rightarrow 36.65 = 0.97 l_1 - 0.83 l_2$

$\Rightarrow 0.97 l_1 - 0.83 l_2 = 36.65$ —— (2)

on solving equation ① & ②

$0.26 l_1 + 0.55 l_2 = 658.34$

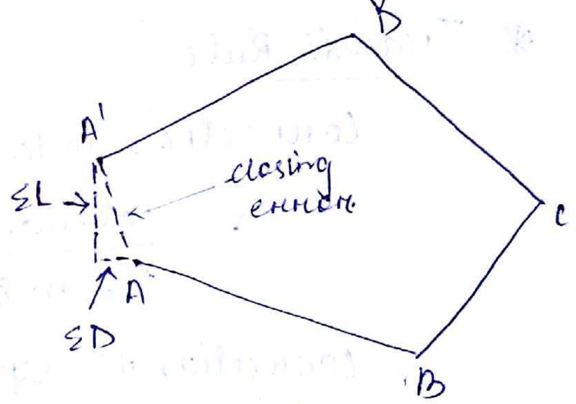
$0.97 l_1 - 0.83 l_2 = 36.65$

$l_1 = 756.145 \text{ m}$

$l_2 = 839.53 \text{ m}.$

* Closing Error :-

Due to errors in field measurements of angles and lengths, sometimes the finishing point may not coincide with the starting point of a closed traverse.



so, closing error

$$AA_1 = \sqrt{(\Sigma L)^2 + (\Sigma D)^2}$$

L = Latitude

D = departure

the direction of closing error 'θ' is given by

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

$$\text{Relative closing error} = \frac{\text{closing error}}{\text{Perimeter of traverse}}$$

* Bowditch Rule :

For correction of latitude & longitude departure is distributed in proportion to the lengths of the traverse legs.

correction to latitude of any side

$$= \frac{\text{length of that side}}{\text{Perimeter of traverse}} \times \text{total error in latitude}$$

Correction to departure of any side

$$= \frac{\text{length of that side}}{\text{Perimeter of traverse}} \times \text{total error in departure}$$

Q

Line	Length	Consecutive Coordinates L	Consecutive Coordinates D	Correction L	Correction D	Corrected Coordinates L	Corrected Coordinates D
AB	70	+21.5	-65.45	+0.072	-0.064	+21.57	-65.514
BC	80	-80.76	-5.25	+0.083	-0.073	-80.67	-5.323
CD	43	-41.00	+13.55	+0.044	-0.039	-40.956	+13.511
DE	38	-14.25	+35.15	+0.038	-0.034	-14.212	+35.116
EA	115	+114.15	+22.315	+0.118	-0.105	+114.268	+22.210
	346	-0.355	+0.315	+0.355	-0.315	0	0
		error		correction		Adjusted.	

* Transit Rule

correction to latitude of any side

$$= \frac{\text{latitude of that side}}{\text{Sum of all latitudes}} \times \text{total error in latitude}$$

correction to departure of any side

$$= \frac{\text{departure of that side}}{\text{Sum of all departures}} \times \text{total error in departures}$$

* Axis method :

Here the corrections is applied to lengths only. Thus

$$\text{correction to any length} = \text{that length} \times \frac{\frac{1}{2}\text{ closing error}}{\text{length of axis}}$$

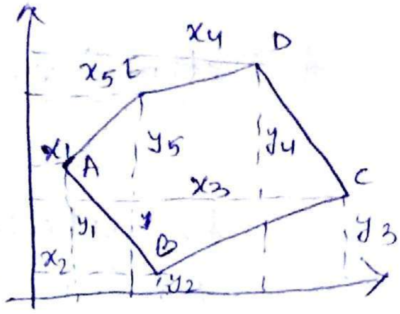
* Graphical Method :-

Is similar to the method discussed in compass surveying.

* Calculation of Area by co-ordinates method :

The consecutive co-ordinates are converted into the independent co-ordinates & thus the whole traverse is transferred to the first quadrant. Let say A is the most westerly station.

Then the co-ordinates are arranged as follows.



$$\begin{matrix} y_1 & y_2 & y_3 & y_4 & y_5 & y_1 \\ x_1 & x_2 & x_3 & x_4 & x_5 & x_1 \end{matrix}$$

Sum of the products of two lines

$$\Sigma P = (y_1 x_2 + y_2 x_3 + y_3 x_4 + y_4 x_5 + y_5 x_1)$$

$$\Sigma Q = (x_1 y_2 + x_2 y_3 + x_3 y_4 + x_4 y_5 + x_5 \times y_1)$$

Area Required = $\frac{1}{2}(\Sigma P - \Sigma Q)$

[8]. COMPUTATION OF AREA AND VOLUME :-

* Determination of Area :-

The area of particular traverse can be determined in different methods based on the shape & accuracy required. Wherein the ~~stra~~ plan enclosed with in the straight boundaries is divided into simple geometrical shapes such as triangles, rectangle, etc. Thus by determining the area of these shapes the area of the plan can be determined.

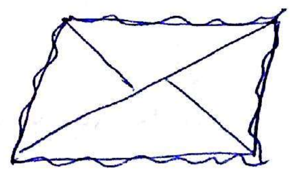
* Computation of areas from plans :

- Considering entire area
- Considering Boundary Area
  - Mid-Ordinate rule
  - Average Ordinate rule
  - Trapezoidal rule
  - Simpson's rule.

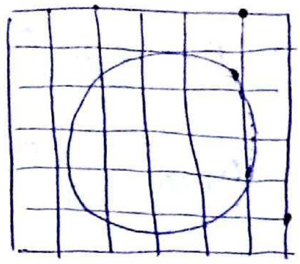
Case 1 Considering entire area :-

The area is divided into no. of continued shapes :

(i). Area into triangles :

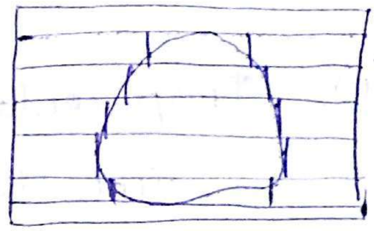


Triangles are so drawn to equalise the irregular boundaries. Then by measuring the bases & altitudes the areas of ~~triangles~~ triangles are calculated (i.e. area = $\frac{1}{2}$ × base × altitude) (ii). Area into Squares :



The area is divided into number of equal squares of unit area. as shown Thus the total area is calculated by multiplying the no. of squares into the unit area.

(iii). Parallel lines converted to rectangles :

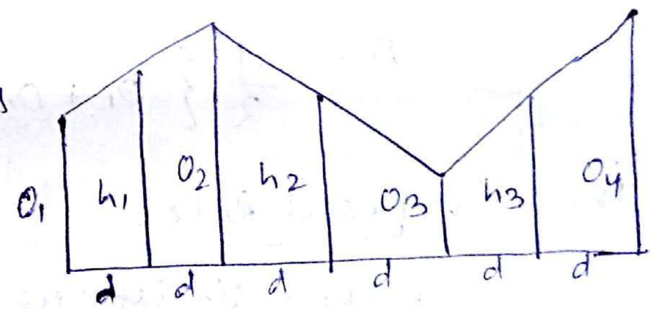


A series of equidistance parallel lines shall be drawn. Thus the area is divided into number of strips & curved ends are replaced by perpendicular lines forming rectangles

∴ Required area = Σ length of rectangles × constant distance

Case 2

(i). Mid- Ordinate Rule :



$O_1, O_2, \ldots O_4$ are ordinates at equal distance. This method, the tract is divided into segments & the length of the middle ordinate of each segment is measured.

$N =$ Total no. of equal segments $= n-1$

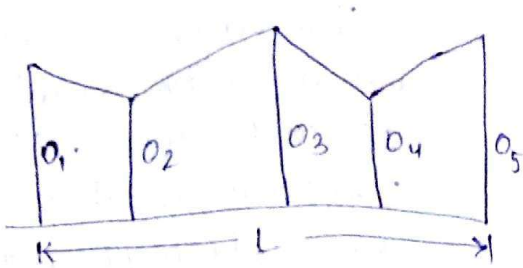
$n =$ Total no. of ordinates.

So,

$$A = d\left[h_1 + h_2 + \ldots + h_{n-1}\right]$$

where $h_1 = \frac{O_1 + O_2}{2}$ & ... & $h_{n-1} = \frac{O_{n-1} + O_n}{2}$

(ii) Average Ordinate Rule



$$\text{Area} = \left(\frac{O_1 + O_2 + \cdots + O_n}{O_n}\right) \times L$$

L = length of base line
n = no. of divisions
n+1 = no. of ordinates

(iii). Trapezoidal Rule :

Here the track is divided into number of trapezoids, & area of each is determined seperately.

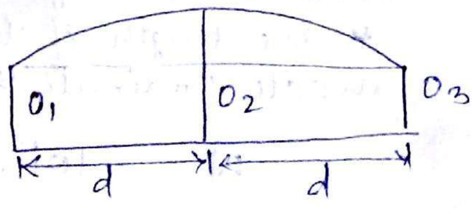
$$A = d\left\{\left(\frac{O_1 + O_n}{2}\right) + O_2 + O_3 + \cdots + O_{n-1}\right\}$$

OR

$$A = \frac{d}{2}\left\{O_1 + O_n + 2O_2 + 2O_3 + \cdots + 2O_{n-1}\right\}$$

(iv). Simpson's Rule :

If the ordinates are odd then only this formula is used.



Area of segment = $\frac{2}{3}$ × area of Parallelogram

= [illegible]

So,

$$\text{Area} = \frac{d}{3}\left\{(O_1 + O_n) + 4(O_2 + O_4 + \cdots + O_{n-1}) + 2(O_3 + O_5 + \cdots + O_{n-2})\right\}$$

* Calculation Of Volumes :-

The volume is calculated by multiplying the mean area of the cross section with length of the track

(i) Prismoidal formula : (For odd number of ordinates)

$$V = \frac{h}{3}\left\{ (A_1 + A_n) + 4(A_2 + A_4 + \cdots + A_{n-1}) + 2(A_3 + A_5 + \cdots + A_{n-2}) \right\}$$

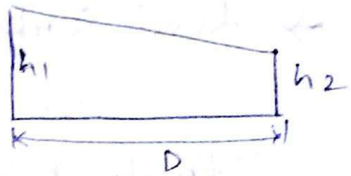
h = equal distance of the segment

A = Area of each segments.

(ii). Trapezoidal formula :

$$V = h\left\{ \frac{(A_1 + A_n)}{2} + A_2 + A_3 + \cdots + A_{n-1} \right\}$$

* Prismoidal Corrections :-

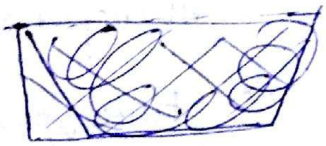


1. Correction for level section.

$$C_p = \frac{D \times S}{6}(h_1 - h_2)^2$$

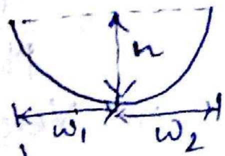
Slope = 1 in s

2. Correction for two level section



$$C_p = \frac{D \times S}{6} \times \left(\frac{n^2}{n^2 - s^2}\right) \times (h_1 - h_2)^2$$

* Curvature Correction for Volumes :



- Correction for two level section

$$C_c = \frac{d}{6R}(w_1^2 - w_2^2)\left(h + \frac{b}{2n}\right)$$

R = Radius of curve

(7). LEVELLING AND CONTOURING

The aim of levelling is to determine the relative heights of different objects on or below the surface of the earth & to determine the undulation of the ground surface.

Purpose of levelling :

→ To find the elevations of given points w.r.t a given or assumed datum.

→ To deal with angular & linear measurements in vertical plane.

→ To prepare a contour map for fixing sites.

→ To prepare a longitudinal section & c/s of a project.

* Important Definitions :-

→ Level Surface:

The surface of a still water is a truly level surface. Any surface parallel to the mean spheroid surface of the earth is therefore, a level surface

→ Horizontal plane :

Any plane tangential to the level surface at any point is known as the horizontal plane

→ Verctical plane :

Any plane passing through the direction indicated by a plumb line is known as the Vertical plane.

→ Datum :

It is an imaginary level surface from which the vertical distances of different points are measured

→ Reduced level (RL) :

Vertical distance above or below an arbitrarily assumed level surface or datum.

→ Bench Mark :

Relative permanent point of reference whose elevations with reference to some assume datum is known.

→ Line of collimation :

It is an imaginary line passing through the the intersection of the cross hairs at the diaphragm & the optical centre of the object glass & its continuation, is called as line of collimation.

→ Axis of Telescope :

It is an imaginary line passing through the optical centre of the object glass & the optical centre of the eye piece

→ Axis of Bubble Tube :

It is an imaginary line tangential to the longitudinal curve of the bubble tube at its middle point.

* Instruments used for levelling

- Level
  - Dumpy
  - Wye
  - Reversible
  - Tilting
  - Autolevel
- Levelling staff
  - Solid – 3m
  - Folding – 4m

* Temporary adjustment of level :

(a). Selection of suitable position (i.e a flat & firm ground is selected for positioning).

(b). Fixing level with tripod
(level is fixed on the top of tripod).

(c). Approximate levelling by legs of tripod stand

(d). Perfect levelling by foot screws

(e). Focussing the eye piece

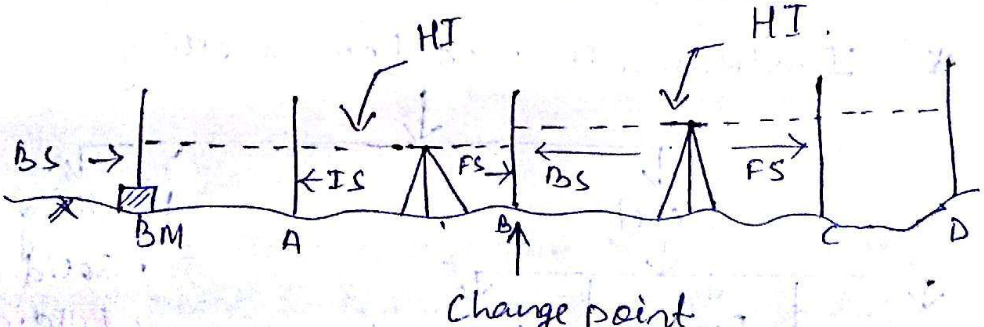
(f) Focussing the object glass

(g). Taking the staff readings.

* Terms related to Bench mark :-

→ Backsight reading (BS):

This is the first staff reading taken in any set up of the instrument. This reading is always taken on a point of known RL i.e Bench mark



→ Foresight reading (FS)

It is the last staff reading in any set up of the instrument.

→ Intermediate sight (IS) :

It is any other staff reading between the BS & FS.

→ Change point (CP) :

This point indicates the shifting of instrument.

→ Height of Instrument (HI) :

When the levelling instrument is properly levelled, the RL of the line of collimation is known as ~~focussing~~ height of instrument.

* height of collimation method	Rise & Fall method
→ Rapid, involves few steps of calculations	→ Laborious
→ No. check on the RL	→ There is check on the RL of Intermediate point.
→ errors cannot be detected	→ error can be detected.
→ Suitable for longitudinal levelling where there are a number of intermediate sights	→ suitable for fly levelling where there is no intermediate sights.

Example The following consecutive readings were taken with a dumpy level along a chain line at a common interval of 15 m. The first reading was at a chainage of 165 m where the RL is 98.085. The instrument was shifted after the fourth and ninth readings.

3.150, 2.245, 1.125, 0.860, 3.125, 2.760, 1.835, 1.470, 1.965, 1.225, 2.390, and 3.035 m.

Mark rules on a page of your notebook in the form of a level book page and enter on it the above readings and find the RL of all the points by:

1. By the collimation system:

Station point	Chainage	BS	IS	FS	RL of collimation line (HI)	RL	Remark
1	165	3.150			101.235	98.085	
2	180		2.245			98.990	
3	195		1.125			100.110	
4	210	3.125		0.860	103.500	100.375	changed point
5	225		2.760			100.740	
6	240		1.835			101.665	
7	255		1.470			102.030	
8	270	1.225		1.965	102.760	101.535	Change point
9	285		2.390			100.370	
10	300			3.035		99.725	
Total =		7.500		5.860			

Arithmetical check:

$$\Sigma BS - \Sigma FS = 7.500 - 5.860 = +1.640$$

$$\text{Last RL} - \text{1st RL} = 99.725 - 99.085 = +1.640$$

2. By the rise-and-fall system:

Station point	Chainage	BS	IS	FS	Rise (+)	Fall (–)	RL	Remark
1	165	3.150					98.085	
2	180		2.245		0.905		98.990	
3	195		1.125		1.120		100.110	
4	210	3.125		0.860	0.265		100.375	changed point
5	225		2.760		0.365		100.740	
6	240		1.835		0.925		101.665	
7	255		1.470		0.365		102.030	
8	270	1.225		1.965		0.495	101.535	changed point
9	285		2.390			1.165	100.370	
10	300			3.035		0.645	99.725	
Total =		7.500		5.860	3.945	2.305		

* Effects of curvature & Refraction :

1. Curvature Correction :

Due to curvature, objects appear lower than they really are. It is always substractive.

$$C_c = \frac{d^2}{2R} \qquad R = 6370\,KM$$

$$= 0.07857\,d^2 \text{ m}$$

where, d in km.

2. Correction for Refraction :

Due to refraction, object appear higher than they really are. It is always Positive

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

$$= 0.01122\,d^2 \text{ m}.$$

· Thus combined correction

$$= C_C + C_R$$

$$= -0.0785d^2 + 0.0112d^2$$

$$= -0.0673\,d^2\ m$$

where

d = horizontal distance in km.

5.8 PROBLEMS ON CORRECTIONS AND SENSITIVENESS

Problem 1 A level is set up at a point 150 m from A and 100 m from B; the observed staff readings at A and B are 2.525 and 1.755 respectively. Find the true difference of level between A and B.

Solution Combined correction for curvature and refraction to staff reading at

$$A = 0.0673 \times D^2 = 0.0673 \times \left(\frac{150}{1,000}\right)^2 = 0.0015 \text{ m}$$

Correct reading on A = 2.5250 – 0.0015
= 2.5235 m (1)

Combined correction for curvature and refraction to staff reading at

$$B = 0.0673 \times \left(\frac{100}{1,000}\right)^2$$

= 0.000673 m = 0.0007 m (say)

Correct reading at B = 1.7550 – 0.0007 = 1.7543 m

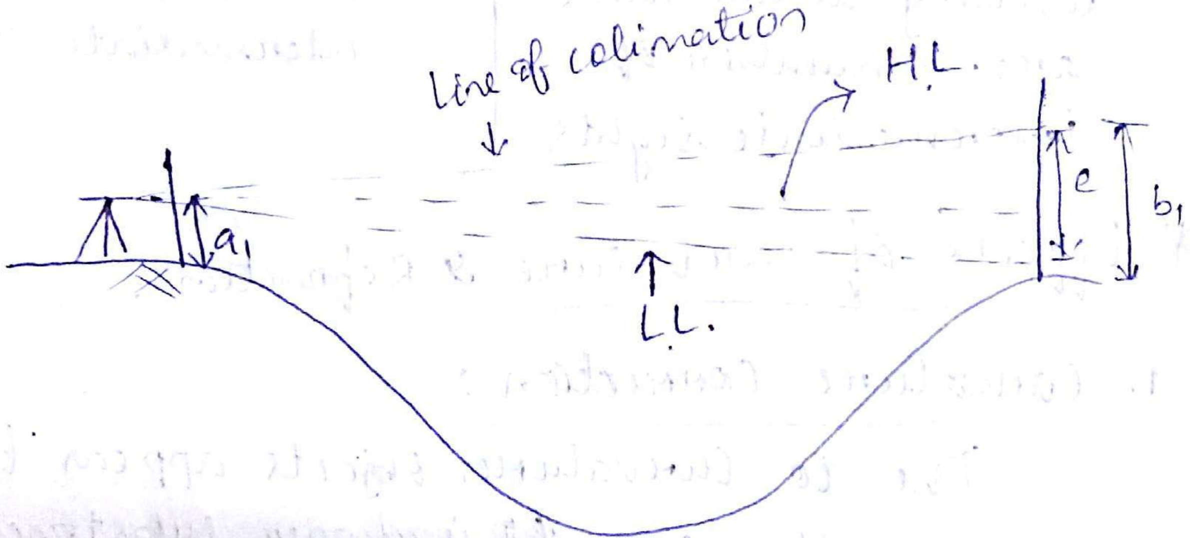
True difference of level between A and B = 2.5235 – 1.7543

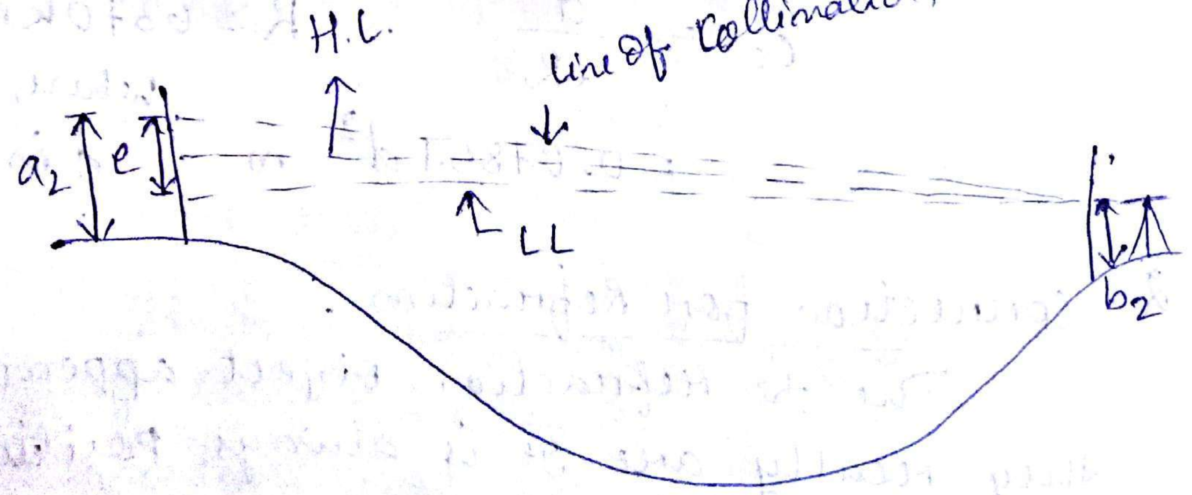
= 0.7692 m (fall from B to A)

sk ugmit

* Reciprocal levelling

In this type of levelling the level is setup at both banks of the river or valley and two sets of staff readings are taken by holding the staff on both banks. Thus the true difference of level is equal to mean of two apparent distance of level.





Problem 2 The following records refer to an operation involving reciprocal levelling.

Instrument at	Staff reading on		Remarks
	A	B	
A	1.155	2.595	Distance AB = 500 m
B	0.985	2.415	RL of A = 525.500

Find:

(a) The true RL of B,
(b) The combined correction for curvature and refraction,
(c) The collimation error, and
(d) Whether the line of collimation is inclined upwards or downwards.

Solution

(a) True difference of level between A and B

$$= \frac{(2.595 - 1.155) + (2.415 - 0.985)}{2}$$

$$= 1.435 \text{ m} \qquad \text{(fall from A to B)} \qquad (1)$$

$$\text{RL of B} = 525.500 - 1.435 = 524.065 \text{ m}$$

(b) Combined correction for 500 m = $0.0673 \times (0.5)^2 = 0.0168$ m (negative)

(c) Let us assume that the line of collimation is inclined upwards.
Let, Collimation error in 500 m = e (positive, as it is inclined upwards)

(*Note*: When the error is positive, correction will be negative and vice versa.)

When the instrument is at A,
Correct staff reading at A = 1.155 m (as level is near A)
Correct staff reading at B = $(2.595 - 0.0168 - e)$

True difference of level between A and B

$$= (2.595 - 0.0168 - e) - 1.155$$
$$= 1.4232 - e \qquad (2)$$

From (1) and (2),

$$1.4232 - e = 1.4350 \quad e = -0.0118$$

$$\text{Collimation error per 100 m} = -\frac{0.0118 \times 100}{500} = -0.0023 \text{ m}$$

(d) The collimation error was assumed positive, but the result is negative. So the assumption is wrong. The line of collimation is actually inclined downwards.

* Errors in levelling:

(a). Instrumental
- due to imperfect adjustment
- due to sluggish bubble
- due to movement of objective slide
- due to defective joints

(b). Natural
- Earth's curvature
- Atmospheric refraction
- Variation in temperature
- Wind vibrations

(c). Personal
- error in sighting
- mistake in recording
- mistake in reading
- mistake in manipulations

* Contour:

A contour may be defined as an imaginary line passing through the points of equal elevation.

* Characteristics of contour lines:

→ All the points on a contour line have a same elevation

→ The elevation of the contour is indicated by a number close to contour line.

→ A zero meter contour line represents the coast line

→ Two contour lines donot intersect each other, except in case of overhanging cliffs.

→ equal spaced contour represents uniform slope

→ A set of closed contours with higher figures inside indicates hillock, whereas in case of depressions, the higher figures are outside.

→ Irregular contour represent uneven ground.

-> A watershed or ridge line crosses the contour at right angle

-> A part of land in form of tongue which just out forms hilly area is called peak

* ~~Methods of contour~~

* ~~Interpolation of contours~~

* Use of contour Maps

-> Drawing cross-section

For a given contour plan, the section along any given direction can be drawn to know the general shape of the ground or the general shape of the ground or to use it for earthwork calculation.

-> Tracing of contour gradient & location of route

A contour plan is very much usefull in locating the route of a highway, railway, canal or any other communication line

-> Measurement of earth work,

The volume of contour plan can be determined with the help of cross-section of existing ground surface i.e by cross-section besides it can also be determined by Prismoidal & trapezoidal formula.

Method of Locating Contour :→

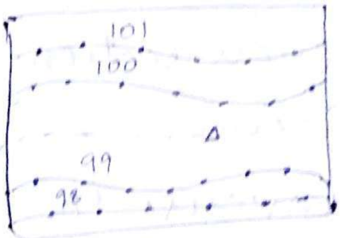
There are two method of locating contour:

(i) Direct method. — [Vertical contour. / Horizontal "]

(ii) Indirect method.

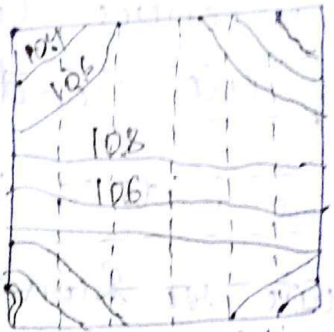
The location of a point in topographic survey involves both horizontal & vertical .... contour.

Topographic



Indirect Method :→

1) by squares :



The diff in the contour lines is 0.2

Interpolation

The method is used when the area is small & the ground is not very much undulating.

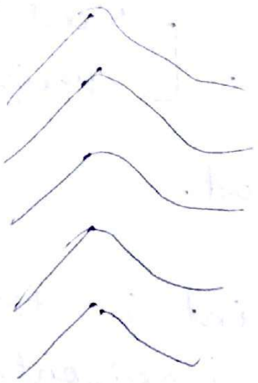
The area to be surveyed is divided into a number of squares. The size of square may vary from 5- depending upon the nature of the contour & contour interval.

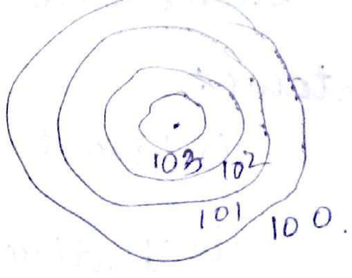
The elevation of the corner of the square are then determined by the means of the level of and a staff.

The contour line may then be

drawn by interpolation.

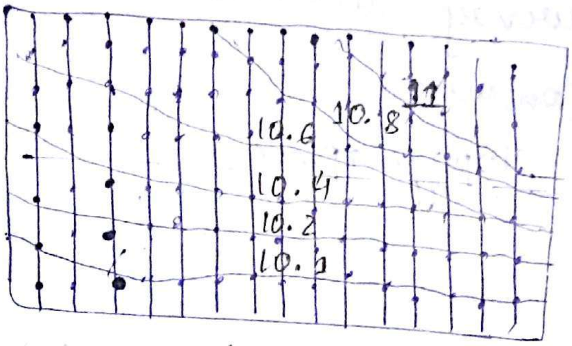
2) By Cross Section.





Hill.

In this method the cross sections are run transverse to the centre line of the road.



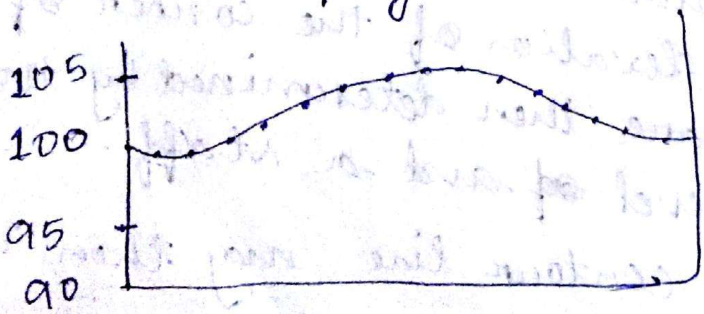
Contour map.

The method is most suitable for railway route surveying.

The spacing of the cross section depends upon character of the terrain.

The contour interval & the purpose of the surveying.

The cross section should be more closely spaced where the contours curve abruptly as in Ravines or on spurs.



(4) MAP READING CADESTRAL MAPPING

* **Scale**

Scale of map is the ratio of a distance on the map, to the corresponding distance in the ground.

* **Grid reference**

It defines locations ~~on~~ in Maps or indicates a location on the map in terms of a series of vertical and horizontal grid lines, identified by numbers or letters

* **Grid square**

The square of a map denoted by a grid formed by a series of numbered horizontal and vertical lines.

* **Cadestral map**

It is a large scale map showing the boundaries ~~of~~ of property and ownership of land Parcels. It consist of additional details such as survey district names, unique identification numbers for parcels, certificate of title number, position of existing structures, etc.

The unique parcel identification number may be defined as a code for recognizing, selecting & arranging information to facilitate organized storage & retrieval of parcel records.

The basic approaches adopted for cadastral surveying & mapping:

→ Ground survey techniques
→ Combination of Photogrammetric & ground survey techniques.

* Positioning of control points:

It means determining the position of the control points with respect to latitudes & longitude or well defined coordinates. There are three methods of positioning:

(i). Point Positioning:

Position of a stationary or moving point is determined with respect to a well defined co-ordinate.

(ii). Relative Positioning:

The co-ordinate of an unknown point is determined with respect to a known point.

(iii) Differentially positioning:

It is a system in which differences between observed & computed co-ordinates or ranges known as differential corrections at a particular known point called reference station.

Sanjanya K