

BHUBANANANDA ODISHA SCHOOL OF ENGINEERING, CUTTACK
DEPARTMENT OF CIVIL ENGINEERING



LECTURE NOTE ON: LAND SURVEYING -I (TH-3) 4th SEMESTER

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BOSE, CUTTACK

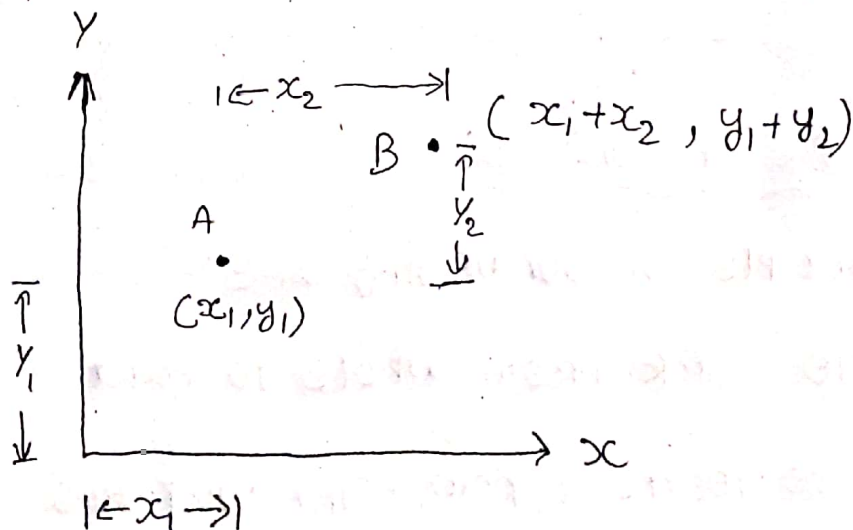
1.1- Surveying: Definition, Aims and objectives

Definition of surveying

*- surveying is an art of determining the relative position of different point or object on the surface of the earth by measuring the horizontal distance between them and preparing a map to any suitable scale.

Aim & Object of surveying :-

- *- The aim of surveying is to prepare a map to show the relative position of the object on the surface of the earth
- *- map shows ~~natural features of a country~~ and artificial features of a country. such as towns, village, road, railway, river, etc.



(Relative position)

USE OF SURVEY -

(2)

* - TO prepare a topographical map.

→ Topography → Topography is a study of features of land surface (natural & artificial)

→ Topographical map shows villages, towns, hills, rivers, forest, etc of a country.

* - TO prepare a cadastral map which shows boundaries of fields, houses, estates, etc

* - TO prepare an engineering map which shows the details of engineering works, such as roads, railway, Irrigation work, etc.

* - TO prepare a contour map. (A map showing the level of different points).

1.2 - Principle of survey → plane surveying, Geodetic surveying, Instrumental surveying

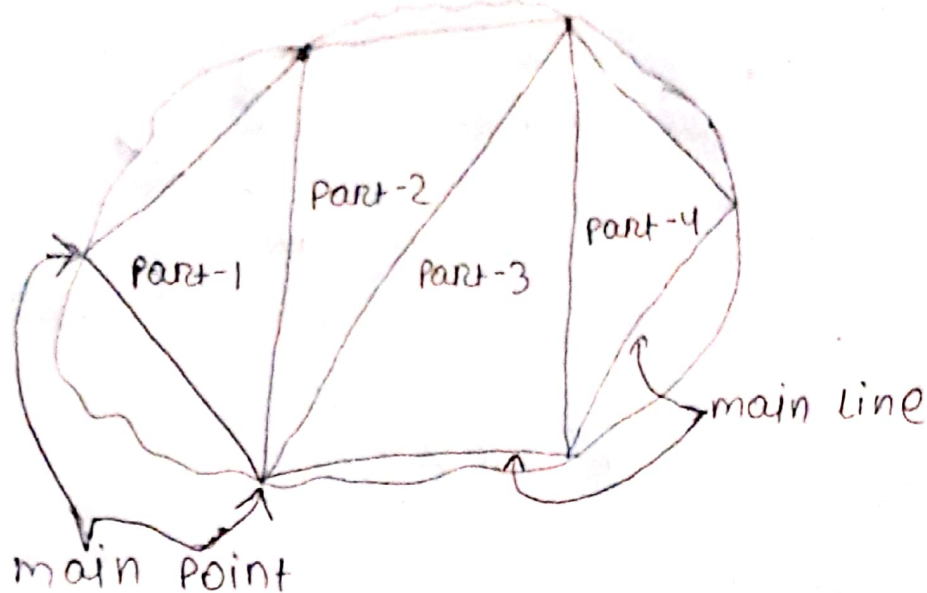
Principle of survey :-

* - Principle of surveying are :-

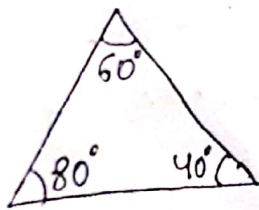
1 - TO work from whole to part

2 - TO locate a new point WRT two reference point.

1- TO WORK FROM WHOLE TO PART :-



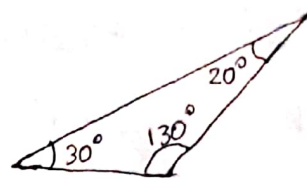
* - In this principle whole area is divided into no of parts by forming well condition triangles.



(well condition Δ)



(Ideal Δ)



(Ill condition Δ)

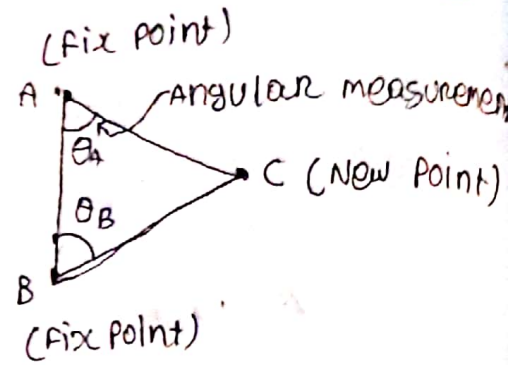
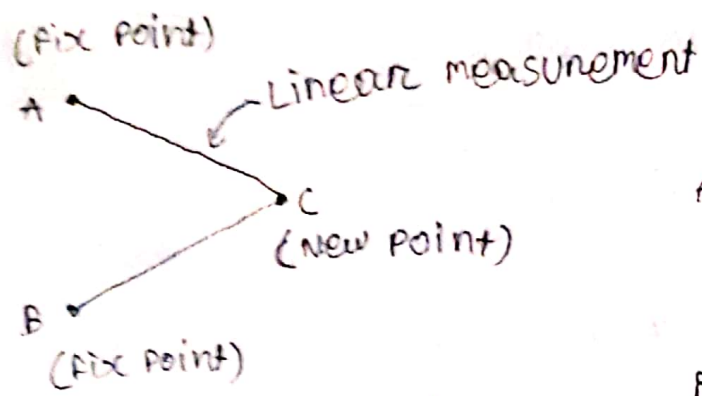
* - In well condition Δ no angle is $< 30^\circ$ or $> 120^\circ$

* - In Ill Δ any angle is $< 30^\circ$ or $> 120^\circ$

2- TO LOCATE A NEW POINT WRT TWO REFERENCE POINT :-

* - In this principle a new station fixed by at least two measurements from fixed reference point :

* - measurement may be angular or linear.



Classification of survey :-

A - Primary classification

B - Secondary classification

A - Primary classification :-

* - Primary classification classified as :-

1 - Plane survey

Earth

2 - Geodetic survey

Earth

1 - Plane survey :-

* - In plane survey we don't consider the curvature of the earth.

* - Plane survey is carried out for a small area of less than $< 250 \text{ km}^2$

* - Plane survey is conducted by the state agencies like Irrigation department, road transport department, PWD, etc

2- Geodetic Survey :-

(5)

- * In geodetic survey we consider the curvature of the earth
- * Geodetic survey is carried out for a large area of greater than $> 250 \text{ km}^2$
- * Geodetic Survey is carried out by survey of India department.

B- Secondary Classification :-

1- Based on Instrument :-

- a- chain surveying
- b- Compass))
- c- Plane table))
- d- Theodolite))
- e- Tacheometric))

2- Based on methods

- a- Triangulation surveying
- b- Traverse))

1.3 - Precision and accuracy of measurements, instrument used for measurement of distance, Types of tapes and chain :-

Precision & Accuracy :-

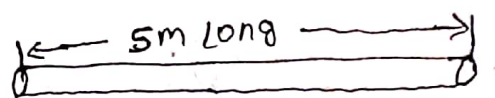
(6)

*- The closeness of two or more measurements to each other is known as precision.

Ex $\rightarrow$ 3.2 m , 3.206 m , 3.208 m , 3.205 m

precision taken as = 3.2 m

*- The ability of the instrument to measure the accurate value of an object is known as accuracy.



when measure by chain
it given = 5m

Accuracy = 5m

Accessories used for linear measurement :-

Ranging Rod :-

- *- when we measure a distance by using chain or tape that is known as linear measurement.
- *- Ranging $\rightarrow$ The process of making a straight line is known as ranging.
- *- The instrument used in ranging process is known as ranging rod.
- *- chaining $\rightarrow$ To measure distance b/w two points by using chain or tape is known as chaining.

* Following are the different accessories used in linear measurement ⑦

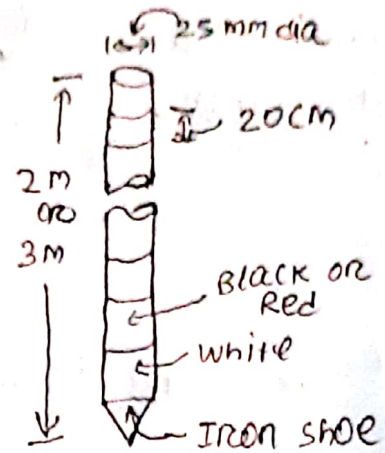
1- Ranging Rod :-

* Ranging rods are made of seasoned timber or seasoned bamboo or GI pipes.

* Circular dia of ranging rod is 25 mm

* Sometimes wooden ranging rods are square in section

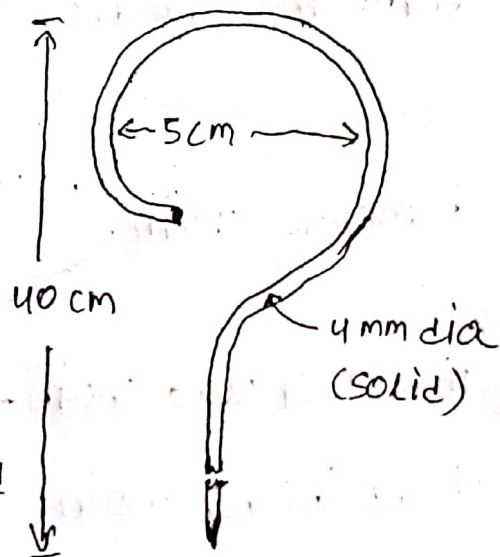
* Ranging rods are alternatively coloured red-white or black-white so that the rod is visible from a long distance.



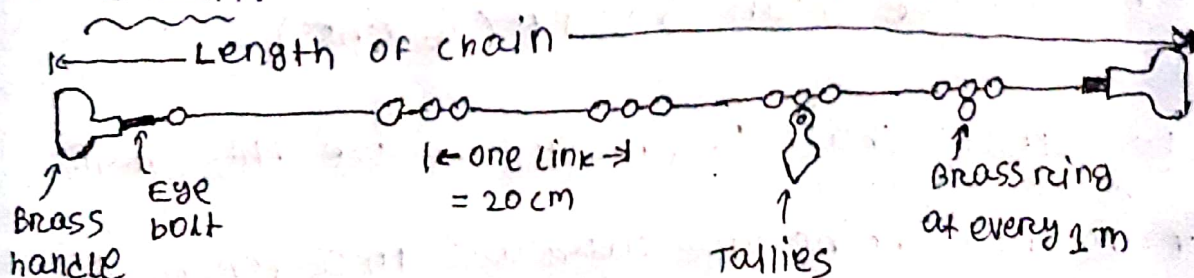
2- Arrow :-

* Arrow is used for marking the station

* Arrows are made of solid steel wire of 4 mm dia.

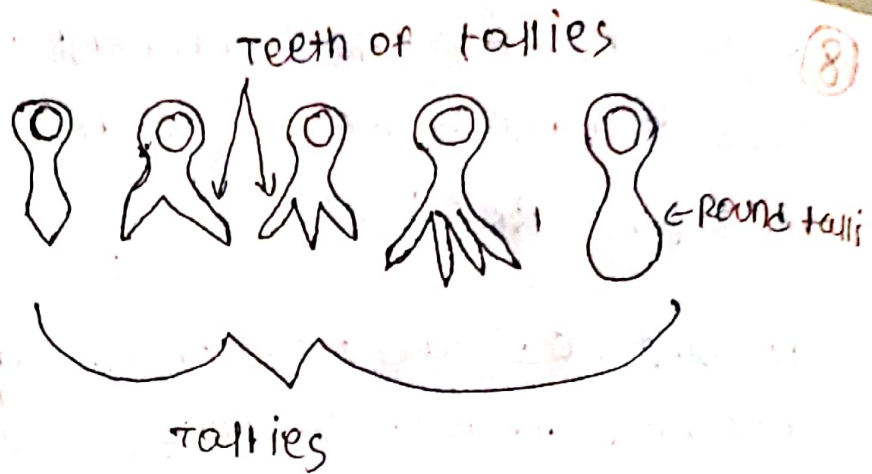


3- Chain :-



(chain)

Brass ring
at every 1m



*- A chain is made of galvanised mild steel wire of 4 mm diameter

*- Tallies are provided at every 10 or 25 links for easy counting

*- one link means the distance between centre of adjacent middle rings.

*- Following are the different types of chains:-

Tallies provided at every

i - metric chain	→ 20m (100 links)	→ 10 links (2m)
	→ 30m (150 links)	→ 25 links (5m)

ii - steel band chain → 20m & 30m

iii - Engineers chain → 100 ft (100 links) → 10 links (10 ft)

iv - Gunter chain → 66 ft (100 links)

v - Revenue chain → 33 ft (16 links)

i - metric chain :- (mostly we use this chain)

*- metric chains are available in a length of 20m & 30m.

* - 20m chain having 100 links & 30m chain having 150 links (each link is of 0.2m or 20cm) ⑨

* - Tallies are provided at every 10 links for 20m chain & every 25 links for 30m chain.

ii- steel band chain :-

* - It consists of ribbon of steel having a width of 16mm and a length of 20m & 30m.

* - It has a brass handle at each end.

* - It is graduated in meters and centimeters on one side and has 0.2m link on other side

* - steel band chain is used where more accuracy is required.

iii- Engineer's chain :-

* - Engineer's chain is 100ft long and divided into 100 links (each link is of 1ft)

* - Tallies are provided at every 10 links (10ft)

* - Engineer's chain was previously used for all engineering works.

iv- Gunter's chain :-

* - Gunter's chain having 66ft long and divided into 100 links (each link is of 0.66ft)

* - Gunter's chain was used for measuring distance in mile & furlong.

1 mile = 1.6 km

(10)

1 furlong = 201.168 m

V - Revenue chain :-

* - Revenue chain is of 33 ft long and divided into 16 links

* - Revenue chain is mostly used for cadastral survey
↓
marking borders

U - Tapes :-

1 mile = 1.6 km

(10)

1 Furlong = 201.168 m

V - Revenue chain :-

* - Revenue chain is of 33 ft long and divided into 16 links

* - Revenue chain is mostly used for cadastral survey
↓
marking borders

4 - Tapes :-

* - following are the different types of tapes:-

i - cloth or Linen tape

ii - metallic tape

iii - steel tape

iv - Invar tape → most accurate

i - cloth or Linen tape :-

* - cloth or Linen tape is 15 mm wide and available in a length of 10m & 15m

* - This tape is normally used for measuring offset and ordinary work

ii - metallic tape :-

* - when Linen tape is reinforced with brass or copper wires to make it durable, then it is called as metallic tape.

* - metallic tape is available in a length of 15m.

20m & 30m

(11)

- *- metallic tape is commonly used for all engineering work

iii- steel tape :-

- *- steel tape is made of steel ribbon of width varying from 6 mm to 16 mm and a length of 10m, 15m, 20m, 30m, 50m, etc
- *- It is widely used for measuring of all construction work

iv- Invar tape :-

- *- Invar tape is made of an alloy of steel (64%) & nickel (36%)
- *- Invar tape is available in a length of 30m, 50m, 100m, etc.
- *- Invar tape is widely used where max^m precision (perfect) is required.

1.4:→ ERRORS and mistakes in linear measurement,

Classification source of error and remedies:-

1- ERRORS :-

- *- Errors in chaining may be caused due to variation in temperature and pull, defects in instruments, etc.

2- mistakes :-

- *- Error occurs due to carelessness of human being is called mistake.

* - Following are the different mistakes

(12)

- i - Improper marking of arrow
- ii - A full chain length may not be calculated
- iii - Improper ranging

3 - Precaution against error :-

* - The point where the arrow is fixed on the ground should be marked with a cross mark (X)

* - The zero end of chain & tape perfectly hold

* - Ranging should be done properly.

1.5 - correction to measured length due to incorrect length, temperature variation, pull, sag, numerical problem, applying correction:

Chain & Tape correction :-

* - Following are the different chain & tape correction :-

1 - correction due to incorrect length :-

Let,

L = True / actual / corrected length of line (in m)

L' = False / error / measured length of line (in m)

l = True / actual / standard length of chain (in m)

l' = False / error / incorrect length of chain (in m)

$$l' = l \pm \text{error}(e)$$

(13)

+ = IF chain is too long

- = IF chain is too short

True $\times$ True = False False

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

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

$$\boxed{\text{True/Actual/Corrected length of line (L)} = L' \times \left(\frac{l'}{l}\right)} \text{ in m}$$

2-correction due to temperature change (C_t)

$$\boxed{C_t = \alpha (T_m - T_0) \times L} \text{ in m}$$

where,

C_t = Temperature correction (in m)

α = Co-efficient of thermal expansion (in $1/^\circ\text{C}$)

$$\alpha_{\text{steel}} = 11 \times 10^{-6} / ^\circ\text{C}$$

T_m = Temperature during measurement (in $^\circ\text{C}$)

T_0 = Standardise Temperature

L = Length of chain or tape (in m)

"IF, $T_m > T_0 \rightarrow$ then correction is +ve

$T_m < T_0 \rightarrow$ " " " -ve

3- Pull correction (C_p) :-

(14)

$$C_p = \frac{(P_m - P_0) L}{A E} \quad \text{In m}$$

where,

C_p = pull correction (in m)

P_m = pull applied during measurement (in kg)

P_0 = pull at which chain or tape was standardised (in kg)

L = Length of chain or tape (in m)

A = C/S Area of chain/tape (in cm^2)

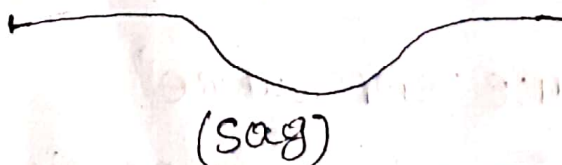
E = Young's modulus of chain/tape (in kg/cm^2)

$$E_{\text{steel}} = 2 \times 10^6 \text{ kg/cm}^2$$

If, $P_m > P_0 \rightarrow$ then correction will be " +ve "

$P_m < P_0 \rightarrow$ " " " " " -ve "

4- sag correction (C_s) :-



$$\text{sag correction } (C_s) = \frac{L W^2}{24 n^2 P_m^2} = \frac{L (WL)^2}{24 n^2 P_m^2} \quad \text{In m}$$

where,

C_s = sag correction (in m)

L = length of chain or tape (in m)

w = weight of chain or tape per unit length (in kg/m)

W = Total weight of chain or tape (in kg)

n = NO OF SPAN

P_m = PULL applied during measurement (in kg)

* sag correction is always negative.

Q-1

The distance b/w two points measured with a 20 m chain was recorded as 327 m. It was afterwards found that the chain was ^{3 cm} too long. What was the true distance b/w the points.

Ans

$$L' = 327 \text{ m}$$

$$L = 20 \text{ m}$$

$$e = + 3 \text{ cm} = + 0.03 \text{ m}$$

$$l' = L + e = 20 + 0.03 = 20.03$$

where,

L' = False length of line

L = True length of chain

e = Error in chain

l' = false length of chain

let, L = True/Actual length of line

As we know that,

$$\text{True} \times \text{True} = \text{False} \times \text{False}$$

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

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

$$= 327 \times \left(\frac{20.03}{20} \right)$$

$$= 327.49 \text{ m}$$

∴ True/Actual length of line (L) = 327.49 m

Q-2

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 under a pull of 10 kg. The cross sectional area of the tape is 0.22 cm² and its total weight is 400g. The Young's modulus and co-efficient of linear expansion of steel are $2.1 \times 10^6 \text{ kg/cm}^2$ & $11 \times 10^{-6} / ^\circ\text{C}$ respectively. Find the correct horizontal distance.

Ans

Given data :-

$$L = 20 \text{ m}$$

$$A = 0.22 \text{ cm}^2$$

$$T_0 = 20^\circ\text{C}$$

$$W = 400\text{g} = 0.4 \text{ kg}$$

$$P_0 = 15 \text{ kg}$$

$$E_{\text{steel}} = 2.1 \times 10^6 \text{ kg/cm}^2$$

$$T_m = 30^\circ\text{C}$$

$$\alpha_{\text{steel}} = 11 \times 10^{-6} / ^\circ\text{C}$$

$$P_m = 10 \text{ kg}$$

(a) - Temperature correction (C_t) :- (17)

$$\begin{aligned} C_t &= \alpha (T_m - T_0) L \\ &= 11 \times 10^{-6} (30 - 20) 20 \\ &= 0.0022 \text{ m (+ve)} \end{aligned}$$

Because $T_m > T_0$ (so correction +ve)

(b) - Pull correction (C_p) :-

$$\begin{aligned} C_p &= \frac{(P_m - P_0) \times L}{A E} \\ &= \frac{(10 - 15) \times 20}{0.22 \times 2.1 \times 10^6} \\ &= -0.0024 \text{ (-ve)} \end{aligned}$$

-ve because $P_m < P_0$

(c) - sag correction (C_s) :-

$$\begin{aligned} C_s &= \frac{L w^2}{24 n^2 P_m^2} \\ &= \frac{20 \times (0.4)^2}{24 \times 1^2 \times 10^2} \quad \left\{ n=1, \text{ because one tape length is given (re 20m)} \right\} \\ &= 0.0013 \text{ (-ve)} \end{aligned}$$

(-ve, because sag correction is always -ve)

$$\begin{aligned} \text{Total correction} &= +0.0022 - 0.0024 - 0.0013 \\ &= -0.0015 \end{aligned}$$

corrected horizontal distance = $20 - 0.0015$

(18)

$$= 19.9985 \text{ m}$$

Chaining $\rightarrow$ The process of measure distance b/w two points by using chain or tape is known as chaining.

1. Equipment and accessories used for chaining:-

* - same accessories ~~used~~ which was used in Linear measurement.

* - 1. e

i - Ranging Rod

ii - Arrow

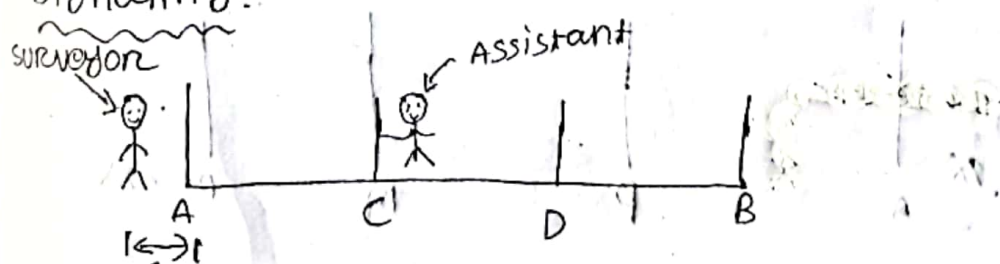
iii - chain

iv - Tape

2.2 $\rightarrow$ Ranging - Purpose, signaling, direct and Indirect ranging

* The process of making a straight line is known as ranging.

signaling:-



* Surveyor stand 2m behind the ranging rod A

* Assistant hold ranging rod at arms length by by using thumb & forefinger

* - Now surveyor directs the assistant to move the ranging rod left & right, until the ranging rod comes into a straight line.

* - When the surveyor is satisfied that the ranging is perfect, he signals the assistant to fix the ranging rod on the ground by waving both his hands up & down.

* - min^m ranging rods required for ranging process is 3 nos (for direct ranging) & 4 nos for indirect ranging.

Methods of ranging :-

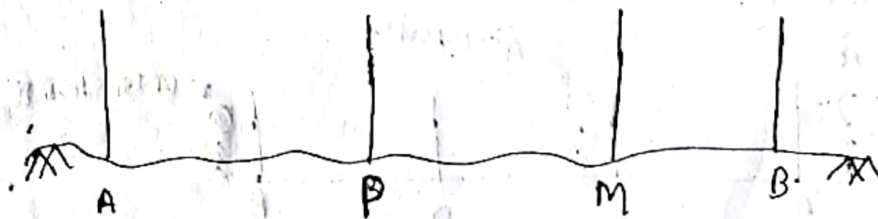
* - There are 2 methods of ranging :-

1- Direct ranging

2- Indirect » (or Reciprocal Levelling)

1- Direct ranging :-

* - when end stations are intervisible ~~then~~ then ranging rods are fixed by using direct way. This method is known as Direct ranging.



(Direct Ranging)

procedure is adopted for direct ranging.

Assume that A and B are two end stations of a chain line, where two ranging rods are already fixed. Suppose it is required to fix a ranging rod at the intermediate point P on the chain line in such a way that the points A, P and B are in the same straight line. The surveyor stands about 2 m behind the ranging rod at A by looking towards the line AB. The assistant holds a ranging rod at P vertically at arm's length. The rod should be held lightly by the thumb and forefinger. Now, the surveyor directs the assistant to move the ranging rod to the left or right until the three ranging rods come exactly in the same straight line. To check the non-verticality of the rods, the surveyor bends down and looks through the bottom of the rods. The ranging will be perfect, when the three ranging rods coincide and appear as a single rod. When the surveyor is satisfied that the ranging is perfect, he signals the assistant to fix the ranging rod on the ground by waving both his hands up and down. Following the same procedure, the other ranging rods may be fixed on the line (Fig. 1.6).

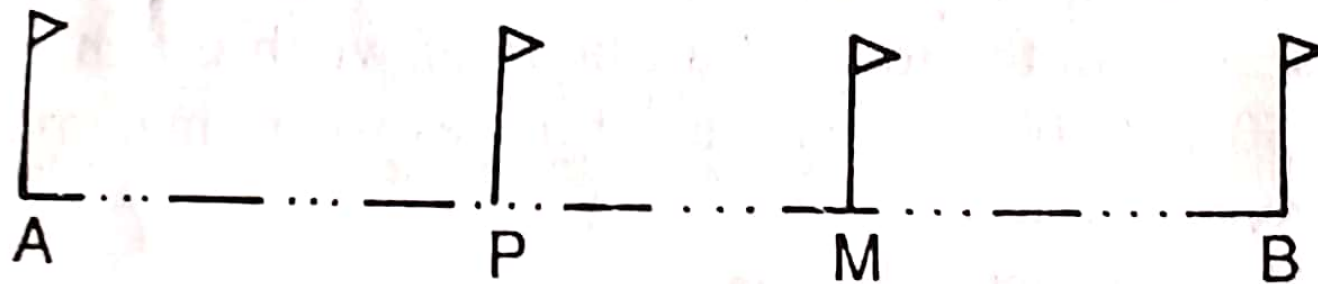
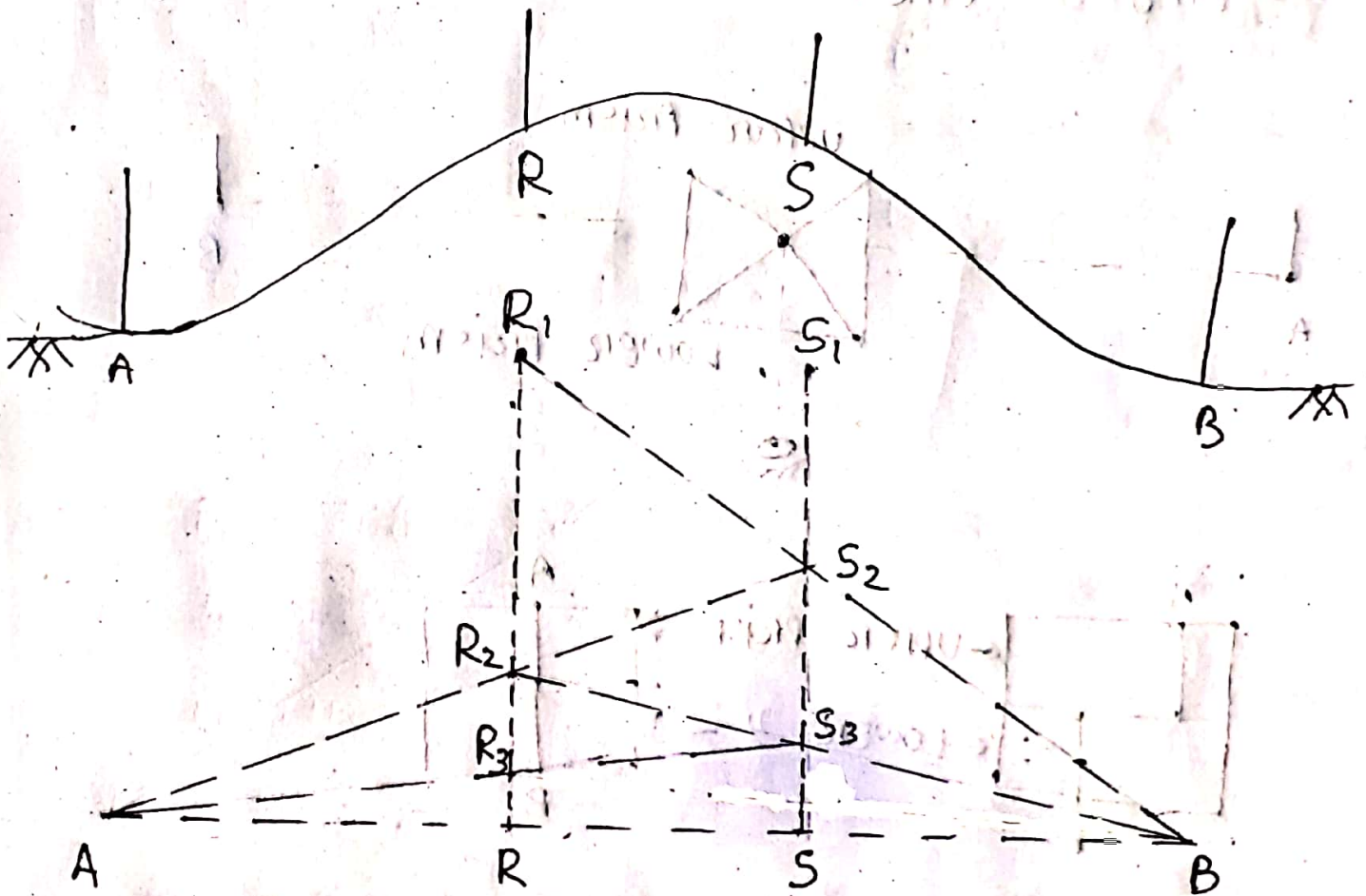


Fig. 1.6 Direct Ranging

2- Indirect or Reciprocal levelling : 20 (21)

* - when end stations are ~~not~~ not intervisible, then ranging rods are fixed by using indirect way. This method is known as Indirect / Reciprocal levelling.



(Indirect levelling)

(Reciprocal levelling)

(Indirect / Reciprocal levelling)

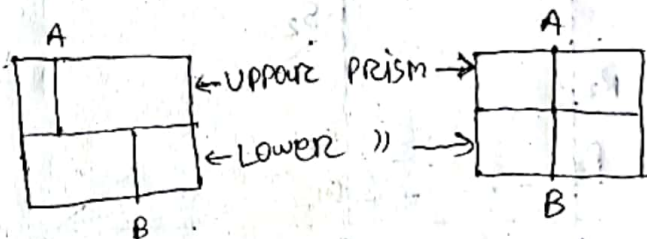
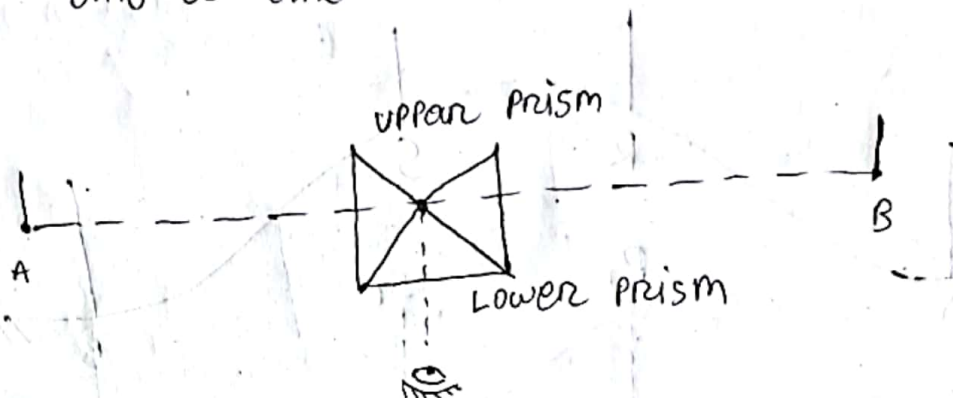
Suppose A and B are two end stations which are not intervisible due to high ground existing between them. Suppose it is required to fix intermediate points between A and B. Two chain men take up positions at R_1 and S_1 with ranging rods in their hands. The chainman at R_1 stands with his face towards B so that he can see the ranging rods at S_1 and B. Again, the chainman at S_1 stands with his face towards A so that he can see the ranging rods at R_1 and A. Then the chainmen proceed to range the line by directing each other alternately. The chainman at R_1 directs the chainman at S_1 to come to the position S_2 so that R_1 , S_2 and B are in the same straight line. Again, the chainman at S_2 directs the chainman at R_1 to move to the position at R_2 so that S_2 , R_2 and A are in the same straight line. By directing each other alternately in this manner, they change their positions every time until they finally come to the positions R and S, which are in the straight line AB. This means the points A, R, S and B are in the same straight line (Fig. 1.7).

is known as "cumulative +ve". (2)

* Line ranger

~~* Line ranger is used for ranging a line~~

* Line ranger is an instrument which is used for ranging a line.



(Incorrect ranging)

(Correct ranging)

2.3 → methods of chaining - chaining on flat ground, chaining on sloping ground - stepping method, clinometer, slope correction :-

Leader, Follower & Surveyor :-

Leader :-

* Following are the duties of a leader

1- To drag the chain forward with some arrow and ranging rod.

2- TO fix arrow on the ground at the end of every chain.

3- TO obey the instructions of the follower.

Follower :-

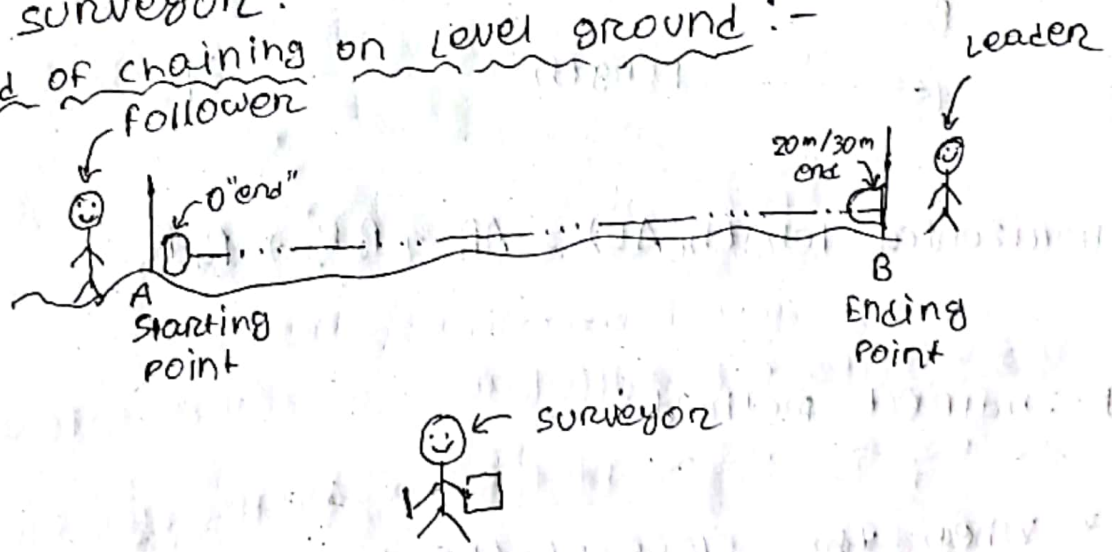
* - following are the duties of a follower :-

- 1- TO direct the leader at the time of ranging
- 2- TO carry the rear handle of the chain
- 3- TO pick up the arrow inserted by the leader

Surveyor :-

* - A man who record the data is known as surveyor.

Method of chaining on level ground :-



Method of chaining on sloping ground :-

* - following are the different method for

chaining on sloping ground :-

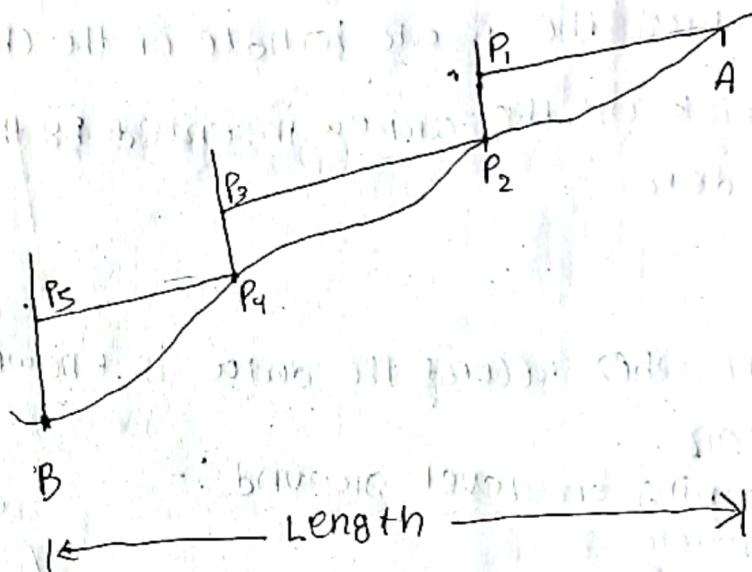
- A - Direct method or stepping method
- B - Indirect method.

A - Direct method or stepping method :-

* ~~Chaining~~

* Horizontal distance are required in surveying.

So in chaining along a sloping ground, the horizontal distance b/w two stations are measured carefully.



$$\text{Horizontal length}(AB) = AP_1 + P_1P_2 + P_2P_3 + P_3P_4$$

B - Indirect method :-

* When the slope of the ground surface is long, then the stepping method is not suitable.

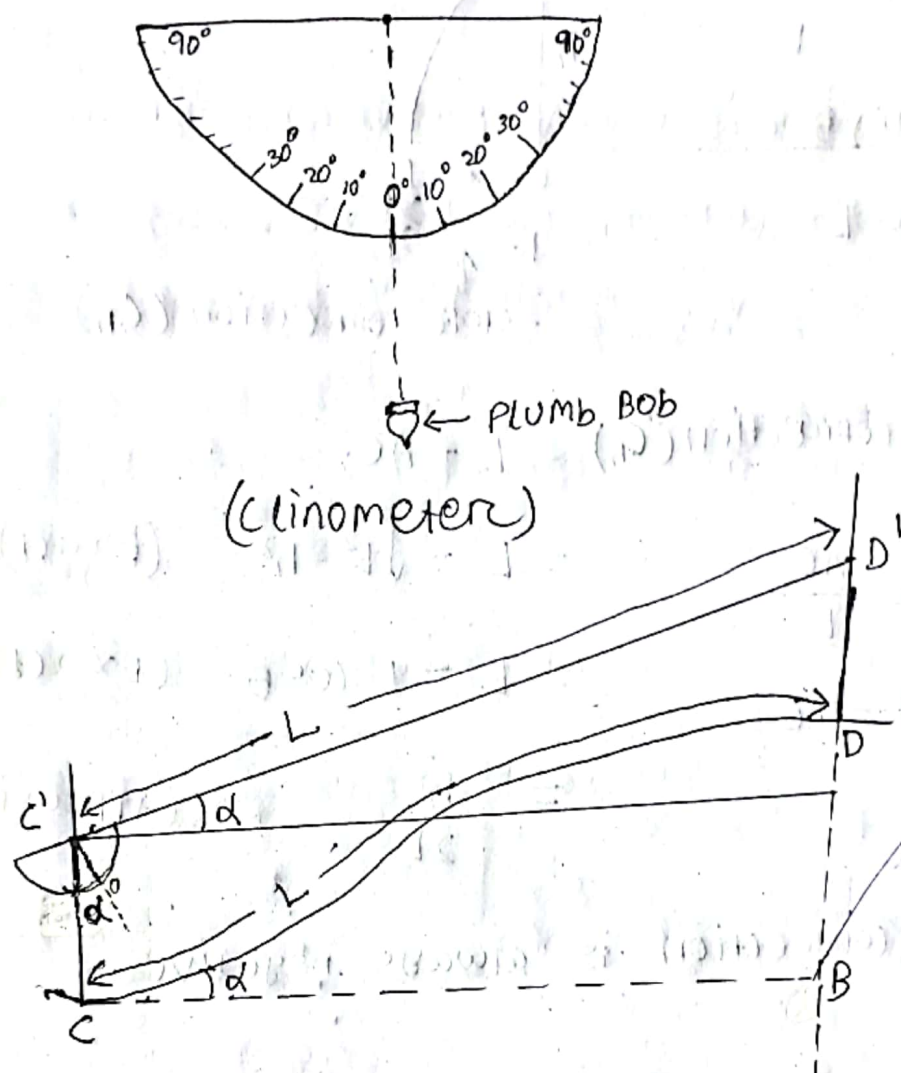
* In such case horizontal distance may be obtained by the following process :-

1- By measuring the slope with a Clinometer

2- By knowing the difference of level b/w the points.

1- measuring the slope with a clinometer :-

(25)



$$CC' = DD'$$

$$\text{sloping distance} = CD = C'D' = L$$

(we assume $CD = C'D'$)

$$\text{Required horizontal distance } (CB) = L \cos \alpha$$

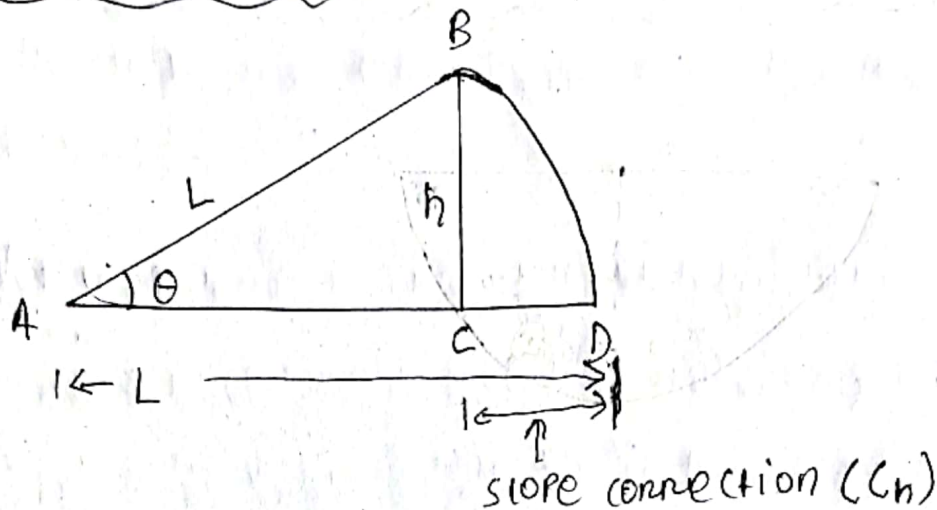
$$\cos \alpha = \frac{CB}{CD}$$

$$\Rightarrow \cos \alpha = \frac{CB}{L}$$

$$\Rightarrow L \cos \alpha = CB$$

Slope correction :-

(26)



$$\text{slope correction } (C_h) = L - AC$$

$$\cos \theta = \frac{AC}{L}$$

$$\Rightarrow L \cos \theta = AC$$

$$= L - \sqrt{L^2 - h^2} \quad (\text{Exact})$$

$$= L - L \cos \theta \quad (\text{Exact})$$

$$= \frac{h^2}{2L} \quad (\text{Approximate})$$

* - sag correction is always negative ..

2.4 $\rightarrow$ setting perpendicular with chain & tape • Chaining across different types of obstacles - numerical problem on chaining across obstacle :-

setting perpendicular :-

i - By using chain & tape

ii - By using builder's square

$\rightarrow$ By swinging the tape

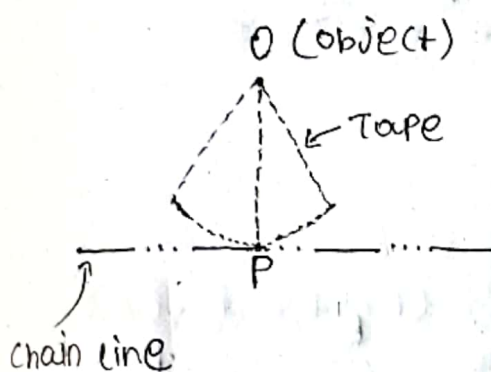
$\rightarrow$ By 3:4:5 method

i- By using chain & tape : (27)

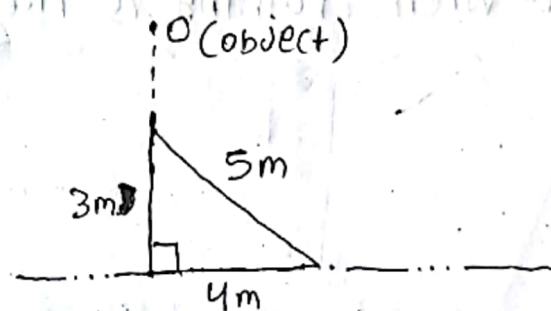
* - we can setting a perpendicular by swinging a tape from the object to the chain line.

* - The point of minimum reading on the tape will be the perpendicular.

* - we can also setting a perpendicular by plotting a right angle in the ratio of 3:4:5.

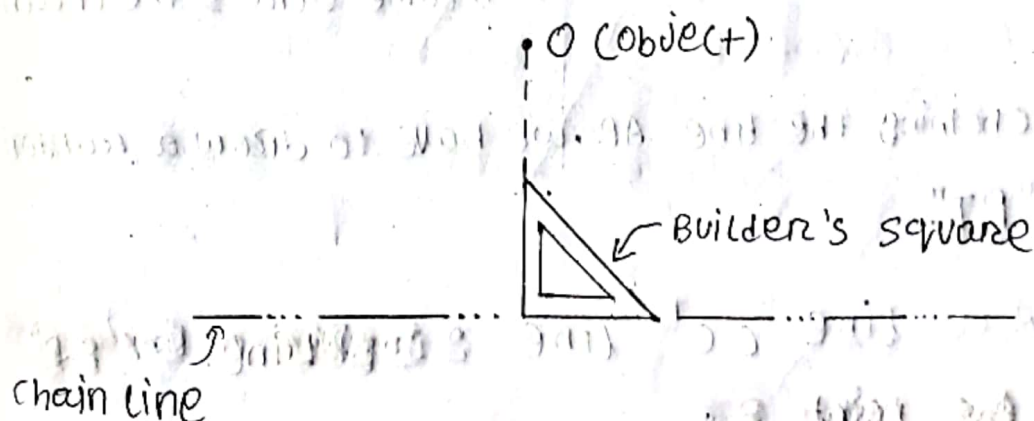


(setting perpendicular
By swinging the tape)



(setting perpendicular
By 3:4:5 method)

ii - By using Builder's square :-

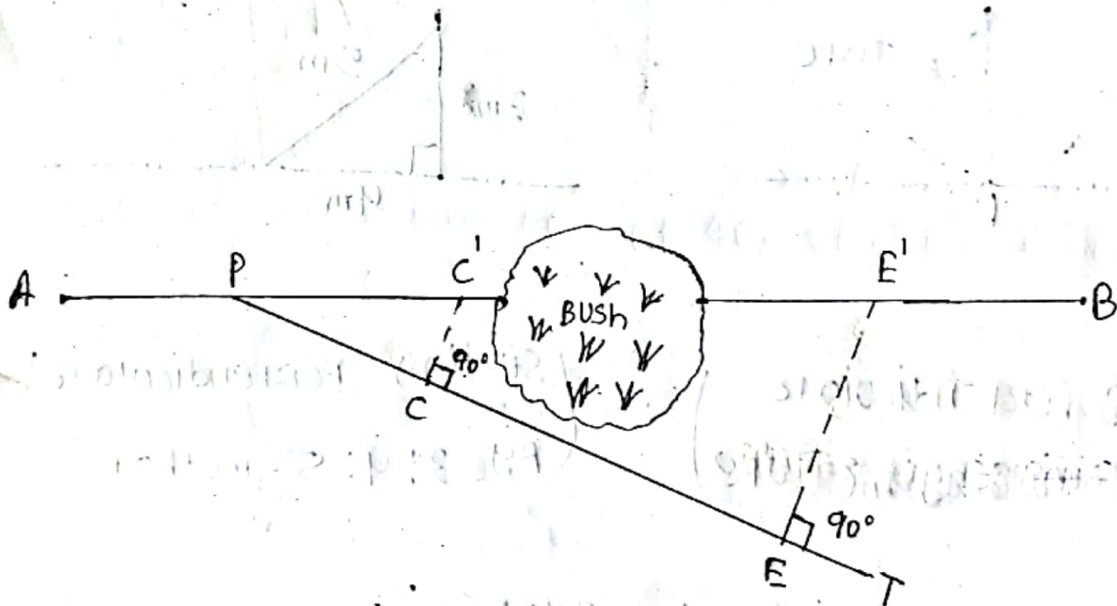


Chaining across different types of obstacles! (28)

*- Following are the different Obstacles in Chaining:-

- 1- When chaining is free but vision(ranging) is obstructed
- 2- when vision(ranging) is free but chaining is obstructed.
- 3- when both vision(ranging) & chaining are ~~both~~ obstructed.

1- when chaining is free but vision(ranging) is obstructed



*- Here let AB line is to be measured:

*- But an obstacle (here BUSH) come across the chain line.

*- For chaining the line AB, we have to draw a random line "PT".

*- Draw a line CC' line & EE' Line.

Now, from triangle PCC' & PEE' (29)

$$\frac{EE'}{PE} = \frac{CC'}{PC} \quad (\text{similar } \Delta \text{ law})$$

$$\Rightarrow EE' = \frac{CC'}{PC} \times PE$$

Now for a right angle triangle

$$h^2 = p^2 + b^2$$

$$\Rightarrow PE' = \sqrt{PE^2 + EE'^2}$$

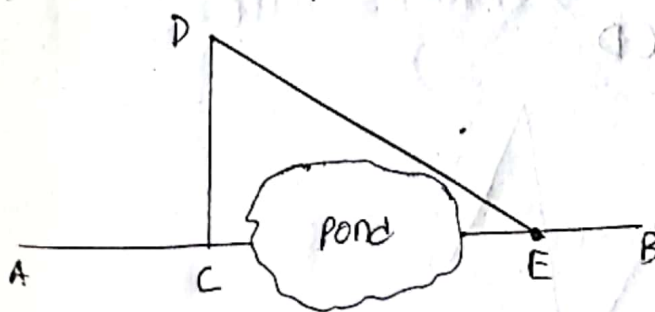
Now, the distance $AB = AP + PE' + E'B$

ii - when vision (ranging) free but chaining is obstructed:-

A - when a pond come across a chain line

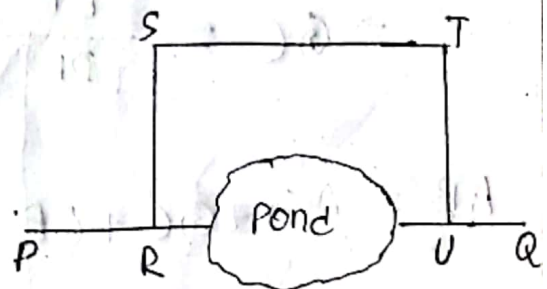
B - when a river come " " " "

A - when a pond come across a chain line:-



$$CE = \sqrt{CD^2 + DE^2}$$

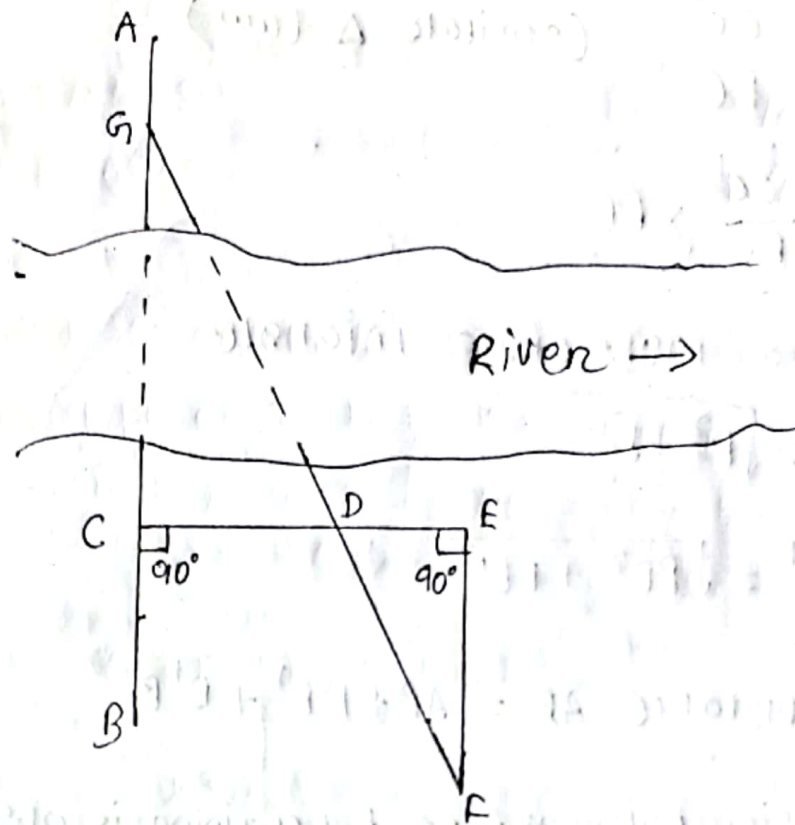
$$AB = AC + CE + EB$$



$$RU = ST$$

$$PQ = PR + ST + UQ$$

B-when a river comes across a chain line :- (30)



*-measure the distance $\Rightarrow AG, CD, DE, EF, CB$

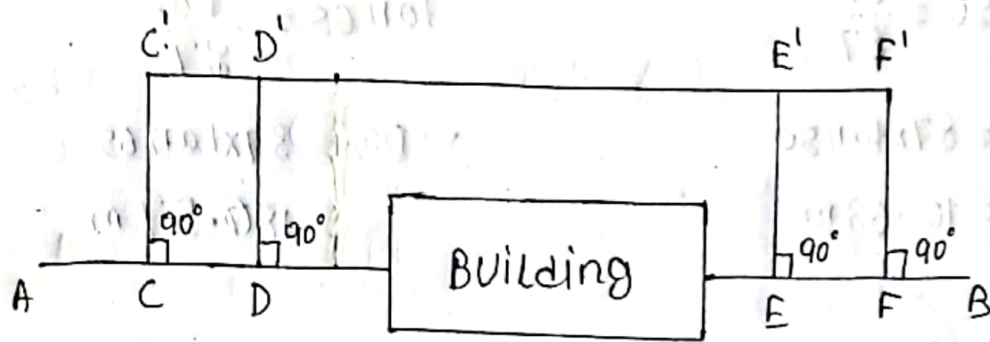
From ΔGCD & ΔDEF

$$\therefore \frac{GC}{CD} = \frac{EF}{DE}$$

$$\Rightarrow GC = \frac{EF}{DE} \times CD$$

$$AB = AG + GC + CB$$

iii- when both vision (ranging) & chaining obstructed (31)



$$CC' = DD' = EE' = FF'$$

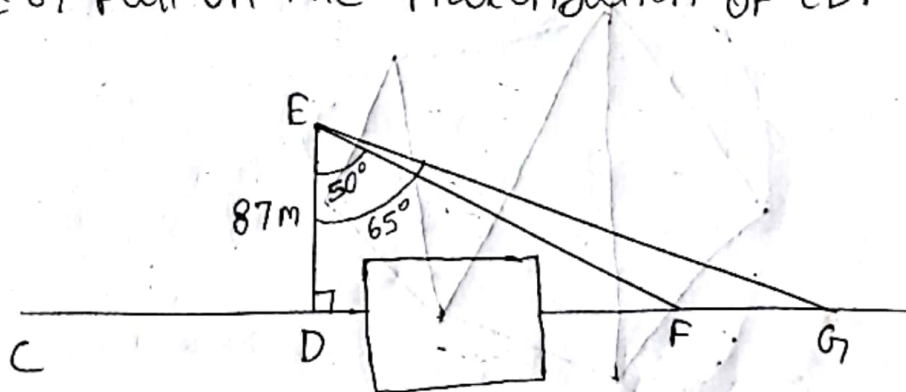
$$CF = C'F'$$

measure AC, C'F' & FB

$$AB = AC + C'F' + FB$$

Q. A survey line CD intersects a building. To overcome the obstacle a perpendicular DE 87m long is set out from D. From E two lines EF & EG are set out at angle 50° & 65° respectively with ED. Find the length EF, EG, DF, DG such that point F & G fall on the prolongation of CD.

Ans



From ΔDEF :-

$$\cos 50 = \frac{87}{EF}$$

$$\Rightarrow EF = \frac{87}{\cos 50} = 135.35 \text{ m}$$

From ΔDEG :-

$$\cos 65 = \frac{87}{EG}$$

$$\Rightarrow EG = \frac{87}{\cos 65} = 205.86 \text{ m}$$

From ΔDEF :-

$$\tan 50 = \frac{DF}{87}$$

$$\Rightarrow DF = 87 \times \tan 50 \\ = 103.68 \text{ m}$$

From ΔDEG :-

$$\tan 65 = \frac{DG}{87}$$

$$\Rightarrow DG = 87 \times \tan 65 \\ = 186.57 \text{ m}$$

(32)

2.5 $\rightarrow$ purpose of chain surveying, It's principles
concept of field book, selection of survey
station, base line, tie line, check line :-

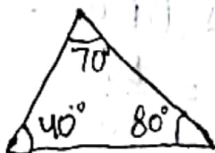
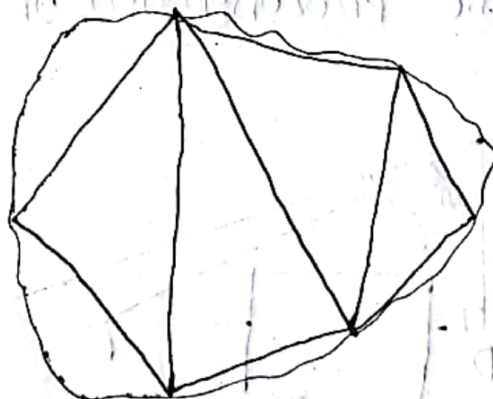
purpose of chain surveying :-

* - Chain surveying is carried out for plotting a map
to any suitable scale.

principle of chain surveying :-

* - The principle of chain surveying is triangulation.

* - Triangulation means whole area is divided into
a number of well condition triangle.



well condition Δ



Ideal Δ



Ill condition Δ

From ΔDEF :-

$$\tan 50 = \frac{DF}{87}$$

$$\Rightarrow DF = 87 \times \tan 50 \\ = 103.68 \text{ m}$$

From ΔDEG :-

$$\tan 65 = \frac{DG}{87}$$

$$\Rightarrow DG = 87 \times \tan 65 \\ = 186.57 \text{ m}$$

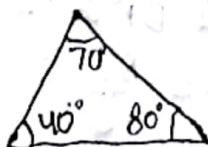
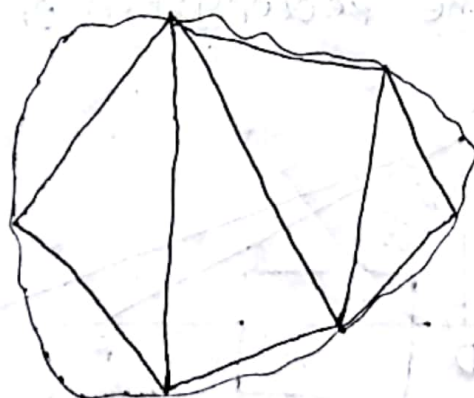
2.5 $\rightarrow$ purpose of chain surveying, It's principles
concept of field book, selection of survey
station, base line, tie line, check line :-

Purpose of chain surveying :-

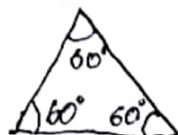
* - Chain surveying is carried out for plotting a map
to any suitable scale.

Principle of chain surveying :-

* - The principle of chain surveying is triangulation
* - Triangulation means whole area is divided into
a number of well condition triangle.



well condition Δ



Ideal Δ



Ill condition Δ

field book :-

(33)

- *-field book is used to record the data of surveying.

Survey Stations :-

- *-survey stations are the points beginning & ending of a chain line.

- *-survey stations is of following types:-

1-main station

2-subsidary station-

3-tie station.

1-main station :-

- *-stations taken along the boundary of an area is known as main station.

- *-The line joining the main station are called main line/main survey line.

- *-main stations are denoted by " Δ " with

- *-Name of main station given as A, B, C, D, etc.

2-subsidary station :-

- *-stations which are on the main survey line or any other survey line is known as subsidiary stations.

- *-subsidary stations are denoted by " $\odot$ "

- *-Name of subsidiary stations given as S_1, S_2, S_3 , etc.

3- Tie station :-

(34)

2

* These are also subsidiary stations used for find the properties of particular object is known as tie station

* The line joining the tie station is known as tie line.

* Tie stations are denoted by "⊙"

* Name of tie station given as $T_1, T_2, T_3, \text{etc}$

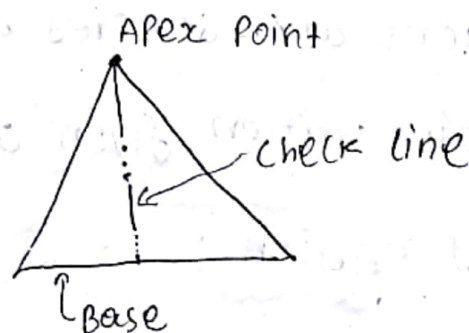
(Diagram $\rightarrow$ P-51, N.N. Basak)

Base line :-

* Generally the longest line of the main surveyed line is known as base line.

check line :-

* The line joining apex point of a triangle to some fixed point on its base is known as check line.



* check line is normally used in triangulation survey.

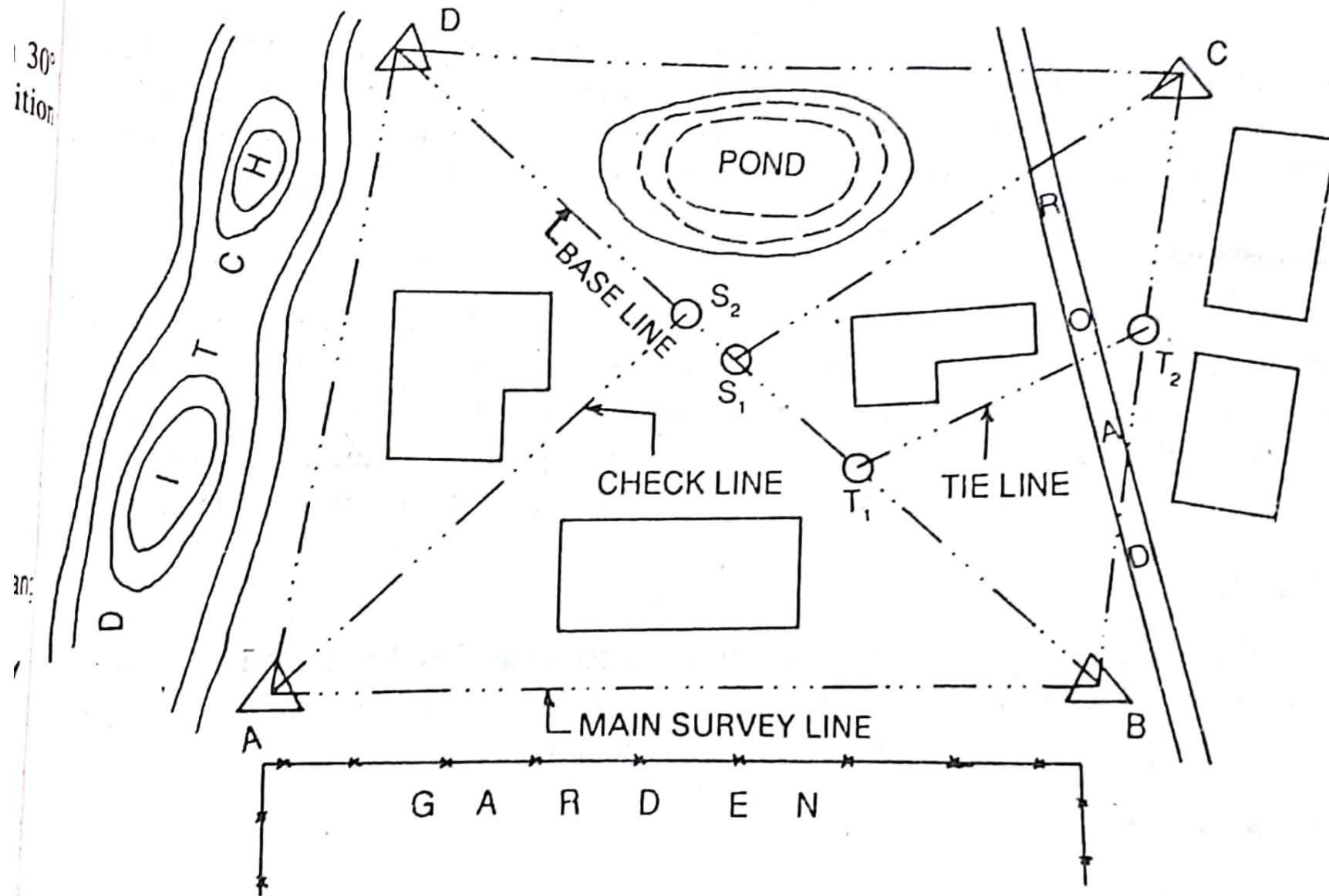


Fig. 2.2 Index Sketch

4) 2.7 → Offset - necessity, perpendicular and oblique (35)
Offset, Instrument used for setting offset - Cross
Staff, Optical Square:-

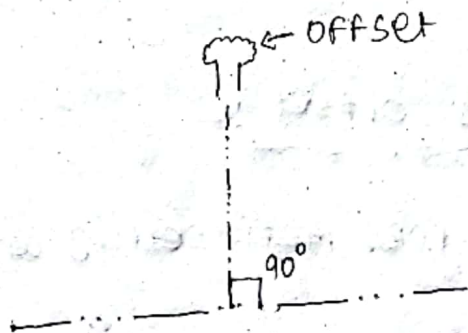
Offset:-

* - The lateral measurement taken from an object to the chain line is known as offset.

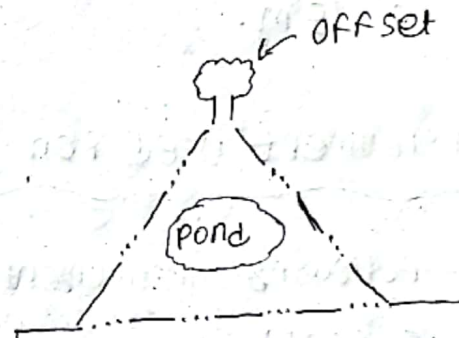
* - Offset may be of two kinds

i - Perpendicular offset

ii - Oblique offset



(Perpendicular offset)



(Oblique offset)

* - When lateral measurement are taken perpendicular to the chain line is known as perpendicular offset.

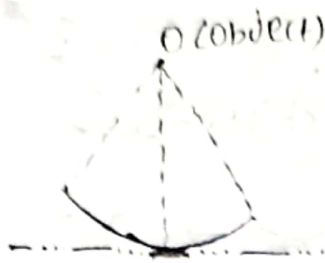
* - When lateral measurement is not perpendicular to the chain line is known as oblique offset

* - We can setting a perpendicular by following methods:-

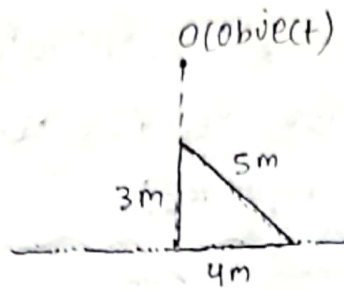
1 - By swinging a tape

2 - By setting a right angle in the ratio of 3:4:5

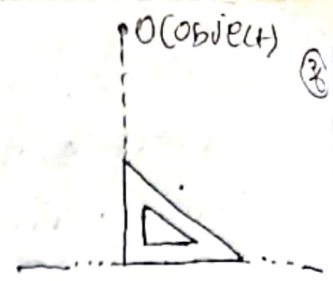
3 - By using Builder's square.



(By swinging the tape)



(By 3:4:5 ratio)



(By using Builders square)

- * - The max^m length of the offset should not be more than the length of the tape used in survey
- * - Generally the max^m length of offset is ~~not~~ limited to 15 m.

Instrument used for setting offset :-

- * - Following instrument used for ~~Plotting~~ setting an offset :-

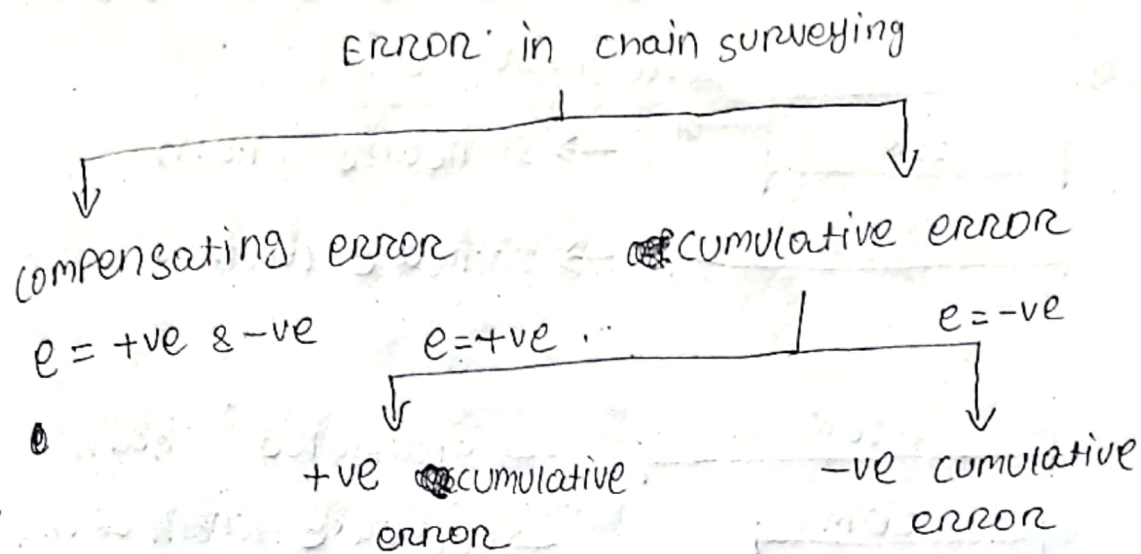
- 1- Optical square
- 2- Cross staff

2-8 → Error in chain surveying - compensating and ~~non~~ cumulative error causes 2 remedies, precautions to be taken during chain surveying :-

Error in chain surveying :-

- * - Following are the different error occur during chain survey :-
- * - Error due to increase or decrease in the length of chain.
- * - Error due to temperature variation
- * - Error due to excessive pull applied in chain
- * - Error due to sagging of chain

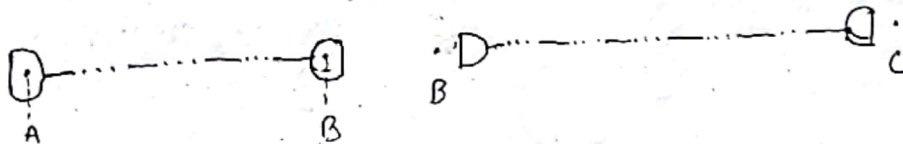
* - Errors in chain surveying is classified into following types:- (37)



compensating error:-

* - In this error, errors are neutralise by itself. by alternative +ve & -ve errors: or it has very negligible error occur in total length.

EX →



$$AC = AB + BC$$

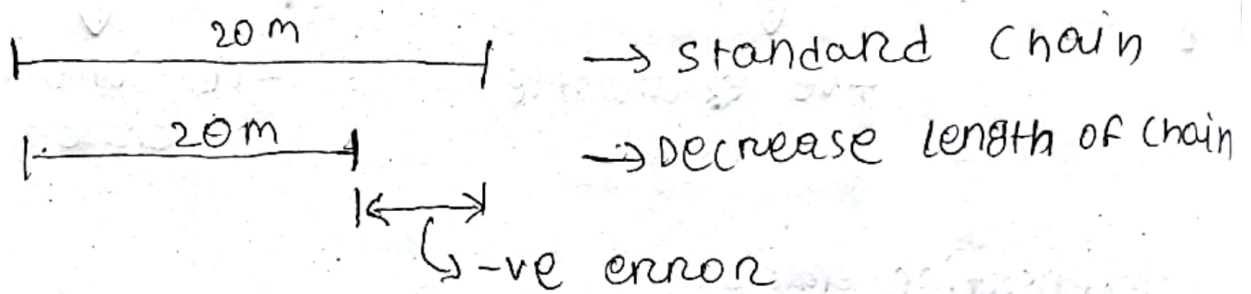
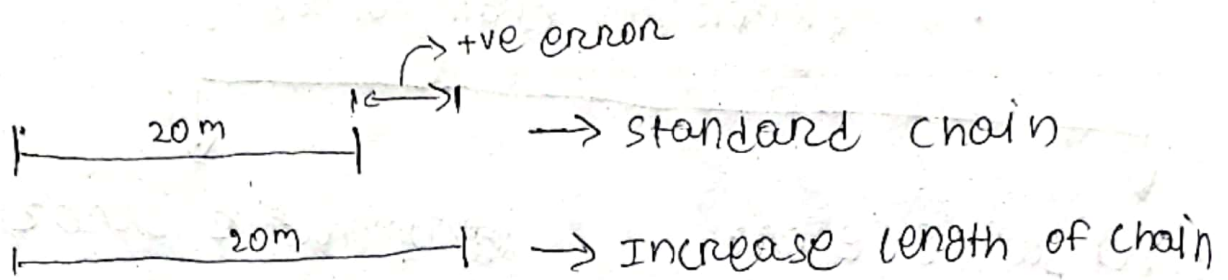
* ~~shortage~~ -ve error in AB is adjusted by +ve error in BC

cumulative error:-

* - when total error either increase or decrease with increase in length is known as cumulative error.

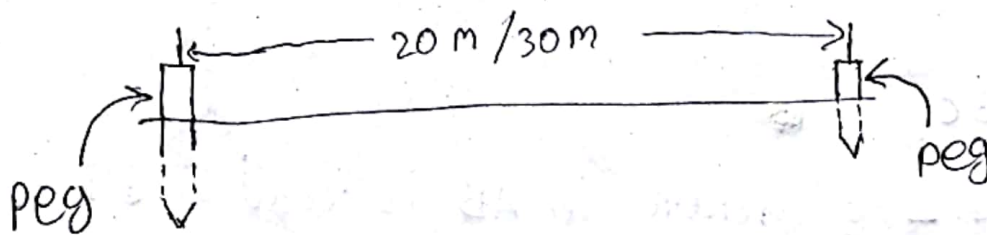
* - If the error increase with increase in length i.e known as +ve cumulative error.

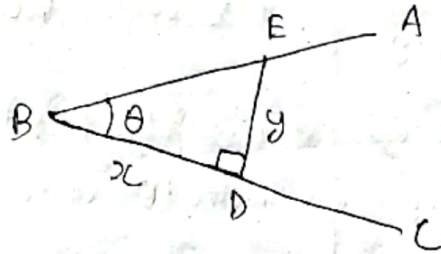
* - If the error decrease with increase in length (38)
then the error is known as -ve cumulative error



* - To avoid such error, chain is properly tested before experiment.

Testing of chain :-



3.1 → measurement of angles with chain & tape :-

measure the length BD & DE

Let, $BD = x$ $DE = y$

$$\tan \theta = \frac{DE}{BD}$$

$$\Rightarrow \theta = \tan^{-1} \left(\frac{DE}{BD} \right)$$

Compass:-

*- compass is an instrument which is used to directly measure the angles.

*- There are two types of compass used in survey work. I.e

1- Prismatic compass

2- Surveyor's compass

Parts of compass :-

1- Graduated circle

2- Magnetic needle

3- Eye vane

4- object vane / sight vane

5- Break pin

6- Prism } Extra in
7- mirror } Prismatic compass

Difference b/w Prismatic compass & Surveyor compass

Prismatic compass	Surveyor compass
* - Magnetic Needle fix with graduated circle	* - Magnetic needle does not fix with graduated circle
* - Magnetic Needle rotates with graduated circle	* - Magnetic needle does not rotate with graduated circle
* - Reading are taken with the help of prism	* - Reading are taken with direct eye.
* - In prismatic compass we we can take WCB	* - In surveyor compass we can take QB or RB

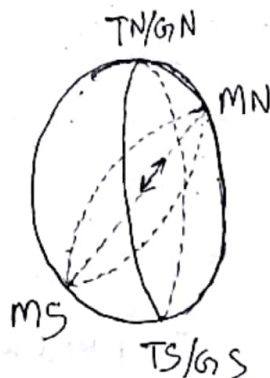
WCB $\rightarrow$ whole circle Bearing

QB $\rightarrow$ Quadrantal Bearing } same

RB $\rightarrow$ Reduced Bearing }

Meridian :-

* - A fixed reference line is known as meridian



~~True meridian~~

TN/GN = True north / Geographical North

MN = magnetic North

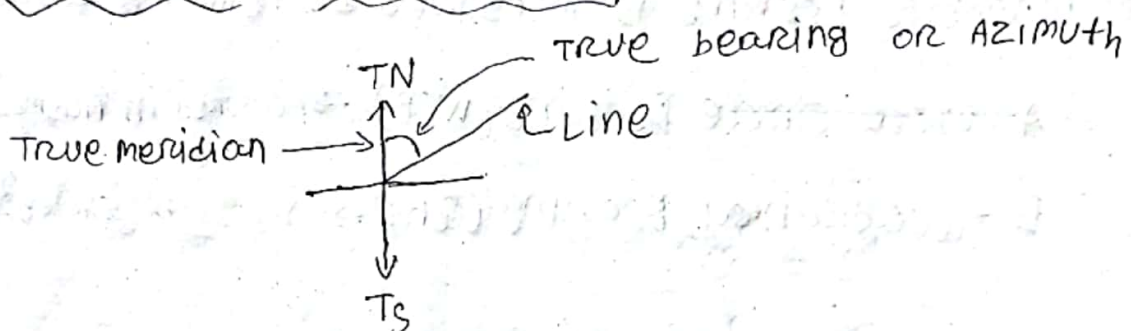
TS/GS = True South / Geographical South

MS = magnetic South.

True meridian (TM) :-

* - The line joining Geographical North Pole & Geographical South Pole of the earth is known as true meridian.

True bearing or Azimuth :-



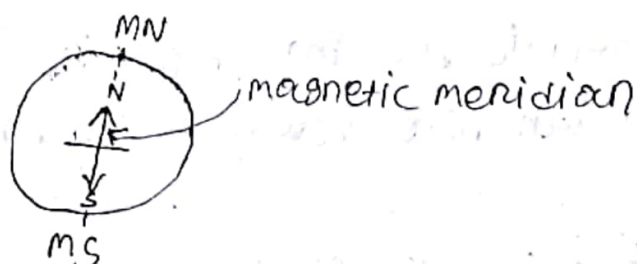
* - The angle b/w true meridian and a line is known as true bearing or Azimuth.

Magnetic meridian (MM) :-

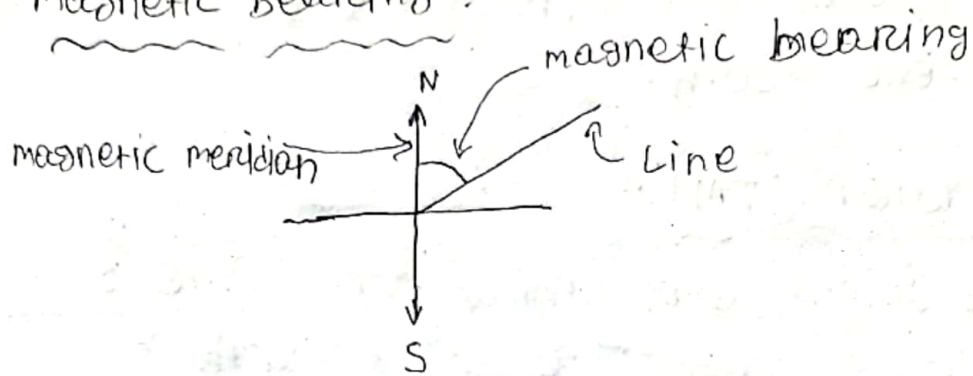
* - A line joining magnetic north pole & magnetic south pole is known as magnetic meridian

* - When a magnetic needle is suspended freely and balanced properly it indicates north dirⁿ.

* - This dirⁿ is known as magnetic meridian.



magnetic bearing :-



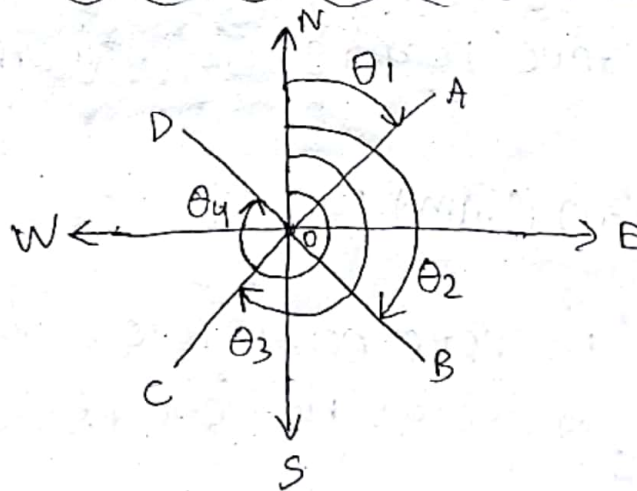
* - The angle b/w magnetic meridian and a line is known as magnetic bearing

* - magnetic bearing is measured by following 2 system:-

A - whole circle Bearing (WCB) $\rightarrow$ measured in Prismatic compass

B - Quadrantal Bearing (QB) $\rightarrow$ " " surveyor "

Whole circle Bearing (WCB) :-



WCB OF OA = θ_1

WCB OF OC = θ_3

)) OB = θ_2

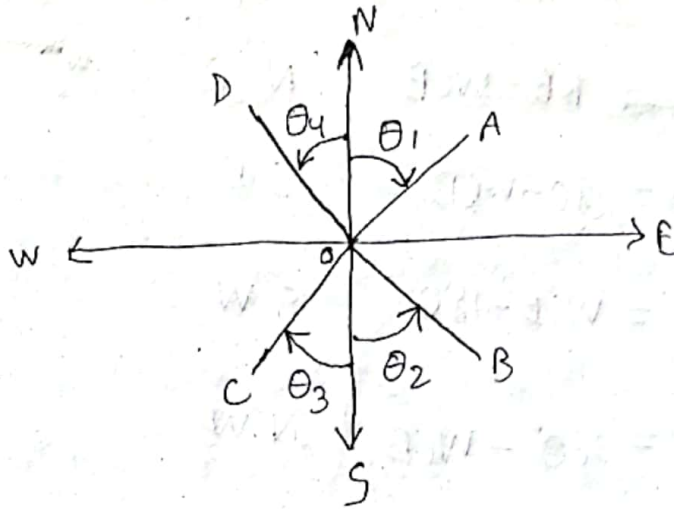
)) OD = θ_4

* - The magnetic bearing of a line measured clockwise from north pole towards a line is known as WCB

* - In WCB the value of angle lies in b/w 0° to 360°

*- WCB of a line is obtain by using Prismatic compass

B- Quadrantal Bearing (QB) :-



*- QB of OA = $N \theta_1^\circ E$ QB of OC = $S \theta_3^\circ W$

1) 1) OB = $S \theta_2^\circ E$ 1) 1) OD = $N \theta_4^\circ W$

*- The magnetic bearing of a line measured from clockwise or counter clockwise (Anti-clockwise) from North or South pole (whichever is nearer to the line) towards east or west is known as QB.

*- In QB the value of angle lies in b/w 0° to 90°

*- QB of a line is obtain by using Surveyor compass.

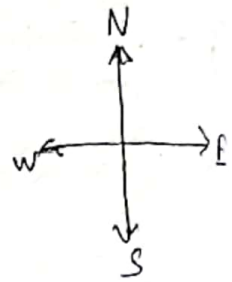
Reduced Bearing :-

*- when we convert WCB of a line to QB, then it is termed as Reduced Bearing (RB)

*- The value of " θ " in RB lies in b/w 0° to 90°

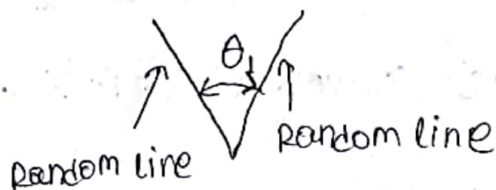
* - following are the conversion of WCB to RB

<u>WCB</u>	<u>corresponding RB</u>	<u>Quadrant</u>
$\theta = 0^\circ - 90^\circ$	RB = WCB $RB = WCB$	N E
$\theta = 90^\circ - 180^\circ$	$RB = 180 - WCB$	S E
$\theta = 180^\circ - 270^\circ$	$RB = WCB - 180$	S W
$\theta = 270^\circ - 360^\circ$	$RB = 360^\circ - WCB$	N W

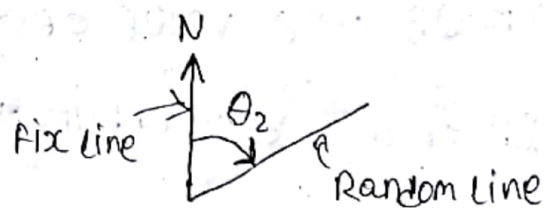


Ex $\Rightarrow$ $WCB = 70^\circ$ $RB = WCB = 70^\circ = N 70^\circ E$
 $WCB = 150^\circ$ $RB = 180 - 150 = 30^\circ = S 30^\circ E$
 $WCB = 230$ $RB = WCB - 180 = 230 - 180 = 50^\circ = S 50^\circ W$
 $WCB = 290^\circ$ $RB = 360 - WCB = 360 - 290 = 70^\circ = N 70^\circ W$

Difference b/w Angle & Bearing: -



$\theta_1 = \text{Angle}$



$\theta_2 = \text{Bearing}$

Arbitrary meridian :-

* - Sometimes for the survey of small area, a convenient dirⁿ is assumed as a meridian. It is known as arbitrary meridian.

Q Convert the following QB to WCB

QB of AB = S $36^{\circ} 30'$ W

)))) BC = S $43^{\circ} 30'$ E

)))) CD = N $26^{\circ} 45'$ E

)))) DE = N $40^{\circ} 15'$ W

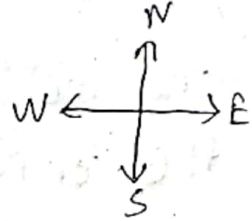
Ans

WCB of AB = $180 + 36^{\circ} 30' = 216^{\circ} 30'$

)))) BC = $180 - 43^{\circ} 30' = 136^{\circ} 30'$

)))) CD = $26^{\circ} 45'$

)))) DE = $360^{\circ} - 40^{\circ} 15' = 319^{\circ} 45'$



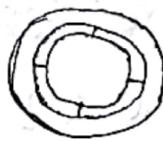
Use of compass:-

*- Before ~~using~~ ~~for~~ taking reading in compass we have to follow the following steps:-

- 1- Centering
- 2- Levelling
- 3- Taking readings



(centering)



(Levelling)

*- In centering we fix the compass ~~accordingly~~ in tripod stand so that the exact point on the

ground touches the center of the compass by using a plumb bob.

*- In levelling we fix the compass in tripod stand and adjust the tripod stand so that needle of the compass don't touches the glass of the compass.

*- Or we can say that in levelling we adjust the compass so that needle of the compass is free to move without touching the cover glass of the compass.

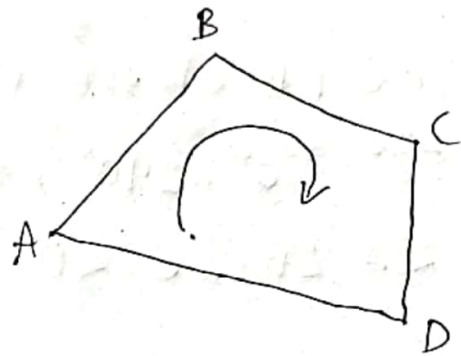
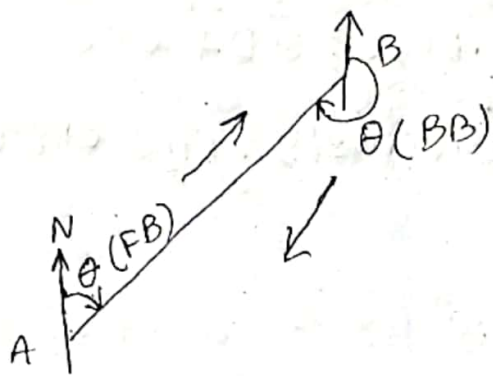
*- After centering & levelling the compass we adjust the eye vane & object vane so that reading can take easily.

Fore Bearing (FB) :-

*- The bearing of a line measured in the dirⁿ of the progress of survey work is called as FB.

Back Bearing (BB) :-

*- The bearing of a line measured in the opposit dirⁿ of the survey work is called as BB.



Relation b/w FB & BB :-

$$BB = FB \pm 180^\circ$$

NOTE :-

Difference b/w FB & BB is always 180

+ $\rightarrow$ when $FB < 180$

- $\rightarrow$ " $FB > 180$

EX $\rightarrow$

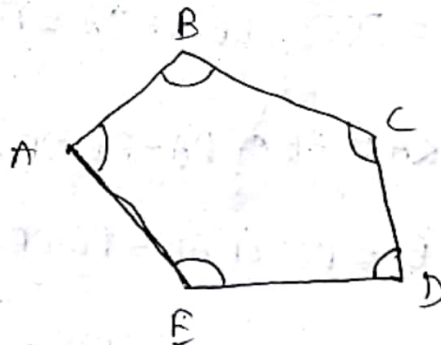
If, $FB = 50^\circ$

$$BB = FB + 180^\circ = 50 + 180 = 230^\circ$$

$$FB = 190$$

$$BB = FB - 180^\circ = 190 - 180 = 10^\circ$$

Interior angle :-



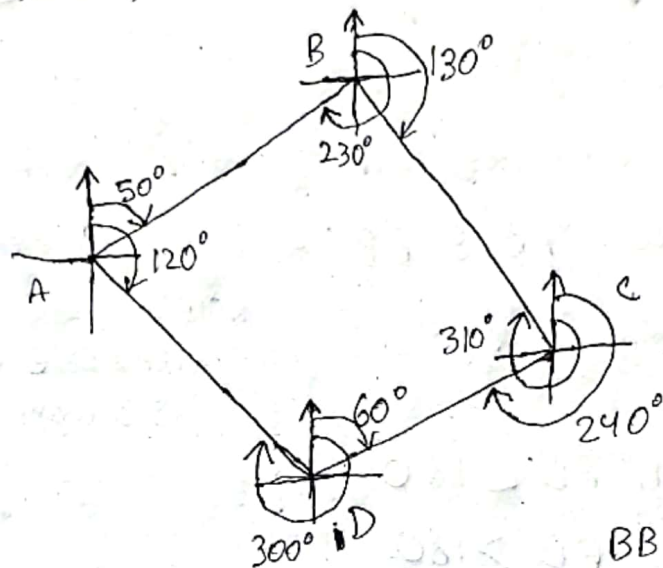
Sum of all interior angle = $(2n - 4) \times 90$

n = NO of sides

Q

The FB of the line AB, BC, CD & DA are 50° , 130° , 240° , 300° respectively. Find angles $\angle A$, $\angle B$, $\angle C$, $\angle D$:

Ans



$$FB \text{ of } AB = 50^\circ \quad BB \text{ of } AB = FB + 180^\circ = 50 + 180 = 230^\circ$$

$$FB \text{ of } BC = 130^\circ \quad BB \text{ of } BC = FB + 180^\circ = 130 + 180 = 310^\circ$$

$$FB \text{ of } CD = 240^\circ \quad BB \text{ of } CD = FB - 180^\circ = 240 - 180 = 60^\circ$$

$$FB \text{ of } DA = 300^\circ \quad BB \text{ of } DA = FB - 180^\circ = 300 - 180 = 120^\circ$$

$$\text{Interior } \angle A = BB \text{ of } DA - FB \text{ of } AB = 120^\circ - 50^\circ = 70^\circ$$

$$1) \quad \angle B = BB \text{ of } AB - FB \text{ of } BC = 230^\circ - 130^\circ = 100^\circ$$

$$1) \quad \angle C = BB \text{ of } BC - FB \text{ of } CD = 310^\circ - 240^\circ = 70^\circ$$

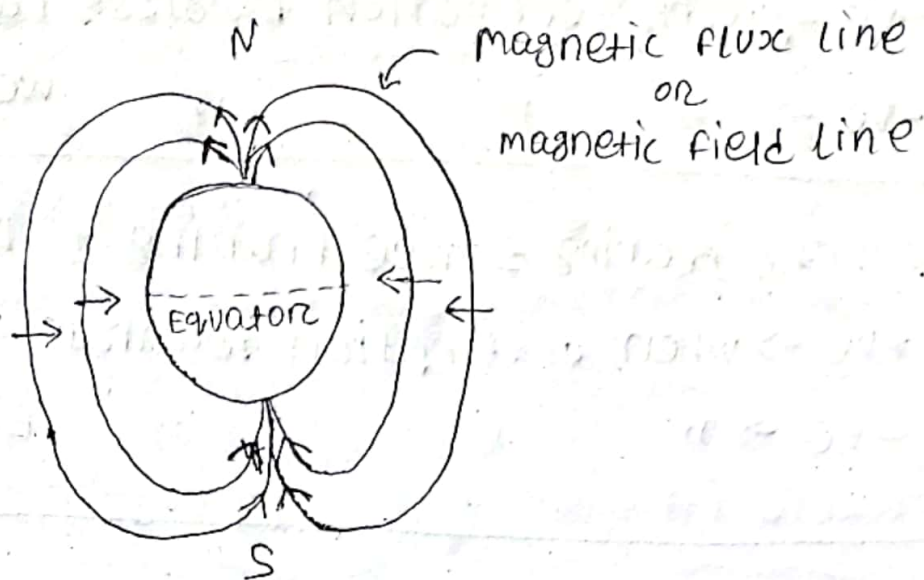
$$1) \quad \angle D = 360 - (FB \text{ of } DA - BB \text{ of } CD) = 360 - (300 - 60) \\ = 360 - 240 = 120^\circ$$

$$\text{Sum of } \angle A + \angle B + \angle C + \angle D = 70^\circ + 100^\circ + 70^\circ + 120^\circ = 360^\circ$$

$$\text{Sum of all interior angle} = (2n - 4) \times 90 = (2 \times 4 - 4) \times 90 = 360^\circ$$

(Ans)

Dip or Angle of Dip :-



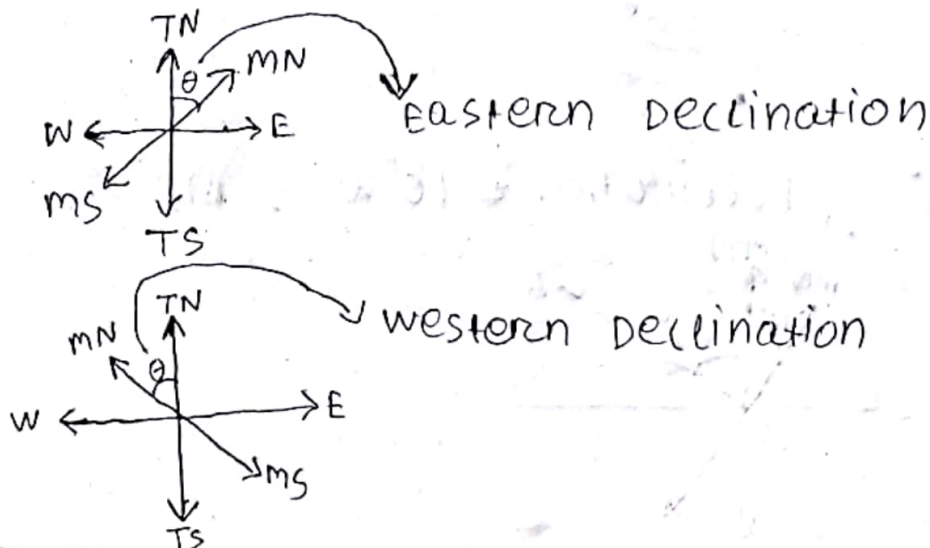
* The angle b/w magnetic field line & horizontal is known as dip or angle of dip

* At pole angle of dip = 90°

* At equator ,, ,, ,, = 0°

Magnetic Declination :-

* The horizontal angle b/w true meridian and magnetic meridian is called as declination or magnetic declination.



True Bearing = magnetic bearing $\pm$ declination

+ve $\rightarrow$ when declination towards East

-ve $\rightarrow$ " " " " West

Magnetic bearing = True bearing $\pm$ declination

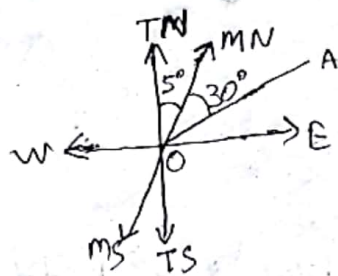
+ve $\rightarrow$ when declination towards West

-ve $\rightarrow$ " " " " East

Q
magnetic bearing of a line is 30° , declination is 5° E. Find true bearing of that line.

Ans

MB = 30° declination = 5° E TB = ?



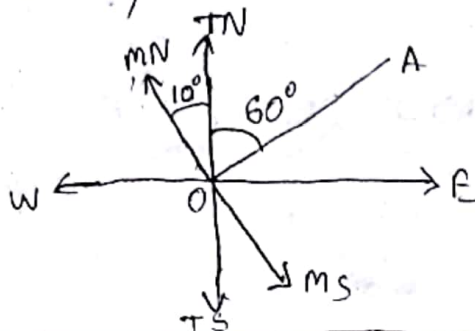
True bearing = MB + declination (Eastern declination)

$$= 30 + 5$$

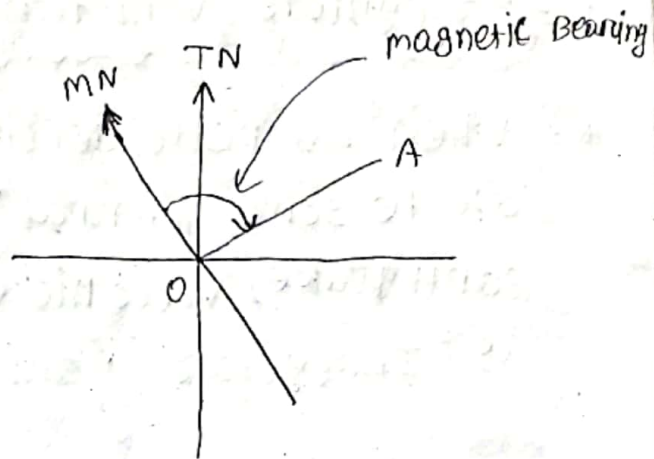
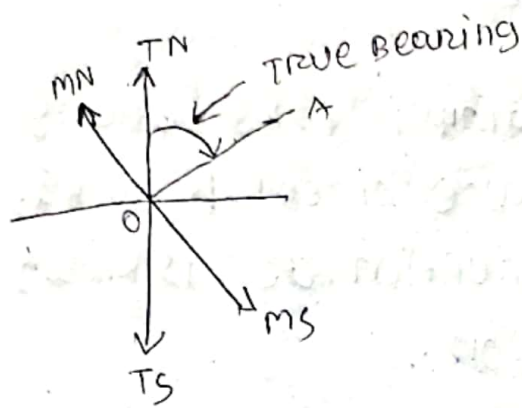
$$= 35^\circ$$

Q
TB = 60° , declination = 10° W, MB = ?

Ans



$$MB = 10 + 60 = 70^\circ$$



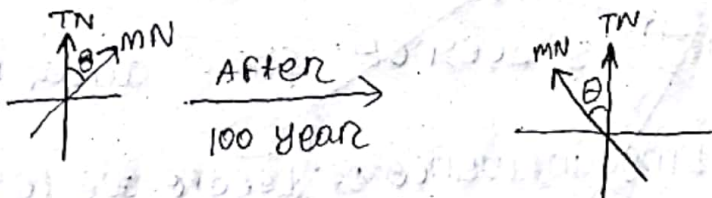
Variation in magnetic declination :-

* - The magnetic declination at a place is not constant.

It varies due to the following reason:-

(a) - secular variation :-

* - After every 100 year magnetic meridian swinging from one dirⁿ to opposite dirⁿ. This variation is known as secular variation.



(b) - Annual variation :- (1-2 minute)

* - magnetic declination varies due to rotation of earth ~~around~~ the sun annually. This variation is known as Annual variation.

(c) Diurnal variation :- (3-12 minute)

* - magnetic declination varies due to rotation of earth on its own axis in 24 hours. This variation

is known as Diurnal variation.

(d) - Irregular variation :-

- * - When magnetic declination is found suddenly due to some internal cause of earth such as earthquake, volcanic eruption, etc. is known as Irregular variation.

Error in compass surveying :-

Local Attraction :-

- * - A magnetic needle always indicates north dirⁿ when suspended freely.
- * - But if the needle ~~comes~~ comes near magnetic substance like Iron ore, steel, electric cable carrying current, etc. it's deflect from its original dirⁿ & doesnot show actual north dirⁿ.
- * - This disturbing influence of needle due to magnetic substance is known as local attraction.

or

- * - Due to the presence of some magnetic substance, needle of compass deflect. This deflection is known as local attraction.
- * - If the difference b/w FB & BB of a line is not exact 180° , then we can say that needle is

affected by local attraction.

correction of local attraction :-

A - correction by calculating interior angle

B -)) without))))))

A - correction by calculating interior angle :-

* - sum of all interior angle = $(2n-4) \times 90$

n = no of sides ~~of traverse~~

* - If it is not so then the error is equally distributed among all the angles

* - Then starting from unaffected line (whose diff b/w FB & BB = 180°) bearing of all the line connected by using corrected interior angle.

~~* - This method is the accurate method.~~

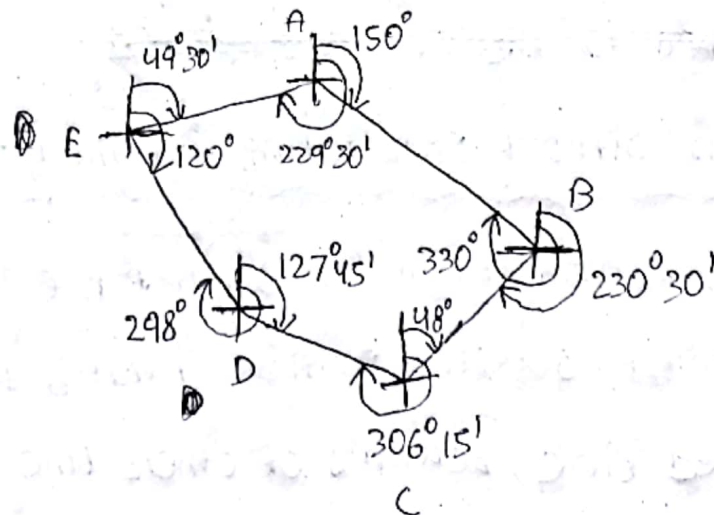
B - correction without calculating the interior angle :-

* - In this method from the given table, unaffected line is first detected & then starting from the unaffected line, bearing of other line are calculated.

Following are the bearings observed in traversing with a compass where local attraction was suspected. Calculate the interior angles of the traverse and correct it if necessary.

<u>Line</u>		<u>FB</u>		<u>BB</u>
AB	-	150°	-	330°
BC	-	$230^\circ 30'$	-	48°
CD	-	$306^\circ 15'$	-	$127^\circ 45'$
DE	-	298°	-	120°
EA	-	$49^\circ 30'$	-	$229^\circ 30'$

Ans



$$\text{Interior } \angle A = \text{BB of EA} - \text{FB of AB} = 229^\circ 30' - 150^\circ = 79^\circ 30'$$

$$1) \quad \angle B = \text{BB of AB} - \text{FB of BC} = 330^\circ - 230^\circ 30' = 99^\circ 30'$$

$$\begin{aligned} 2) \quad \angle C &= 360 - (\text{FB of CD} - \text{BB of BC}) \\ &= 360 - (306^\circ 15' - 48^\circ) = 360^\circ - 258^\circ 15' = 101^\circ 45' \end{aligned}$$

$$\text{Interior } \angle D = 360 - (\text{FB of DE} - \text{BB of CD})$$

$$= 360 - (298^\circ - 127^\circ 45') = 360^\circ - 170^\circ 15' = 189^\circ 45'$$

$$\therefore \angle E = \text{BB of DE} - \text{FB of EA} = 120^\circ - 49^\circ 30' = 70^\circ 30'$$

check:-

$$\begin{aligned} \angle A + \angle B + \angle C + \angle D + \angle E &= 79^\circ 30' + 99^\circ 30' + 101^\circ 45' + 189^\circ 45' + 70^\circ 30' \\ &= 541^\circ \end{aligned}$$

But, sum of all interior angle should be

$$= (2n - 4) \times 90 = (2 \times 5 - 4) \times 90 = 540^\circ$$

$$\text{Error} = 541^\circ - 540^\circ = +1^\circ$$

$$\text{correction} = -1^\circ$$

$$\text{correction per angle} = \frac{-1^\circ}{5} = -12'$$

Error should be equally distributed among all the angles.

Angle	Calculated value	correction	corrected value
$\angle A$	$79^\circ 30'$	$-12'$	$79^\circ 18'$
$\angle B$	$99^\circ 30'$	$-12'$	$99^\circ 18'$
$\angle C$	$101^\circ 45'$	$-12'$	$101^\circ 33'$
$\angle D$	$189^\circ 45'$	$-12'$	$189^\circ 33'$
$\angle E$	$70^\circ 30'$	$-12'$	$70^\circ 18'$
	$\Sigma = 541^\circ$	$\Sigma = -1^\circ$	$\Sigma = 540^\circ$

Q

<u>Line</u>		<u>FB</u>	<u>BB</u>
AB	-	$191^{\circ}45'$	13°
BC	-	$39^{\circ}30'$	$222^{\circ}30'$
CD	-	$22^{\circ}15'$	$200^{\circ}30'$
DE	-	$242^{\circ}45'$	$62^{\circ}45'$
EA	-	$330^{\circ}15'$	$147^{\circ}45'$

Find the correct bearing of lines.

Ans

A - First method (without calculating interior angle):

$$\text{FB of DE} = 242^{\circ}45'$$

$$\text{BB of DE} = 62^{\circ}45'$$

$$\text{Difference} = 180^{\circ}$$

*- SO Line DE is free from local attraction.

*- i.e point D & E is " " " "

*- SO FB of EA is also correct = $330^{\circ}15'$

*- correct BB of EA = $330^{\circ}15' - 180^{\circ} = 150^{\circ}15'$

BUT given BB of EA = $147^{\circ}45'$

SO a correction of $= 150^{\circ}15' - 147^{\circ}45' = +2^{\circ}30'$ should be applied at A

*- correct FB of AB = $191^{\circ}45' + 2^{\circ}30' = 194^{\circ}15'$

*- correct BB of AB = $194^{\circ}15' - 180^{\circ} = 14^{\circ}15'$

BUT given BB of AB = 13°

so a correction of $= 14^\circ 15' - 13^\circ = +1^\circ 15'$ should be applied at B

* correct FB of BC = $39^\circ 30' + 1^\circ 15' = 40^\circ 45'$

*) BB of BC = $40^\circ 45' + 180^\circ = 220^\circ 45'$

BUT given BB of BC = $222^\circ 30'$

so a correction of $= 220^\circ 45' - 222^\circ 30' = -1^\circ 45'$

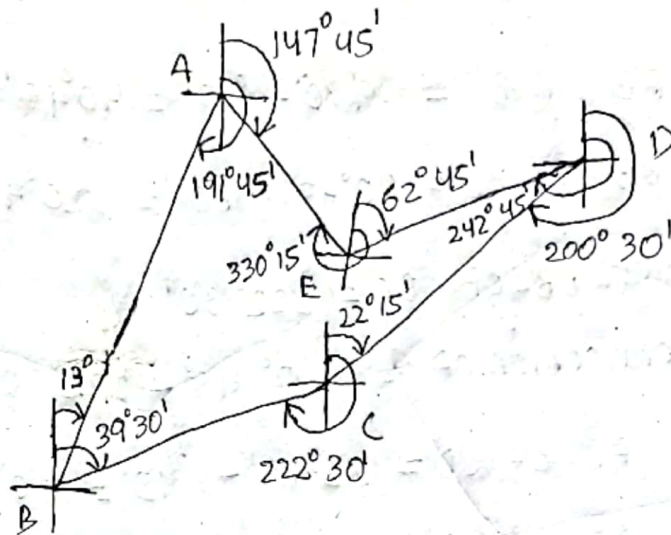
* - correct FB of CD = $22^\circ 15' - 1^\circ 45' = 20^\circ 30'$

*) BB of CD = $20^\circ 30' + 180^\circ = 200^\circ 30'$

(Because of point D is free from local attraction BB of CD agrees with our answer)

Line	corrected FB	corrected BB
AB	$144^\circ 15'$	$14^\circ 15'$
BC	$40^\circ 45'$	$220^\circ 45'$
CD	$20^\circ 30'$	$200^\circ 30'$
DE	$242^\circ 45'$	$62^\circ 45'$
EA	$330^\circ 15'$	$150^\circ 15'$

B- 2nd method (calculate with interior angle) :-



Interior $\angle A = \text{FB of AB} - \text{BB of EA} = 191^\circ 45' - 147^\circ 45' = 44^\circ$

1) $\angle B = \text{FB of BC} - \text{BB of AB} = 39^\circ 30' - 13^\circ = 26^\circ 30'$

1) $\angle C = 360 - (\text{BB of BC} - \text{FB of CD})$
 $= 360 - (222^\circ 30' - 22^\circ 15') = 360 - 200^\circ 15' = 159^\circ 45'$

1) $\angle D = \text{FB of DE} - \text{BB of CD} = 242^\circ 45' - 200^\circ 30' = 42^\circ 15'$

1) $\angle E = \text{FB of EA} - \text{BB of DE} = 330^\circ 15' - 62^\circ 45' = 267^\circ 30'$

$\angle A + \angle B + \angle C + \angle D + \angle E = 44^\circ + 26^\circ 30' + 159^\circ 45' + 42^\circ 15' + 267^\circ 30'$
 $= 540^\circ$

But, sum of all interior angle should be

$= (2n - 4) \times 90 = (2 \times 5 - 4) \times 90 = 540^\circ$

* So calculated angle is correct. Now calculate correct bearing. (Point D & E is free from local attraction)

FB of DE = $242^\circ 45'$ (correct)

BB of DE = $62^\circ 45'$ (correct)

$$FB \text{ of } DE = 330^\circ 15'$$

$$BB \text{ of } EA = 330^\circ 15' - 180^\circ = 150^\circ 15'$$

$$FB \text{ of } AB = BB \text{ of } EA + \angle A = 150^\circ 15' + 44^\circ = 194^\circ 15'$$

$$FB \text{ of } AB = BB \text{ of } EA + \text{Interior } \angle A = 150^\circ 15' + 44^\circ = 194^\circ 15'$$

$$BB \text{ of } AB = FB \text{ of } AB - 180^\circ = 194^\circ 15' - 180^\circ = 14^\circ 15'$$

$$FB \text{ of } BC = BB \text{ of } AB + \text{Interior } \angle B = 14^\circ 15' + 26^\circ 30' = 40^\circ 45'$$

$$BB \text{ of } BC = FB \text{ of } BC + 180^\circ = 40^\circ 45' + 180^\circ = 220^\circ 45'$$

$$FB \text{ of } CD = BB \text{ of } BC - \text{Exterior } \angle C$$

$$= 220^\circ 45' - (360^\circ - \text{Interior } \angle C)$$

$$= 220^\circ 45' - (360^\circ - 159^\circ 45') = 220^\circ 45' - 200^\circ 15' = 20^\circ 30'$$

$$BB \text{ of } CD = FB \text{ of } CD + 180^\circ = 20^\circ 30' + 180^\circ = 200^\circ 30'$$

Line	Corrected FB	Corrected BB
AB	194° 15'	14° 15'
BC	40° 45'	220° 45'
CD	20° 30'	200° 30'
DE	242° 45'	62° 45'
EA	330° 15'	150° 15'

Principle of Compass Surveying :-

* The principle of compass surveying is traversing.

* - A series of connected lines is known as traverse & the survey conducted for plotting

a traverse is known as traversing.

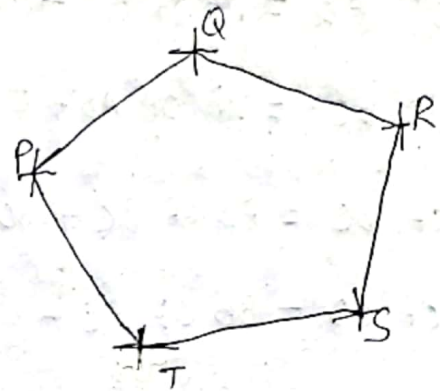
*- A traverse may be:-

1- open traverse

2- close))



(open traverse)



(close traverse)

*- when a series of connected lines form a close circuit is called as close traverse

*- when a series of connected lines doesn't form a close circuit is called as open traverse.

• Methods of traversing:-

*- Following are the different methods of traversing:

1- chain traversing

2- compass))

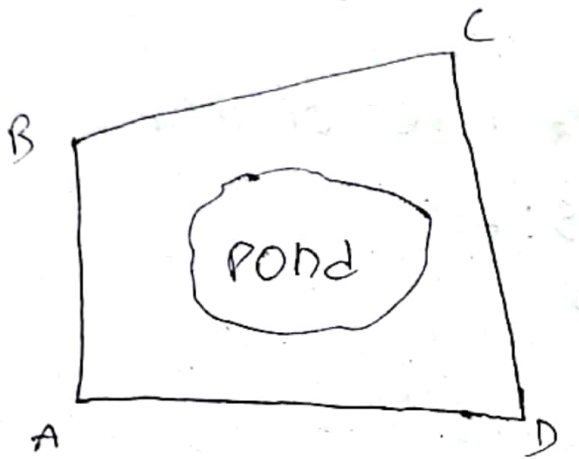
3- Theodolite))

4- Plane table))

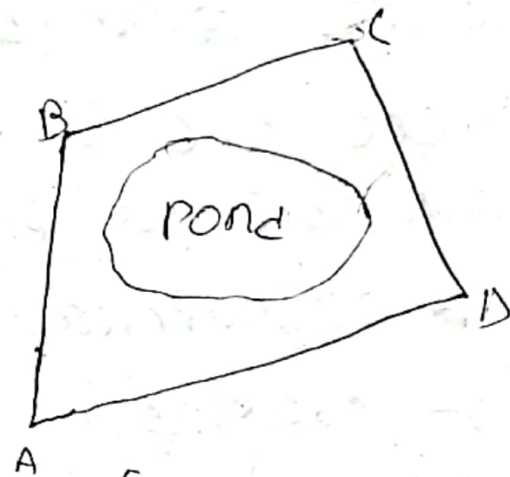
*- when traversing is done by using chain i.e known as chain traversing

*- When traversing is done by using compass i.e known as compass traversing

*- similarly when traversing is to be done by using theodolite & plane table i.e known as theodolite traversing & plane table traversing respectively.



(Chain Traversing)



(Compass Traversing)

Map :-

* - A map is an illustration of an area such as city, country, etc. which showing different features of an area

* - There are different types of map available as follows :-

1 - Topographical map

2 - Cadastral))

3 - Engineering))

4 - Military))

5 - Contour)) ✓

* - A map which shows the natural & artificial features (such as village, towns, hills, rivers, forest, etc) of a place is known as topographical map

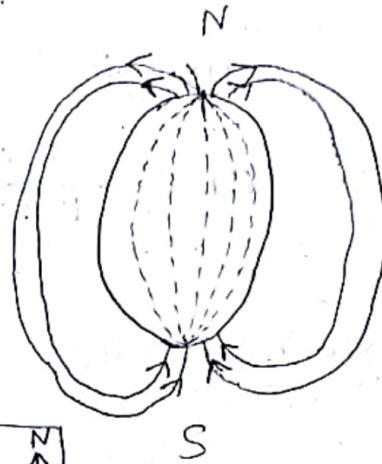
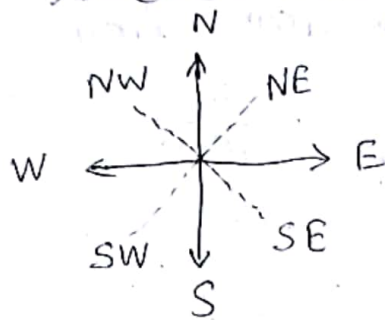
* - A map which shows the boundaries of fields, houses & estates of a place is known as cadastral map.

* - A map which shows the details of engineering work is known as Engineering map

* - A map which shows different military properties of a place is known as military map.

* - A map which shows RL of different points is known as contour map.

STUDY OF DIRECTION ON MAP :-



Scale :-

- * - It is not always possible to represent the actual length of an object on a drawing.
- * - So it is required to reduce the size of object in some proportion.
- * - The ratio b/w size of object on drawing to the ~~size of object~~ actual size of object is known as scale.
- * - scale can be represented as 2 types :-
 - 1- Representative Fraction (RF)
 - 2- Graphical scale.

1- RF :-

$$RF = \frac{\text{Distance on drawing of object}}{\text{corresponding actual distance of object}}$$

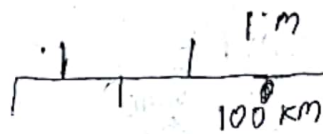
Note: → Both distance is in same unit.

For ex →

Scale is 1 cm = 10 m , then

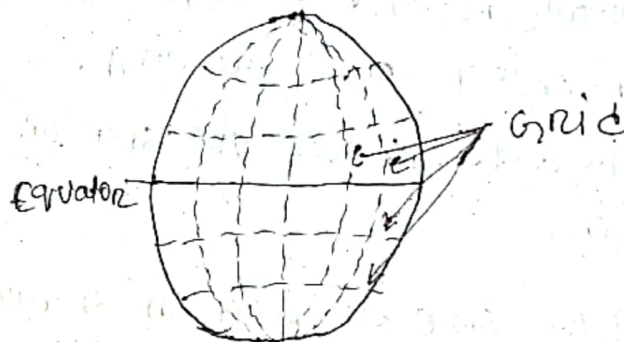
$$RF = \frac{1 \text{ cm}}{10 \times 100 \text{ cm}} = \frac{1}{1000}$$

2- Graphical Scale

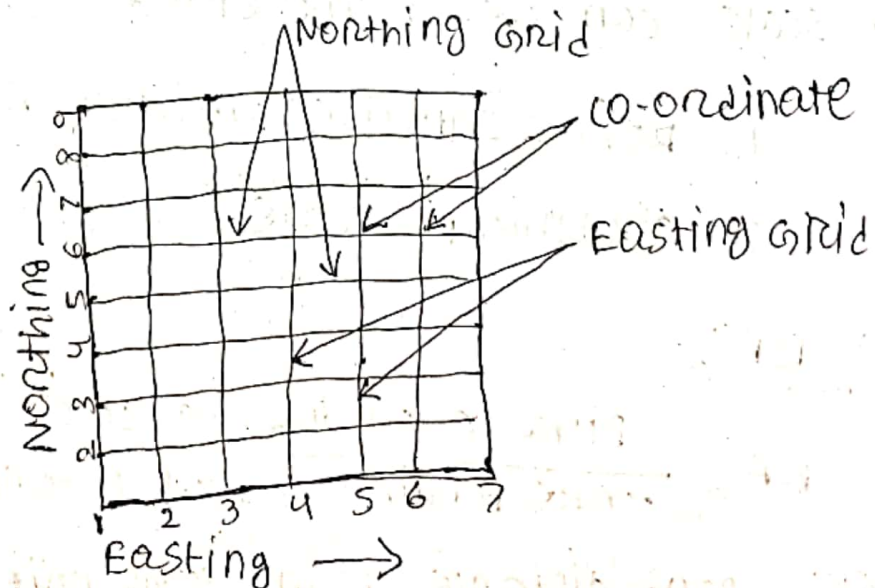


Grid reference:-

*



* - Grid is a network of, horizontal & vertical lines used to identify exact location on a map.



* - The grid which is increase towards north dirⁿ is known as Northing grid.

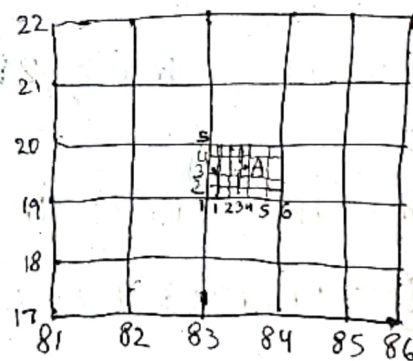
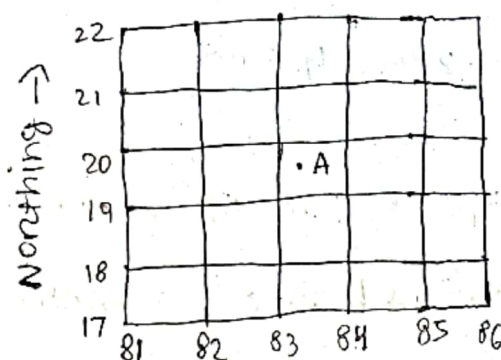
* - The grid which is increase towards East dirⁿ is known as Easting grid.

* - A point at which horizontal line (Northing grid) & vertical line (Easting grid) of the grids cross ^{each other} is known as co-ordinate.

* - Grid reference is calculated by following two methods:-

1 - 4 figure grid reference line

2 - 6 1) 1) 1) 1)



Easting →

4th. Figure grid reference of Point 'A' = 83 19

6th. Figure grid reference of Point 'A' = 83 ^{Left Easting} 1 ^{Bottom Northing} 19 1

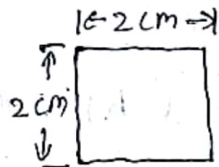
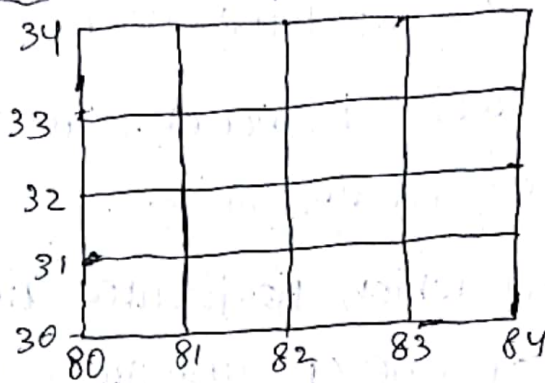
(Easting) $\rightarrow = \frac{3}{2} = 1.5 \approx 1$

round off below this value

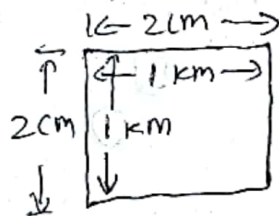
(Northing) $\rightarrow = \frac{3}{2} = 1.5 \approx 1$

round off below this value

Grid square



Let scale, $1 \text{ cm} = \frac{1}{2} \text{ km}$



Area of 1 box = $1 \text{ km} \times 1 \text{ km} = 1 \text{ km}^2$

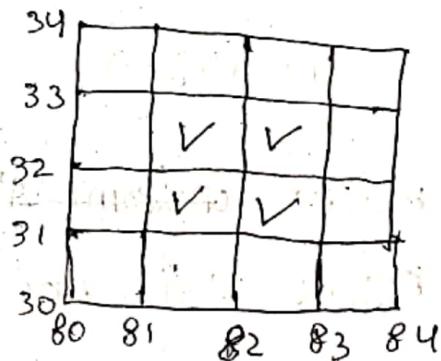
Q Find the area in square km of the region enclosed by Easting 81 to 83 & Northing 31 to 33. Let the scale is $1 \text{ cm} = 0.5 \text{ km}$.

Ans

No of boxes = 4

Area of 1 box = 1 km^2

Area of 4 boxes = $4 \times 1 = 4 \text{ km}^2$

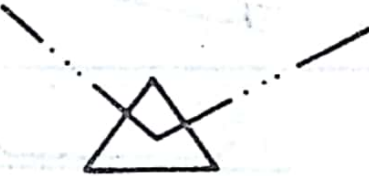
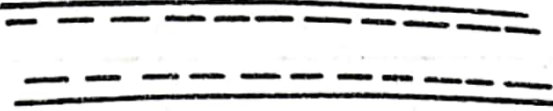


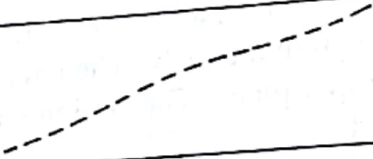
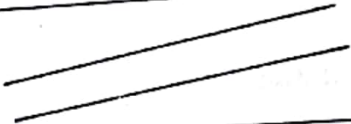
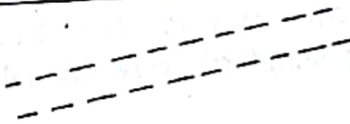
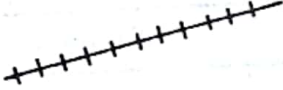
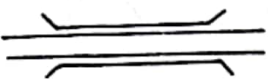
sign and symbols used in map :-

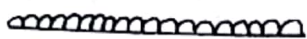
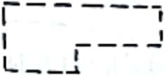
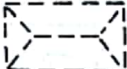
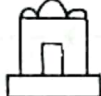
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S. No.	Object	Symbol	Colour
1.	North line		Black
2.	Main stations or triangulation stations		Red or crimson lake
3.	Traverse stations or substations		Red or crimson lake
4.	Chain line		Red or crimson lake
5.	River		Prussian blue
6.	Canal		Prussian blue

S. No.	Object	Symbol	Colour
7.	Lake or pond		Prussian blue
8.	Open well		Prussian blue
9.	Tube well		Black
10.	Footpath		Black
11.	Metalled road		Burnt sienna
12.	Unmetalled road		Burnt sienna
13.	Railway line (single)		Black
14.	Railway line (double)		Black
15.	Road bridge or culvert		Black
16.	Railway bridge or culvert		Black
17.	Level-crossing		Black and burnt sienna
18.	Wall with gate		Black
19.	Boundary line		Black

S. No.	Object	Symbol	Colour
20.	Hedge		Green
21.	Wire fencing		Black
22.	Pipe fencing		Prussian blue
23.	Wood fencing		Yellow
24.	Building (<i>Pukka</i>)		Crimson lake
25.	Building (<i>katcha</i>)		Umber
26.	Huts		Yellow
27.	Temple		Crimson lake
28.	Church		Crimson lake
29.	Mosque		Crimson lake
30.	Benchmark		Black
31.	Tree		Green
32.	Jungle		Green
33.	Orchard		Green

S. No.	Object	Symbol	Colour
34.	Cultivated land		Black and green
35.	Barren land		Black
36.	Rough pasture		Black
37.	Marsh or swamp		Black
38.	Embankment		Black
39.	Cutting		Black
40.	(a) Telegraph line		Black
	(b) Telegraph post		Black
41.	(a) Electric line		Black
	(b) Electric post		Black
42.	Burial ground or cemetery		Crimson lake

Cadastral map Preparation methodology :-

* - A map which shows the boundaries of fields, houses & estates of a place is known as cadastral map

* - Cadastral map is required for following purpose:-

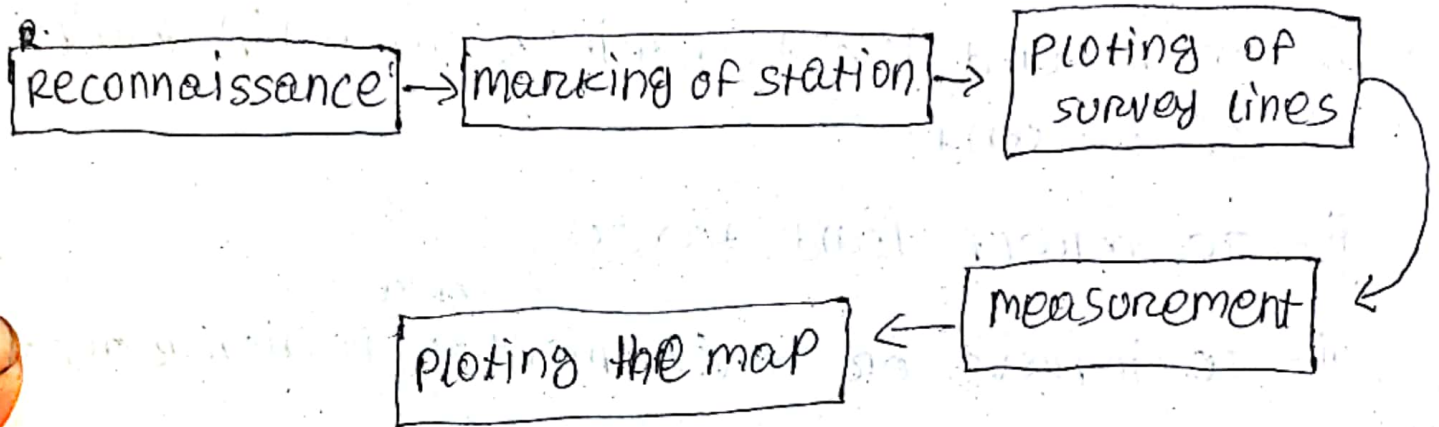
- i - TO record the boundaries & ownership details of a land
- ii - TO collect land taxes
- iii - TO improve or development ^{of a} ~~the~~ particular area

* - Following are the different methods for plotting or preparing a cadastral ~~survey~~ map:-

- 1- BY using chain / tape surveying
- 2- BY)) plane table))
- 3- Remote sensing
- 4- Total station

1- By using chain / tape surveying :-

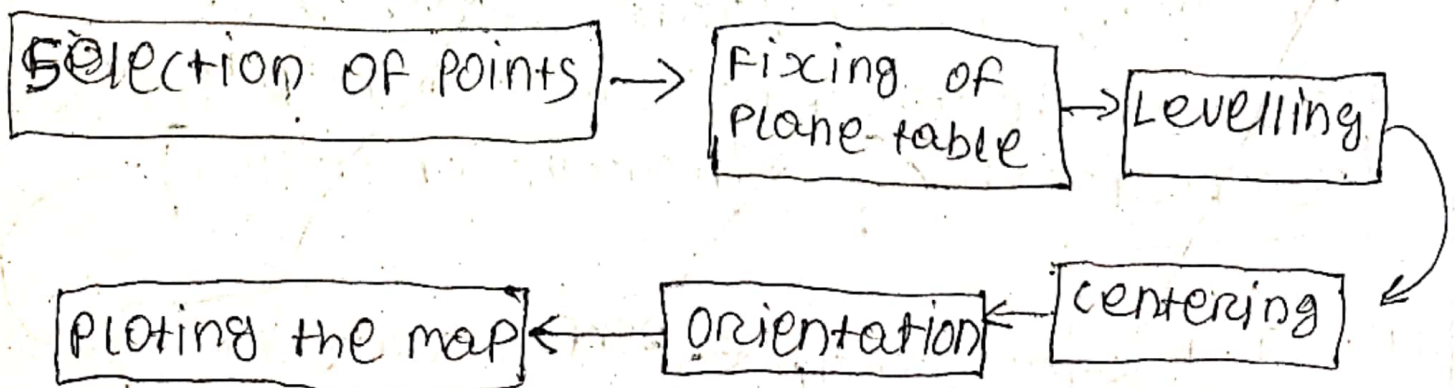
* - Following are the different steps for plotting a cadastral map by using chain / tape surveying:-



* - Before survey work, the area which will be surveyed is primary investigated. This primary investigation is known as Reconnaissance / Reconnaissance survey.

2- By using plane table :-

* - Following are the different steps for plotting a cadastral map by using plane table.

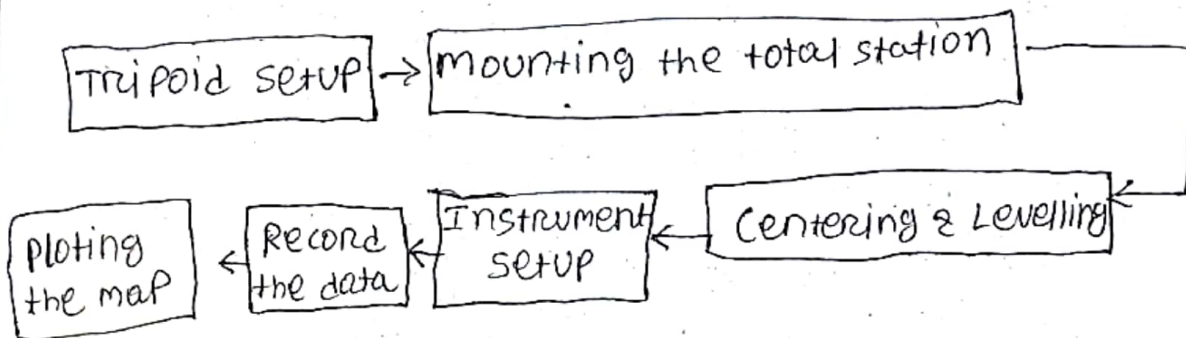


3- By using Remote Sensing :-

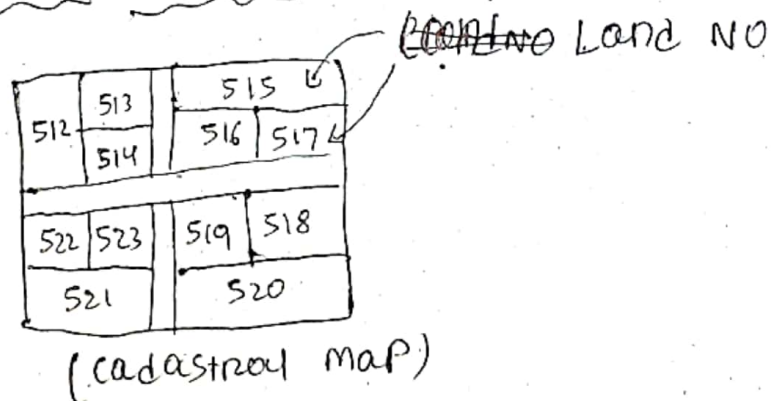
- *- In this method satellite images are used for plotting a cadastral map.
- *- This method is a quick method but not ~~exact~~ accurate method for plotting a cadastral map.

4- By using total station :-

- *- Following are the different steps for plotting a cadastral map by using total station :-



Unique Identification Number of parcel for land



- *- In this system ~~whole land~~ we provide ~~a~~ unique identification number for each and every land.
- *- Due to which it will be easy for tracking the land.

Plane table surveying :-

S.1

Objects of plane table surveying :-

- * Object of plane table surveying is to find the relative position of the objects on the ground & ~~prepare~~ plot different point of objects in ~~the~~ a drawing sheet.

Principle :-

- * The principle of plane table surveying is parallelism.
- * means the rays drawn from stations to the objects on the paper are parallel to the lines from station to the object on the ground

S.2

Instrument & accessories used in plane table surveying :-

1- The plane table :-

- * plane table is a drawing board of size 750mm x 600mm made of well seasoned wood.
- * The top surface of the table is well levelled & the bottom surface consists of a threaded circular plate for fixing the table on the tripod stand by a wing nut.

2- The alidade

*- The function of alidade is to sight the objects.

*- There are two types of alidade used in plane table surveying:-

A - plain alidade

B - Telescopic "

A - plain alidade :-

*- plain alidade consists of a metal or wooden rule of length about 50 cm.

*- one edge is bevelled which is known as fiducial edge.

*- It consists of two vanes at its both end. One is known as object vane (which consists of a horse hair) & other is sight vane.

B - Telescopic alidade :-

~~*- In this~~

*- The alidade which is fitted with a telescope is known as telescopic alidade.

*- This alidade has no vanes at the ends, but it is provided with fiducial edge.

3 - Spirit level :-

*- It consists of a small metal tube which contains a small bubble.

*- The table is truly levelled when the bubble remains at its centre.

*- ~~the~~ spirit level is used to check the level of plane table.

4- magnetic compass :-

*- magnetic compass consist of a rectangular box made of non magnetic metal containing a magnetic needle at its centre.

*- magnetic needle indicates magnetic north & south pole.

5- U-Fork or Plumbing fork with Plumb bob :-

*- U-Fork is a metal strip bent in the shape of a "U" having equal arm length.

*- Top arm is pointed & bottom arm carries a hook for suspending a plumb bob.

Orientation :-

*- The method of setting the plane table at each of the successive stations parallel to the position occupied at the starting point is known as orientation.

*- orientation is done at the each set up of the plane table.

*- orientation may be done by using magnetic needle or backsighting.

Procedure of setting up plane table over a station

* - Following steps have to be performed in order to set up a plane table over a station:-

- 1- Fixing the table on the tripod stand
- 2- Levelling the table (By using spirit level)
- 3- Centering the table (By using U-fork & Plumb bob)
- 4- Marking the north line (By using magnetic compass → ~~Compass~~ Trough compass)
- 5- orientation (Necessary when instrument shift from one station to another)

Levelling → centering → orientation

5.3 → methods of plane table surveying :-

* - Following are the 4 methods of plane table surveying:-

- 1- Radiation
- 2- Intersection
- 3- Traversing
- 4- Resection

1- Radiation :-

*- This method is suitable for locating the objects from a single station.

1. Radiation This method is suitable for locating the objects from a single station. In this method, rays are drawn from the station to the objects, and the distances from the station to the objects are measured and plotted to any suitable scale along the respective rays.

Procedure (a) Suppose P is a station on the ground from where the objects A, B, C and D are visible.

(b) The plane table is set up over the station P. A drawing sheet is fixed on the table, which is then levelled and centered. A point p is selected on the sheet to represent the station P.

(c) The north line is marked on the right-hand top corner of the sheet with trough compass or circular box compass.

(d) With the alidade touching p , the ranging rods at A, B, C and D are bisected and the rays drawn.

(e) The distances PA, PB, PC, and PD are measured and plotted to any suitable scale to obtain the points a, b, c, and d, representing the objects A, B, C and D (Fig. 4.10), on paper.

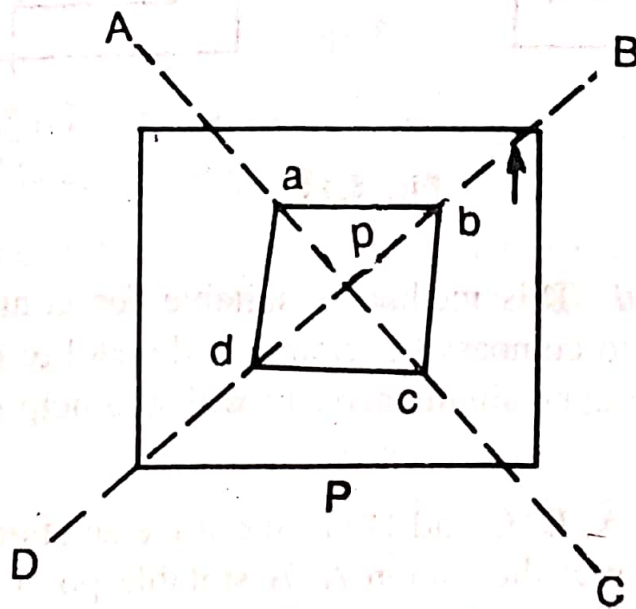


Fig. 4.10

2- Intersection

* - This method is suitable for locating inaccessible points .

2. The Intersection method This method is suitable for locating inaccessible points by the intersection of the rays drawn from two instrument stations.

Procedure (a) Suppose A and B are two stations and P is an object on the far bank of a river. Now it is required to fix the position of P on the sheet by the intersection of rays, drawn from A and B.

(b) The table is set up at A. It is levelled and centred so that a point *a* on the sheet is just over the station A. The north line is marked on the right-hand top corner. The table is then clamped.

(c) With the alidade touching *a*, the object P and the ranging rod at B are bisected, and rays are drawn through the fiducial edge of the alidade.

(d) The distance AB is measured and plotted to any suitable scale to obtain the point *b*.

(e) The table is shifted and centred over B and levelled properly. Now the alidade is placed along the line *ba* and orientation is done by backsighting. At this time it should be remembered that the centring, levelling and orientation must be perfect simultaneously.

(f) With the alidade touching *b*, the object P is bisected and a ray is drawn. Suppose this ray intersects the previous ray at a point *p*. This point *p* is the required plotted position of P (Fig. 4.11).

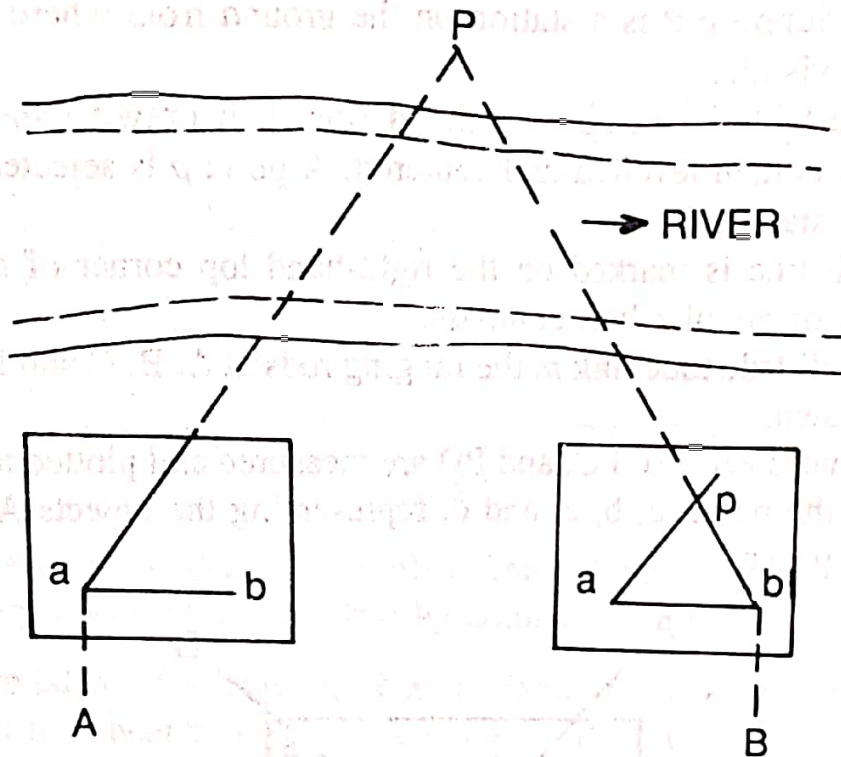


Fig. 4.11

3 - Traversing :-

- * - This method is suitable for connecting the traverse stations.
- * - Closing error may be adjusted by using Bowditch's method.

3. The traversing method This method is suitable for connecting the traverse stations. This is similar to compass traversing or theodolite traversing. But here fielding and plotting are done simultaneously with the help of the radiation and intersection methods.

Procedure (a) Suppose A, B, C and D are the traverse stations.

(b) The table is set up at the station A. A suitable point *a* is selected on the sheet in such a way that the whole area may be plotted in the sheet. The table is centred, levelled and clamped. The north line is marked on the right-hand top corner of the sheet.

(c) With the alidade touching point *a* the ranging rod at B is bisected and a ray is drawn. The distance AB is measured and plotted to any suitable scale.

(d) The table is shifted and centred over B. It is then levelled, oriented by back-sighting and clamped.

(e) With the alidade touching point *b*, the ranging rod at C is bisected and a ray is drawn. The distance BC is measured and plotted to the same scale.

(f) The table is shifted and set up at C and the same procedure is repeated.

(g) In this manner, all stations of the traverse are connected.

(h) At the end, the finishing point may not coincide with the starting point and there may be some closing error. This error is adjusted graphically by Bowditch's rule (given in Sec. 3.13).

- (i) After making the corrections for closing error, the table is again set up at A. After (centering, levelling and orientation, the surrounding details are located by radiation.
- (j) The table is then shifted and set up at all the stations of the traverse and after proper adjustments the details are located by the radiation and intersection methods (Fig. 4.12).

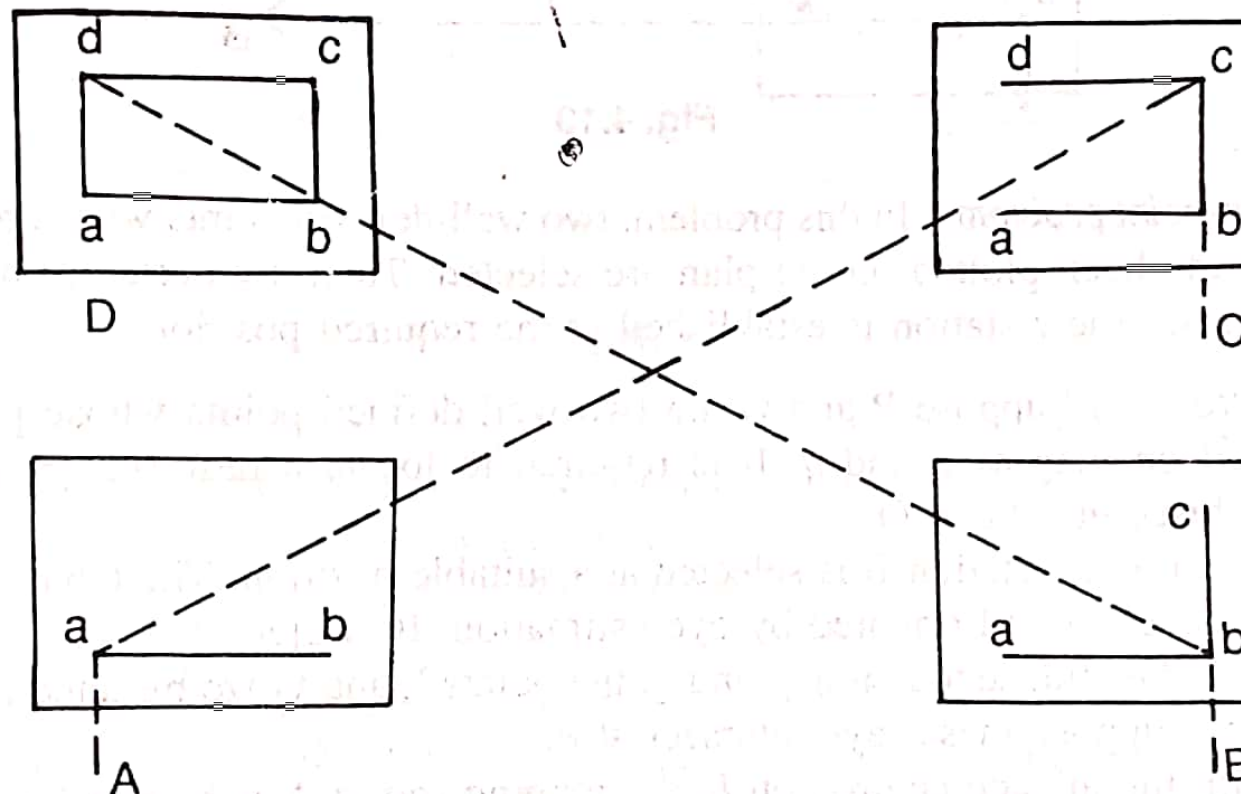


Fig. 4.12

4- Resection method :-

* - This method is suitable for establishing any missing data

~~* - (P-123, N.N. Basak)~~

* - some times it may be noticed that an important object has not been located due to oversight.

* - In this case special methods of resection is applied as follows :-

A - Two point problem

B - Three point problem

* - following are the different method of resection :-

A - BACK SIGHT method

B - TWO point method / problem

C - THREE point method / 1)

A - BACK SIGHT method :-

Procedure (a) Suppose it is required to establish a station at position P. Let us select two points A and B on the ground. The distance AB is measured and plotted to any suitable scale. This line AB is known as the “base line”.

(b) The table is set up at A. It is levelled, centred and oriented by bisecting the ranging rod at B. The table is then clamped.

(c) With the alidade touching point *a*, the ranging rod at P is bisected and a ray is drawn. Then a point P_1 is marked on this ray by estimating with the eye.

(d) The table is shifted and centred in such a way that P_1 is just over P. It is then oriented by backsighting the ranging rod at A.

(e) With the alidade touching point *b*, the ranging rod at B is bisected and a ray is drawn. Suppose this ray intersects the previous ray at a point P. This point represents the position of the station P on the sheet. Then the actual position of the station P is marked on the ground by U-fork and plumb bob (Fig. 4.13).

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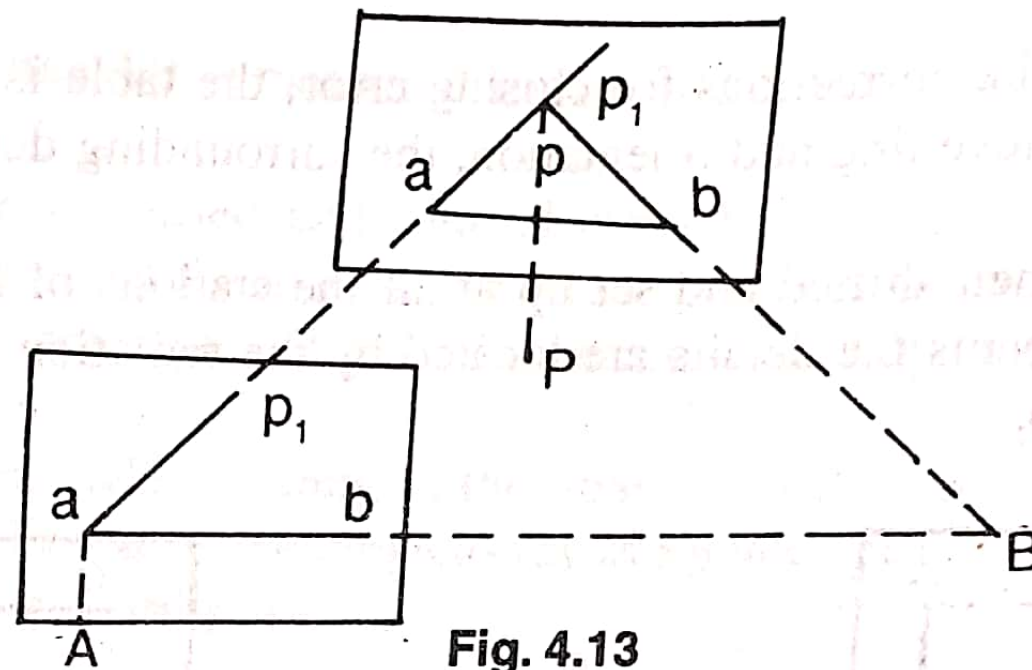
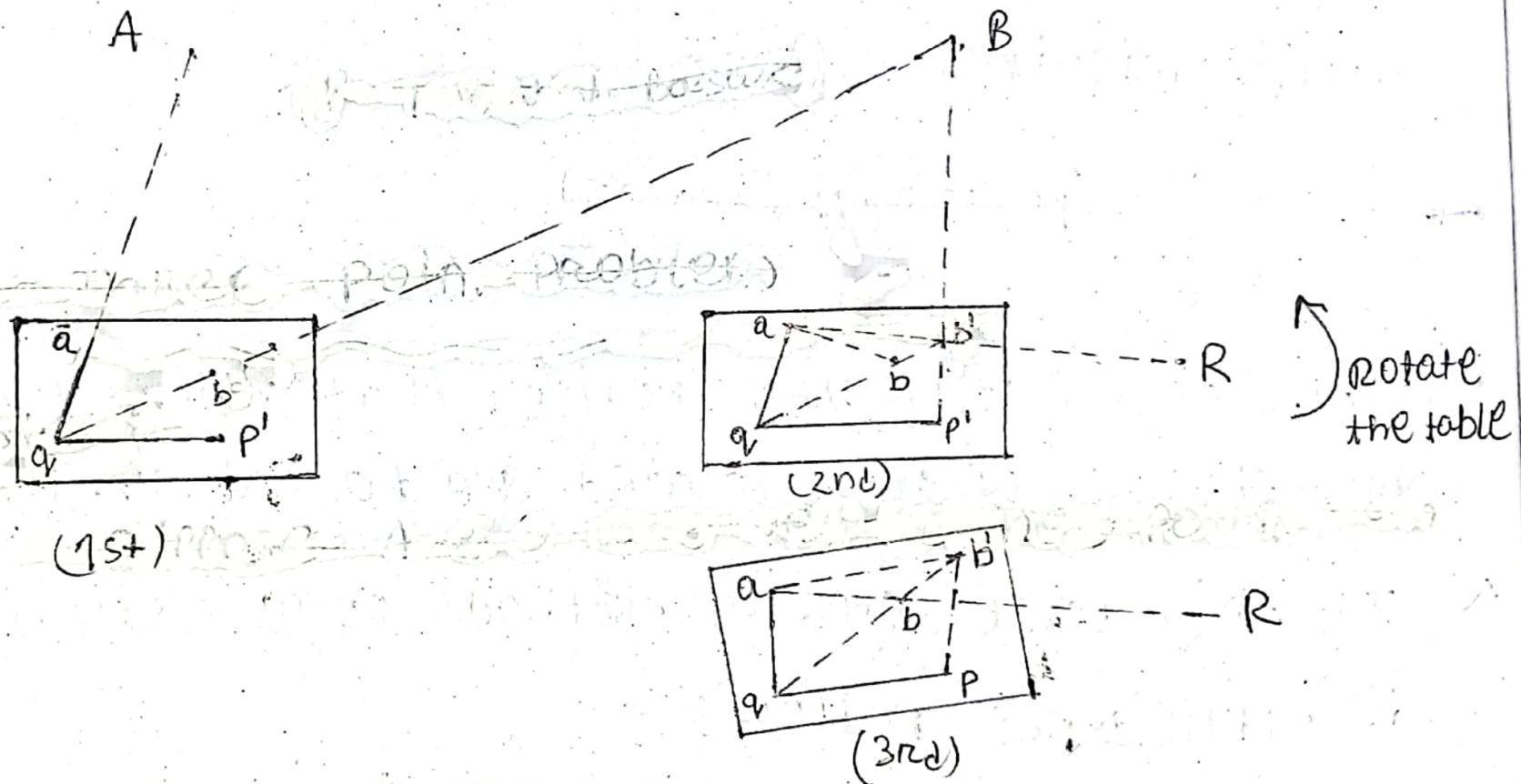


Fig. 4.13

B - Two point method :-

* - If two well defined points whose position have already plotted on map & a new point is established on map with reference to this two points is known as two point problem.



steps:-

- *- suppose A & B are well defined points whose position are already plotted on map as a & b.
- *- It is required to locate a new point 'P' on map. with respect to A & B.
- *- Fix the table at a nearby station 'Q' & keep approximate orientation of the table.
- *- Draw two lines Aa & Bb meeting at 'q'.
- *- From 'q' draw a line towards 'P' & measure its length & draw a line qP' on map.
- *- Now shift the table to 'P' & orient the table so that orientation of table becomes same as it was at "Q".
- *- Draw a line from P' towards 'B' meeting line qb at b'.
- *- The triangle abb' is known as Δ of error which is required to eliminate by orientation.
- *- Fix a point 'R' on ground in front of b' in the line ab'.
- *- Now rotate the table to make line ab in the dirⁿ of R.
- *- This is the correct orientation of table.
- *- Now draw line Aa & Bb meeting at exact location of P.

C - Three point method / problem :-

* - If three well defined points whose position have already plotted on map & a new point is established on map with reference to this three point is known as three point method.

* - In three point method No auxiliary station is required.

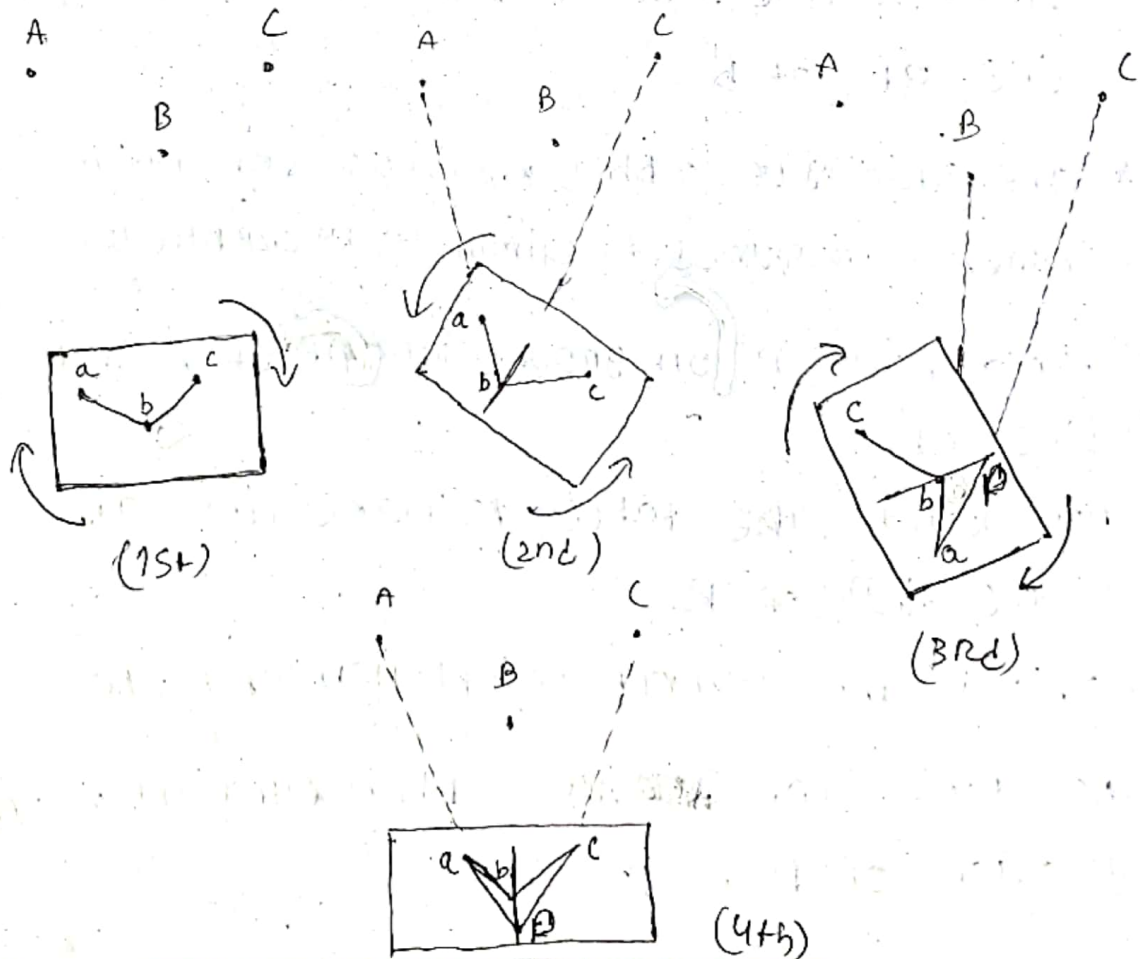
* - Three point method can solve by following method:-

i - Graphical method / Bessel's method

ii - mechanical method

iii - Trial & error method.

i - Graphical method / Bessel's method :-



*- Let the point A, B, C already plotted in plane table a, b, c

*- Now let a point P is required to plot in plane table.

*- Now set the plane table at point 'P' & centered & levelled properly. (1st)

*- Keep alidade on ba & rotate the table so that ba bisect A. (i.e baA) (2nd)

*- Now put the alidade b & bisect c & draw a line at b (2nd)

*- Again rotate the plane table so that ab is bisect B (i.e abB) (3rd)

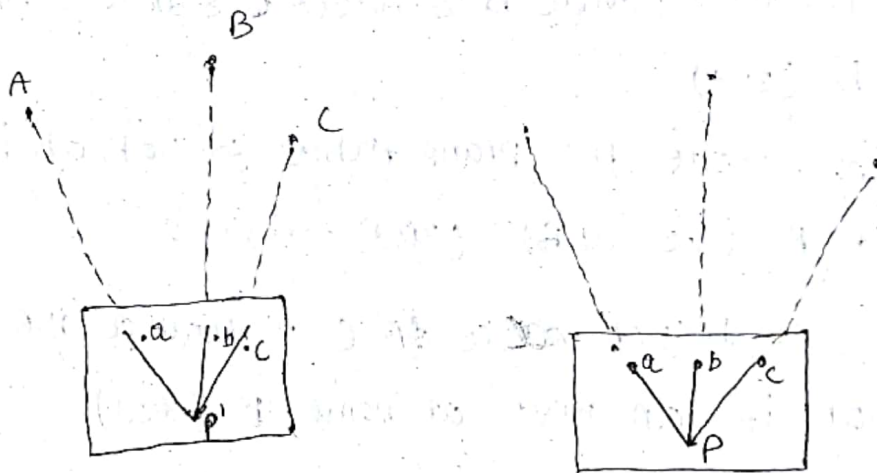
*- And also bisect a & c & draw a line so that it can meet at point P (3rd)

*- Again rotate the plane table so that PCG in a straight line (4th)

*- It is the actual orientation of plane table & the point P also plotted on plane table.

ii- Graphical mechanical method :-

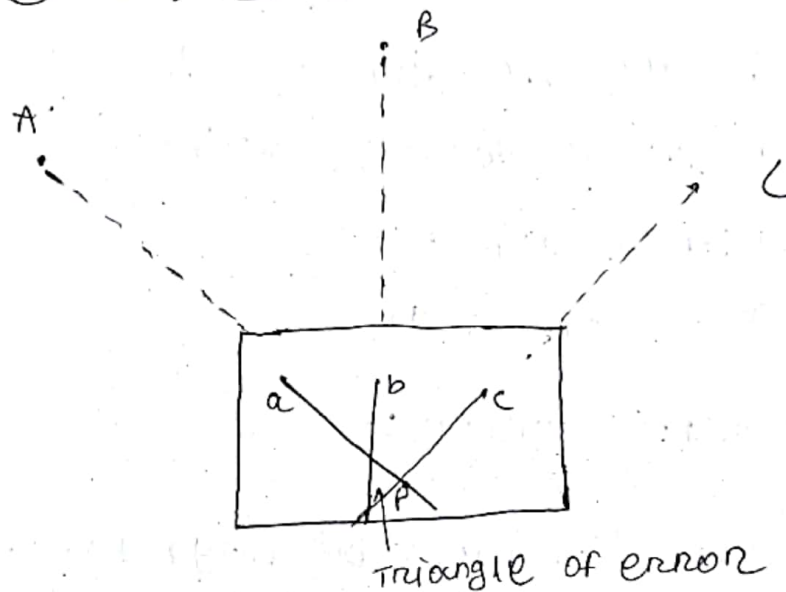
- * - Suppose A, B, C are 3 well defined points which have been plotted on map as a, b, c
- * - It is required to locate a station at P.
- * - The table is placed at 'P' centered, levelled properly.
- * - A tracing paper is fixed on the map and a point P' is marked on it.



- * - With the alidade centered on P the point A, B, C are bisected and rays are drawn.
- * - These rays may not pass through the points a, b, c (because orientation done approximately)
- * - Now the tracing paper moved over the map until the rays are drawn on tracing paper bisect point a, b, c.
- * - After bisecting these points a mark / impression on the point P' is given.

*- Then we remove the tracing paper & point P' is marked as point P .

iii - Trial & Error method:-



*- Suppose A, B, C are 3 well defined points which have been plotted as a, b, c on the map

*- Now it is required to establish a station at P .

*- The table is set up at P and levelled & centered properly & orientation is done by eye estimate

*- With the alidade rays Aa, Bb, Cc are drawn

*- These rays may not intercept at point P (Because orientation is done approximately).

*- It may form a small triangle which is known as triangle of error.

*- To get the actual point P , this triangle of error is eliminated by turning the table clockwise or anticlockwise.

- * - After eliminate this triangle of error, the rays Aa , Bb & Cc meet at a point P .

Errors in plane table :-

- * - Following are the different types of error found in plane table surveying :-

A - Instrumental error

B - Personal error

A - Instrumental error :-

- * - The surface of the table may not be perfectly level.
- * - Fiducial edge of alidade may not be straight.
- * - The horse hair used in object vane may be loose & not vertical.
- * - The needle of the compass may not be perfectly balanced.

B - Personal error

- * - Levelling, centering & orientation may not be done perfectly.
- * - The object may not be bisect properly.
- * - The rays drawn in drawing sheet may not be drawn perfectly.

precaution should be taken to eliminate error:-

- * - ~~Def~~ Instrumental error can be eliminate by proper testing the instrument before conducting the survey work.
- * - Centering, levelling, orientation done properly
- * - Bisect done properly by using alidade
- * - The stations on the ground are marked as A, B, C, D, etc. But while these station are plot on map marked as a, b, c, d, etc.

6 -

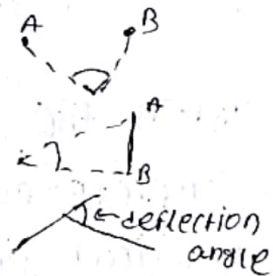
Theodolite traversing

6.1

* - The theodolite is an instrument used mainly for accurate measurement of horizontal & vertical angles upto $10''$ or $20''$ accuracy.

* - followings are the ~~the~~ uses of theodolite :-

- 1 - for measuring horizontal angle
- 2 -)))) vertical))
- 3 -)))) deflection))
- 4 -)))) magnetic bearing
- 5 -)))) Horizontal distance b/w two point
- 6 -)))) vertical height
- 7 - for ranging a line



* - Because of its various uses, the theodolite is sometimes known as a universal instrument.

* - The size of theodolite is defined according to the diameter of the main horizontal graduated circle. (i.e. lower plate)

for ex $\rightarrow$ 10 cm theodolite means, the diameter of the main graduated circle is 10 cm.

* - In engineering survey 8 cm to 12 cm theodolites are generally used.

Classification of theodolite :-

A - Based on transiting

i - Transit theodolite

ii - Non-transit theodolite

B - Based on scale

i - Vernier theodolite

ii - micrometer theodolite.

* - when the telescope can revolved through a complete revolution about horizontal axis in a vertical plane is known as transiting.

* - when a telescope transit about horizontal axis in a vertical plane is known as transit theodolite otherwise it is known as non-transit theodolite.

6.2

Definations :-

1 - centering :-

* - The setting of a theodolite exactly over a station with the help of Plumb-bob is known as centering.

2 - Transiting :-

* - The method of turning the telescope about its horizontal axis in a vertical plane through 180° is known as transiting.

3-face left :-

* - When the vertical circle of the theodolite is on left side ^{that} ~~during the observation~~ is known as face left.

* - The observation taken in face left position is known as face left observation.

* - Face left position is also known as telescope normal / telescope direct / Bubble up.

4-face right :-

* - When the vertical circle of the theodolite is on right side, that is known as face right.

* - The observation taken in face right position is known as face right observation.

* - Face right position is also known as telescope inverted / telescope reversed / Bubble down.

5-changing face :-

* - The operation of bringing the vertical circle from one side to another is known as changing face.

6-swinging the telescope :-

* - Turning the telescope in vertical axis through horizontal plane is known as swinging.

* - When telescope is turned clockwise, that is called right swing.

* - when telescope is turned anti-clockwise, that is called left swing.

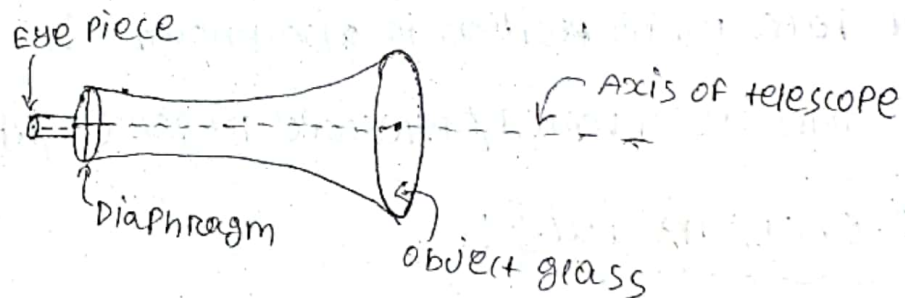
7- Line of collimation :-

* - It is an imaginary line passing through the intersection of the cross hair at the diaphragm & the optical centre of the object glass and its continuation is known as line of collimation.

* - It is also known as line of sight.

8- Axis of the telescope :-

* - It is an imaginary line passing through the intersection of the optical centre of the object glass and the optical centre of the eye piece.



9- Temporary adjustment :-

* - setting of the theodolite over a station at the time of taking any observation is known as temporary adjustment.

* - Temporary adjustment is necessary for every set up of the instrument.

10- Least count of the vernier :-

* - This is the difference b/w the value of smallest division of the main scale & the value of smallest division of the vernier scale

* - Least count is the smallest value that can be measured by a theodolite.

Let, ~~the~~

$(n-1)$ division of the main scale is divided into n divisions in the vernier scale.

V = Value of smallest division of vernier scale

d = value of smallest division of main scale.

we can say that,

$$(n-1) \times d = n \times V$$

$$\Rightarrow V = \frac{(n-1)d}{n}$$

According to the definition,

$$\text{Least count} = d - V = d - \frac{(n-1)d}{n}$$

$$= d - \frac{(dn - d)}{n}$$

$$= \frac{dn - dn + d}{n}$$

$$= \frac{d}{n} = \frac{\text{value of smallest division of main scale}}{\text{No of division in vernier scale}}$$

for ex $\rightarrow$

1- If, $d = 20' = 20 \times 60 = 1200''$ & $n = 60$

$$\text{Least count} = \frac{d}{n} = \frac{1200''}{60} = 20''$$

2- If, $d = 15' = 15 \times 60 = 900''$ & $n = 60$

$$\text{Least count} = \frac{d}{n} = \frac{900''}{60} = 15''$$

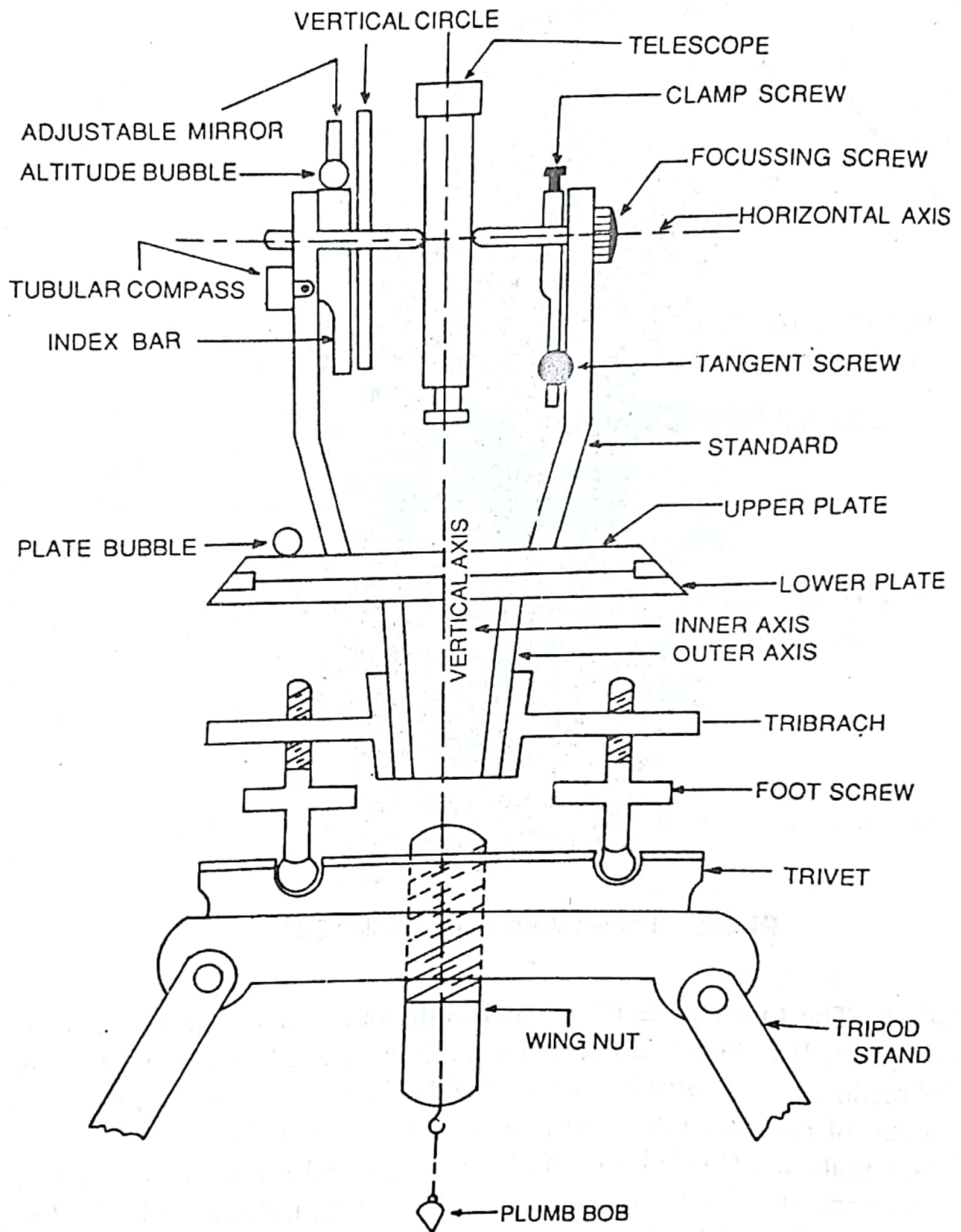


Fig. 9.2

Different parts of a theodolite :-

1- Trivet :-

- * - It is a circular plate having a central threaded hole for fixing the theodolite on the tripod stand by a wing nut
- * - It is also called base plate
- * - Three foot screw attach in trivet by ball and socket arrangement

2- Foot screw :-

- * - Foot screw are used for levelling the instrument
- * - Foot screw are ~~connect~~ connected attach in trivet by ball & socket arrangement

3- Tribrach :-

- * - It is a triangular plate carrying three foot screw at its end

4- Levelling head:-

- * - The tribrach, foot screw, tribrach together is known as levelling head.

5- Lower Plate:-

- * - A plate which contains a main scale from 0° to 360° in a clockwise direction is known as lower plate.
- * - The lower plate is attached with a clamp screw & tangent screw. Which control the movement of main scale. (which is known as lower clamp screw & lower tangent screw)
- * - The size of the theodolite is designated according to the diameter of the lower plate.

6- Upper plate:-

- * - A plate which contains a vernier scale A & B is known as upper plate.
- * - The upper plate is also attached with a clamp screw & tangent screw. Which control the movement of vernier scale. (which is known as upper clamp screw & upper tangent screw)

Temporary adjustment of theodolite:-

- * - Following are the different steps taken for temporary adjustment of a theodolite over any station.

- i - setting the theodolite over any station
- ii - Approximate levelling by using tripod stand

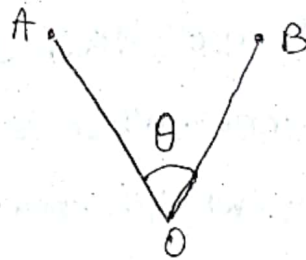
- iii - centring
- iv - perfect levelling by using foot screw
- v - focussing the eye piece
- vi - focussing the object glass
- vii - setting the vernier.

6-3 - measurement of horizontal angle :-

* - followings are the different methods for measuring horizontal angle :-

- 1 - Direct method
- 2 - Repetition method
- 3 - Reiteration method

1 - Direct method :-



SUPPOSE $\angle AOB$ is to be measured

- * - The instrument is set up over "O". It is centered & levelled properly.
- * - suppose the instrument initially face left position
- * - The lower clamp is kept fixed & upper clamp ~~get~~ is loosened & by turning the telescope clockwise/anti

Clockwise vernier A is set to 0° & vernier B is set to 180° . (Approximately). The upper clamp is then tightened. Now by turning the upper tangent screw vernier A & B are set exactly 0° & 180° by looking through magnifying glass.

*- The upper clamp is tightly fixed. The lower one is loosen and the telescope is directed to the point A.

*- The ranging rod at A is bisected approximately by properly focussing the telescope towards A. Then the lower clamp is tightened and by turning the lower tangent screw the ranging rod A is perfectly bisect.

~~*- The lower clamp screw~~

*- After bisect of A, lower clamp screw is kept fixed & upper clamp screw is loosen & the telescope turned clockwise & approximate bisect the ranging rod B. The upper clamp is tightened and the ranging rod at B bisect accurately by turning the upper tangent screw.

*- Now the reading on vernier A & B are noted.

*- vernier A gives the angle directly. But in the case of vernier B, the angle is obtained by subtracting initial reading from final reading.

* - The face of the instrument is changed and the previous procedure is followed & prepare a data in a tabular form as follows.

Station	Object	Angle	Observation	Reading on vernier		Angle on vernier		mean angle of vernier	mean angle of observation
				A	B	A	B		
1	2	3	4	5	6	7	8	9	10
O	A	$\angle AOB$	Face left	$0^{\circ} 0' 0''$	$180^{\circ} 0' 0''$	$30^{\circ} 20' 20''$	$30^{\circ} 20' 40''$	$30^{\circ} 20' 30''$	$30^{\circ} 20' 30''$
	B			$30^{\circ} 20' 20''$	$210^{\circ} 20' 40''$				
O	A	$\angle AOB$	Face right	$0^{\circ} 0' 0''$	$180^{\circ} 0' 0''$	$30^{\circ} 20' 40''$	$30^{\circ} 20' 20''$	$30^{\circ} 20' 30''$	$30^{\circ} 20' 30''$
	B			$30^{\circ} 20' 40''$	$210^{\circ} 20' 20''$				

Note: -

Upper clamp screw $\rightarrow$ used to move the vernier scale A & B

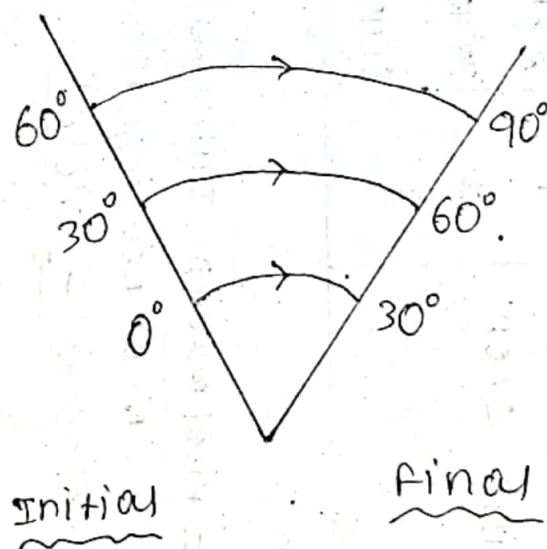
Lower clamp screw $\rightarrow$ used to move the main scale

Upper tangent screw $\rightarrow$ used to exact co-inside the vernier scale along with main-scale

Lower tangent screw $\rightarrow$ used to perfectly bisect the object.

2- Repetition method :-

- * In this method the angle is taken by number of times & the value of angle is find out by dividing sum of angle into no of angle taken.



$$\angle AOB = \frac{\text{sum of angle}}{\text{No of reading}} = \frac{90^\circ}{3} = 30^\circ$$

A. Repetition Method

In this method, the angle is added a number of times. The total is divided by the number of readings to get the angle. The angle should be measured clockwise in the face left and face right positions, with three repetition at each face. The final reading of the first observation will be the initial reading of the second observation, and so on. The following procedure should be adopted:

Procedure

1. Suppose the angle $\angle AOB$ (Fig. 9.8) is to be measured by the repetition process. The theodolite is set up at O. The instrument is centred and levelled properly. Vernier A is set to 0° and vernier B to 180° .
2. The upper clamp is fixed, and the lower one loosened. By turning the telescope, the ranging rod at A is perfectly bisected with the help of the lower clamp screw and the lower tangent screw. Here the initial reading of vernier A is 0° .
3. The upper clamp is loosened and the telescope is turned clockwise to perfectly bisect the ranging rod at B. The upper clamp is clamped. Suppose the reading on vernier A is 30° .
4. The lower clamp is loosened and the telescope turned anticlockwise to exactly bisect the ranging rod at A. Here, the initial reading is 30° for the second observation.

5. The lower clamp is tightened. The upper one is loosened and the telescope is turned clockwise to exactly bisect the ranging rod at B. Let the reading on vernier A be 60° .
6. The initial reading for the third observation is set to 60° . $\angle AOB$ is again measured. Let the final reading on the vernier A be 90° , which is the accumulated angle.

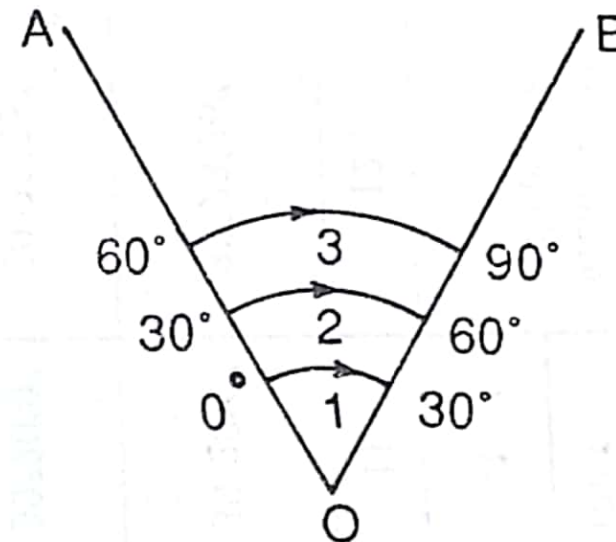


Fig. 9.8

$$\begin{aligned}\angle AOB &= \frac{\text{accumulated angle}}{\text{no. of reading}} \\ &= \frac{90^\circ}{3} = 30^\circ\end{aligned}$$

7. The face of the instrument is changed and the previous procedure is followed.
8. The mean of the two observations gives the actual angle $\angle AOB$. The result is shown in Table 9.2.

Station	Object	Observation	Angle	No of readings	Initial angle on vernier		Final angle on vernier		Angle on vernier		Mean angle of vernier
					A	B	A	B	A	B	
1	2	3	4	5	6	7	8	9	10	11	12
O	A	Face left	$\angle AOB$	1	$0^{\circ} 0' 0''$	$180^{\circ} 0' 0''$	$30^{\circ} 40' 0''$	$210^{\circ} 40' 20''$	$30^{\circ} 26' 46''$	$30^{\circ} 20' 6''$	$30^{\circ} 23' 26''$
	B			2	$30^{\circ} 40' 0''$	$210^{\circ} 40' 20''$	$61^{\circ} 40' 0''$	$240^{\circ} 20' 20''$			
				3	$61^{\circ} 40' 0''$	$240^{\circ} 20' 20''$	$91^{\circ} 20' 20''$	$271^{\circ} 0' 20''$			
O	A	Face right	$\angle AOB$	1	$0^{\circ} 0' 0''$	$180^{\circ} 0' 0''$	$30^{\circ} 40' 20''$	$210^{\circ} 40' 0''$	$30^{\circ} 26' 46''$	$30^{\circ} 20' 0''$	$30^{\circ} 23' 23''$
	B			2	$30^{\circ} 40' 20''$	$210^{\circ} 40' 0''$	$61^{\circ} 40' 20''$	$240^{\circ} 20' 40''$			
				3	$61^{\circ} 40' 20''$	$240^{\circ} 20' 40''$	$91^{\circ} 20' 20''$	$271^{\circ} 0' 0''$			

Face left observation :-

Angle on vernier A = Final reading - Initial reading

$$= \frac{91^{\circ} 20' 20'' - 0^{\circ} 0' 0''}{\text{No of readings taken}} = \frac{91^{\circ} 20' 20''}{3} = 30^{\circ} 26' 46''$$

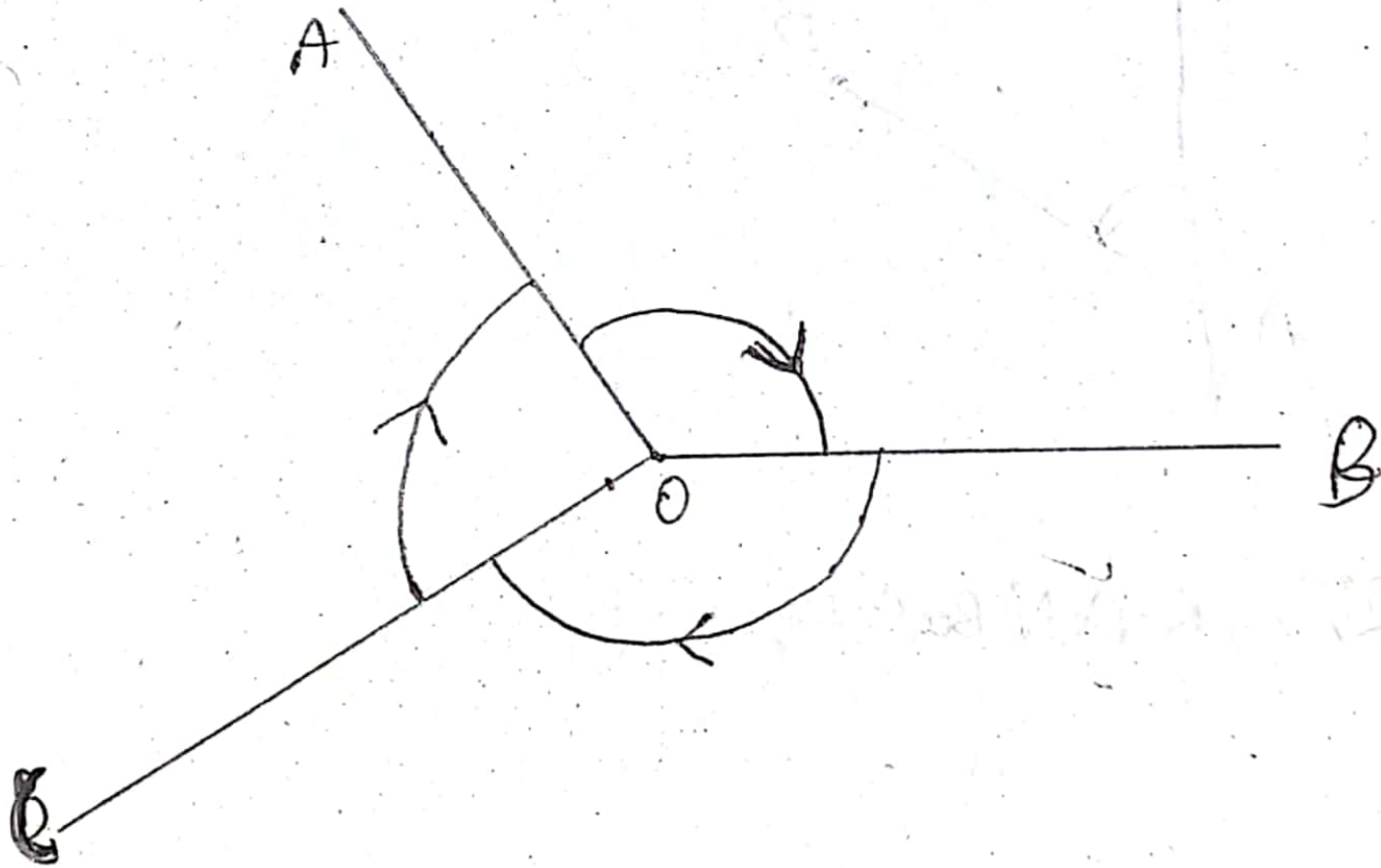
Angle on vernier B = $\frac{\text{Final reading} - \text{Initial reading}}{\text{No of readings taken}}$

$$= \frac{271^{\circ} 0' 20'' - 180^{\circ} 0' 0''}{3} = \frac{91^{\circ} 0' 20''}{3} = 30^{\circ} 20' 6''$$

Mean angle of observation	Remark
13	14
$30^{\circ} 23' 24''$	

3- Reiteration method :-

* - This method is suitable when several angles are measured from a single station.



First set

1. The theodolite is perfectly centred over O (Fig. 9.9) and levelled properly in the usual manner. Suppose, the observation is taken in the face left position and the telescope is turned clockwise (right swing).

2. Vernier A is set to 0° (i.e. 360°) and vernier B to 180° .

3. The upper clamp is fixed and the lower one loosened. The ranging rod at A is perfectly bisected. Now, the lower clamp is tightened.

4. The upper clamp is loosened, and the ranging rod or object at B is bisected properly by turning the telescope clockwise. The readings on both the verniers are taken. $\angle AOB$ is noted.

5. Similarly, the object C is bisected properly, and the readings on the verniers are noted. $\angle BOC$ is recorded.

6. Now the horizon is closed, i.e. the last angle $\angle COA$ is measured. The position of the leading vernier is noted. The leading vernier should show the initial reading on which it was set. If it does not, the amount of discrepancy is noted. If it is small, the error is distributed among the angles. If the discrepancy large, the observation should be taken again.

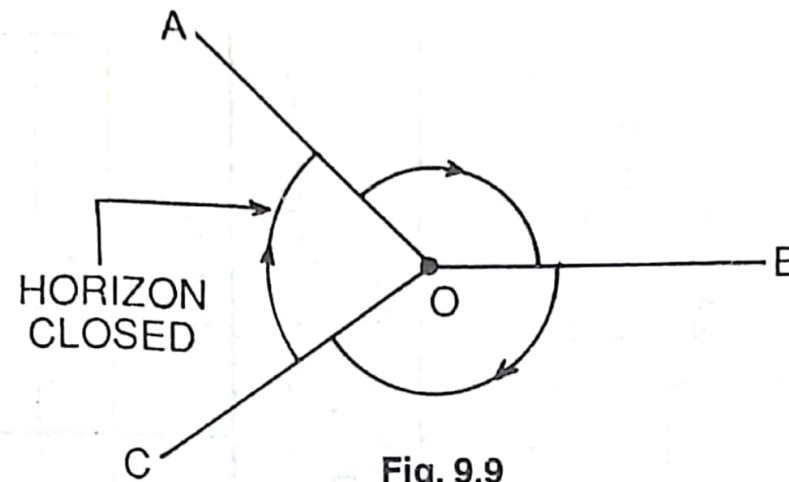


Fig. 9.9

Second set

1. The face of the instrument is changed. Again the verniers are set at their initial positions. This time the angles are measured anticlockwise (left swing).

2. The upper clamp is fixed, and the lower one loosened. Then the object A is perfectly bisected.

3. The lower clamp is tightened. The telescope is turned anticlockwise, and the object C bisected by loosening the upper clamp screw. The readings on both the verniers are taken. $\angle COA$ is noted.

4. Then the object B is bisected by turning the telescope anticlockwise, and the readings on the verniers are taken. $\angle BOC$ is recorded.

5. Finally, the horizon is closed i.e. the object A is bisected. Here, the leading vernier A should show a reading of 0° (since it was initially set to 0°). The last angle $\angle AOB$ is noted.

The mean angles of the two sets give the actual values of the angles. If some error is found after arithmetical check, it should be equally distributed among the angles. The observations are noted as shown in Table 9.3.

Table 9.3 (Measurement of Angle by) Reiteration Process

Inst. Station	Station bisected	Observation	Reading on vernier A	Reading on vernier B	Angle	Angle on vernier A	Angle on vernier B	Mean angle of vernier A and B	Mean angle of observation
1	2	3	4	5	6	7	8	9	10
O	A	Face left, right swing (clockwise)	0°0'0"	180°0'0"	∠AOB	100°40'40"	100°40'20"	100°40'30"	$\angle AOB = 100^{\circ}40'15''$ $\angle BOC = 60^{\circ}40'20''$ $\angle COA = 198^{\circ}39'40''$
	B		100°40'40"	280°40'20"	∠BOC	60°40'0"	60°40'20"	60°40'10"	
	C		161°20'40"	341°20'40"	∠COA	198°39'40"	198°39'40"	198°39'40"	
O	A	Face right, left swing (anticlockwise)	0°0'0"	180°0'0"	∠COA	198°39'40"	198°39'40"	198°39'40"	$\angle AOB = 100^{\circ}40'15''$ $\angle BOC = 60^{\circ}40'20''$ $\angle COA = 198^{\circ}39'40''$
	C		161°20'20"	341°20'20"	∠BOC	60°40'20"	60°40'40"	60°40'30"	
	B		100°40'20"	280°39'40"	∠AOB	100°40'20"	100°39'40"	100°40'0"	

Total angle = $360^{\circ}0'15''$

Error = + 15"

Correction per angle = - 5"

Correction (-ve)	Corrected angle	Remark
11	12	13
- 5" - 5" - 5"	$\angle AOB = 100^{\circ}40'10''$ $\angle BOC = 60^{\circ}40'15''$ $\angle COA = 198^{\circ}39'35''$	The error is distributed equally among all the angles

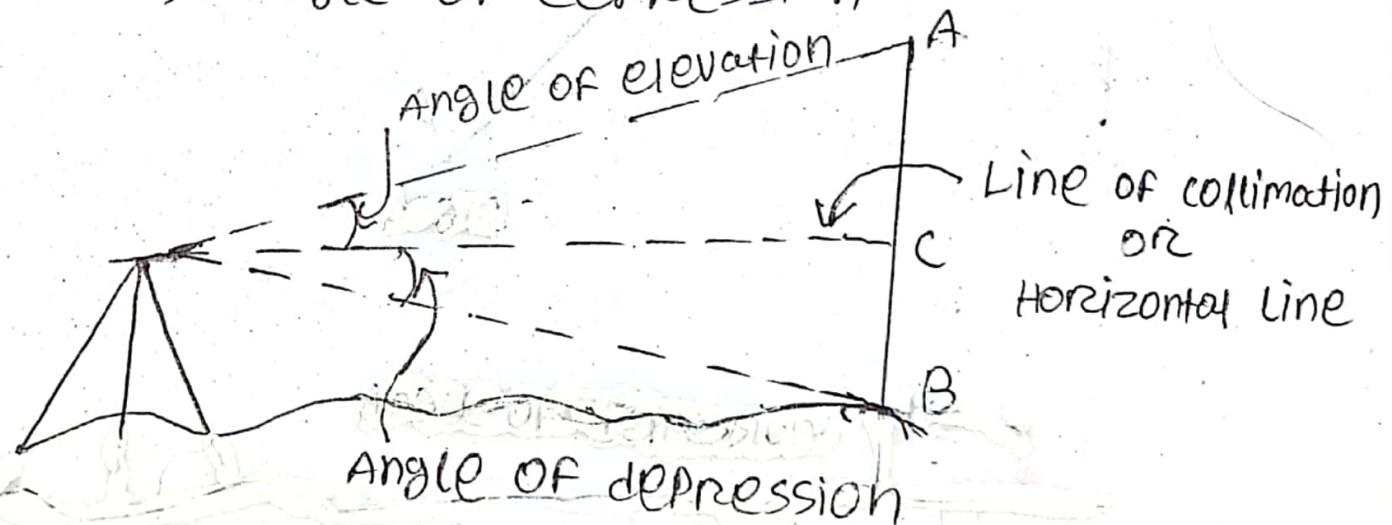
Total angle = $360^{\circ}0'0''$

measurement of vertical angle ∴ -

* - vertical angle is the sum of angle of elevation & angle of depression

* - The angle b/w line of collimation & upward line is known as angle of elevation

* - The angle b/w line of collimation & downward line is known as angle of depression



9.9 MEASURING VERTICAL ANGLE

The vertical angle is the one between the horizontal line (i.e. line of collimation) and the inclined line of sight. When it is above the horizontal line, it is known as the angle of elevation. When this angle is below the horizontal line, it is called the angle of depression.

Consider Fig. 9.10. Suppose the angle of elevation $\angle AOC$ and that of depression $\angle BOC$ are to be measured. The following procedure is adopted:

1. The theodolite is set up at O. It is centred and levelled properly. The zeros of the verniers (generally C and D) are set at the $0^\circ-0^\circ$ mark of the vertical circle (which is fixed to the telescope). The telescope is then clamped.
2. The plate bubble is brought to the centre with the help of foot screws (in the usual manner). Then the altitude bubble is brought to the centre by means of a clip screw. At this position the line of collimation is exactly horizontal.
3. To measure the angle of elevation, the telescope is raised slowly to bisect the point A accurately. The readings on both the verniers are noted, and the angle of elevation recorded.

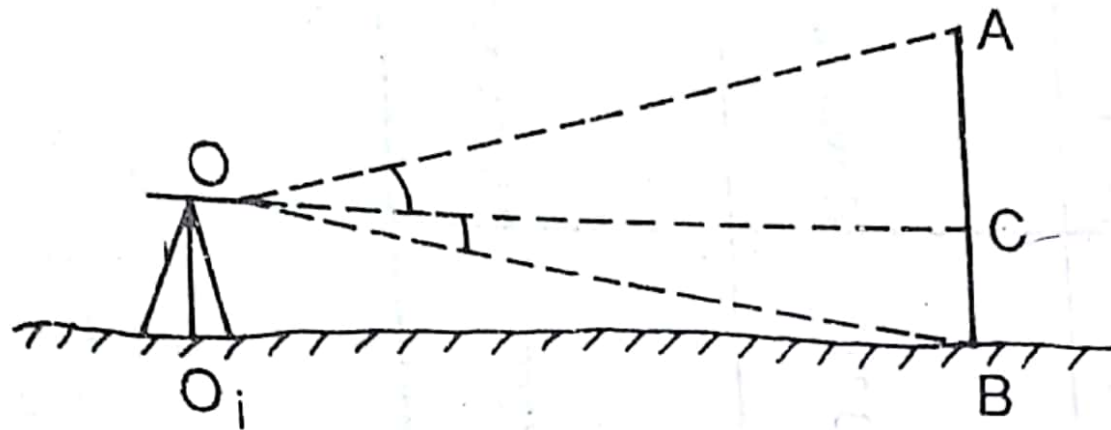


Fig. 9.10

4. The face of the instrument is changed and the point A is again bisected. The readings on the verniers are noted. The mean of the angles of the observed is assumed to be the correct angle of elevation.
5. To measure the angle of depression, the telescope is lowered slowly and the point B is bisected. The readings on the verniers are noted for the two observations (face left and face right). The mean angle of the observation is taken to be the correct angle of depression. The result is tabulated as shown in Table 9.4.

Table 9.4 Measurement of vertical angle

Inst. Station	Object	Face	Angle	Reading on vernier		Angle on vernier		Mean angle of vernier	Mean angle of observation	Remark
				C	D	C	D			
1	2	3	4	5	6	7	8	9	10	11
O	Horizontal A	Left	— Elevation $\angle AOC$	0°0'0" 10°40'20"	0°0'0" 10°40'40"	10°40'20"	10°40'40"	10°40'30"	10°40'35"	Elevation
	Horizontal A	Right	— Elevation $\angle AOC$	0°0'0" 10°40'40"	0°0'0" 10°40'40"	10°40'40"	10°40'40"	10°40'40"		
O	Horizontal B	Left	— Depression $\angle BOC$	0°0'0" 8°20'20"	0°0'0" 8°21'0"	8°20'20"	8°21'0"	8°20'40"	8°21'25"	Depression
	Horizontal B	Right	— Depression $\angle BOC$	0°0'0" 8°22'40"	0°0'0" 8°21'40"	8°22'40"	8°21'40"	8°22'10"		

9.11 MEASUREMENT OF MAGNETIC BEARING

Consider Fig. 9.12. Suppose the magnetic bearing of the line AB is to be measured. The procedure is as follow:

1. The theodolite is set up at A, and centred and levelled properly. Vernier A is set at 0° and vernier B at 180° . The upper clamp is fixed.
2. Now a trough compass or tubular compass is fixed on the left hand standard (A-frame) with a fixing screw. In some theodolites, a circular compass is provided over the vernier scale between the standards. However, the needle of the compass is released.
3. By loosening the lower clamp, the telescope is rotated until it points to the north (i.e. the magnetic needle coincides with the '0-0' mark). At this time, the position of the telescope is said to be perfectly oriented along the magnetic meridian.
4. The lower clamp is fixed and the upper clamp loosened. Then by turning the telescope clockwise, the ranging rod at B is bisected with the help of the upper tangent screw.
5. The readings on both the verniers are taken. The mean of these readings is the magnetic bearing of AB.
6. The face of the instrument is changed, and the magnetic bearing of AB is measured in a similar manner.

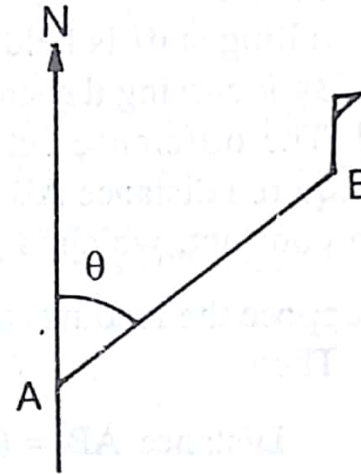


Fig. 9.12



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7. The mean of the two observations will give the correct magnetic bearing of the line.

9.10 MEASUREMENT OF DEFLECTION ANGLE

The deflection angle is the angle by which a line is deflected from its original direction. In other words, it is the angle which a survey line makes with the extension of the preceding line. The deflection may be towards the right or the left, depending upon whether the angle is measured in the clockwise or anticlockwise direction from the extension of the preceding line. Deflection angles are measured for designing horizontal curves in railways, highways, etc.

Consider Fig. 9.11. 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 $\angle PBC$ (ϕ) is known as the angle of deflection, and has to be measured. The following procedure is adopted:

1. The theodolite is set up at B, and centred and levelled properly. Vernier A is set at 0° and B at 180° .
The upper clamp is tightened and the lower one loosened. By turning the telescope, the ranging rod at A is perfectly bisected. The lower clamp is then fixed.
2. The telescope is transited and a ranging rod at P is fixed along the prolongation of AB.
3. The upper clamp is loosened. By turning the telescope clockwise, the ranging rod at C is properly bisected. The readings on both the verniers are taken. The upper clamp is then tightened. Now, the verniers give the deflection angle ϕ .

4. The lower clamp is loosened, and by turning the telescope clockwise the ranging rod at A is again bisected. (At this time the vernier readings are left undisturbed.) The lower clamp is fixed.

5. The telescope is transited. The upper clamp is loosened and by turning the telescope clockwise the ranging rod at C is bisected once more. The readings on the vernier are taken.

6. Thus the deflection angle is doubled. The average of the two verniers is taken. One-half of this average value will give the correct value of the deflection angle.

The deflection angle is doubled in order to eliminate errors owing to wrong adjustment of the instrument, and those due to eccentricity of the centre.

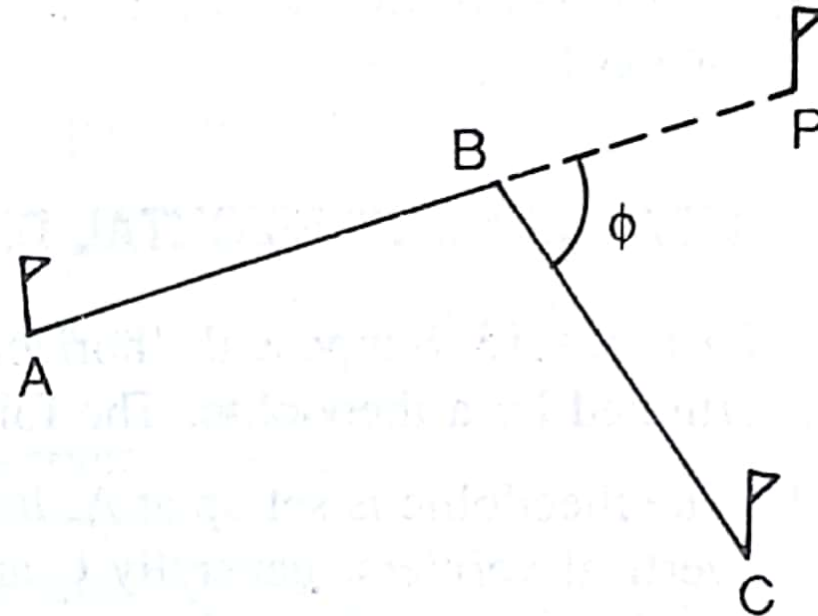


Fig. 9.11

A. Ranging a Line

Ranging is the process of establishing intermediate points on a straight line between the terminal points. Let AB (Fig. 9.14) be the straight line on which intermediate points are to be fixed by theodolite. The procedure is as follows:

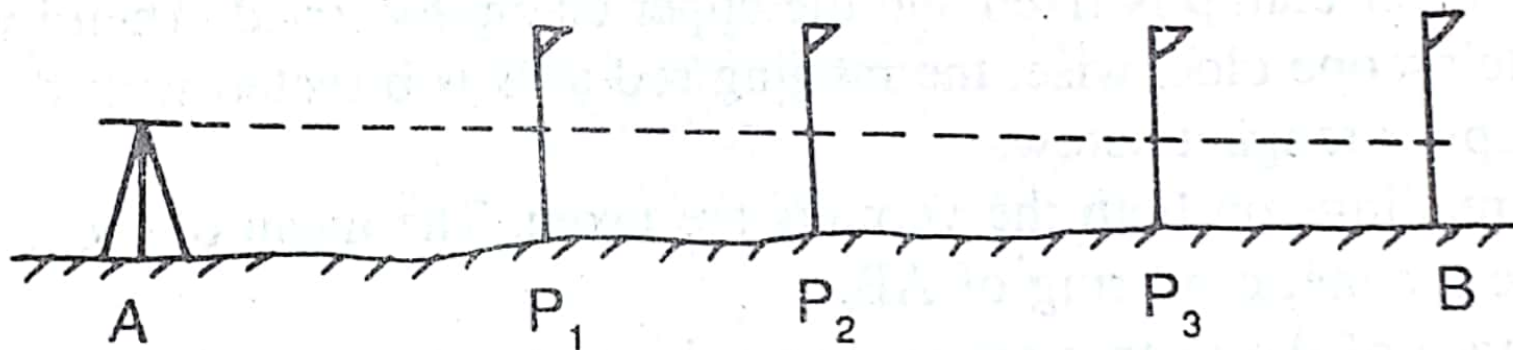
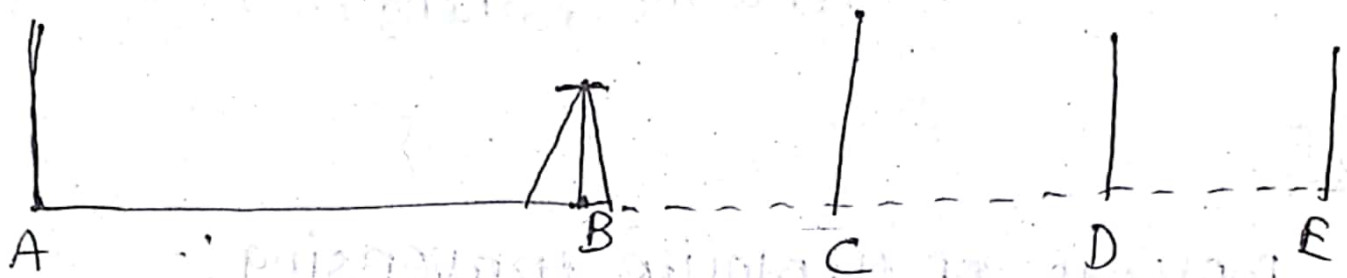


Fig. 9.14

1. The theodolite is centred over A and levelled properly. The upper clamp is fixed, and the lower clamp loosened. By turning the telescope the ranging rod at B is perfectly bisected with the help of the lower tangent screw. The lower clamp is now tightened.
2. Looking through the telescope, the observer directs the assistant to move the ranging rod to the left or right until it is on the straight line AB. Then the assistant fixes the ranging rod at P_1 .
3. Then by lowering the telescope the observer finds the exact point P_1 on the ground which is marked by a nail or stake.
4. Similarly, the other points P_2 , P_3 , etc. are fixed and marked on the line.

Prolonging / Extension of a line



- *- Let AB line is required to extend upto E.
- *- Now set the theodolite at B, centered & levelled properly & bisect the point 'A'.
- *- After bisect both upper & lower clamp is fixed
- *- Then transit the theodolite with 180° & bisect the
- *- After transiting ~~move~~ by moving the ranging rod left or right the point C, D, E are find out.
- *- Now we can say that ABCDE in a straight line

Errors in theodolite :-

* - Following are the different errors occur during theodolite traversing :-

- i - Error due to imperfect adjustment in theodolite
- ii -))) Line of collimation is not straight
- iii -))) Unequal graduation in both main & vernier scale
- iv - Error due to inaccurate levelling & centering
- v -))))) sighting & taken reading
- vi -))))) Natural cause
(High temperature, strong wind, bad weather, etc)

6.5

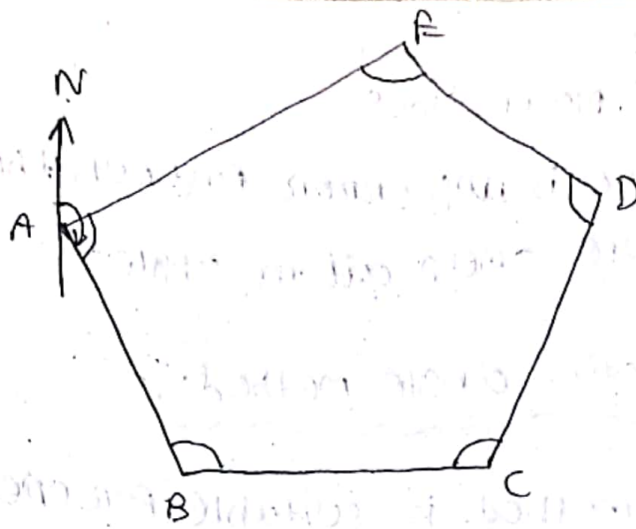
methods of theodolite traversing :-

* - Following are the different methods of traversing.

- 1 - Included angle method
- 2 - Deflection angle method
- 3 - Fast angle (or magnetic bearing) method.

1 - Included angle method :-

* - This method is suitable for closed traverse



- *- Theodolite is set up at A, centering & levelling done properly. & the vernier A is set at 0° & vernier B is set up at 180° . Then the upper clamp is - fixed.
- *- The telescope is oriented along the north line with the help of tubular compass fitted to the instrument. Then the magnetic bearing of AB is measured.
- *- Then vernier A & B is set at 0° & 180° & upper clamp kept fixed & bisect the ranging rod E.
- *- After bisect lower clamp kept fixed & upper clamp loosen & bisect the ranging rod B.
- *- Then the reading of vernier are note down & find out the $\angle A$.
- *- Similarly by setting the theodolite at B, C, D & E the angle $\angle B, \angle C, \angle D$ & $\angle E$ find out.
- *- After find out of all angles, the arithmetical checks applied as follows:-

$$\text{sum of all interior angle} = (2n-4) \times 90^\circ$$

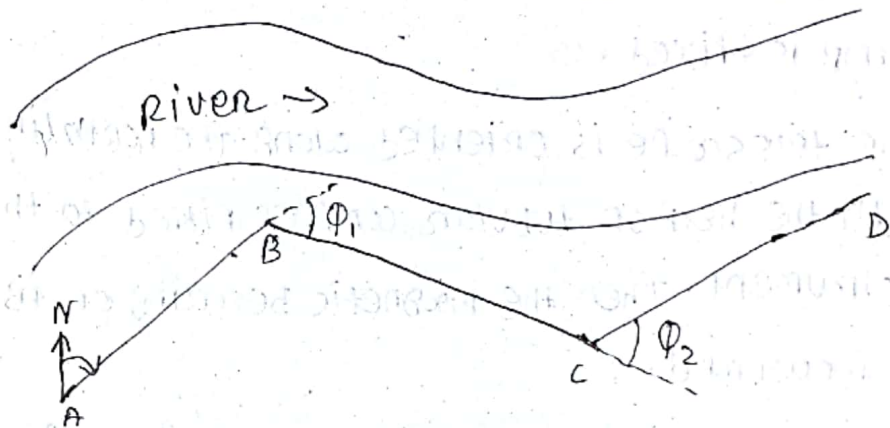
where,

n = No of sides.

- * - If there is any error find out, then error is distribute among all the angles.

2-Deflection angle method :-

- * - This method is suitable for open traverse
- * - This method is suitable for surveying of rivers, coast lines of sea, roads, railway, etc



- * - The theodolite is set up at A, centered, levelled properly & the North line is find out by using tubular compass
- * - Then bearing of AB is find out.
- * - Then the theodolite is set up at B, centered & levelled properly & the vernier A & B is set at 0° & 180° respectively & upper clamp screw tighten & lower clamp screw loosen & bisect the Ranging rod A.
- * - After bisect lower clamp screw loosen & the telescope is transited

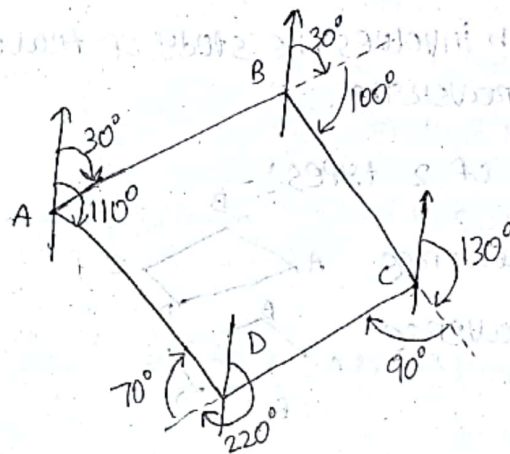
*- After transiting the upper clamp screw loosen & by turning the telescope ranging rod at C is bisect.

*- By taking the reading of vernier deflection angle at B (i.e ϕ_1) is find out.

*- Similarly deflection angle ϕ_2 is find out.

3- Fast Needle (or magnetic bearing) method :-

*- In this method we find out the magnetic bearing of each line.



*- The theodolite is set up at A & centered & levelled properly. By using through compass the telescope is oriented along the north line.

*- Then the bearing of AB & AD line is find out.

let, FB of AB = 30° & BB of DA = 110°

*- Then the telescope is shifted at Point B. & the point A is bisect. After bisecting the theodolite is transit & by turning the telescope point C is bisect.

& the bearing of BC is find out (i.e. fore bearing of BC).

*- Similarly FB of CD & DA is find out.

*- At last we check the FB & BB of line CD.

* Diff b/w FB & BB of CD should be $= 180^\circ$

Traversing

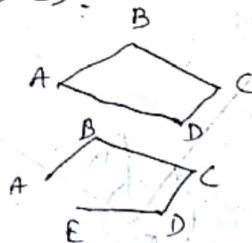
*- A series of connected lines is known as traverse

*- surveying which involves the study of traverse is known as traversing.

*- Traverse is of 2 types:-

1- Close traverse

2- Open traverse



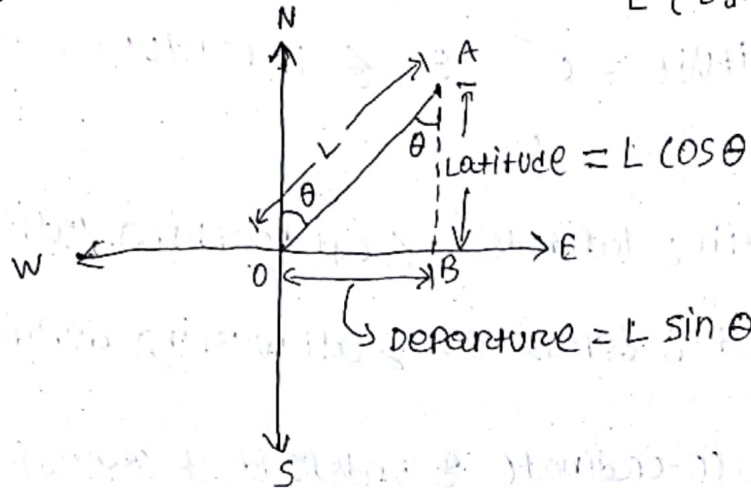
*- when a series of connected lines form a close circuit is called as close traverse

*- when a series of connected lines does not form a close circuit is called as open traverse

*- open traverse is suitable for the survey of roads, rivers, coastal line, etc

Latitude & Departure :-

$L (\text{adj}) = \text{Latitude}$



" θ " is always in the form of RB

$$\cos \theta = \frac{AB}{OA}$$

$$\sin \theta = \frac{OB}{OA}$$

$$\Rightarrow OA \cos \theta = AB$$

$$\Rightarrow OA \sin \theta = OB$$

$$\Rightarrow L \cos \theta = AB$$

$$\Rightarrow L \sin \theta = OB$$

$$\Rightarrow L \cos \theta = \text{Latitude}$$

$$\Rightarrow L \sin \theta = \text{Departure}$$

* - Line parallel to the N-S line is known as Latitude.

* - Line parallel to the E-W line is known as Departure.

Northing Latitude = +ve Easting Departure = +ve
 Southing Latitude = -ve Westing Departure = -ve

Line	Length (L)	RB (θ)	Latitude (L cos θ)	Departure (L sin θ)
AB	L	N θ E	+ L cos θ	+ L sin θ
BC	L	S θ E	- L cos θ	+ L sin θ
CD	L	S θ W	- L cos θ	- L sin θ
DA	L	N θ W	+ L cos θ	- L sin θ

for a closed traverse:-

$$\sum \text{Latitude} = 0 \quad \& \quad \sum \text{Departure} = 0$$

or

$$\sum \text{All Northing latitude} = \sum \text{all southing latitude}$$

$$\sum \text{All Easting departure} = \sum \text{all westing departure}$$

Consecutive co-ordinate & Independent co-ordinate:-

* - when latitude & departure of a point calculated with reference to the preceding point is called as consecutive co-ordinate.



* - consecutive co-ordinate may be +ve or -ve, it's depend upon the quadrant in which they lie.

* - The co-ordinates of any point with respect to a common origin are said to be independent co-ordinate

* - Independent coordinate is always +ve (ie Northing & Easting)

Point	Line	Consecutive co-ordinate				Independent co-ordinate	
		Northing (+)	Southing (-)	Easting (+)	Westing (-)	Northing (+)	Easting (+)
A	—	—	—	—	—	150.00	50.00
B	AB		115.00		40.00	35.00	10.00
C	BC	5.00		50.00		40.00	60.00
D	CD	80.00		25.00		120.00	85.00
A	DA	30.00			35.00	150.00	50.00
Total =		+115.00	-115.00	+75.00	-75.00		

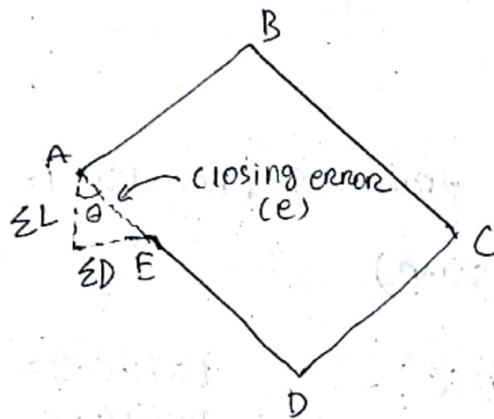
max^m -ve latitude = -115.00

max^m -ve departure = -40.00

Assume a reference point of (A) = +150, +50

Closing error :-

*- When the measurement (Length & Bearing) are drawn on the paper, there may be some closing error.



Using Pythagorean theorem, we can say that

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

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

ΣL = sum of all latitude / Error in latitude

ΣD = sum of all departure / Error in departure

θ = Dirⁿ of closing error

Calculation of missing data (only for close traverse)

*- If the length or bearing of any line will not be given then we can find out missing data by using :-

$$\Sigma L = 0$$

$$\Sigma D = 0$$

(Because for a close traverse $\sum L = 0$ & $\sum D = 0$)

Q

Line	Length (L)	Bearing (θ)
AB	200	0°
BC	1000	45°
CD	907	180°
DA	? (let x)	? (let y)

Ans

Here it is a close traverse (because its starting and ending point is same)

For a close traverse :-

$$\text{Latitude} = L \cos \theta$$

$$\text{Departure} = L \sin \theta$$

$$\sum L = 0$$

$$\Rightarrow 200 \cos 0 + 1000 \cos 45 + 907 \cos 180 + x \cos y = 0$$

$$\Rightarrow 200 + 707 - 907 + x \cos y = 0$$

$$\Rightarrow x \cos y = 0$$

$$\Rightarrow \cos y = 0$$

$$y = 90^\circ \text{ or } 270^\circ$$

$$\sum D = 0$$

$$\Rightarrow 200 \sin 0 + 1000 \sin 45 + 907 \sin 180 + x \sin y = 0$$

$$\Rightarrow 0 + 707 + x \sin y = 0$$

$$\Rightarrow x \sin y = -707$$

$$\Rightarrow x \sin (270) = -707$$

$$\{y = 270, \text{ because } \sin (270) = -1\}$$

$$\Rightarrow x \cdot x(-1) = -707$$

$$\Rightarrow x = 707$$

$$\therefore x = 707 \quad \& \quad y = 270^\circ$$

Q

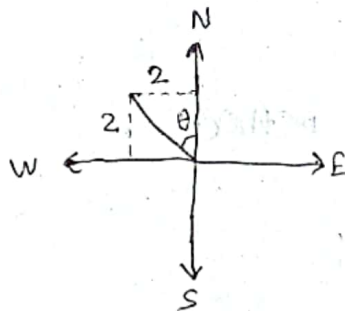
Station	Northing(+)	Southing(-)	Easting(+)	Westing(-)
P	400.75			300.50
Q	100.25		199.25	
R		199.00	399.75	
S		300.00		300.50

Find the magnitude of error & bearing of error (or angle of error)

Ans

$$\sum L = 400.75 + 100.25 - 199.00 - 300.00 = +2$$

$$\sum D = 199.25 + 399.75 - 300.50 - 300.50 = -2$$



$$\text{Total error (e)} = \sqrt{\sum L^2 + \sum D^2}$$

$$= \sqrt{2^2 + 2^2}$$

$$= 2\sqrt{2}$$

$$\text{Bearing of error, } \Rightarrow \tan \theta = \frac{\sum D}{\sum L} = \frac{2}{2} = 1 = \tan(45)$$

$$\Rightarrow \theta = 45^\circ$$

Gale's table :-

*- Gale's

Methods of closing error / correction in latitude & departure
or Balancing traverse :-

*- If ~~$\Sigma L \neq 0$~~ for a closed traverse $\Sigma L \neq 0$ & $\Sigma D \neq 0$, then the above methods are used for correction in latitude & departure

*- Following are the different methods used for ~~adjust~~ closing error / correction in latitude & departure / Balancing the traverse.

1- Bowditch method

2- Transit method

3- Graphical method

4- Axis method

5- Gale's table method

1- Bowditch method :-

*- this method is used when length and angle both were measured with exact precision

*- correction for latitude of any side (L)

$$= \frac{\text{Length of that side } (L)}{\text{Perimeter of traverse or total length } (\Sigma L)} \times \text{Total error in latitude } (\Sigma L)$$

* - correction for departure of any side (C_d)

$$= \frac{\text{Length of that side (L)}}{\text{Perimeter of traverse or total length } (\Sigma L)} \times \text{Total error in departure } (\Sigma D)$$

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

$$C_D = \frac{L}{\Sigma L} \times \Sigma D$$

2- Transit method :-

* - This method is used when angular measurement were measured with exact precision.

* - correction for latitude of any side (C_L)

$$= \frac{\text{Latitude of that side (L)}}{\text{Arithmetical sum of all latitude } (L_T)} \times \text{Total error in latitude } (\Sigma L)$$

Arithmetical sum of all latitude = consider all latitude +ve
or
without considering the sign

$$L_T = L_1 + L_2 + L_3 - - - - + L_n$$

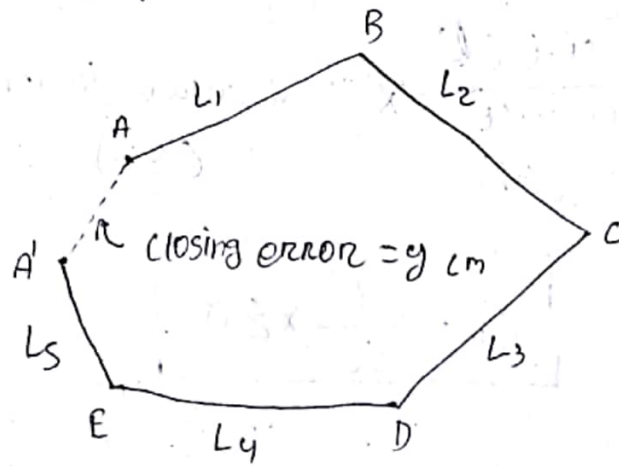
* - correction for departure of any side (C_D)

$$= \frac{\text{Departure of that side (D)}}{\text{Arithmetical sum of all departure } (L_D)} \times \text{Total error in departure } (\Sigma D)$$

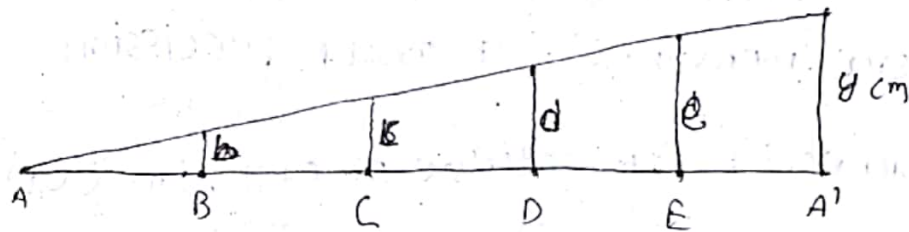
Arithmetical sum of all departure = consider all departure +ve

$$D_T = D_1 + D_2 + D_3 - - - - + D_n$$

3- Graphical method :-

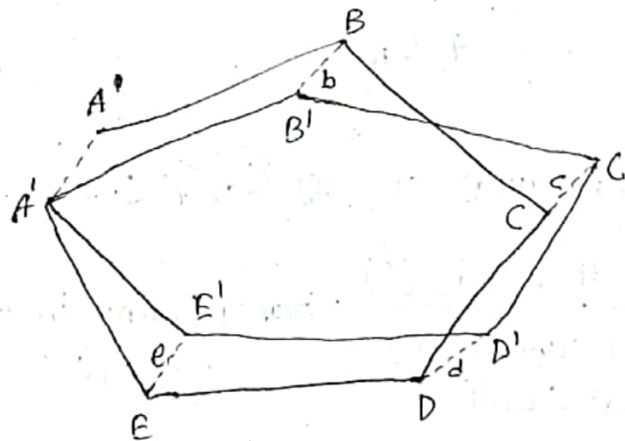


* Plot the perimeter of traverse in a straight line



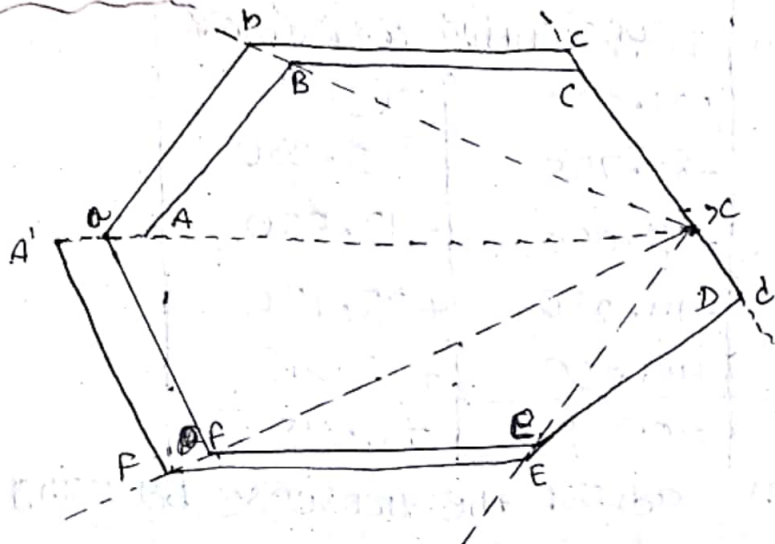
closing error at $A A' = y$

* Now plot the value of b, c, d, e at the point B, C, D, E parallel to the error line AA'



* Now $A'B'C'D'E'A'$ is the corrected traverse.

ii- Axis method



*- Extend the error line AA' & this line meet our traverse at any point (Here X)

*- Then join each station of traverse with the point X

*- Now locate a point 'a' at the mid point of AA'

$$\text{i.e. } A'a = aA$$

*- Now draw a line ab parallel to AB

1) " " bc " " BC

" " " cd " " CD

" " " de " " DE

" " " ef " " EF

*- Now abcdefa is the corrected traverse.

Line	Length (m)	consecutive co-ordinate	
		Latitude	Departure
AB	70	+21.500	-65.450
BC	80	-80.755	-5.250
CD	43	-41.000	+13.550
DE	38	-14.250	+35.150
EA	115	+114.150	+22.315
Total=	346	-0.355	+0.315

If necessary adjust the traverse by using Bowditch method & Transit method.

Ans

It is a closed traverse & for closed traverse

$$\sum L = 0 \quad \& \quad \sum D = 0$$

*- But here $\sum L \neq 0$ & $\sum D \neq 0$, so correction is required.

A- correction by using Bowditch method :-

correction for latitude :-

$$\text{for AB} = \frac{70}{346} \times$$

$$\text{Here error in latitude} = -0.355$$

$$\text{so, correction required in latitude} = +0.355$$

correction for latitude :-

$$\text{for AB} = \frac{70}{346} \times (+0.355) = +0.072$$

$$1) \text{ BC} = \frac{80}{346} \times (+0.355) = +0.082$$

$$2) \text{ CD} = \frac{43}{346} \times (+0.355) = +0.044$$

$$\text{for DE} = \frac{38}{346} \times (+0.355) = +0.039$$

$$\text{EA} = \frac{115}{346} \times (+0.355) = +0.118$$

$$\text{Total} = +0.355$$

Here error in Departure = +0.315

so, correction required in departure = -0.315

correction for departure :-

$$\text{for AB} = \frac{70}{346} \times (-0.315) = -0.064$$

$$\text{BC} = \frac{80}{346} \times (-0.315) = -0.073$$

$$\text{CD} = \frac{43}{346} \times (-0.315) = -0.039$$

$$\text{DE} = \frac{38}{346} \times (-0.315) = -0.035$$

$$\text{EA} = \frac{115}{346} \times (-0.315) = -0.104$$

$$\text{Total} = -0.315$$

Line	Length	consecutive co-ordinate		correction		corrected consecutive co-ordinate	
		Latitude	Departure	Latitude	Departure	Latitude	Departure
AB	70	+21.500	-65.450	+0.072	-0.064	+21.572	-65.514
BC	80	-80.755	-5.250	+0.082	-0.073	-80.673	-5.323
CD	43	-41.000	+13.550	+0.044	-0.039	-40.956	+13.511
DE	38	-14.250	+35.150	+0.039	-0.035	-14.211	+35.115
EA	115	+114.150	+22.315	+0.118	-0.104	+114.268	+22.211
Total =		-0.355	+0.315	+0.355	-0.315	0	0

B - correction by transit rule :-

Arithmetical sum of all latitude

$$= 21.500 + 80.755 + 41.000 + 14.250 + 114.150$$

$$= 271.655$$

Arithmetical ~~sum~~ sum of all departure

$$= 65.450 + 5.250 + 13.550 + 35.150 + 22.315$$

$$= 141.715$$

~~Correction for latitude :-~~

~~For AB = $\frac{21.500}{271.655}$~~

Here error in latitude = -0.315

So, correction required in latitude = $+0.315$

correction for latitude :-

$$\text{For AB} = \frac{21.500}{271.655} \times (+0.315) = +0.025$$

$$1) \quad BC = \frac{80.755}{271.655} \times (+0.315) = +0.094$$

$$2) \quad CD = \frac{41.000}{271.655} \times (+0.315) = +0.048$$

$$3) \quad DE = \frac{14.25}{271.655} \times (+0.315) = +0.017$$

$$4) \quad EA = \frac{114.150}{271.655} \times (+0.315) = +0.132 \approx +0.131$$

$$\text{Total} = +0.315$$

Here, error in departure = +0.315

so, correction required in departure = -0.315

correction for departure :-

$$\text{for AB} = \frac{65.450}{141.715} \times (-0.315) = -0.145$$

$$)) \text{ BC} = \frac{5.250}{141.715} \times (-0.315) = -0.012$$

$$)) \text{ CD} = \frac{13.550}{141.715} \times (-0.315) = -0.030$$

$$)) \text{ DE} = \frac{35.15}{141.715} \times (-0.315) = -0.078$$

$$)) \text{ EA} = \frac{22.315}{141.715} \times (-0.315) = -0.050$$

$$\text{Total} = -0.315$$

Line	Length	consecutive co-ordinate		correction		corrected consecutive co-ordinate	
		Latitude	Departure	Latitude	Departure	Latitude	Departure
AB	70	+21.500	-65.450	+0.025	-0.145	+21.525	-65.595
BC	80	-80.755	-5.250	+0.094	-0.012	-80.661	-5.262
CD	43	-41.000	+13.550	+0.048	-0.030	-40.952	+13.520
DE	38	-14.250	+35.150	+0.017	-0.078	-14.233	+35.072
EA	115	+114.150	+22.315	+0.131	-0.050	+114.281	+22.265
Total =		-0.355	+0.315	+0.355	-0.315	0	0

Station point	Angle	Line	Length (m)	WCB
A	73°31'0"	AB	66.6	30°30'
B	107°42'0"	BC	135.7	102°47'36"
C	187°8'0"	CD	66.3	95°39'12"
D	77°30'0"	DE	76.6	198°8'48"
E	94°7'0"	EA	214.3	284°1'24"

Find the latitude & departure of the above point & correct it using Bate's Table.

using gale's table.		Total correction		+ 0.056		- 0.341	
		Total Error		- 0.056		+ 0.341	
Instrument station point	A	B	C	D	E		
Observed angle	73°31'0"	107°42'0"	187°8'0"	77°30'0"	94°7'0"	539°58'0"	
Correction	+ 24"	+ 24"	+ 24"	+ 24"	+ 24"	+ 0°2'0"	
Connected angle	73°31'24"	107°42'24"	187°8'24"	77°30'24"	94°7'24"	540°0'0"	
Line	-	AB	BC	CD	DE	EA	
Length (L)		66.6	135.7	66.3	76.6	214.3	
WCB		30°30'0"	102°47'36"	95°39'12"	198°8'48"	284°1'24"	
Reduced bearing (θ)		30°30'0" NE	77°12'24" SE	84°20'48" SE	188°48" SW	75°58'36" NW	
Point	A	B	C	D	E	A	
Northing (+)	-	57.385				51.929	
Southing (-)			30.049	6.531	72.790		
Eastings (+)	-	33.802	132.331	65.978			
Westings (-)	-				23.857	207.913	
Northing (+)	-	+0.015				+0.013	+ 0
Southing (-)	-		-0.008	-0.002	-0.018		- 0
Eastings (+)	-	-0.025	-0.097	-0.049			- 0
Westings (-)	-				+0.017	+0.153	+ 0
Northing (+)	-	57.400				51.942	
Southing (-)	-		30.041	6.529	72.772		
Eastings (+)	-	33.777	132.234	65.929			
Westings (-)	-				23.874	208.066	
Northing (+)	100.000	157.400	127.359	120.830	48.058	100.000	
Eastings (+)	250.000	283.777	416.011	481.940	458.066	250.000	

Correction :-

$$\text{Northing } (+) = 57.385 + 51.929 = 109.314$$

$$\text{Southing } (-) = 30.049 + 6.531 + 72.790 = 109.370$$

$$\text{Error} = +109.314 - 109.370 = -0.056$$

$$\text{correction} = +0.056$$

$$\frac{0.056}{2} = 0.028$$

$$\text{Northing } (+) = 109.314 + 0.028 = 109.342$$

$$\text{Southing } (-) = 109.370 - 0.028 = 109.342$$

correction for northing :- (sum of northing = 109.314)

$$\text{for AB} = \frac{57.385}{109.314} \times (+0.028) = +0.015$$

$$\text{for EA} = \frac{51.929}{109.314} \times (+0.028) = +0.013$$

correcting for southing :- (sum of southing = 109.370)

$$\text{for BC} = \frac{30.049}{109.370} \times (-0.028) = -0.008$$

$$\text{for CD} = \frac{6.531}{109.370} \times (-0.028) = -0.002$$

$$\text{for DE} = \frac{72.790}{109.370} \times (-0.028) = -0.019 \approx -0.018$$

$$\text{Easting (+)} = 33.802 + 132.331 + 65.978 = 232.111$$

$$\text{Westing (-)} = 23.857 + 207.913 = 231.770$$

$$\text{Error} = +232.111 - 231.770 = +0.341$$

$$\text{Correction} = -0.341$$

$$\frac{0.341}{2} = 0.171$$

$$\text{Easting (+)} = 232.111 - 0.171 = 231.940$$

$$\text{Westing (-)} = 231.770 + 0.170 = 231.940$$

Correction for Easting: - (sum of Easting = 232.111)

$$\text{for AB} = \frac{33.802}{232.111} \times (-0.171) = -0.025$$

$$\text{for BC} = \frac{132.331}{232.111} \times (-0.171) = -0.097$$

$$\text{for CD} = \frac{65.978}{232.111} \times (-0.171) = -0.049$$

Correction for Westing: - (sum of Westing = 231.770)

$$\text{for DE} = \frac{23.857}{231.770} \times (+0.170) = +0.017$$

$$\text{for EA} = \frac{207.913}{231.770} \times (+0.170) = +0.153$$

Check for a closed traverse :-

* - Sum of all interior angle should be $= (2n-4) \times 90^\circ$

* - Sum of all exterior angle should be $= (2n+4) \times 90^\circ$

where, $N = \text{No of sides}$

* - Algebraic sum of the deflection angle should be $= 360^\circ$

Considering, Right hand deflection = +ve

Left " " " " = -ve

* - Difference b/w fore bearing & Back bearing of the finishing line should be $= 180^\circ$

* - Sum of all latitude should be $= 0$

i.e, sum of Northing = sum of southing

* - Sum of all departure should be $= 0$

i.e, sum of Easting = sum of Westing

Calculation area of a closed traverse :-

* - following are the different methods of calculating area of a closed traverse :-

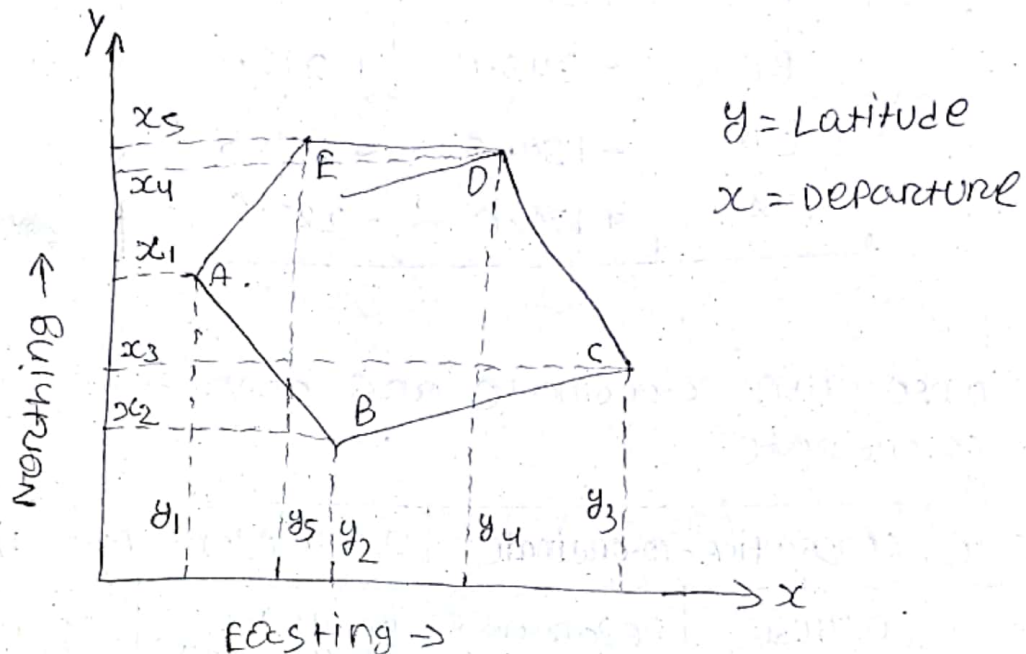
1 - The co-ordinate method (x & y)

2 - The latitude & double meridian distance (DMD) method

3 - The departure & total latitude method

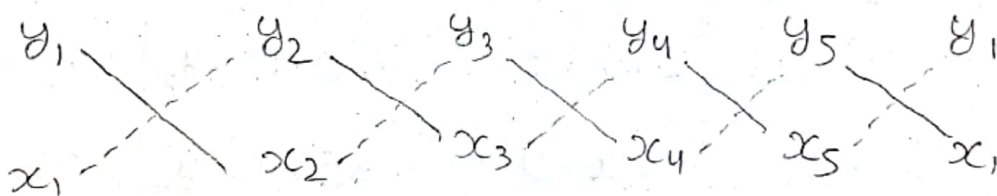
1- The co-ordinate method (x & y) :-

*- In this method all consecutive co-ordinates ~~are~~ of traverse are converted into independent co-ordinate. (i.e North & East)



x & y = Independent co-ordinate of traverse

*- Then co-ordinates are arranged in following form:-



Sum of the product of solid line

$$\sum P = y_1 x_2 + y_2 x_3 + y_3 x_4 + y_4 x_5 + y_5 x_1$$

Sum of the product of dotted line

$$\sum Q = x_1 y_2 + x_2 y_3 + x_3 y_4 + x_4 y_5 + x_5 y_1$$

$$\text{Double Area} = \sum P - \sum Q$$

$$\text{Required Area} = \frac{1}{2} \times \text{Double Area} = \frac{1}{2} \times (\sum P - \sum Q)$$

Q:-

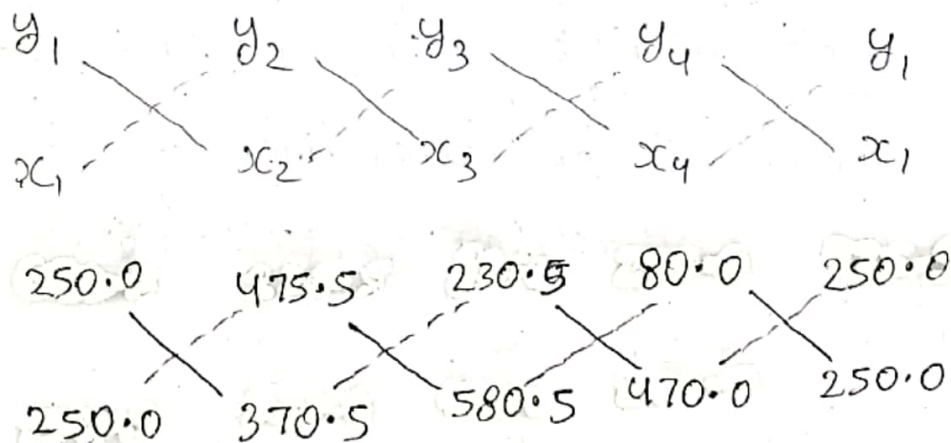
Find the area of a closed traverse ABCDA by using co-ordinate method by using following data:-

Side	Latitude	Departure
AB	+225.5	+120.5
BC	-245.0	+210.0
CD	-150.5	-110.5
DA	+170.0	-220.0

Ans

consecutive co-ordinate are arranged to independent co-ordinate.

Side	consecutive-co-ordinate		Independent co-ordinate	
	Latitude	Departure	Latitude (+250.0 = y_1)	Departure (+250.0 = x_1)
AB	+225.5	+120.5	+475.5 = y_2	+370.5 = x_2
BC	-245.0	+210.0	+230.5 = y_3	+580.5 = x_3
CD	-150.5	-110.5	+80.0 = y_4	+470.0 = x_4
DA	+170.0	-220.0	+250.0 = y_1	+250.0 = x_1



sum of product of solid lines:-

$$\sum P = 250.0 \times 370.5 + 475.5 \times 580.5 + 230.5 \times 470.0 \\ + 80.0 \times 250.0$$

$$= 496987.75$$

sum of product of dotted lines:-

$$\sum Q = 250.0 \times 475.5 + 370.5 \times 230.5 + 580.5 \times 80.0 \\ + 470.0 \times 250.0$$

$$= 368215.25$$

$$\text{Double area} = \sum P - \sum Q$$

$$= 496987.75 - 368215.25$$

$$= 128772.5$$

$$\text{Required area} = \frac{1}{2} \times \text{Double Area}$$

$$= \frac{1}{2} \times 128772.5$$

$$= 64386.25 \text{ m}^2$$

2- Latitude & Double meridian distance (DMD) method:-

DMD Line calculation:-

* DMD of first line = Departure of first line

* DMD of second line = DMD of 1st line + Departure of 1st line + Departure of 2nd line

* DMD of 3rd line = DMD of 2nd line + Departure of 2nd line + Departure of 3rd line

* DMD of last line = Departure of last line with opposite sign

Area calculation:-

- i - Each DMD is multiplied by the latitude of that line.
- ii - The algebraic sum of these product is find out
- iii - Algebraic sum represen the double area
i.e, Double area = Algebraic sum
- iv - Required area = $\frac{1}{2} \times \text{Double Area}$

Q Find the area of a closed traverse by using DMD method.

side	Latitude	Departure
AB	+225.5	+120.5
BC	-245.0	+210.0
CD	-150.5	-110.5
DA	+170.0	-220.0

Ans

calculation of DMD:-

$$\text{DMD of AB line} = +120.5$$

$$\text{DMD of BC line} = +120.5 + 120.5 + 210.0 = +451.0$$

$$\text{DMD of CD line} = +451.0 + 210.0 - 110.5 = +550.5$$

$$\text{DMD of DA line} = +550.5 - 110.5 - 220.0 = +220.0$$

side	Latitude	Departure	DMD	Double Area = (COL(2) X COL(4))	
1	2	3	4	5(+)	6(-)
AB	+225.5	+120.5	+120.5	27172.75	—
BC	-245.0	+210.0	+451.0	—	110495.00
CD	-150.5	-110.5	+550.5	—	82850.25
DA	+170.0	-220.0	+220.0	37400.00	—
Total =				+64572.75	-193345.25
				Algebraic sum = -128772.50	

(-ve sign neglected)

$$\text{Double Area} = \text{Algebraic sum} = 128772.50$$

$$\text{Required Area} = \frac{1}{2} \times \text{Double Area}$$

$$= \frac{1}{2} \times 128772.50$$

$$= 64386.25 \text{ m}^2$$

3- The departure & total Latitude method :-

- * - Total latitude of each station of the traverse is find out.
- * - The algebraic sum of departure of two lines meeting at a station, is determined
- * - Total latitude is multiplied by the algebraic sum of departure for each individual point.
- * - The algebraic sum of this product gives double area.

* Half of this sum gives the required area.

Q
Find the area of the closed traverse having the following data by using Departure & total latitude method:-

Side	Latitude	Departure
AB	+225.5	+120.5
BC	-245.0	+210.0
CD	-150.5	-110.5
DA	+170.0	-220.0

Ans

Total latitude of B = +225.5

)))) C = +225.5 - 245.0 = -19.5

)))) D = +225.5 - 245.0 - 150.5 = -170.0

)))) A = +225.5 - 245.0 - 150.5 + 170.0 = 0.0

Algebraic sum of departure at: B =

B = AB + BC = +120.5 + 210.0 = +330.5

C = BC + CD = +210.0 - 110.5 = +99.5

D = CD + DA = -110.5 - 220.0 = -330.5

A = DA + AB = -220.0 + 120.5 = -99.5

Total Algebraic sum of latitude

side	Latitude	Departure	Station	Total Latitude	Algebraic sum of departure	Double Area = (01(5) x (01(6)	
						(+)	(-)
1	2	3	4	5	6		
AB	+225.5	+120.5	B	+225.5	+330.5	74527.75	-
BC	-245.0	+210.0	C	-19.5	+99.5	-	1940.25
CD	-150.5	-110.5	D	-170.0	-330.5	56185.00	-
DA	+170.0	-220.0	A	0.0	-99.5	-	0
Total =						+130712.75	-1940.25
Algebraic sum = 128772.50							

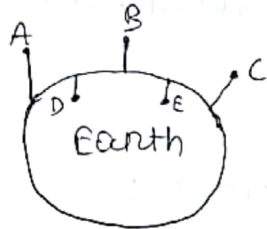
$$\text{Double Area} = \text{Algebraic sum} = 128772.50$$

$$\text{Required Area} = \frac{1}{2} \times (\text{Algebraic sum}) = \frac{1}{2} \times 128772.50 = 64386.25$$

Levelling

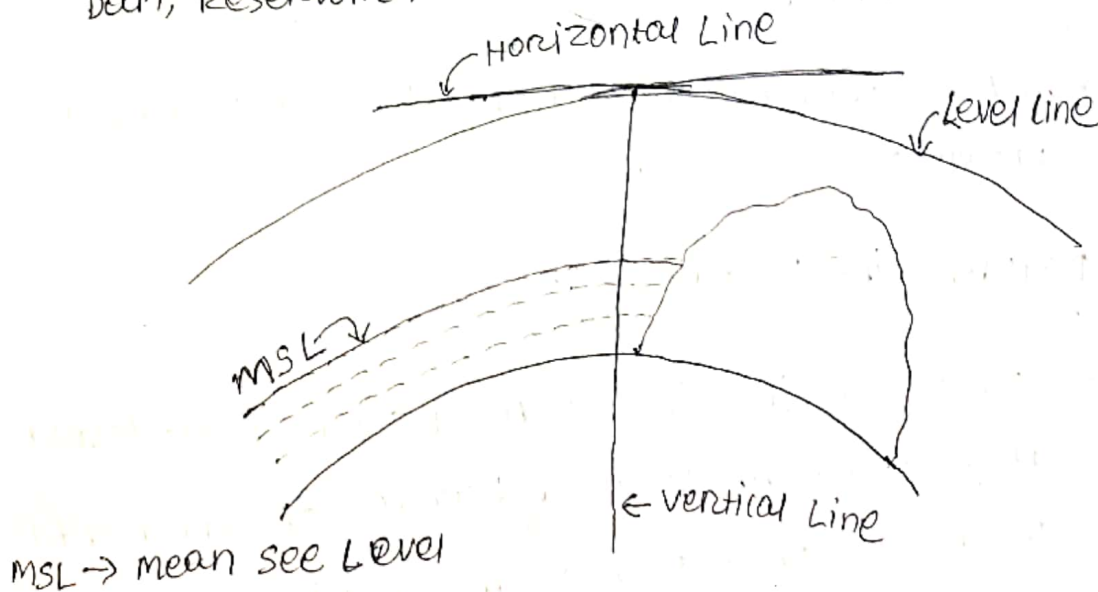
Definition of levelling:-

- * - The art of determining the relative heights of different points on or below the surface of the earth is known as levelling



Aim/object of levelling:-

- * - Aim of levelling is to determine the relative heights of different objects on or below the surface of the earth
- * - To prepare a contour map
- * - To find the height of different objects, like hills, dams, reservoirs, etc.



Level surface

- * - Any surface parallel to the mean spheroidal surface of the earth is known as level surface.

- * - Level surface ~~curved~~ are curved as parallel to the surface of the earth.
- * - The water surface of a still lake is also considered as a level surface.

Level line:-

- * - Any line laying on a level surface is called as level line.

Horizontal surface/plane:-

- * - Any surface/plane tangential to the level surface at any point is known as Horizontal surface/plane.

Horizontal line:-

- * - Any line laying on horizontal plane is known as Horizontal line.
- * - Horizontal line is perpendicular to the plumb line.

Vertical line:-

- * - A line perpendicular to the horizontal line is known as vertical line.

Datum Line/surface:-

- * - It is an imaginary level surface or level line from which the vertical distances of different points or objects (above or below this line) is to be measured.
- * - In India Datum line adopted by Great Trigonometrical Survey (G.T.S.) is the MSL at Karachi (Pakistan).

it is in Pakistan)

*(Because GTS established in 1802)

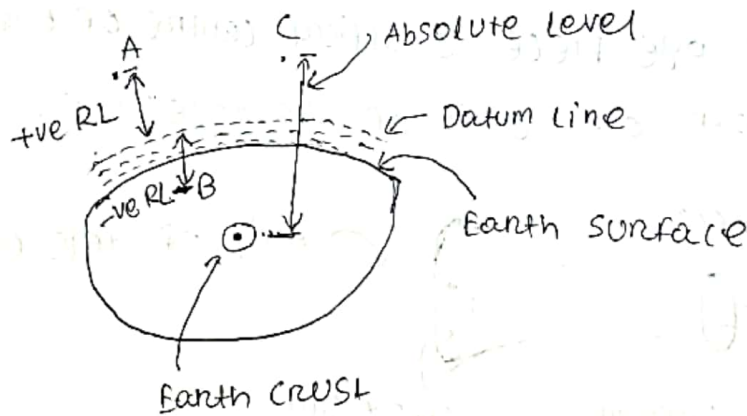
Reduced Level (RL) :-

*- The vertical distance of a point above or below the datum line is known as Reduced level (RL)

*- RL of a point ~~is~~ may be "tve" or "-ve" according to the point above or below the datum-line.

Absolute level :-

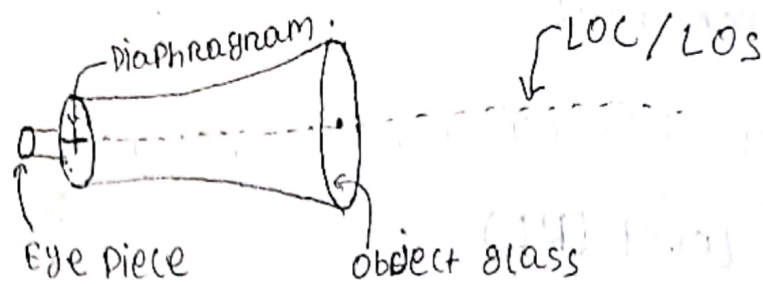
*- When we measure a distance from earth crust i.e known as absolute level.



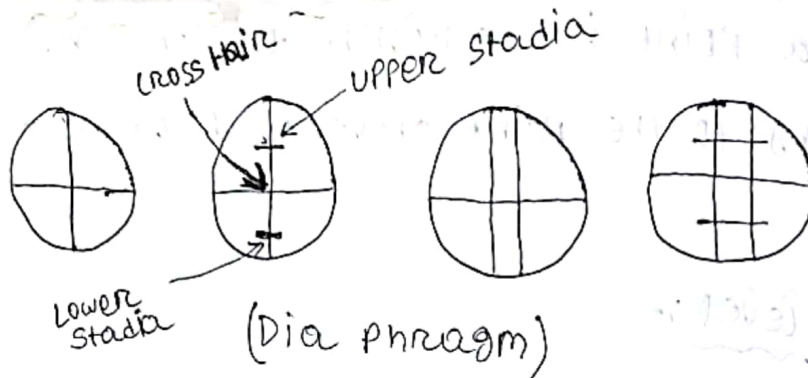
Line of collimation / Line of sight :-

*- It is an imaginary line passing through the intersection of the cross hairs of diaphragm and the optical centre of the object glass and its continuation.

*- It is also known as line of sight.



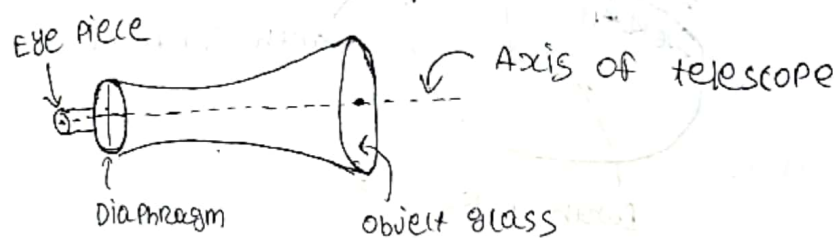
(Telescope)



(Diaphragm)

Axis of the telescope:-

- * - An imaginary line passing through the optical center of the eye piece & optical centre of the object glass is known as axis of the telescope.



Bench mark (BM) :-

- * - A fixed point or marks of known RL (RL determine w.r.t datum line) is known as bench mark (BM)

- * - BM is of 4 types:-

- 1- Great Trigonometrical survey (GTS) Bench mark
- 2- Permanent Bench mark

3- Temporary Bench mark

4- Arbitrary Bench mark

1- GTS Bench mark

* - The BM established by the survey of India department at a large interval all over the country is known as GTS Bench mark.

BOM

2- Permanent Bench mark :-

* - BM established by different govt. department like PWD, Railway, Irrigation, etc is known as Permanent Bench mark.

* - These BM established with reference to the GTS BM.

3- Temporary Bench mark :-

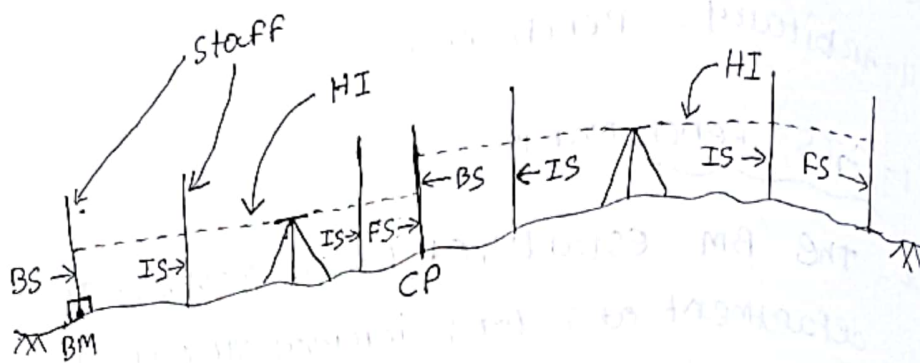
* - When the BM are established temporarily at the end of a day's work is known as Temporary BM.

* - Temporary BM may be a root of a tree, parapet of a culvert, a furlong post, etc.

4- Arbitrary Bench mark :-

* - When the RL of a fix point is assumed then it is termed as Arbitrary Bench mark.

* - Arbitrary BM adopted when very small operation is to be carried out.



Levelling staff / staff :-

*- Levelling staff / staff is a wooden/metal bar used for measuring vertical distance. b/w ground & Line of collimation / Line of sight.

*- Levelling staff is of following 2 types:-

A - Target staff

B - self reading staff

A - Target staff :-

*- The target staff consists of a movable target which is adjusted by the staff man according to the direction from the levelman.

*- This staff is used for long sightings

B - self reading staff :-

*- self reading staffs is of following types:-

i - Telescopic staff

ii - metric staff

iii - one length staff

iv - Invar staff

* In self-reading staff we can take reading by level man as well as staffman

* In self reading staff readings are marked in staff

i- Telescopic staff:-

* Such a staff is arranged in three lengths which is placed one into the other.

* It can be extended to its full length by pulling.

* Bottom box portion is hollow & 1.5 m long

* Central box " " " & 1.25 m "

* Top portion is solid & 1.25 m long.

* The staff is graduated in such a way that smallest division of 5 mm (0.005 m)

ii- metric staff

* metric staff is available in a length of 4 m & divided into two parts having a length of 2 m each.

iii- one length staff:-

* It is a solid staff made of 3 m long & graduated same way as telescopic staff.

IV- Invar staff:-

* Invar staff is also 3 m long and graduated in millimeters.

* Invar staff is used where more accuracy is required.

(Diagram → P-140, N.N. Basak)



✓ Consistent print quality

ordinary papers.

Backsight Reading (BS) :-

* - This is the first staff reading taken in any setup of the instrument. (After levelling has been done properly)

or

* - The first staff reading taken in any setup of the instrument is known as backsight reading (BS)

* - ~~BS~~ This reading is always taken on a point of known RL (i.e. on a bench mark or change point)

Foresight Reading (FS) :-

* - It is the last staff reading taken in any setup of the instrument

~~* - It is any staff reading b/w~~

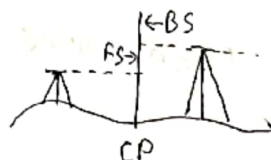
Intermediate sight reading (IS) :-

* - It is any other staff reading b/w the BS & FS in the same setup of the instrument

Change Point (CP) :-

* - The point which indicates shifting of the instrument is known as change point (CP)

* - In CP, FS is taken from one setting and BS is taken from next setting.



Height of Instrument (HI):-

- * - When the levelling instrument is properly levelled, the RL of the line of collimation is known as HI.

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

Focussing:-

- * - The operation of setting eye piece & object glass for clear vision is known as focussing.

- * - In focusing we carried out following operation:-

i- Focusing ~~of~~ the eye piece

ii- " " " object glass

i- Focusing the eye piece:-

- * - A sheet of white paper is held in front of the telescope & the eye piece is turned clockwise or anti-clockwise slowly untill the cross hair appear distinct & clear.

ii- Focusing the object glass:-

- * - ~~Focusing the object glass~~ The telescope is directed to the object & the focusing screw is turned clockwise or anti-clockwise untill the image is clear and sharp.

Parallax:-

- * - The apparent movement of the image relative to the cross-hair is known as Parallax.
- * - Parallax occurs due to improper focusing.

~~either~~ of either eye piece or object glass.

* - Parallax is tested by moving the eye up and down.
If the focusing is not correct, the image moves up & down relative to the cross hair.

* - Parallax eliminated by proper focusing the telescope.

Level and types of level

- *Level:- The instrument used to furnish horizontal line of sight for observing staff readings and determining R.L.s*
- *Types*
- *Dumpy level*
- *Tilting level*
- *Wye level*
- *Automatic level*

Dumpy level

- *The Dumpy level is a simple, compact and stable instrument. The telescope is rigidly fixed to its support. Hence it cannot be rotated about horizontal axis.*



Tilting level

- *It is also known as I.O.P. level (Indian office Pattern). In this level the telescope tilts about its horizontal axis hence it is called tilting level*



Wye level

- *The essential difference between wye level and other levels is that in wye level the telescope is carried by two vertical wye supports. The telescope can be rotated, moved or even raised in wyes.*



Automatic level

- *It is also known as self aligning level. It is a recent development. The fundamental difference between auto level and other levels is that the levelling is not manually but it is levelled automatically. It is achieved by inclination compensating device.*



Description of Dumpy Level

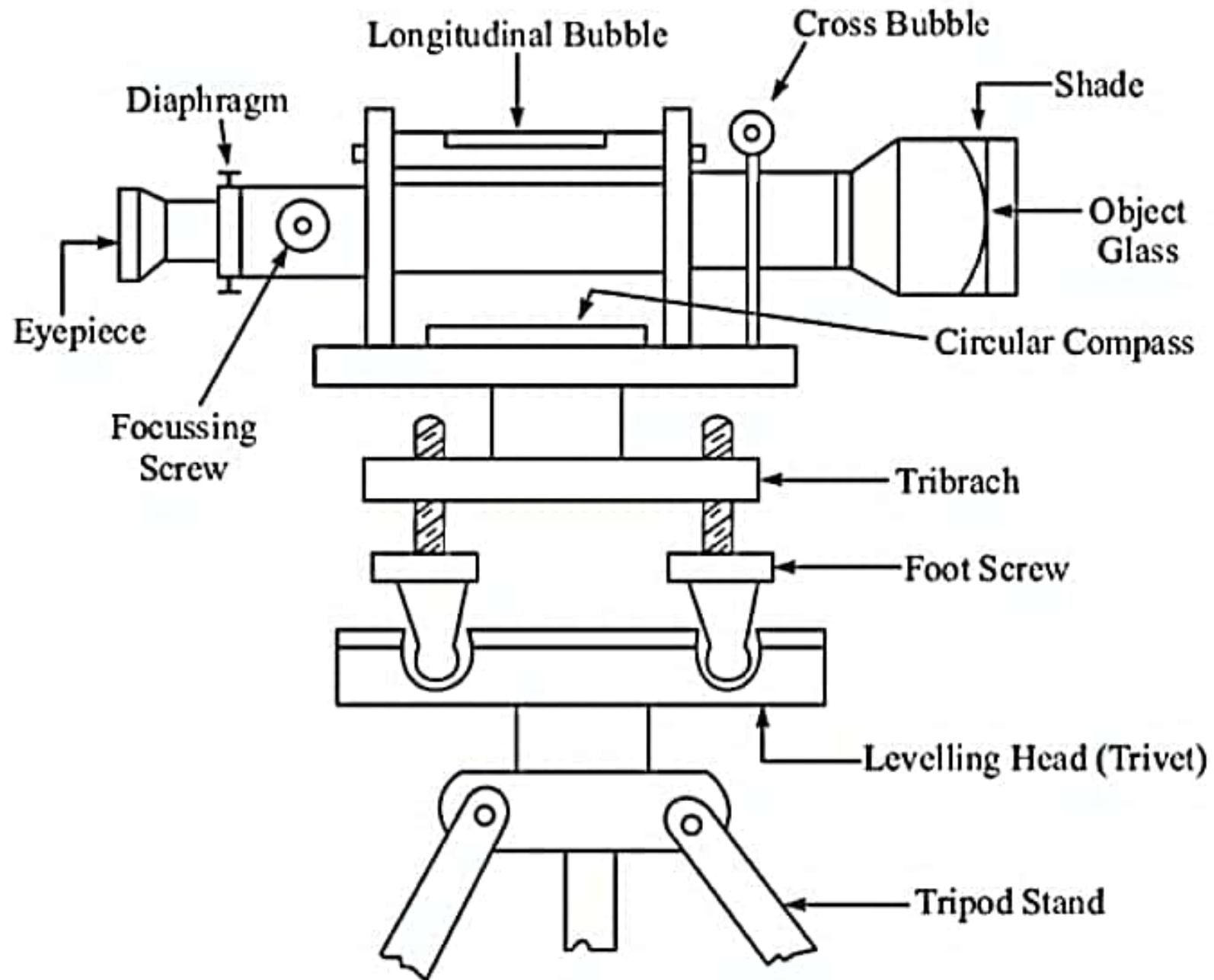


Fig. 5.5 Dumpy Level

1- Trivet :-

*- A circular plate having a central threaded hole for fixing the dumpy level on the tripod stand is known as trivet.

*- It is also known as Base plate.

*- In Trivet/ Base plate 3 foot screws are placed by ball-and-socket arrangement.

2- Tribrach :-

*- ~~is~~ A triangular plate upper portion of foot-screw is known as tribrach.

3- Foot screw :-

*- Foot screws are used for levelling the instrument.

*- Foot)))) provided b/w Trivet & Tribrach.

*- By turning the foot screw clockwise or anti-clockwise we can raise or lower the upper portion of tribrach to bring the instrument for

proper level.

Levelling head :-

- * - The combination of triquet, foot screw & tribrach is known as levelling head.

temporary adjustment of level (dumpy level)

- * - The adjustment made at every setup of the level before the staff readings are taken is known as temporary adjustment.

* - following steps to be followed for temporary adjustment of a dumpy level :-

- 1- selection of suitable position
- 2- Fixing level with tripod stand
- 3- Approximate levelling by legs of tripod stand
- 4- Perfect levelling by using foot screw
- 5- Focusing the eye-piece
- 6- Focusing the object glass
- 7- Taking the staff reading.

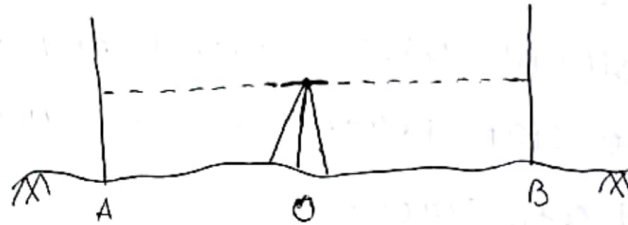
Types of levelling :-

* - following are the different types of levelling :-

- 1- simple levelling
- 2- Differential levelling
- 3- Fly levelling
- 4- Longitudinal or profile levelling
- 5- cross-sectional levelling
- 6- check levelling.

1- Simple levelling :-

*- when the difference of level b/w two points is determined by setting the levelling instrument midway b/w the points, then the process is known as simple levelling.

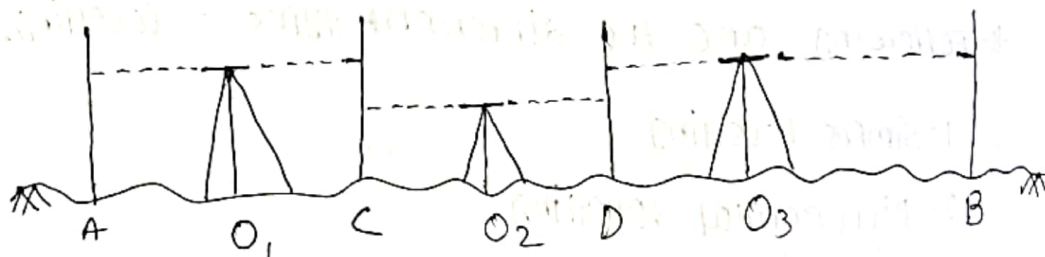


2- Differential levelling :-

*- when the difference of level b/w two points is determined by setting the levelling instrument at different points, then the process is known as differential levelling.

*- Differential levelling adopted when :-

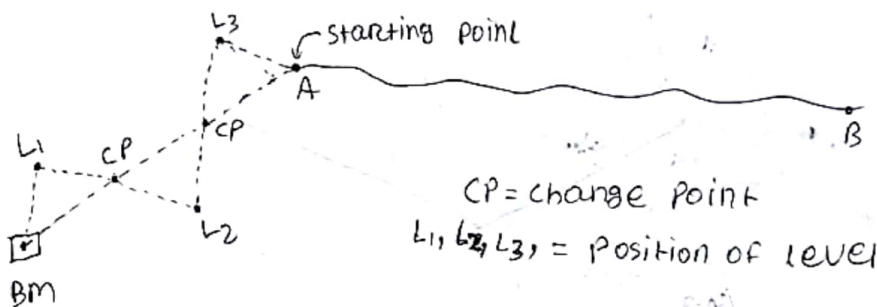
- i - The points are a great distance apart.
- ii - Difference of elevation b/w the points is large
- iii - There are obstacles b/w the points



Fly levelling :-

* - when differential levelling is done in order to connect a Bench mark to the starting point of any project is known as fly levelling

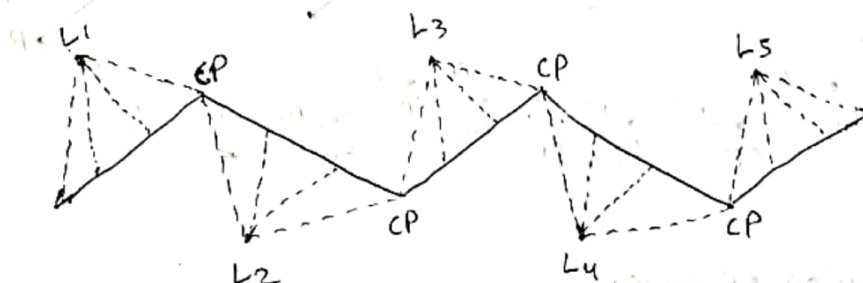
* Fly levelling is also done to connect the BM to any intermediate point to check the accuracy of work



* - In fly levelling only back sight & fore sight readings are taken at every set up.

4- Longitudinal or profile levelling :-

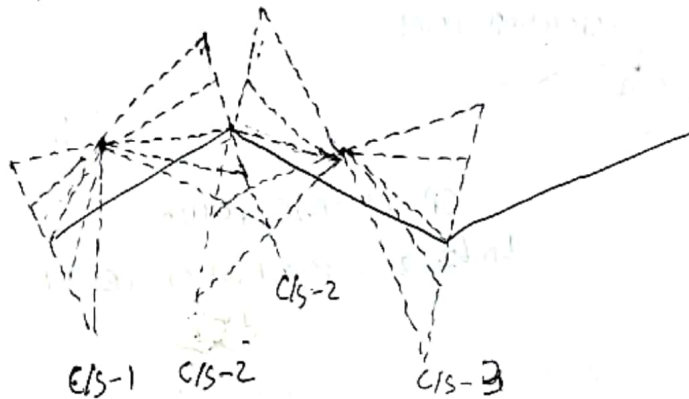
* - The operation of taking levels along the centre line of any alignment (road, railway) at regular interval is known as Longitudinal levelling.



5- Cross-sectional levelling :-

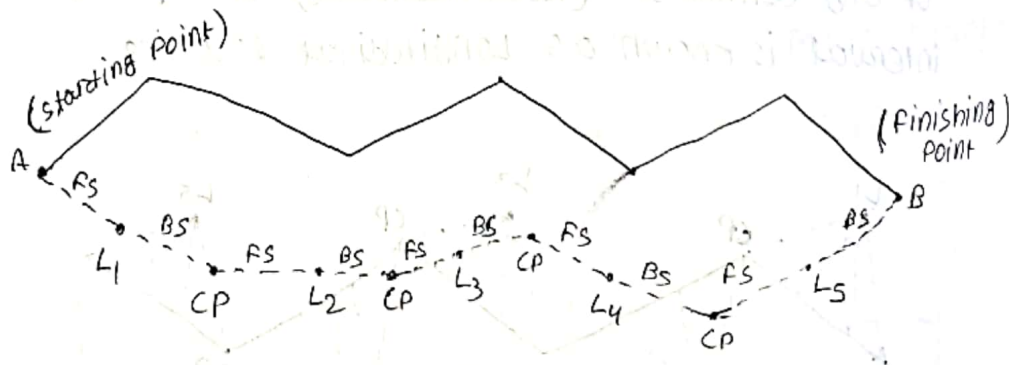
* - The operation of taking levels transverse to the direction of longitudinal levelling is known as cross-sectional levelling.

* - cross-section are taken at regular interval such as 20m, 30m, 40m, 50m, etc along the alignment



6-check levelling

* Fly levelling^{done} at the end of day's work to connect the finishing point with the starting point on that particular day is known as check levelling.



L = Position of Level

LP = change point

BS = BACK sight

FS = fore sight

Methods of calculation of Reduced Level (RL):

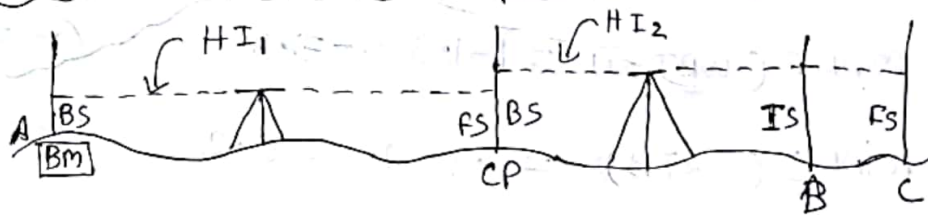
* - Following 2 methods used for calculating RL of any point:-

2A

1- Height of Instrument (HI) or collimation system

2- Rise & Fall method

1- Height of Instrument (HI) method:-



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

Check for HI method:-

$$\sum BS - \sum FS = \text{Last RL} - \text{First RL}$$

Check for Rise & Fall method:-

$$\sum BS - \sum FS = \text{Last RL} - \text{First RL} = \sum \text{Rise} - \sum \text{Fall}$$

Calculation:-

RL of Bm = Given

$$HI_1 = RL \text{ of Bm} + BS$$

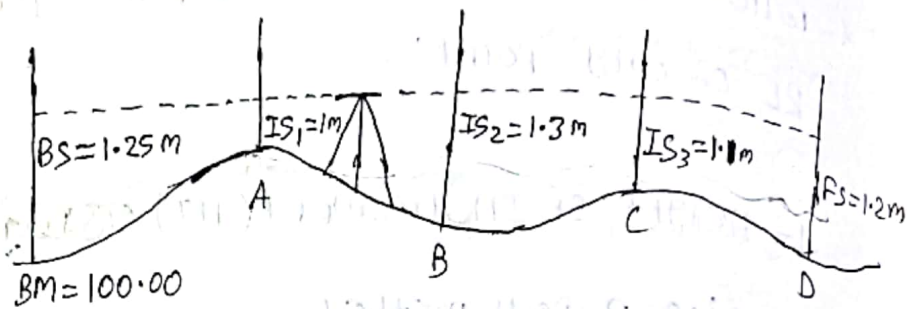
$$RL \text{ of CP} = HI_1 - FS$$

$$HI_2 = RL \text{ of CP} + BS$$

$$RL \text{ of B} = HI_2 - IS$$

$$RL \text{ of C} = HI_2 - FS$$

2- Rise & Fall method :-



Point A (WRT BM) = $1.25 - 1 = 0.25$ (+ = Rise)

Point B (WRT A) = $1 - 1.3 = -0.3$ (- = Fall)

Point C (WRT B) = $1.3 - 1.1 = 0.2$ (+ = Rise)

Point D (WRT C) = $1.1 - 1.2 = -0.1$ (- = Fall)

RL of BM = 100.00

RL of A = $100.00 + 0.25 = 100.25$

RL of B = $100.25 - 0.3 = 99.95$

RL of C = $99.95 + 0.2 = 100.15$

RL of D = $100.15 - 0.1 = 100.05$

check for Rise & Fall method :-

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

Difference b/w Rise & Fall & HI method :-

HI	Rise & Fall
*- It is Rapid process as it involves few calculation *- There is no check on the RL of intermediate point *- ERRORS in intermediate RL cannot be determined *- There are two checks *- This system is suitable for longitudinal levelling where there are a number of intermediate sight.	*- It is laborious. Because it involves several calculation *- There is a check on the RL of intermediate point *- ERRORS in intermediate RL can be determined. Because all the points are co-related *- There are 3 checks *- This system is suitable for fly levelling where there are no intermediate point sight.

*- Always rise and fall method is adopted because there is less possibility of error.

0

in the remark column.

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:

Ans
1- BY HI / collimation method.

Station point	chainage	BS	IS	FS	HI	RL
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
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
9	285		2.390			100.370
10	300			3.035		99.725
Total		7.500		5.860		

$$HI_1 = 98.085 + 3.150 = 101.235$$

$$RL \text{ of } 2 = HI_1 - 2.245 = 101.235 - 2.245 = 98.990$$

$$RL \text{ of } 3 = HI_1 - 1.125 = 101.235 - 1.125 = 100.110$$

$$RL \text{ of } 4 = HI_1 - 0.860 = 101.235 - 0.860 = 100.375$$

$$HI_2 = RL \text{ of } CP_1 + BS = 100.375 + 3.125 = 103.500$$

$$RL \text{ of } 5 = HI_2 - 2.760 = 103.500 - 2.760 = 100.740$$

$$RL \text{ of } 6 = HI_2 - 1.835 = 103.500 - 1.835 = 101.665$$

$$RL \text{ of } 7 = HI_2 - 1.470 = 103.500 - 1.470 = 102.030$$

$$RL \text{ of } 8 = HI_2 - 1.965 = 103.500 - 1.965 = 101.535$$

$$HI_3 = RL \text{ of } CP_2 + BS = 101.535 + 1.225 = 102.760$$

$$RL \text{ of } 9 = HI_3 - 2.390 = 102.760 - 2.390 = 100.370$$

$$RL \text{ of } 10 = HI_3 - 3.035 = 102.760 - 3.035 = 99.725$$

check :-

$$\sum BS - \sum FS = 7.500 - 5.860 = 1.640$$

$$\Delta \text{Last RL} - \text{First RL} = 99.725 - 98.085 = 1.640$$

$$\therefore \sum BS - \sum FS = \text{Last RL} - \text{First RL}$$

By Rise & Fall method :-

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	CP
5	225		2.760		0.365		100.740	
6	240		1.835		0.925		101.665	
7	255		1.470	1.465	0.365		102.030	
8	270	1.225		1.965		0.495	101.535	CP
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

check :-

check :-

$$\sum BS - \sum FS = 7.500 - 5.860 = 1.640$$

$$\text{Last RL} - \text{First RL} = 99.725 - 98.085 = 1.640$$

$$\sum \text{Rise} - \sum \text{Fall} = 3.945 - 2.305 = 1.640$$

$$\therefore \sum BS - \sum FS = \text{Last RL} - \text{First RL} = \sum \text{Rise} - \sum \text{Fall}$$

Problem 4 In fly levelling from a BM of RL 140.605, the following readings were observed:

Backsight—1.545, 2.695, 1.415, 2.925

Foresight—0.575, 1.235, 0.595

From the last position of the instrument, six pegs at 20 m intervals are to be set out on a uniformly rising gradient of 1 in 50, the first peg is to have an RL of 144.000. Find the staff readings and RLs of the pegs.

Station	Chainage	BS	IS	FS	Rise (+)	Fall (-)	RL	Remarks
BM		1.545					140.655	BM
		2.695		0.575	0.970		141.575	
		1.415		1.235	1.460		143.035	
		2.925		0.595	0.820		143.855	
Peg-1	0		2.780		0.145		144.000	RL Given
Peg-2	20		2.380		0.400		144.400	
Peg-3	40		1.980		0.400		144.800	
Peg-4	60		1.580		0.400		145.200	
Peg-5	80		1.180		0.400		145.600	
Peg-6	100		0.780	0.780	0.400		146.000	
Total =		8.580		2.405	5.395	0		
At Peg-1				3.185				

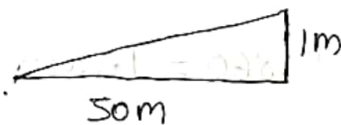
Given RL = 144.000

$$144.000 - 143.855 = 0.145 \text{ (Rise)}$$

$$IS = 2.925 - 0.145 = 2.780$$

Rising gradient from Peg-1 is 1 in 50

i.e., ~~vertical~~ 50 horizontal = 1 vertical



50 m horizontal = 1 m vertical

$$1 \text{ m} \quad \text{)} \quad = \frac{1}{50} \text{ m} \quad \text{)} \quad$$

$$20 \text{ m} \quad \text{)} \quad = \frac{1}{50} \times 20 \quad \text{)} \quad = 0.400$$

(Interval b/w pegs is 20 m)

From Peg-1 to Peg-6 Rise in RL occurs is 0.400 in each peg interval

At peg-2:-

$$\text{Rise} = 0.400$$

$$\text{RL} = \text{RL at peg-1} + \text{Rise} = 144.000 + 0.400 = 144.400$$

$$\text{IS} = 2.780 - 0.400 = 2.380$$

At peg-3:-

$$\text{Rise} = 0.400$$

$$\text{RL} = \text{RL at peg-2} + \text{Rise} = 144.400 + 0.400 = 144.800$$

$$\text{IS} = 2.380 - 0.400 = 1.980$$

At peg-4:-

$$\text{Rise} = 0.400$$

$$\text{RL} = \text{RL at peg-3} + \text{Rise} = 144.800 + 0.400 = 145.200$$

$$\text{IS} = 1.980 - 0.400 = 1.580$$

At peg-5:-

$$\text{Rise} = 0.400$$

$$\text{RL} = \text{RL at peg-4} + \text{Rise} = 145.200 + 0.400 = 145.600$$

$$\text{IS} = 1.580 - 0.400 = \cancel{0.780} 1.180$$

At peg-6:-

$$\text{Rise} = 0.400$$

$$\text{RL} = \text{RL at peg-5} + \text{Rise} = 145.600 + 0.400 = 146.000$$

$$\text{FS} = \cancel{0.780} 0.780 - 0.400 = \cancel{0.380} 0.780$$

CHECK :-

$$\sum BS - \sum FS = 8.580 - \overset{3.185}{\cancel{2.405}} = \cancel{6.175} 5.395$$

$$\text{LAST RL} - \text{first RL} = 146 - 140.605 = 5.395$$

$$\sum \text{RISE} - \sum \text{FALL} = 5.395 - 0 = \textcircled{5.395}$$

$$\therefore \sum BS - \sum FS = \text{LAST RL} - \text{first RL} = \sum \text{RISE} - \sum \text{FALL}$$

Problem 6 The following is the page of a level book, where some readings were missing. Fill in the missing readings and calculate the reduced levels of all the points.

Station	BS	IS	FS	Rise (+)	Fall (-)	RL	Remark
1	3.250					2,49.260	BM
2	1.755		?		0.750		CP
3		1.950					
4	?		1.920				CP
5		2.340		1.500			
6		?		1.000			
7	1.850		2.185				CP
8		1.575					
9		?					
10	?		1.895	1.650			CP
11			1.350	0.750			

Station	BS	IS	FS	Rise (+)	Fall (-)	RL	Remark
1	3.250					249.260	Bm
2	1.755		<u>4.000</u>		0.750	248.510	CP
3		1.950			0.195	248.315	
4	<u>3.840</u>		1.920	0.030		248.345	CP
5		2.340		1.500		249.845	
6		<u>1.340</u>		1.000		250.845	
7	1.850		2.185		0.845	250.000	CP
8		1.575		0.275		250.275	
9		<u>3.545</u>			1.970	248.305	
10	<u>2.100</u>		1.895	1.650		249.955	CP
11			1.350	0.750		250.705	
Total = 12.795			11.350	5.205	3.760		

missing data for line 2 = $3.250 + 0.750 = 4.000$

missing data for line 4 = $2.340 + 1.500 = 3.840$

missing data for line 6 = $2.340 - 1.000 = 1.340$

missing data for line 9 = $1.895 + 1.650 = 3.545$

missing data for line 10 = $1.350 + 0.750 = 2.100$

Check :-

$$\sum BS - \sum FS = \text{Last RL} - \text{First RL} = \sum \text{Rise} - \sum \text{Fall}$$

$$12.795 - 11.350 = 250.705 - 249.260 = 5.205 - 3.760$$

$$1.445 = 1.445 = 1.445$$

correction required in levelling :-

*- following corrections are required in levelling

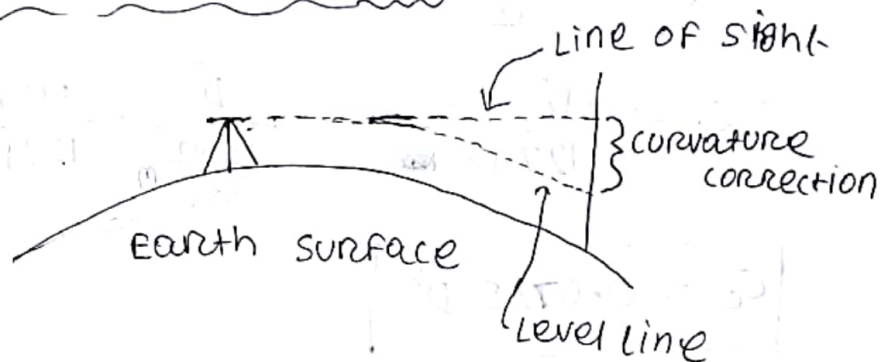
1- curvature correction

2- refraction 1)

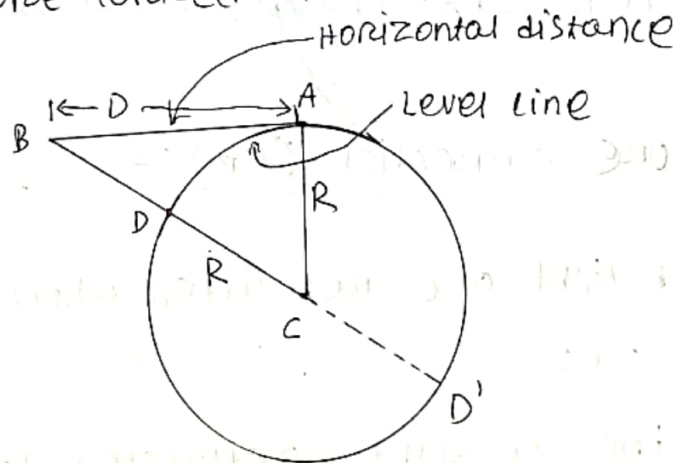
3- combined 2)

4- visible horizon distance

1- curvature correction (C_c) :-



*- The vertical distance b/w the line of sight and the level line at a particular place is called as curvature correction.



Let,

$AB = \text{Horizontal distance (in km)} = D$

$BD = \text{curvature correction } (C_c) \text{ (in m)}$

$AC = DC = R = \text{radius of earth} = 6370 \text{ km}$

$DD' = \text{Diameter of the earth} = 2R = 12742 \text{ km}$

For ΔABC we can say that:-

$$BC^2 = AC^2 + AB^2$$

$$\Rightarrow (BD+CD)^2 = R^2 + D^2$$

$$\Rightarrow (C_c + R)^2 = R^2 + D^2$$

$$\Rightarrow \cancel{C_c^2} + \cancel{R^2} + 2 \cdot C_c \cdot R = \cancel{R^2} + D^2$$

$$\Rightarrow 2 \cdot C_c \cdot R = D^2$$

$$\Rightarrow C_c = \frac{D^2}{2R}$$

$$\Rightarrow C_c = \frac{D^2}{12742} = \frac{D^2}{\frac{12742}{1000}} = \frac{1000 \times D^2}{12742} = 0.0785 D^2 \text{ in m}$$

$C_c = \text{very small}$

$C_c^2 = \text{Negligible}$

$$2R = 12742 \text{ km}$$

$$C_c = 0.0785 D^2$$

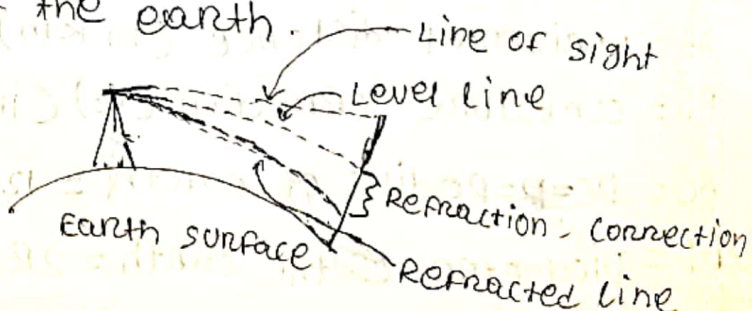
* - Curvature correction is always negative (i.e. subtractive)

True staff reading = Observed staff reading - curvature correction.

2- Refraction correction (C_r):-

* - Rays of light are refracted when they pass through air

* - ~~Refra~~ Line of sight refracted towards the surface of the earth.



* - Refraction correction is taken one seventh of the curvature correction.

$$C_R = \frac{1}{7} \times C_C = \frac{1}{7} \times 0.785 D^2 = 0.0112 D^2$$

* $\Rightarrow \boxed{C_R = 0.0112 D^2}$

* - Refraction correction is positive (i.e. Additive)

* True staff reading = observed staff reading + Refraction correction

3 - combined correction

Combined correction = Curvature correction + Refraction correction

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

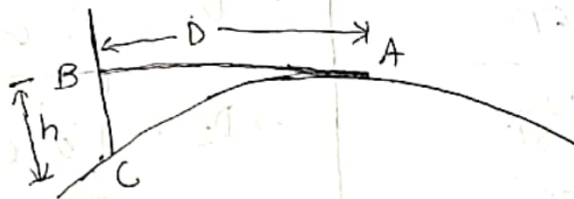
$$= -0.0673 D^2$$

* - Combined correction is negative (i.e. subtractive)

4 - visible horizon distance :-

$AB = D =$ visible horizon distance (in km)

$h =$ Height of the point above mean sea level (in m)



$$\boxed{h = 0.0673 D^2}$$

$h =$ In meters

$D =$ In km

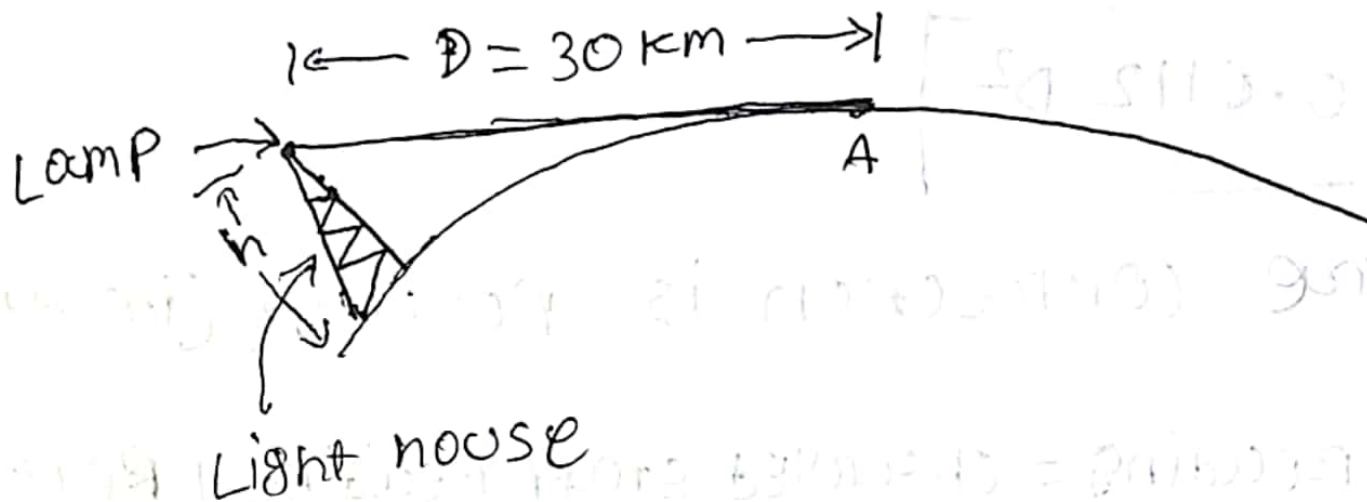
✓ Consistent print quality

JK Easy Copier with ColorLok outperforms ordinary papers.
• Vivid Colours, Just Like Real

Problem 2 A lamp at the top of a lighthouse is visible just above the horizon

152 *Surveying and Levelling*

from a station at sea level. The distance of the lamp from the station is 30 km.
Find the height of the lighthouse.



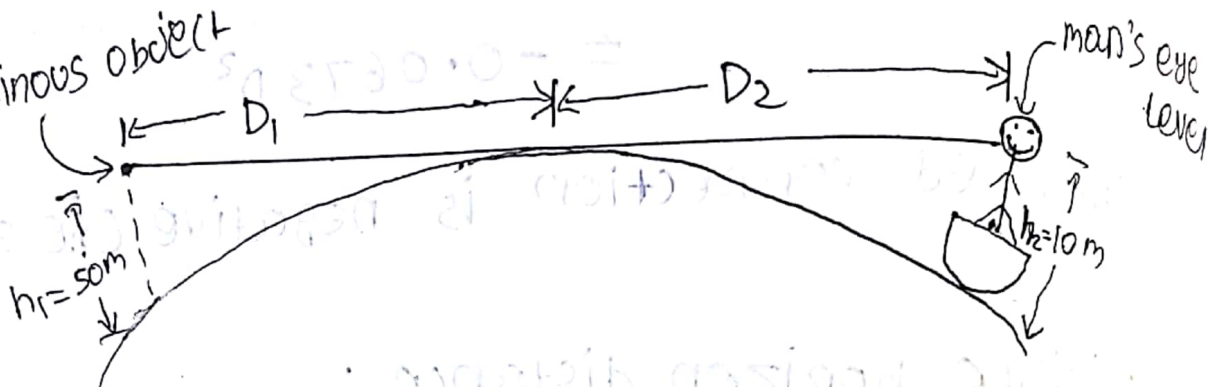
Let, The height of Light house = h

~~we know~~

we know that, $h = 0.0673D^2 = 0.0673 \times 30^2 = 60.57 \text{ m}$

Problem 4 A man on the deck of a ship observes a luminous object, which is 50 m above sea level. If the man's eye-level is 10 m above sea level, find the distance between him and the object.

Luminous object



$$h_1 = 0.0673 D_1^2$$

$$\Rightarrow D_1^2 = \frac{h_1}{0.0673}$$

$$\Rightarrow D_1 = \sqrt{\frac{h_1}{0.0673}}$$

$$\Rightarrow D_1 = \sqrt{\frac{50}{0.0673}}$$

$$\Rightarrow D_1 = 27.26 \text{ km}$$

$$h_2 = 0.0673 D_2^2$$

$$\Rightarrow D_2^2 = \frac{h_2}{0.0673}$$

$$\Rightarrow D_2 = \sqrt{\frac{h_2}{0.0673}}$$

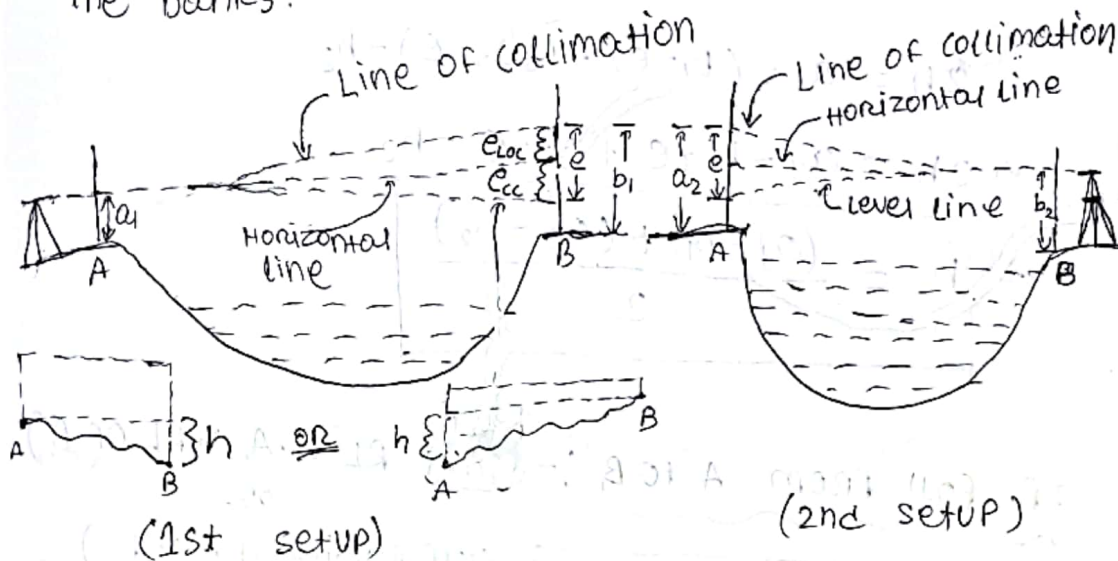
$$\Rightarrow D_2 = \sqrt{\frac{10}{0.0673}}$$

$$\Rightarrow D_2 = 12.19 \text{ km}$$

Distance b/w man & object = $D_1 + D_2 = 27.26 + 12.19 = 39.45$
 $= 39.45 \text{ km}$

reciprocal levelling :-

- *- For taking a reading level is set up midway b/w back sight & fore sight.
- *- But in case of a river or pond it is not possible to set up the level midway b/w two points on opposite bank.
- *- In such case reciprocal levelling is adopted.
- *- In reciprocal levelling, level is set up at both of the banks.



Let, h = True difference ~~of~~ of level b/w A & B
 e = Error due to inclination of line of collimation (e_{loc})
 $\pm$ combined correction (e_c)
 +ve = when LOC is upward from level line
 -ve = when LOC is downward from level line
 In 1st setup, -

correct staff reading at A = a_1

$$)))) : B = b_1 - e$$

True difference b/w of level b/w 'A & B = h

$$h = a_1 - (b_1 - e) \quad \text{--- (1)}$$

Q In 2nd set up :-

correct staff reading at A = $a_2 - e$

1) 1) 1) " B = b_2

True difference of level b/w A & B = h

$$h = (a_2 - e) - b_2 \quad \text{--- (2)}$$

From eq (1) & (2) we get,

$$2h = a_1 - (b_1 - e) + (a_2 - e) - b_2$$

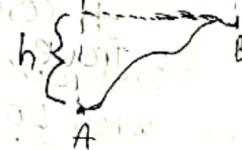
$$\Rightarrow 2h = a_1 - b_1 + e + a_2 - e - b_2$$

$$\Rightarrow h = \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$$

If fall from B to A :- (i.e. RL of B > RL of A) or

$$h = \frac{(a_1 - b_1) + (a_2 - b_2)}{2} \quad (\text{staff reading at A} > \text{B})$$

$$\text{RL of B} = \text{RL of A} + h$$

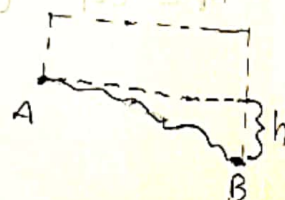


If fall from A to B :- (i.e. RL of A > RL of B) or

$$h = \frac{(b_1 - a_1) + (b_2 - a_2)}{2}$$

(staff reading at B > A)

$$\text{RL of B} = \text{RL of A} - h$$



5.10 PROBLEMS ON RECIPROCAL LEVELLING

Problem 1 In an operation involving reciprocal levelling, two points A and B are taken on opposite banks of a river. When the level was set up near A, the staff readings on A and B were 2.245 and 3.375 respectively. When the level was set up near B, the respective staff readings were 1.955 and 3.055. Find the true difference of level between A and B. What is the RL of B, if that of A is 125.550?

When level is at A

$$a_1 = 2.245$$

$$b_1 = 3.375$$

When level is at B

$$a_2 = 1.955$$

$$b_2 = 3.055$$

$$RL \text{ of } A = 125.550$$

(Here staff reading at $B > A$)



So, true difference ~~b/w~~ of level b/w A & B = h

$$h = \frac{(b_1 - a_1) + (b_2 - a_2)}{2}$$

$$= \frac{(3.375 - 2.245) + (3.055 - 1.955)}{2}$$

$$= 1.115 \text{ m}$$

$$RL \text{ of } B = RL \text{ of } A - h = 125.550 - 1.115 = 124.435 \text{ m}$$



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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 RL of A = 525.500
B	0.985	2.415	

Find:

- The true RL of B,
- The combined correction for curvature and refraction,
- The collimation error, and
- Whether the line of collimation is inclined upwards or downwards.

Ans (a) - True RL of B

(a) staff reading of $B > A$

So, Fall from A to B



True difference b/w A & B $= h$

$$h = \frac{(2.595 - 1.155) + (2.415 - 0.985)}{2} = \frac{(b_1 - a_1) + (b_2 - a_2)}{2}$$

$$= 1.435 \text{ m} \quad \text{--- (1)}$$

$$\text{RL of B} = \text{RL of A} - h$$

$$= 525.500 - 1.435 = 524.065 \text{ m}$$

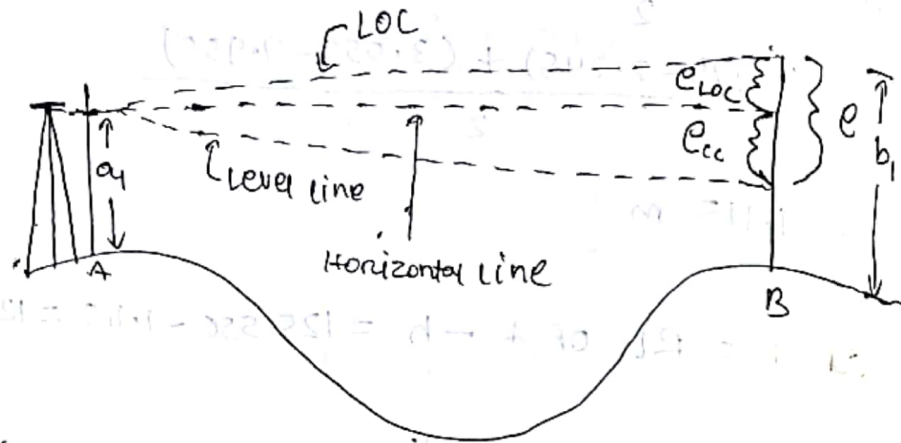
(b) - combined correction (e_{cc}) :-

$$D = 500 \text{ m} = 0.5 \text{ km}$$

$$\begin{aligned}\text{Combined correction } (e_{cc}) &= 0.0673 D^2 \\ &= 0.0673 \times 0.5^2 \\ &= 0.017 \text{ m}\end{aligned}$$

(combined correction is always negative)

(c) - The collimation error (e_{loc}) :-



Here,

e = Error due to inclination of line of collimation (e_{loc})
+ combined correction (e_{cc})

Let us Assume,

LOC is inclined upward. i.e.

$$\therefore e = e_{cc} + e_{loc}$$

Here (error is in +ve so correction will be -ve or vice versa)

Also Assume,

$$\text{LOC error for } 500 \text{ m} = e_{loc}$$

$$\text{Here, combined correction } (e_{cc}) = 0.017$$

when the instrument is set up at A.

$$a_1 = 1.155 \text{ m}$$

$$b_1 = 2.595 \text{ m}$$

True staff reading at A = $a_1 = 1.155 \text{ m}$

" " "

$$B = b_1 - e$$

$$= b_1 - (e_{cc} + e_{loc})$$

$$= b_1 - e_{cc} + e_{loc}$$

$$= 2.595 - 0.017 + e_{loc}$$

True difference of level b/w A & B = h .

$$h = \text{True staff reading at B} - \text{True staff reading at A}$$



$$\Rightarrow h = 2.595 - 0.017 + e_{loc} - 1.155$$

$$\Rightarrow h = 1.423 - e_{loc} \quad \text{--- (2)}$$

from eqⁿ (1) & (2) we get

$$h = 1.435 \quad \text{--- (1)}$$

$$h = 1.423 - e_{loc} \quad \text{--- (2)}$$

$$1.435 = 1.423 - e_{loc}$$

$$\Rightarrow e_{loc} = 1.423 - 1.435$$

$$\Rightarrow e_{loc} = -0.012$$

Here we found that, $e_{loc} = -ve$

so we can say that LOC is inclined downward.

$$\therefore \text{LOC error for } 500 \text{ m} = -0.012$$

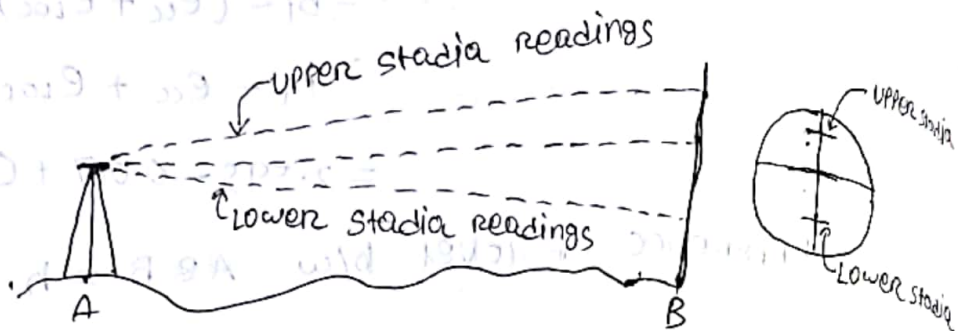
$$\Rightarrow \text{1 m} = -\frac{0.012}{500}$$

$$\Rightarrow \text{100 m} = -\frac{0.012}{500} \times 100 = -0.02 \text{ m}$$

(d)

Line of collimation is inclined downward

measuring horizontal distance by stadia method:



Horizontal distance of AB = (Upper stadia reading - Lower stadia reading) $\times$ Stadia constant

* Normally stadia constant taken = 100 (Given in Instrument from ~~the~~ manufacture)

Ex $\rightarrow$

Let, upper stadia reading = 2.455

Lower " " = 1.235

Stadia constant = 100

Distance of AB = $(2.455 - 1.235) \times 100$
= 122 m

Error in levelling :-

* - following are the different ^{types of} error, occur in levelling

1- Instrumental error

2- personal error

3- Natural error

1- Instrumental error :-

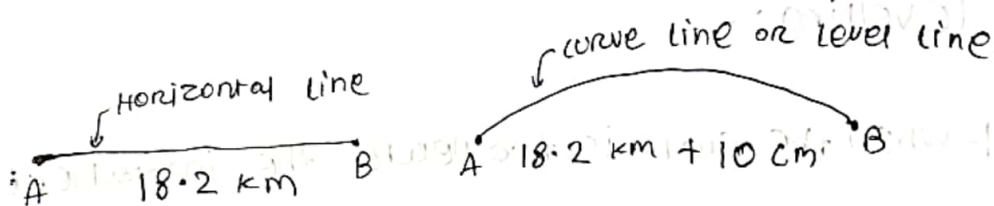
- *- If permanent adjustment is not perfect (i.e. if LOC is not parallel to the axis of bubble tube)
- *- If internal adjustment of focussing tube is not perfect.
- *- The graduation of levelling staff is not perfect.

2- Personal error :-

- *- If the instrument is not centered, levelled perfectly.
- *- If the focusing is not perfect (i.e. parallax is not eliminated)
- *- Position of staff is not held perfectly
- *- Wrong entry in field book (or level book)
- *- Staff may not be properly or fully extended

3- Natural error :-

- *- For taking the reading of a long distance curvature of the earth affect the staff reading



- *- Effect error due to effect of refraction of light
- *- Effect of high wind / sunlight may be shift / shining the staff so that error is occur.

Permissible error in levelling :-

$$E = C\sqrt{D}$$

E = Permissible error in 'm'

C = constant varies from 0.100 to 0.006

D = Distance in 'km'

For rough levelling, $E = \pm 0.100$

1) ordinary) , $C = \pm 0.025$

2) accurate) , $C = \pm 0.012$

3) precise) , $C = \pm 0.006$

Difficulties faced in levelling :-

* - Following are the different difficulties faced in levelling :-

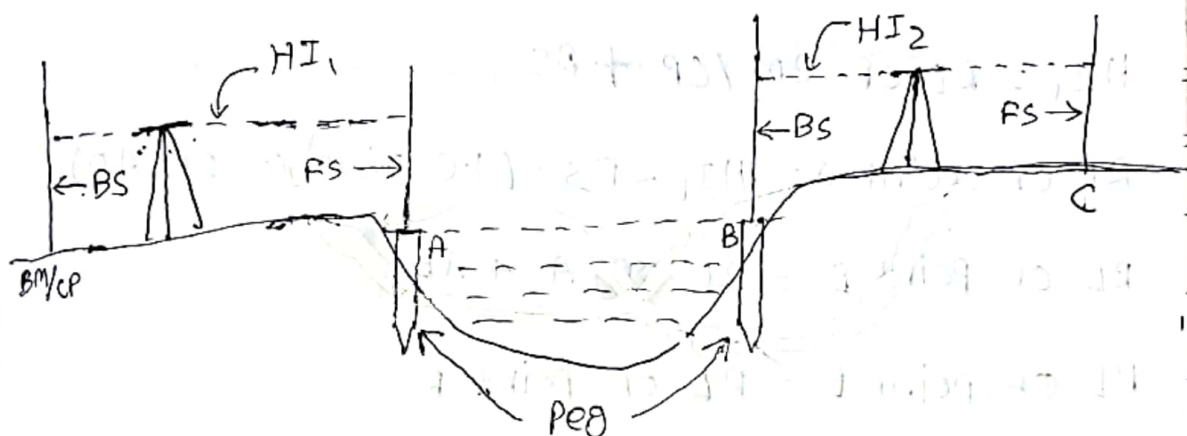
- 1- when the staff is too near the instrument
- 2- Levelling across a large pond or lake
- 3-)) a river
- 4-)) a solid wall
- 5-) when B.M. is above the line of collimation
- 6-) across a steep slope
- 7-)) a rising ground or depression

1- when the staff is too near :-

- * If the staff is too near of the instrument then the graduation of staff are not visible
- * In this case a piece of paper or pen move up & down untill the paper is properly visible by LOC
- * The point at which LOC bisect the paper or pen is marked
- * Then the reading of staff is taken by naked eye.

2- Levelling across a large pond or lake :-

- * surface of still water is considered as a level surface.



$$HI_1 = RL \text{ of BM/CP} + BS$$

$$RL \text{ of A} = HI_1 - FS$$

$$RL \text{ of A} = RL \text{ of B} \quad (\text{Due to still water})$$

$$HI_2 = RL \text{ of B} + BS$$

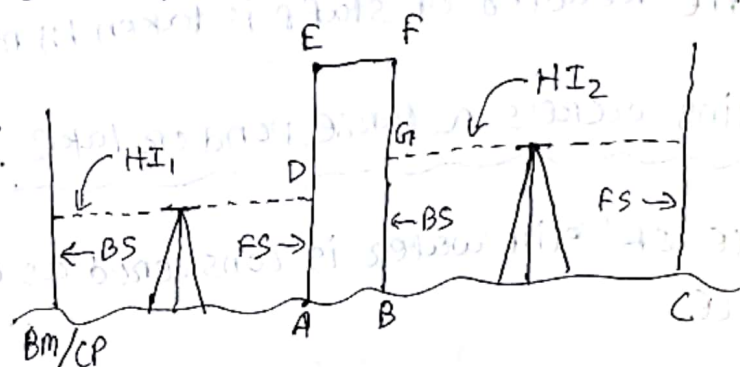
$$RL \text{ of C} = HI_2 + FS$$

3- Levelling across a river :-

* surface of flowing water cannot be considered as level surface

* so in case for levelling across a river Reciprocal levelling is preferred.

4- Levelling across a solid wall :-



$$HI_1 = RL \text{ of BM/CP} + BS$$

$$RL \text{ of point A} = HI_1 - FS \text{ (i.e. distance of AD)}$$

$$RL \text{ of point E} = RL \text{ of A} + AE$$

$$RL \text{ of point E} = RL \text{ of point F}$$

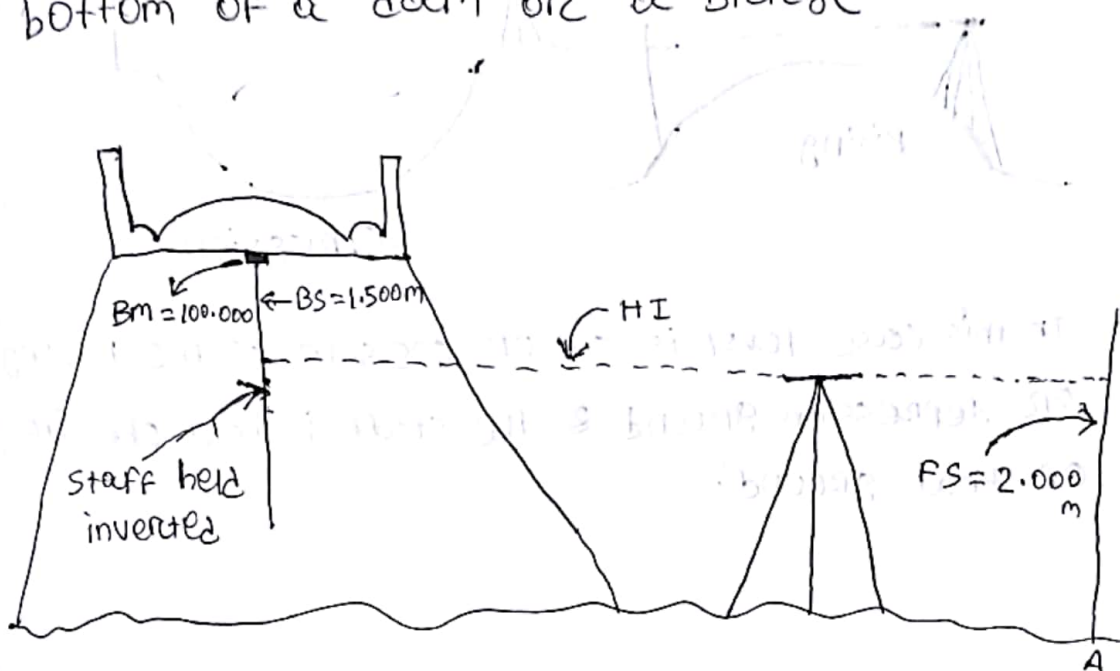
$$RL \text{ of point B} = RL \text{ of point F} - BF$$

$$HI_2 = RL \text{ of point B} + BS$$

$$RL \text{ of point C} = HI_2 - FS$$

5- When BM is above the LOC :-

* This situation happen when the BM is at bottom of a dam or a bridge



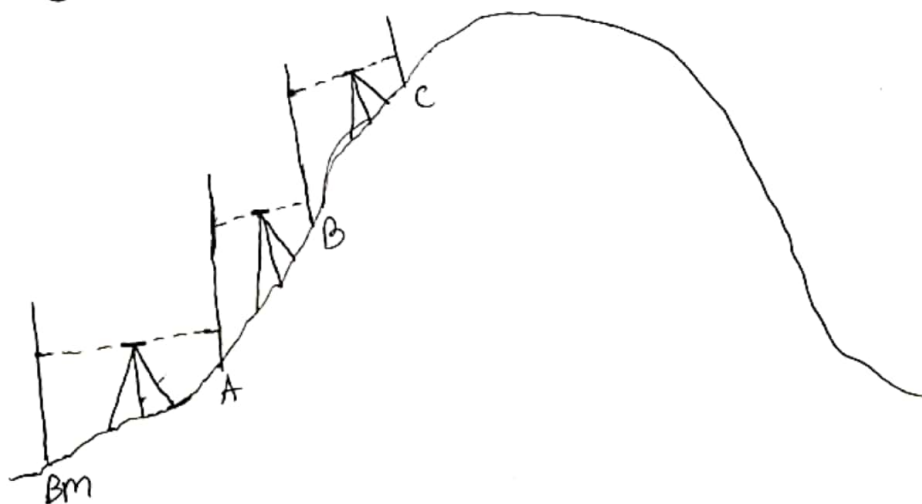
Let,

$$RL \text{ of } BM = 100.000$$

$$HI = RL \text{ of } BM - BS = 100.000 - 1.500 = 98.500 \text{ m}$$

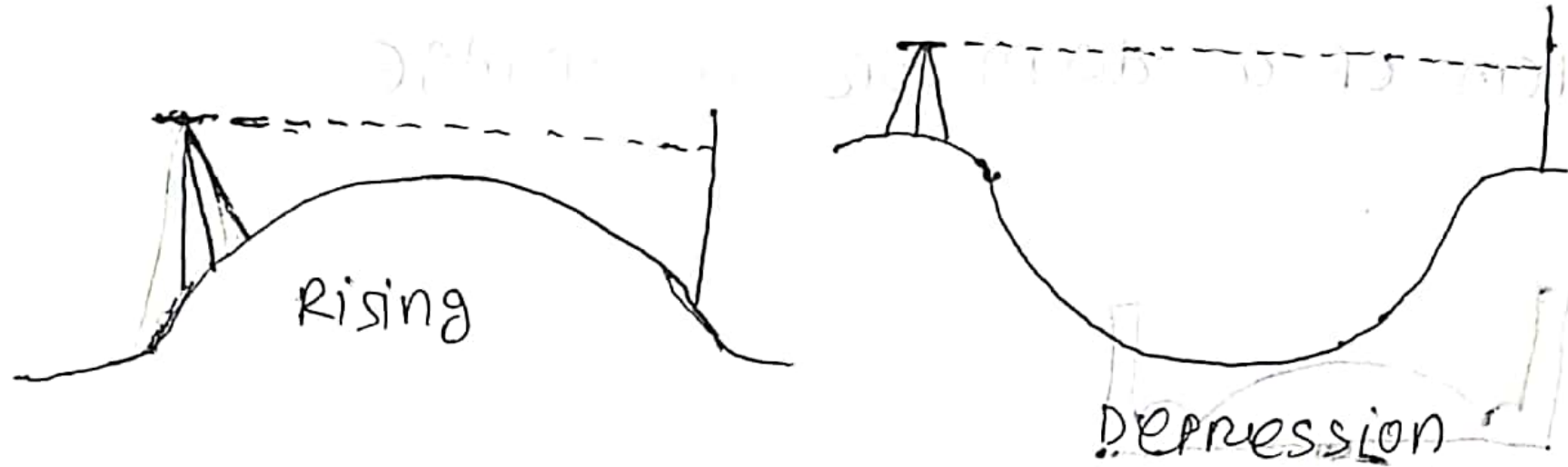
$$RL \text{ of } A = HI - FS = 98.500 - 2.000 = 96.500 \text{ m}$$

6- Levelling along a steep slope :-



* - In this case levelling instrument is set up near the BS & FS - so that we can take reading both BS & FS in one set up.

7- Levelling across a rising ground or depression :-

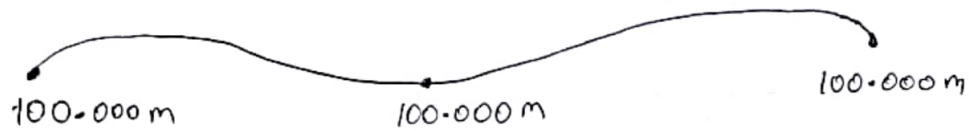


- * - In this case level is set up one side of the rising or depression ground & the staff is held opposite side of that ground.

Contouring

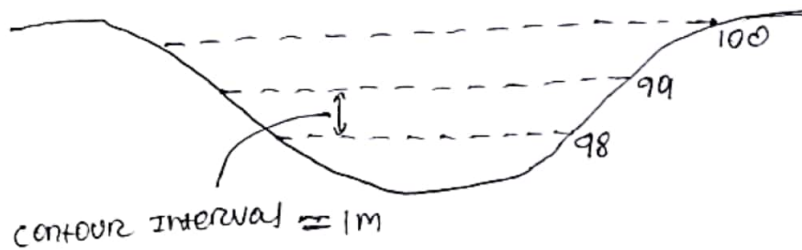
Contour line / contour :-

- * - A line joining the points of equal RL is known as contour line / contour.



(contour line of 100.000 m)

Contour interval :-



- * - The vertical distance b/w any two consecutive contours is known as contour interval.
- * - contour interval for a particular map is constant
- * - contour interval for a flat ground is small.
Ex $\rightarrow$ 0.25m, 0.5m, 0.75m, 1m, etc
- * - contour interval for a steep slope ground or in hilly area is greater.
Ex $\rightarrow$ 5m, 10m, 15m, etc

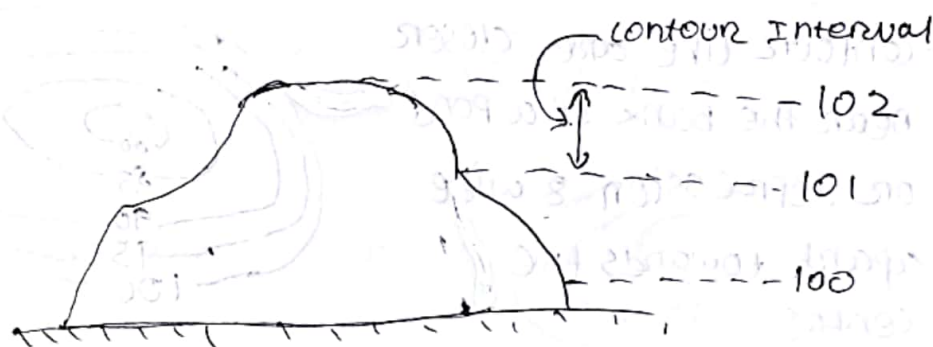
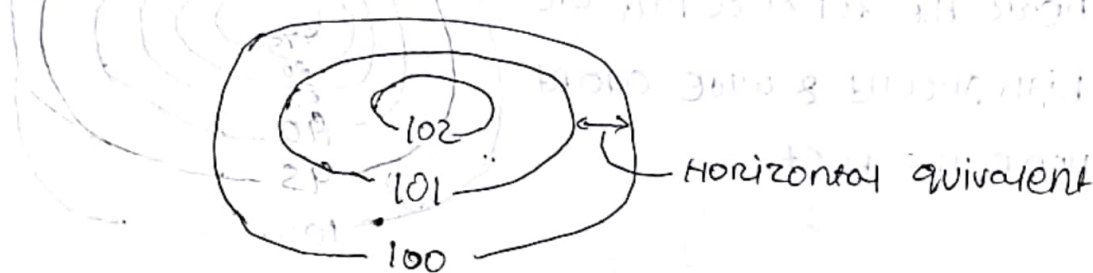
Horizontal equivalent :-

- * - The horizontal distance b/w any two consecutive contour is known as horizontal equivalent

* Horizontal equivalent for a particular map is not constant.

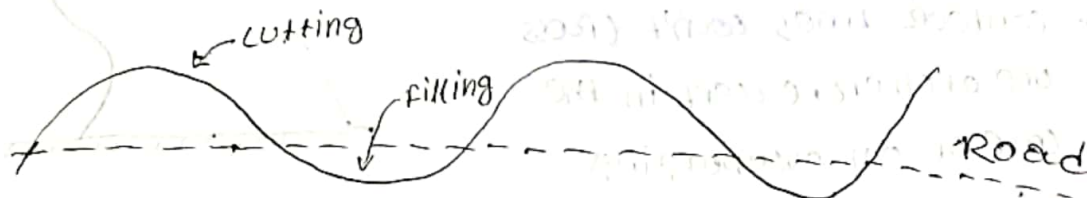
* 1) " " flat ground is wide apart.

* 2) " " steep slope ground is close together



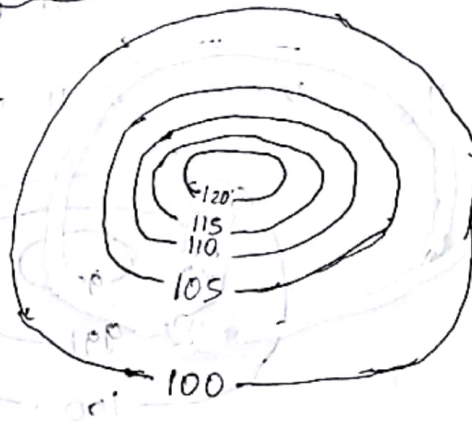
Use of contour map

- * Nature of the ground surface of a country is determined by using contour map
- * The capacity of a reservoir is to be determined
- * Quantity of earth work (either cutting or filling) can be determined.



CHARACTERISTICS OF CONTOUR :-

1- contour lines are closer near the top of a hill or high ground & wide apart near the foot



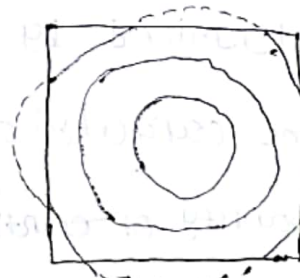
2- contour line are closer near the bank of a pond or depression & wide apart towards the centre



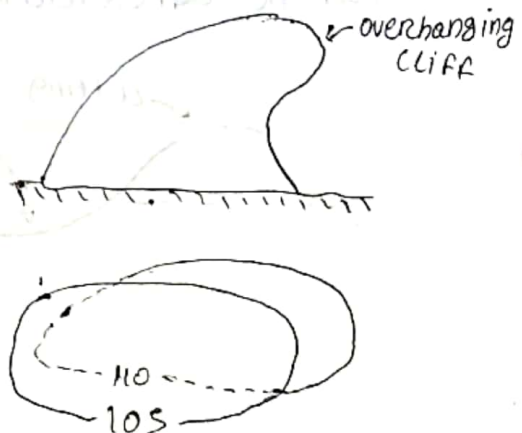
3- uniformly spaced contour lines indicate a uniform slope.



4- contour lines always form a closed circuit. But these lines may be within or outside the limits of the map.

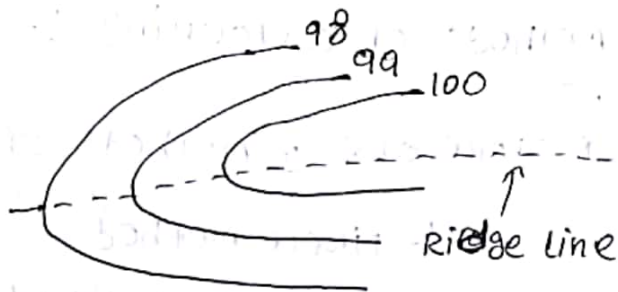


5- contour lines can't cross one another, except in the case of an overhanging cliff (But the overhanging portion must be shown by a dotted line)



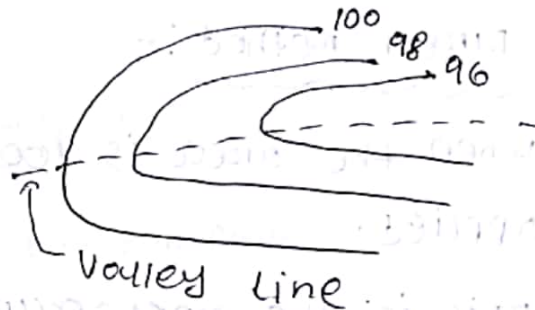
6- when higher values are inside the loop, it indicates a ridge line.

*- contour line cross ridge line at right angle.



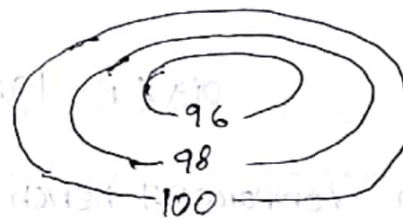
7- when the lower values are inside the loop, it indicates a valley line.

*- contour line cross the valley line at right angle



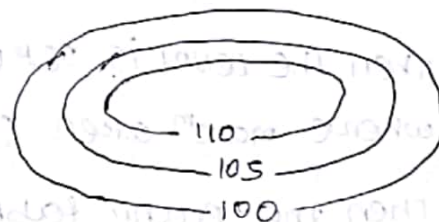
8- A series of closed contours always indicates a depression or summit.

*- Lower value inside the loop indicates depression



(depression)

*- Higher value inside the loop indicates summit.

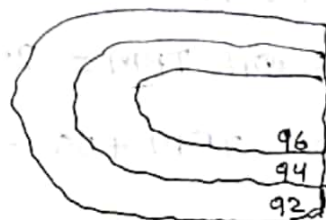


(summit)

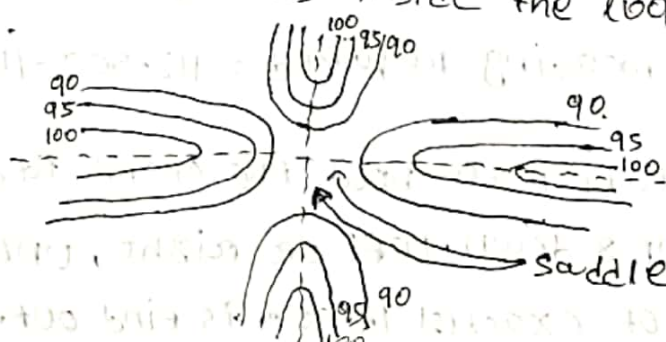
9- contour lines meeting at a point indicates a vertical cliff



10-

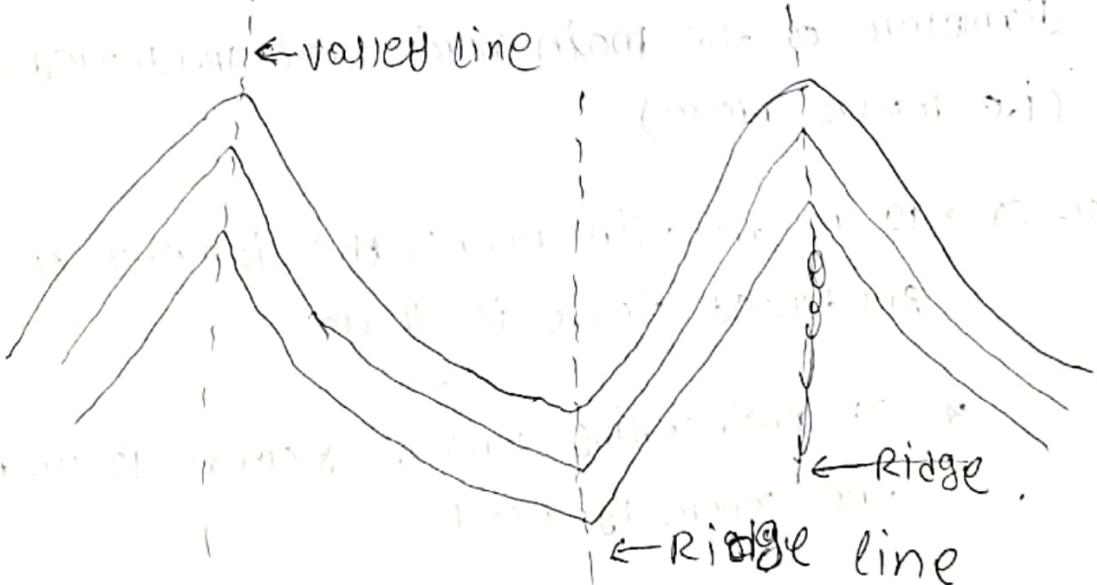
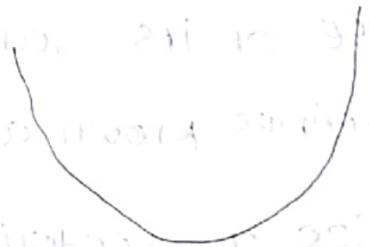
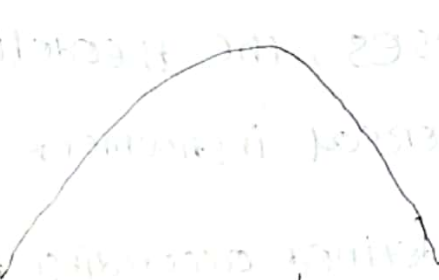
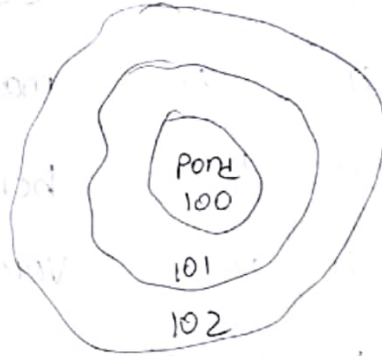
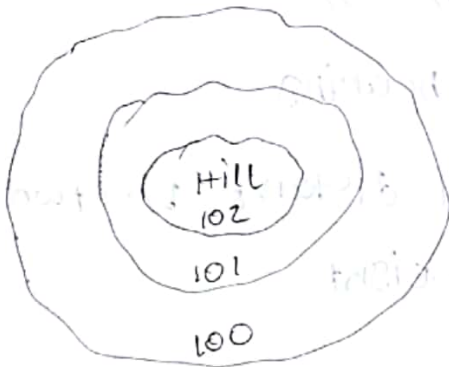
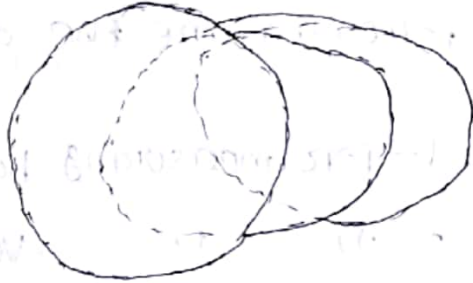
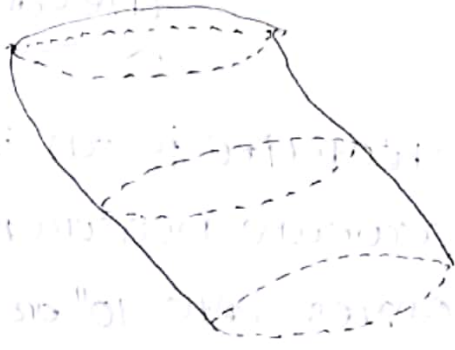
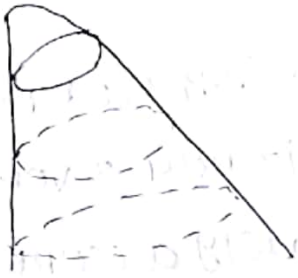


10- when no or valley lines inside the loop, it indicates a saddle.



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✓ Consistent print quality

• Vivid Colours: Richer, brighter images

methods of contouring :-

* - There are 2 methods of contouring

1 - Direct method

2 - Indirect method

1 - Direct method :-

* - When the area is too long & large this method is applied.

* - This is the most accurate method but tedious.

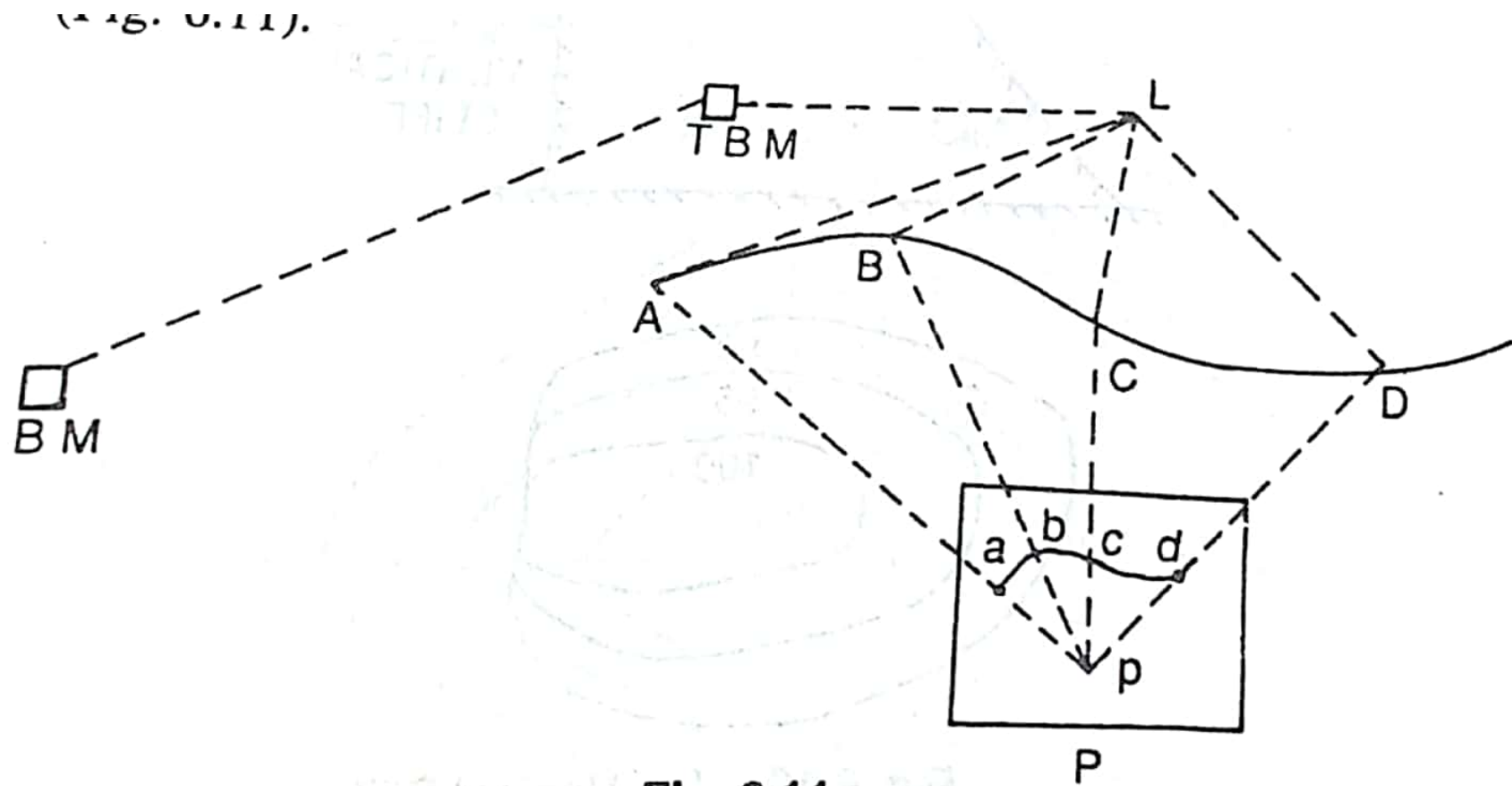


Fig. 6.11

- * - A temporary bench mark (TBM) is set up near the site by taking fly levelling from a permanent bench mark (BM)
- * - Then the level is set up at a suitable position "L" from where max^m area can be covered.
- * - Then the plane table is set up at a suitable station "P" from where the above area can be plotted.

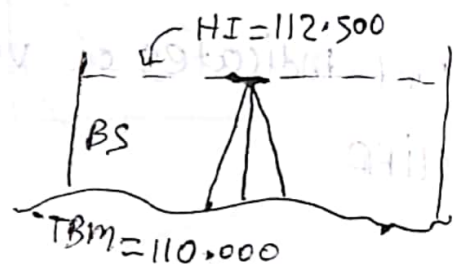
Let,

$$BM = 100.000$$

$$TBM = 110.000$$

$$BS \text{ on } TBM = 2.500$$

$$HI = TBM + BS = 110 + 2.5 = 112.500$$



Let, a contour line / contour required = 111.000 m

So, a staff reading required = $112.500 - 111.000 = 1.500 \text{ m}$

- * - Then the staff man hold the staff at different point and move up & down, left or right, until the staff reading is of exactly 1.500 m is find out.

2- Indirect method :-

*- we can plot a contour map by using indirect method by following 2 types :-

A- By using cross-section

B- By using square.

A- By using cross section :-

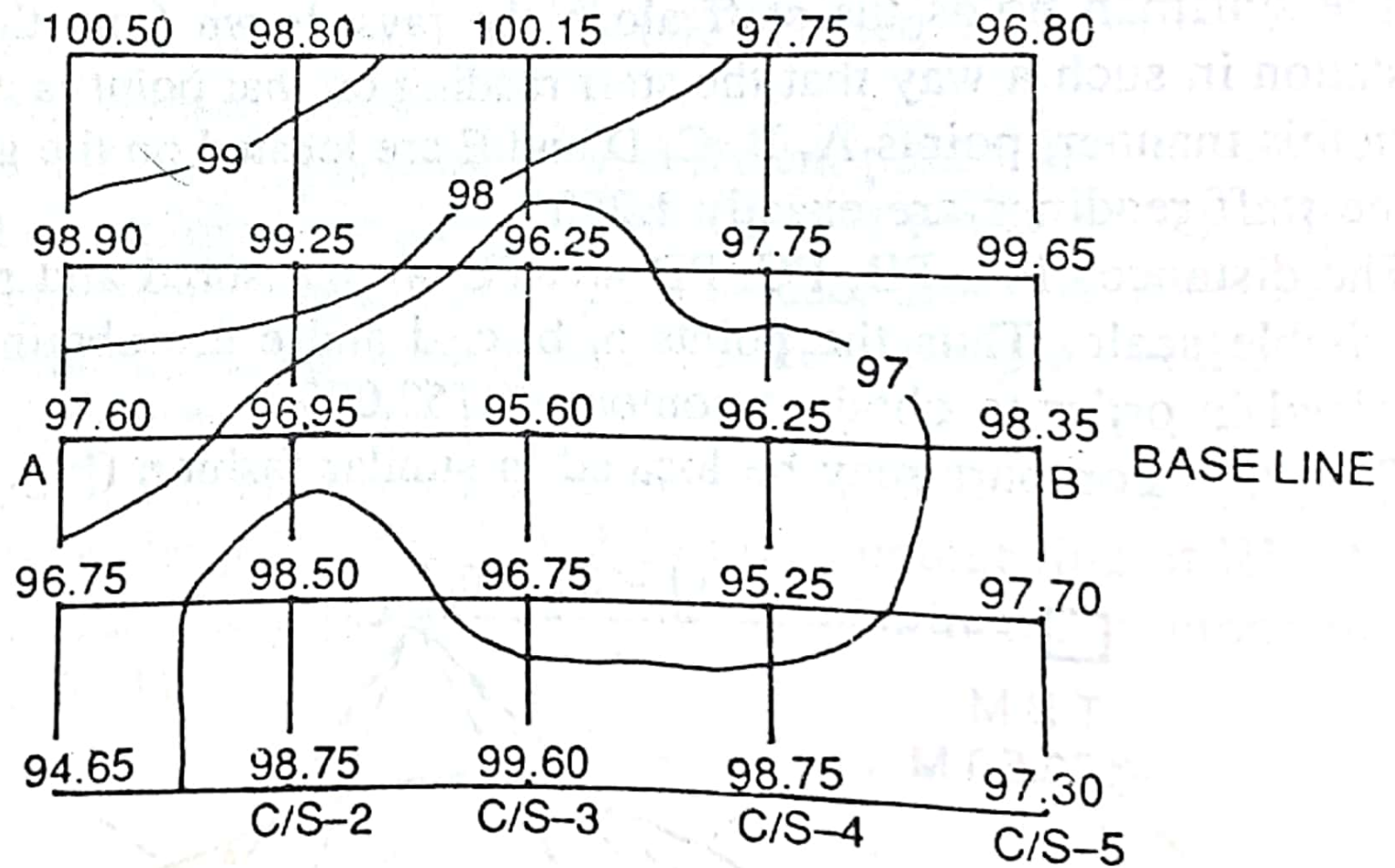


Fig. 6.13

*- In this method base line or center line is considered.

*- Then no of cross sections are taken perpendicular to this line at a regular interval of 10m, 20m, 30m, etc..

*- Then points are marked along the cross section at a regular interval of 5m, 10m, etc.

*- A temporary bench mark (TBM) is set up near the site.

*- Then the RL of each and every point is find out.

*- Then the required contour line is find out by using interpolation.

B - By using square :-

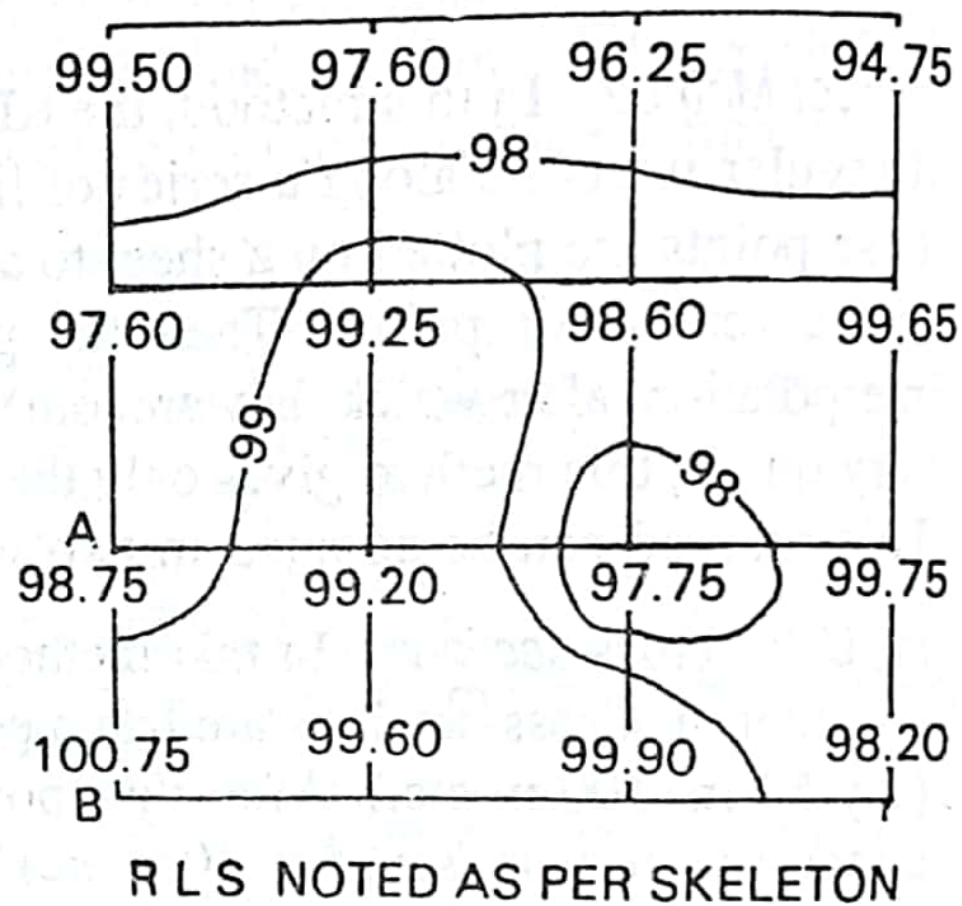
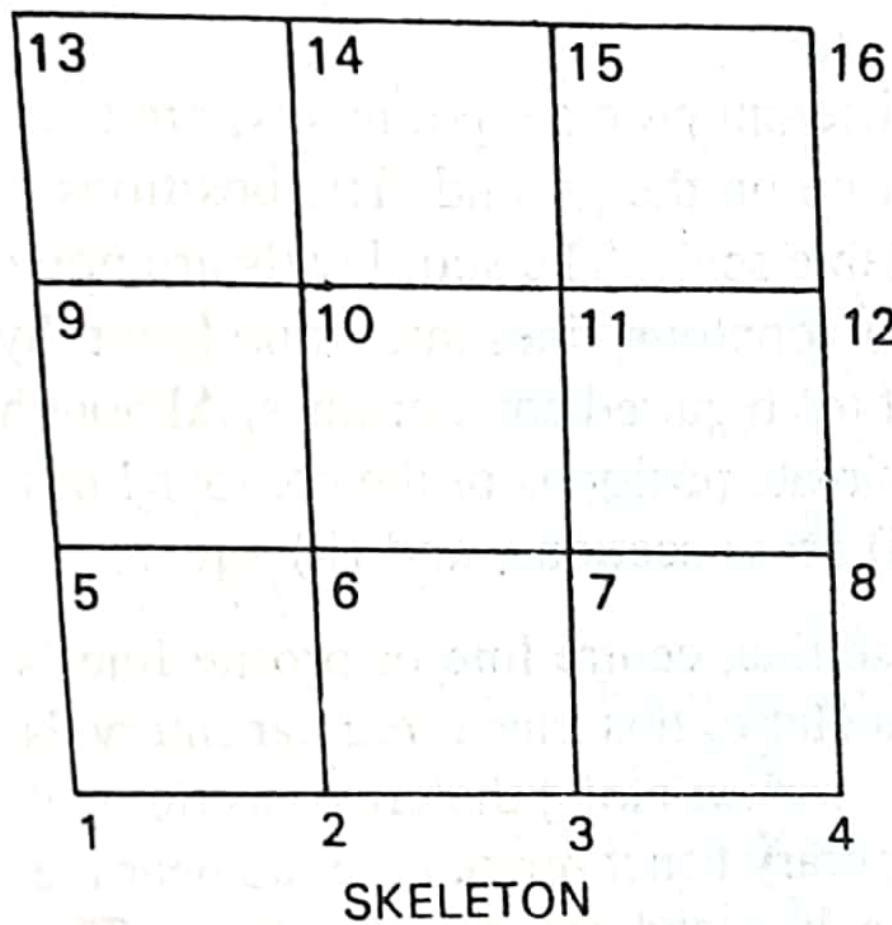


Fig. 6.14

- *- In this method whole area is divided into no. of squares having a side varying from 5m to 20m.
- *- Then the corners of the square are numbered serially as 1, 2, 3, - - - -

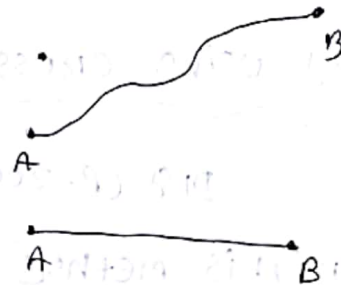
* - A temporary bench mark (TBM) is set up near the site & the RL of each point is calculated.

* - Then the required contour lines are mathematically calculated by using interpolation method.

Interpolation :-

Let, RL of A = 100 m

RL of B = 105 m



Horizontal distance b/w A & B = 10 m

Vertical distance = 105 - 100 = 5 m

Let, a contour line required = 102 m

So, distance b/w A & required contour line

$$= 102 - 100 = 2 \text{ m}$$

$$\text{Distance of RL 102 from A} = \frac{2}{5} \times 10 = 4 \text{ m}$$

Toposheet :-

* - Toposheet is also known as topographical sheet

* - A map which shows natural features (like hills, river, forest, villages) of a country is known as topographical map.

* - Scale of topographical map lies in b/w 1 in 50,000 to 1 in 250,000

Computation of Area

*- Area means area of land projected upon the horizontal plane.

Unit's of land measurement:-

$$1 \text{ Link (शुद्ध)} = 20 \text{ cm} = 0.2 \text{ m}$$

$$1 \text{ chain} = 100 \text{ Links} = 0.2 \times 100 \text{ m} = 20 \text{ m}$$

$$1 \text{ Dismil} \approx 40 \text{ m}^2$$

$$1 \text{ Guntha} = 4 \text{ Dismil} = 4 \times 40 \text{ m}^2 \approx 160 \text{ m}^2$$

$$\begin{aligned} 1 \text{ Acre (or mana)} &= 25 \text{ Guntha} = 25 \times 4 \text{ Dismil} = 100 \text{ Dismil} \\ &= 100 \text{ Dismil} \\ &= 100 \times 40 \text{ m}^2 \\ &\approx 4000 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} 1 \text{ Vati} &= 20 \text{ Acre} = 20 \times 100 \text{ Dismil} = 2000 \text{ Dismil} \\ &= 20 \times 4000 \text{ m}^2 = 80,000 \text{ m}^2 \end{aligned}$$

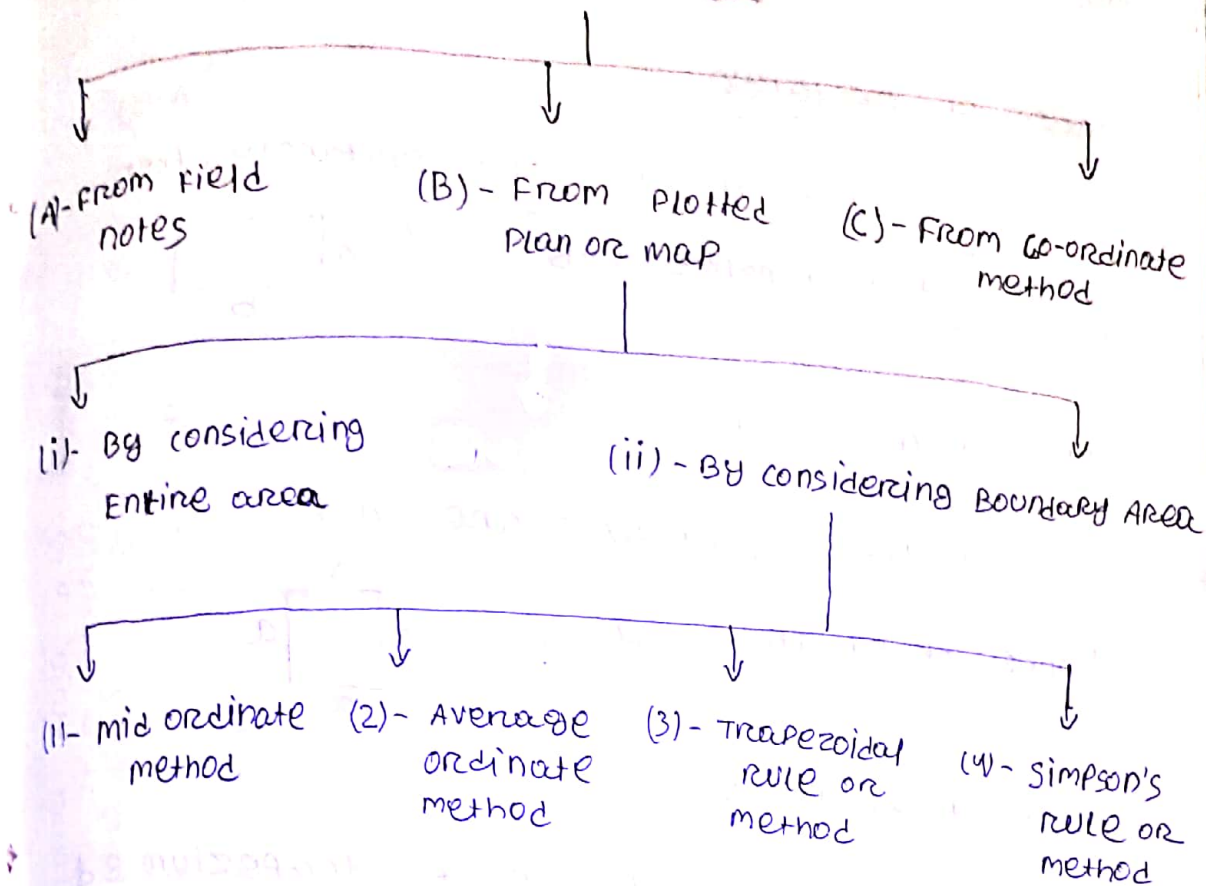
$$1 \text{ are (बराबर)} = 100 \text{ m}^2$$

$$1 \text{ Hectare} = 100 \text{ are} = 100 \times 100 \text{ m}^2 = 10,000 \text{ m}^2$$

$$1 \text{ Hectare} \approx 2.5 \text{ Acre}$$

Methods of computation of Area :-

Calculation of Area



A - Computation of Area from field notes :-

* In this method area of a field can be directly calculated by using field notes / field books.

* In this method the whole area is divided into some geometrical figures, such as triangles, rectangles, square, trapeziums, etc. Then area is calculated by using following formula :-

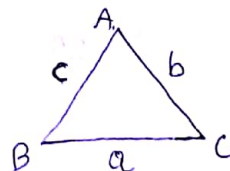
Area of a triangle :-

If, a, b, c are the sides of a triangle, then

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

$$\text{Area of } \Delta = \sqrt{S(S-a)(S-b)(S-c)}$$

Heron's Formula



or

$$\text{Area of a } \Delta = \frac{1}{2} \times b \times h$$

If, $b = \text{Base}$ $h = \text{Height}$

Area of rectangle:-

If, a & b are the sides of a rectangle, then

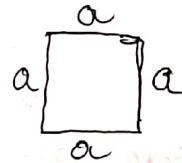
$$\text{Area of rectangle} = a \times b$$



Area of a square

If, ' a ' is the side of the square, then

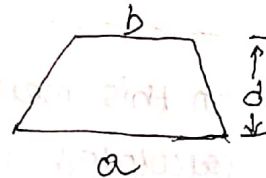
$$\text{Area of square} = a^2$$



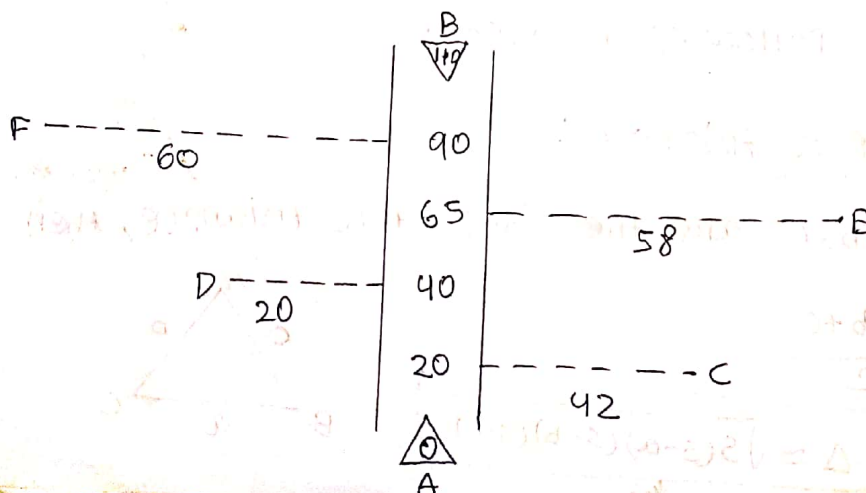
Area of trapezium:-

If, a & b are the parallel sides of a trapezium & d is the perpendicular distance b/w them, then

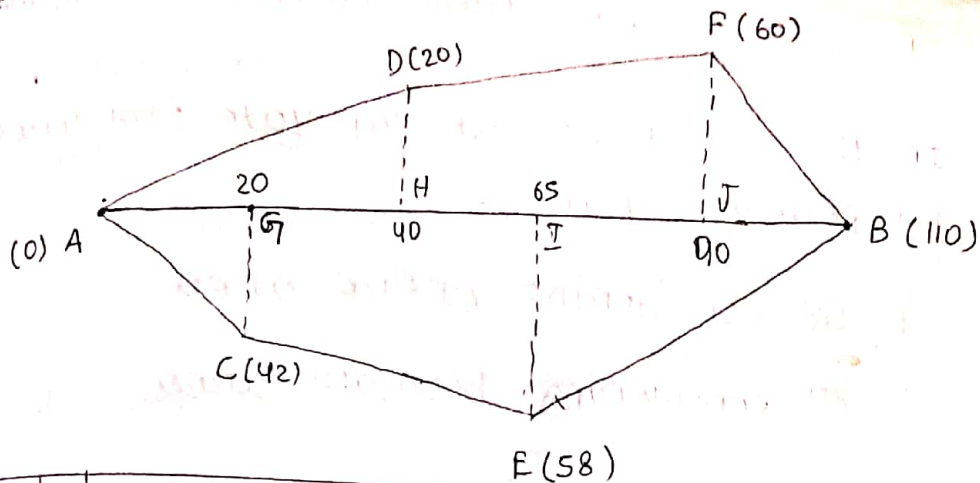
$$\text{Area of trapezium} = \frac{1}{2} (a+b) \times d$$



Q A page of a field book is given below. Find the relevant area by using the following data:-



Ans



SL No	Figure	Chainage (m)	Base (m)	Offset (m)	mean offset (m) = $\frac{1}{2}(a+b)$	Area (m ²) = $\frac{col(u) \times col(c)}{2}$		Remark
						(+)	(-)	
1	2	3	4	5	6	7	8	9
1-	ΔACG	0220	20	0242	21	420		
2-	Trap GCEI	20265	45	42258	50	2250		
3-	ΔIEB	652110	45	5880	29	1305		
4-	ΔBFJ	110290	20	0260	30	600		
5-	Trap JFDH	90240	50	60220	40	2000		
6-	ΔHDA	4020	40	2020	10	400		

Total Area = 6975

Area of field = 6975 m²

B- Computation of Area from Plotted Plan or map:-

* - In this method we can calculate any area by following types:-

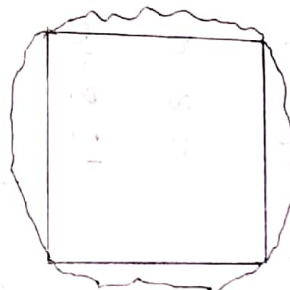
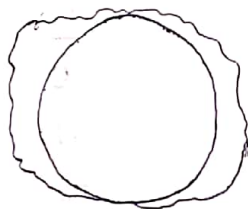
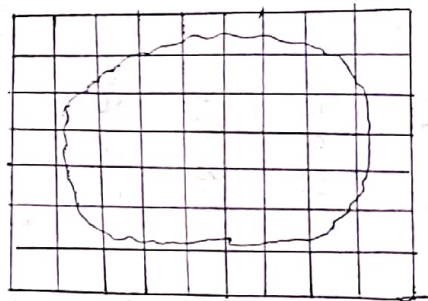
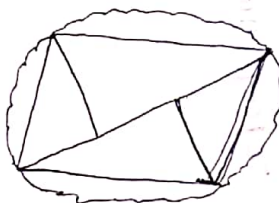
i - By considering entire area

ii - By considering boundary area

i - By considering entire area:-

* - In this method, the whole area is divided into a convenient shape as triangle, rectangle, square, trapezium, circle, etc.

* - And then the area is calculated by using convenient formula:-



ii - By considering boundary area:-

* - The boundary area is calculated by using following rules:-

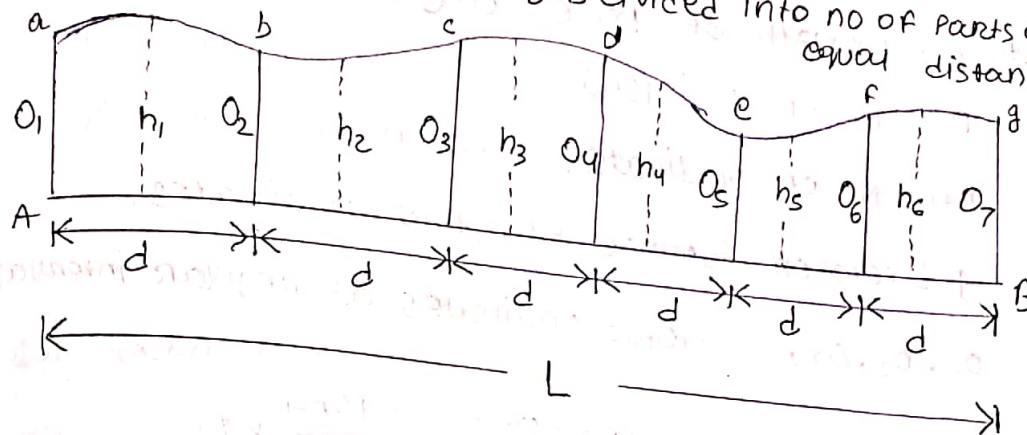
- 1- mid ordinate rule
- 2- Average ordinate rule
- 3- Trapezoidal rule
- 4- Simpson's rule

In this method we assume boundary b/w two ordinates is straight line.

we assume boundary b/w two ordinates is parabolic.

1- mid ordinate rule:-

*- In this method the boundary is divided into no of parts of equal distance.



Let, h = mid ordinates

d = common distance b/w two ordinates

$O_1, O_2, O_3, \dots, O_n$ = ordinates at equal interval

$h_1, h_2, h_3, \dots, h_n$ = mid ordinates

L = Length of base line AB

A = Area of the plot

*- If the value of mid ordinate is not given, then we will find out mid-ordinates as follows:-

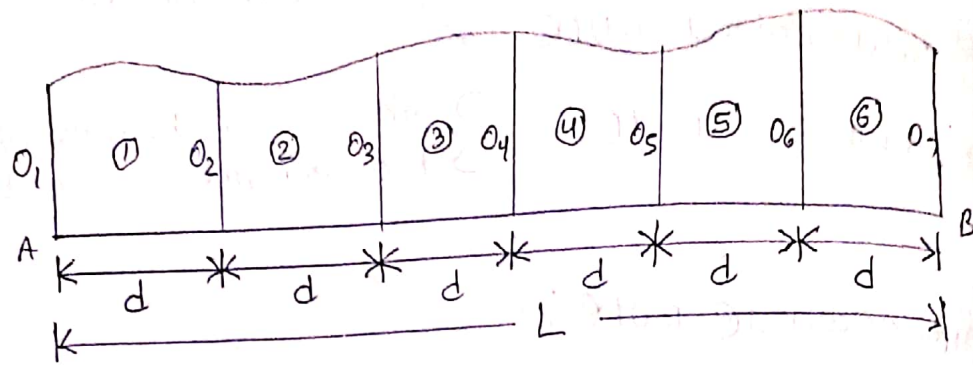
$$h_1 = \frac{O_1 + O_2}{2} \quad h_2 = \frac{O_2 + O_3}{2} \quad h_3 = \frac{O_3 + O_4}{2} \quad \dots \text{so on.}$$

$$\text{Area of the plot (A)} = h_1 d + h_2 d + h_3 d + \dots + h_n d$$

$$= d (h_1 + h_2 + h_3 + \dots + h_n)$$

i.e., $\text{Area (A)} = \text{common distance} \times \text{sum of mid ordinates}$

2- Average ordinate method :-



Let, L = Length of base line AB

n = No of divisions

$n+1$ = No of ordinates

d = common distance b/w two ordinates

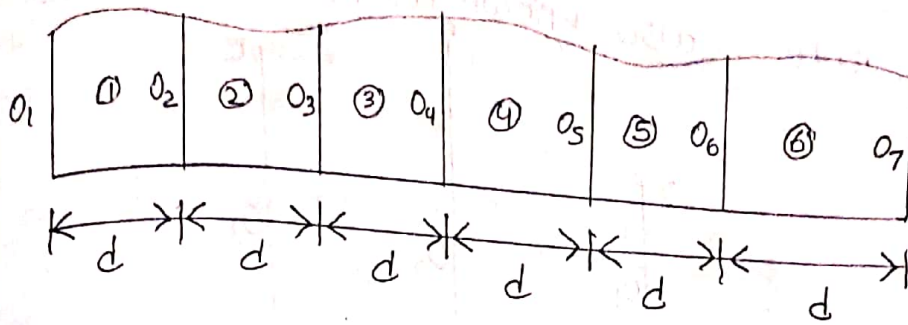
$O_1, O_2, O_3, \dots, O_{n+1}$ = ordinates at regular interval

$$\text{Area of plot (A)} = \frac{O_1 + O_2 + O_3 + \dots + O_{n+1}}{n+1} \times L$$

i.e,
$$\text{Area (A)} = \frac{\text{sum of ordinates}}{\text{No of ordinates}} \times \text{Length of base line}$$

3- Trapezoidal rule :-

3- Trapezoidal rule :-



Let, $n = \text{NO of divisions}$

$n+1 = \text{NO OF ordinates}$

$d = \text{common distance b/w two ordinates}$

$O_1, O_2, O_3, \dots, O_{n+1} = \text{ordinates at equal interval}$

1st Average area $= \left(\frac{O_1 + O_2}{2} \right) \times d$

2nd $= \left(\frac{O_2 + O_3}{2} \right) \times d$

3rd $= \left(\frac{O_3 + O_4}{2} \right) \times d$

Last $= \left(\frac{O_n + O_{n+1}}{2} \right) \times d$

Total Area = 1st Avg Area + 2nd Avg Area + 3rd Avg Area + ... + Last Avg Area

$$= \left(\frac{O_1 + O_2}{2} \right) \times d + \left(\frac{O_2 + O_3}{2} \right) \times d + \left(\frac{O_3 + O_4}{2} \right) \times d + \dots + \left(\frac{O_n + O_{n+1}}{2} \right) \times d$$

$$= \frac{d}{2} \{ O_1 + O_2 + O_2 + O_3 + O_3 + O_4 + \dots + O_n + O_{n+1} \}$$

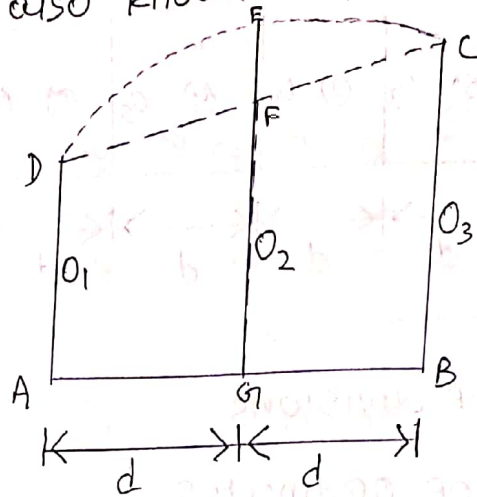
$$= \frac{d}{2} \times \{ O_1 + 2O_2 + 2O_3 + 2O_4 + \dots + 2O_n + O_{n+1} \}$$

$$= \frac{d}{2} \times \{ O_1 + O_{n+1} + 2(O_2 + O_3 + O_4 + \dots + O_n) \}$$

i.e, Total Area $= \frac{\text{common distance}}{2} \times \left\{ \begin{array}{l} \text{1st ordinate + Last ordinate} \\ + 2(\text{sum of intermediate ordinates}) \end{array} \right\}$

4- Simpson's rule :-

*- This rule is also known as parabolic rule.



*- In this method we assume that boundary b/w the ordinates are parabolic

Let, $\Delta_1 = \text{Area of } ABCD$

Area of $ABCD (\Delta_1) = \text{Area of trapezium } ABCD$
 $+$
 Area of $DFCED$

$$\text{Area of trapezium } ABCD = \frac{O_1 + O_3}{2} \times 2d$$

$$\text{Area of segment } DFCE = \frac{2}{3} \times FE \times 2d$$

$$= \frac{2}{3} \times (E - G) \times 2d$$

$$= \frac{2}{3} \times \left(O_2 - \frac{(O_1 + O_3)}{2} \right) \times 2d$$

$$= \frac{2}{3} \times \left(\frac{2O_2 - O_1 - O_3}{2} \right) \times 2d$$

$$= \frac{2O_2 - O_1 - O_3}{3} \times 2d$$

Area b/w 1st two division (i.e. O_1, O_2, O_3)

$$\Delta_1 = \text{Area of } ABCD + \text{Area of } DFCE$$

$$\Delta_1 = \frac{O_1 + O_3}{2} \times 2d + \frac{2O_2 - O_1 - O_3}{3} \times 2d$$

$$= 2d \times \left\{ \frac{O_1 + O_3}{2} + \frac{2O_2 - O_1 - O_3}{3} \right\}$$

$$= 2d \times \left\{ \frac{3O_1 + 3O_3 + 4O_2 - 2O_1 - 2O_3}{6} \right\}$$

$$= \frac{2d}{6} \times \{ 3O_1 - 2O_1 + 4O_2 + 3O_3 - 2O_3 \}$$

$$= \frac{d}{3} \times (O_1 + 4O_2 + O_3) \quad \text{--- (1)}$$

Similarly,

Let Area b/w next two division (i.e. O_3, O_4, O_5) = Δ_2

$$\Delta_2 = \frac{d}{3} \times (O_3 + 4O_4 + O_5) \quad \text{--- (1)}$$

Total area of this two part (i.e. O_1, O_2, O_3 & O_3, O_4, O_5)

$$\Delta = \Delta_1 + \Delta_2$$

$$= \frac{d}{3} \times (O_1 + 4O_2 + O_3) + \frac{d}{3} \times (O_3 + 4O_4 + O_5)$$

$$= \frac{d}{3} \times \{ O_1 + 4O_2 + O_3 + O_3 + 4O_4 + O_5 \}$$

$$= \frac{d}{3} \times \{ O_1 + O_5 + 4O_2 + 4O_4 + 2O_3 \}$$

ie, Total Area = $\frac{\text{Common distance}}{2} \times \left\{ \begin{array}{l} \text{1st ordinate + Last ordinate} \\ + 4(\text{sum of even ordinates}) \\ + 2(\text{sum of remaining odd ordinates}) \end{array} \right\}$

Limitation of Simpson's rule :-

*- Simpson's rule is applicable only when the number of divisions is even (i.e. number of ordinates is odd)

*- If the number of division is odd, then we calculate the area of last division separately & rest are calculated by using Simpson's rule.

ie, $\text{Odd division} = \text{Even division} + 1$

$\downarrow \qquad \qquad \qquad \downarrow$

calculate area by using Simpson's rule calculate area separately.

Difference b/w Trapezoidal rule & Simpson's rule :-

Trapezoidal Rule	SIMPSON'S RULE
*- The boundary b/w the ordinates is consider to be straight.	*- The boundary b/w the ordinates is consider to be parabolic.
*- There is no limitation for no of division as well as no of ordinates	*- To apply this rule, number of division must be even. That is the number of ordinates must be odd.
*- It gives an approximate result.	*- It gives accurate result

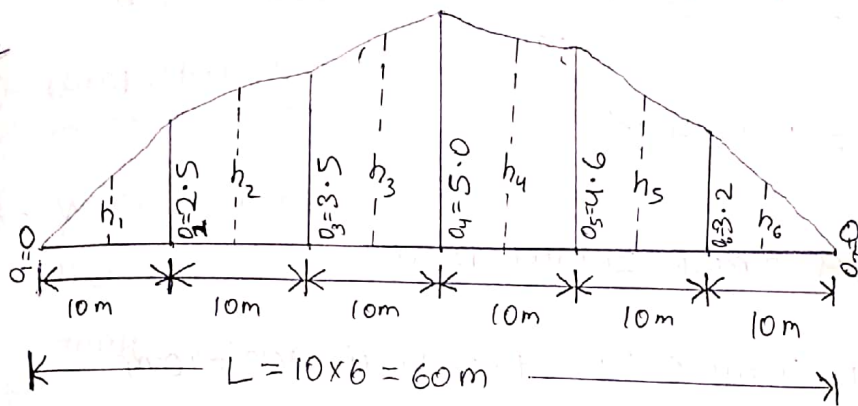
Q The following offset were taken from a chain line to an irregular boundary line at an regular interval of 10m is:-

0, 2.5, 3.5, 5.0, 4.6, 3.2, 0 m

compute the area of boundary by using :-

- a - mid ordinate method
- b - Average ordinate method
- c - Trapezoidal rule
- d - Simpson's rule.

Ans



a - Area by mid ordinate method:-

d = common distance b/w two ordinate = 10m

$$h_1 = \frac{0 + 2.5}{2} = 1.25$$

$$h_4 = \frac{5.0 + 4.6}{2} = 4.80$$

$$h_2 = \frac{2.5 + 3.5}{2} = 3.00$$

$$h_5 = \frac{4.6 + 3.2}{2} = 3.90$$

$$h_3 = \frac{3.5 + 5.0}{2} = 4.25$$

$$h_6 = \frac{3.2 + 0}{2} = 1.60$$

Total Area = common distance x sum of mid ordinates

$$= d \times (h_1 + h_2 + h_3 + h_4 + h_5 + h_6)$$

$$= 10 \times (1.25 + 3.00 + 4.25 + 4.80 + 3.90 + 1.60)$$

$$= 188 \text{ m}^2$$

b- Area by average ordinate method :-

d = common distance b/w two ordinate = 10 m

L = Length of base line = $10 \times 6 = 60$ m

n = No of division = 6

n+1 = No of ordinates = 7

$$\begin{aligned}\text{Total area} &= \frac{\text{sum of ordinates}}{\text{No of ordinates}} \times \text{Length of base line} \\ &= \frac{0 + 2.5 + 3.5 + 5.0 + 4.6 + 3.2 + 0}{7} \times 60 \\ &= 161.14 \text{ m}^2\end{aligned}$$

c- Area by Trapezoidal rule :-

d = common distance b/w two ordinates = 10 m

$$\begin{aligned}\text{Total Area} &= \frac{\text{common distance}}{2} \times \left\{ \begin{array}{l} \text{1st ordinate} + \text{Last ordinate} \\ + 2(\text{sum of intermediate ordinate}) \end{array} \right\} \\ &= \frac{10}{2} \times \{ 0 + 0 + 2(2.5 + 3.5 + 5.0 + 4.6 + 3.2) \} \\ &= 188 \text{ m}^2\end{aligned}$$

d- Area by Simpson's rule :-

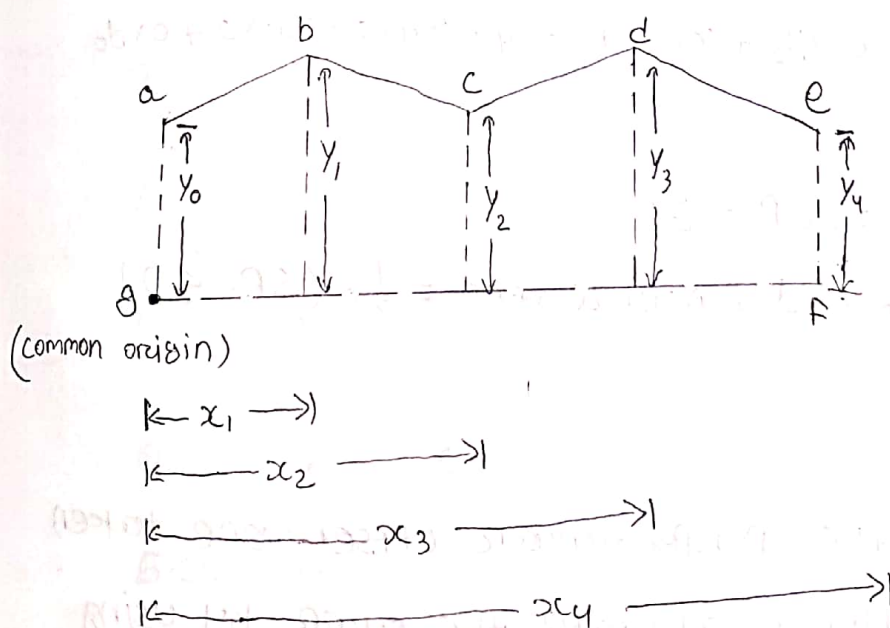
*- Here Simpson's rule is applicable, because no of divisions are even (i.e 6)

d = common distance b/w two ordinates = 10 m

$$\begin{aligned}
 \text{Total Area} &= \frac{\text{Common distance}}{3} \times \left\{ \begin{array}{l} \text{1st ordinate + Last ordinate} \\ + 4 (\text{sum of even ordinate}) \\ + 2 (\text{sum of remaining odd ordinate}) \end{array} \right\} \\
 &= \frac{d}{3} \times \left\{ 0_1 + 0_7 + 4(0_2 + 0_4 + 0_6) + 2 \times (0_3 + 0_5) \right\} \\
 &= \frac{10}{3} \times \left\{ 0 + 0 + 4(2.5 + 5.0 + 3.2) + 2(3.5 + 4.6) \right\} \\
 &= 196.67 \text{ m}^2
 \end{aligned}$$

C- Computation of Area from co-ordinate method :-

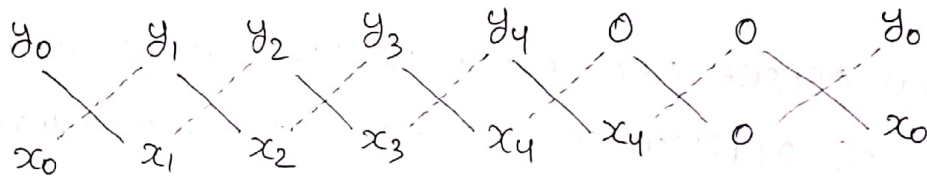
- * - When offset are taken at very irregular interval then the application of mid ordinate, Avg ordinate, Trapezoidal & Simpson's rule is very difficult
- * - In such case the co-ordinate method is applicable.
- * - In this method the co-ordinate of each boundary point is determined from a common origin.



points	co-ordinates	
	x	y
a	$x_0 = 0$	y_0
b	x_1	y_1
c	x_2	y_2
d	x_3	y_3
e	x_4	y_4
f	x_4	0
g	0	0
a	$x_0 = 0$	y_0

*- The co-ordinates are arranged in the following form:-

a b c d e f g a



Sum of product of solid lines:-

$$\sum P = y_0 x_1 + y_1 x_2 + y_2 x_3 + y_3 x_4 + y_4 x_4 + 0 x_0 + 0 x x_0$$

sum of product of dotted lines

$$\sum Q = x_0 y_1 + x_1 y_2 + x_2 y_3 + x_3 y_4 + x_4 x_0 + x_4 x_0 + 0 x y_0$$

$$\text{Double Area} = \sum P - \sum Q$$

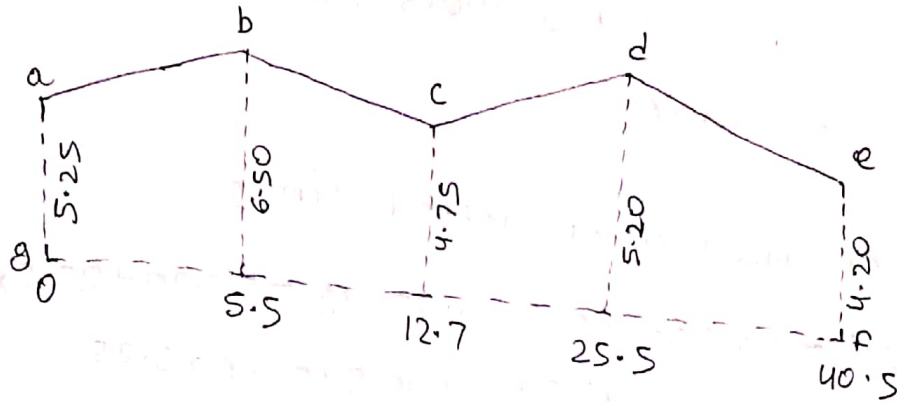
$$\text{Required Area} = \frac{1}{2} \times \text{Double Area} = \frac{1}{2} \times (\sum P - \sum Q)$$

Q

Following are the perpendicular offset were taken from a chain line. calculate the area by using co-ordinate method.

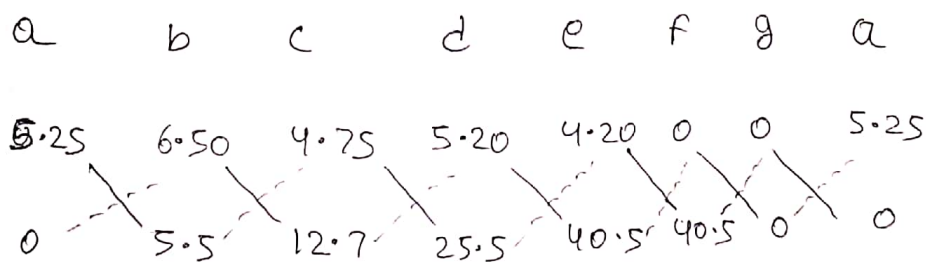
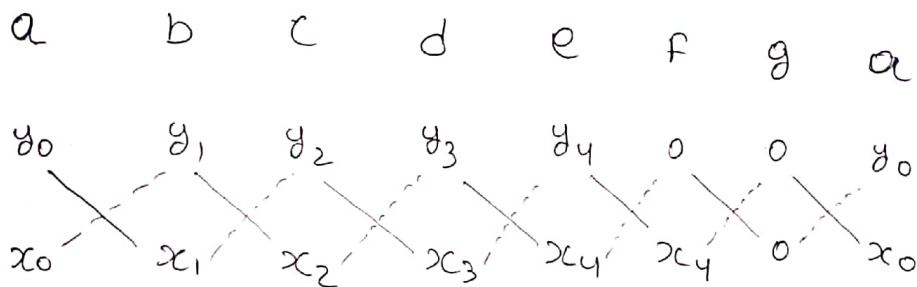
chainage (m) $\rightarrow$ 0, 5.5, 12.7, 25.5, 40.5
 offset (m) $\rightarrow$ 5.25, 6.50, 4.75, 5.20, 4.20

Ans



points	co-ordinates	
	x	y
a	$x_0 = 0$	$y_0 = 5.25$
b	$x_1 = 5.5$	$y_1 = 6.50$
c	$x_2 = 12.7$	$y_2 = 4.75$
d	$x_3 = 25.5$	$y_3 = 5.20$
e	$x_4 = 40.5$	$y_4 = 4.20$
f	$x_4 = 40.5$	0
g	0	0
a	$x_0 = 0$	$y_0 = 5.25$

The co-ordinates are arranged in the following form:-



Sum of product of solid lines

$$\begin{aligned}\Sigma P &= 5.25 \times 5.5 + 6.50 \times 12.7 + 4.75 \times 25.5 + 5.20 \times 40.5 \\ &\quad + 4.20 \times 40.5 + 0 \times 0 + 0 \times 0 \\ &= 613.26\end{aligned}$$

Sum of product of dotted lines

$$\begin{aligned}\Sigma Q &= 0 \times 6.50 + 5.5 \times 4.75 + 12.7 \times 5.20 + 25.5 \times 4.20 \\ &\quad + 40.5 \times 0 + 40.5 \times 0 + 0 \times 5.25 \\ &= 199.27\end{aligned}$$

$$\text{Double Area} = \Sigma P - \Sigma Q = 613.26 - 199.27 = 413.99$$

$$\text{Required Area} = \frac{1}{2} \times \text{Double Area} = \frac{1}{2} \times 413.99 = 206.995 \text{ m}^2$$

A



1.

A - Trapezoidal rule :- (or end area method)

* - volume of cutting or filling = V

$$V = \frac{d}{2} \times \{ A_1 + A_{n+1} + 2(A_2 + A_3 + \dots + A_n) \}$$

i.e, volume = $\frac{\text{common distance}}{2} \times \left\{ \begin{array}{l} \text{Area of 1st section} \\ + \\ \text{Area of last section} \\ + \\ 2 \times (\text{sum of area of other section}) \end{array} \right\}$

A = cross-sectional area.

B - prismoidal rule :-

* - volume of cutting or filling = V

$$V = \frac{d}{3} \times \{ A_1 + A_{n+1} + 4 \times (A_2 + A_4 + \dots + A_n) + 2 \times (A_3 + A_5 + \dots + A_{n+1}) \}$$

i.e, volume = $\frac{\text{common distance}}{3} \times \left\{ \begin{array}{l} \text{Area of 1st section} \\ + \\ \text{Area of last section} \\ + \\ 4 \times (\text{sum of area of even section}) \\ + \\ 2 \times (\text{sum of area of odd section}) \end{array} \right\}$

* - Prismoidal formula is applicable when there are an odd number of section.

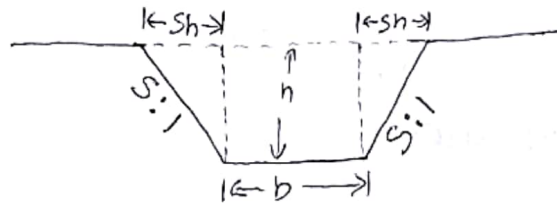
* - If the number of section is even, then the last strip is treated separately & remaining area is calculated by using prismoidal formula.

* - Then both the result are added to obtain the total volume.

Calculation of cross-sectional area :-

* Following are the different area of different level secⁿ :-

A - For level secⁿ :-



side slope = $S:1$
 ↓ ↓
 Horizontal Vertical

i.e.,

For 1 vertical, horizontal will be = S

For h vertical, horizontal will be = Sh

$$\text{cross-sectional area (A)} = b \times h + 2 \times \frac{1}{2} \times sh \times h.$$

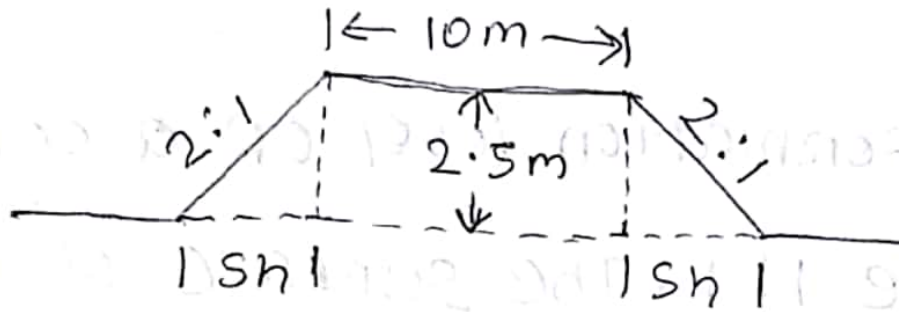
$$= b \times h + Sh^2$$

$$= h(b + Sh)$$

Q

calculate the sectional area of an embankment of 10 m wide with a side slope of 2:1. The ground level in a transverse direction to the centre line. The central height of the embankment is 2.5 m.

Ans



Here, $s = 2$ $b = 10 \text{ m}$ $h = 2.5 \text{ m}$

$$\text{sectional Area} = b \times h + 2 \times \frac{1}{2} \times sh \times h$$

$$= bh + sh^2$$

$$= h(b + sh)$$

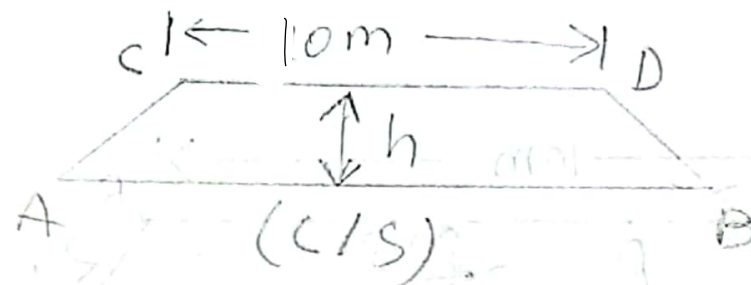
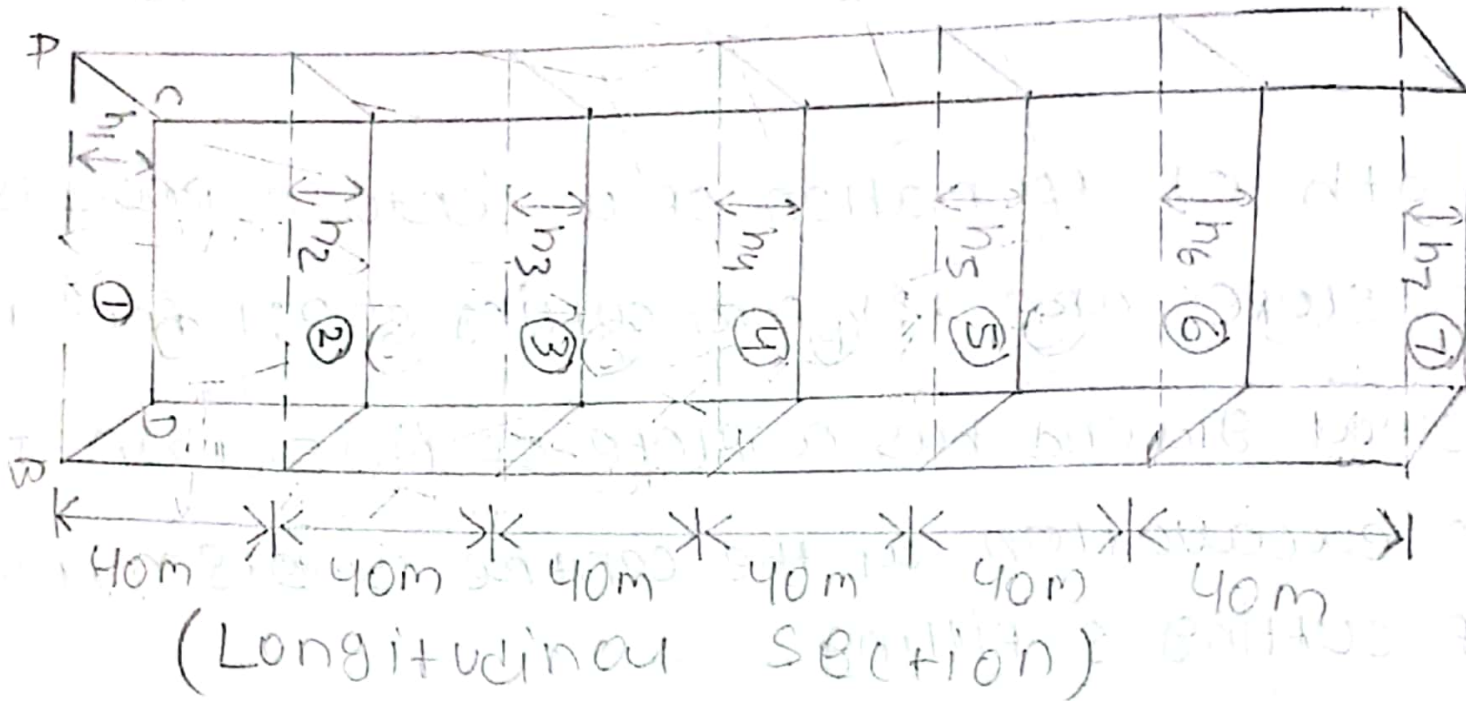
$$\begin{aligned} \text{M.O.P} &= 2.5(10 + 2 \times 2.5) \\ &= 37.5 \text{ m}^2 \end{aligned}$$

Problem 1 An embankment of width 10 m and side slopes $1\frac{1}{2} : 1$ is required to be made on a ground which is level in a direction transverse to the centre line. The central heights at 40 m intervals are as follows:

0.90, 1.25, 2.15, 2.50, 1.85, 1.35, and 0.85

Calculate the volume of earth work according to (i) the trapezoidal formula, and (ii) the prismoidal formula.

Ans



Here, $b = 10\text{m}$ $S = 1.5$ $d = 40\text{m}$
 $h_1 = 0.9\text{m}$ $h_2 = 1.25\text{m}$ $h_3 = 2.5\text{m}$ $h_4 = 2.50$
 $h_5 = 1.85\text{m}$ $h_6 = 1.35\text{m}$ $h_7 = 0.85\text{m}$

Let its A & B Point is in same level

$$\begin{aligned}\text{Cross sectional Area (A)} &= b \times h + 2 \times \frac{1}{2} \times s \times h \times h \\ &= bh + sh^2 \\ &= h(b + sh)\end{aligned}$$

$$A_1 = h_1(b + sh_1) = 0.9(10 + 1.5 \times 0.9) = 10.22 \text{ m}^2$$

$$A_2 = h_2(b + sh_2) = 1.25(10 + 1.5 \times 1.25) = 14.84 \text{ m}^2$$

$$A_3 = h_3(b + sh_3) = 2.15(10 + 1.5 \times 2.15) = 28.43 \text{ m}^2$$

$$A_4 = h_4(b + sh_4) = 2.50(10 + 1.5 \times 2.50) = 34.38 \text{ m}^2$$

$$A_5 = h_5(b + sh_5) = 1.85(10 + 1.5 \times 1.85) = 23.63 \text{ m}^2$$

$$A_6 = h_6(b + sh_6) = 1.35(10 + 1.5 \times 1.35) = 16.23 \text{ m}^2$$

$$A_7 = h_7(b + sh_7) = 0.85(10 + 1.5 \times 0.85) = 9.58$$

A- volume by trapezoidal rule :-

$$\begin{aligned}V &= \frac{d}{2} \times \{ A_1 + A_7 + 2(A_2 + A_3 + A_4 + A_5 + A_6) \} \\ &= \frac{40}{2} \times \{ 10.22 + 9.58 + 2(14.84 + 28.43 + 34.38 + 23.63 + 16.23) \} \\ &= 5096.4 \text{ m}^3\end{aligned}$$

B- volume by prismoidal rule :-

$$\begin{aligned}V &= \frac{d}{3} \times \{ A_1 + A_7 + 4(A_2 + A_4 + A_6) + 2(A_3 + A_5) \} \\ &= \frac{40}{3} \times \{ 10.22 + 9.58 + 4(14.84 + 34.38 + 16.23) + 2(28.43 + 23.63) \} \\ &= 5142.9 \text{ m}^3\end{aligned}$$

Problem 3 The ground level along the centre line of a road is given below:

Chainage (m)—	0	50	100	150	200	250	300
GL (m)—	117.50	116.25	115.95	116.65	117.20	117.85	115.75

It is proposed that the formation level of RL 115.00 should be kept constant of starting from the chainage 'zero'. The formation width of the road is 8 m and the side slope 1 : 1. The ground is level transverse to the centre line.

Solution

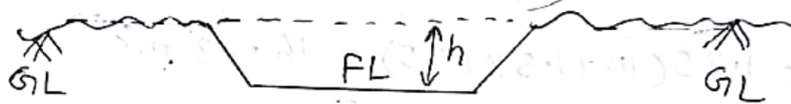
Ans

Here, $b = 8 \text{ m}$ $s = 1$ $d = 50$

B

Chainage	GL	FL	Cutting	Filling
0	117.50	115.00	2.50	
50	116.25	115.00	1.25	
100	115.95	115.00	0.95	
150	116.65	115.00	1.65	
200	117.20	115.00	2.20	
250	117.85	115.00	2.85	
300	115.75	115.00	0.75	

$$h_1 = 2.5 \quad h_2 = 1.25 \quad h_3 = 0.95 \quad h_4 = 1.65 \quad h_5 = 2.20 \quad h_6 = 2.85 \\ h_7 = 0.75$$



$$\text{C/S Area (A)} = b \times h + 2 \times \frac{1}{2} \times s \times h \times h = bh + sh^2 = h(b + sh)$$

$$A_1 = h_1(b + sh_1) = 2.5(8 + 1 \times 2.5) = 26.25 \text{ m}^2$$

$$A_2 = h_2(b + sh_2) = 1.25(8 + 1 \times 1.25) = 11.56 \text{ m}^2$$

$$A_3 = h_3(b + sh_3) = 0.95(8 + 1 \times 0.95) = 8.50 \text{ m}^2$$

$$A_4 = h_4(b + sh_4) = 1.65(8 + 1 \times 1.65) = 15.92 \text{ m}^2$$

$$A_5 = h_5(b + sh_5) = 2.20(8 + 1 \times 2.20) = 22.44 \text{ m}^2$$

$$A_6 = h_6(b + sh_6) = 2.85(8 + 1 \times 2.85) = 30.92 \text{ m}^2$$

$$A_7 = h_7(b + sh_7) = 0.75(8 + 1 \times 0.75) = 6.56 \text{ m}^2$$

A - volume by trapezoidal rule :-

$$V = \frac{d}{2} \times \{ A_1 + A_7 + 2(A_2 + A_3 + A_4 + A_5 + A_6) \} \\ = \frac{50}{2} \times \{ 26.25 + 6.56 + 2(11.56 + 8.50 + 15.92 + 22.44 + 30.92) \}$$

$$= 5287.25 \text{ m}^3$$

B - volume by prismoidal rule :-

$$V = \frac{d}{3} \times \{ A_1 + A_7 + 4(A_2 + A_4 + A_6) + 2(A_3 + A_5) \}$$

$$= \frac{50}{3} \times \{ 26.25 + 6.56 + 4(11.56 + 15.92 + 30.92) + 2(8.50 + 22.44) \}$$

$$= 5471.5 \text{ m}^3$$