

LEARNING MATERIAL

SEMESTER & BRANCH: 4TH SEMESTER CIVIL ENGINEERING

THEORY SUBJECT: LAND SURVEY-1 (TH-3)

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Surveying :-

Definition :-

→ Surveying is the art of determining the relative positions of different objects on the surface of the earth by measuring the horizontal distances between them & by preparing a map to any suitable scale.

→ Measurements are only taken in horizontal plane.

Object of Surveying :-

→ The aim of surveying is to prepare a map to show the relative positions of the object on the surface of the earth.

→ The map is drawn to some suitable scale. It shows the natural features of the country, such as towns, villages, road, railways, rivers, irrigation canals.

Uses of Surveying :-

(1) To prepare a Topographical map :-

It shows the hills, rivers, villages, towns of a country.

(2) To prepare a cadastral map :-

It shows the boundaries of fields, houses & other properties.

(3) To prepare an engineering map :- It shows

the details of engineering work such as roads

railways, Irrigation canals, Town Hall.

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(4) To prepare a military map:-

which shows the road & railway communications with different parts of a country. Such a map also shows the different important points for the defence of the country.

(5) To prepare a contour Map:-

It is used to determine the capacity of a reservoir & to find the best possible routes for roads & railways.

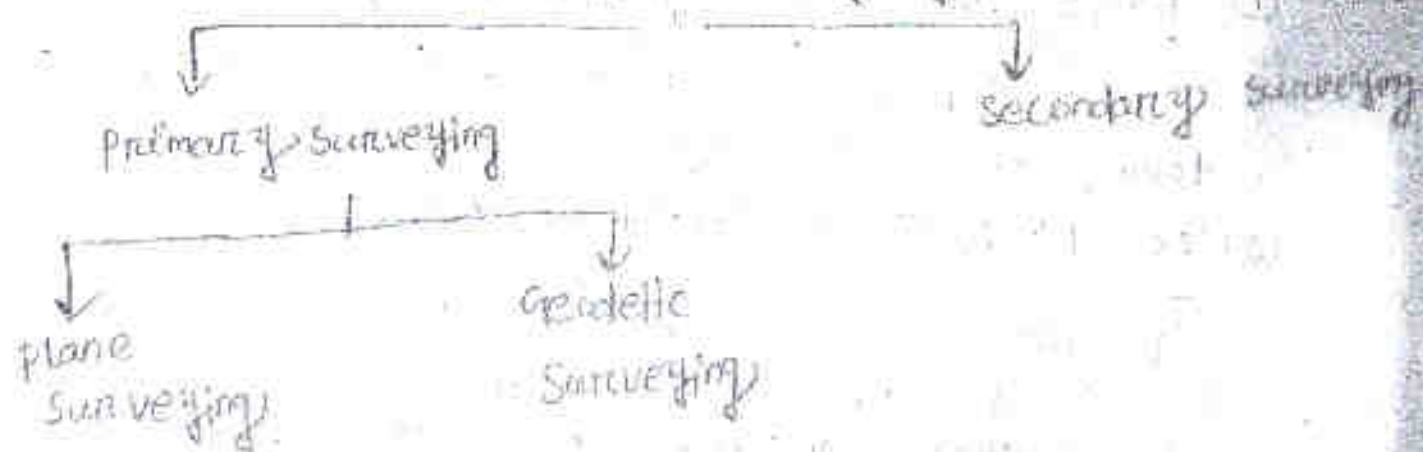
(6) To prepare a geological map:-

which shows the areas including underground resources.

(7) To prepare a archaeological map:-

The map including places where ancient relics exist.

classification of surveying



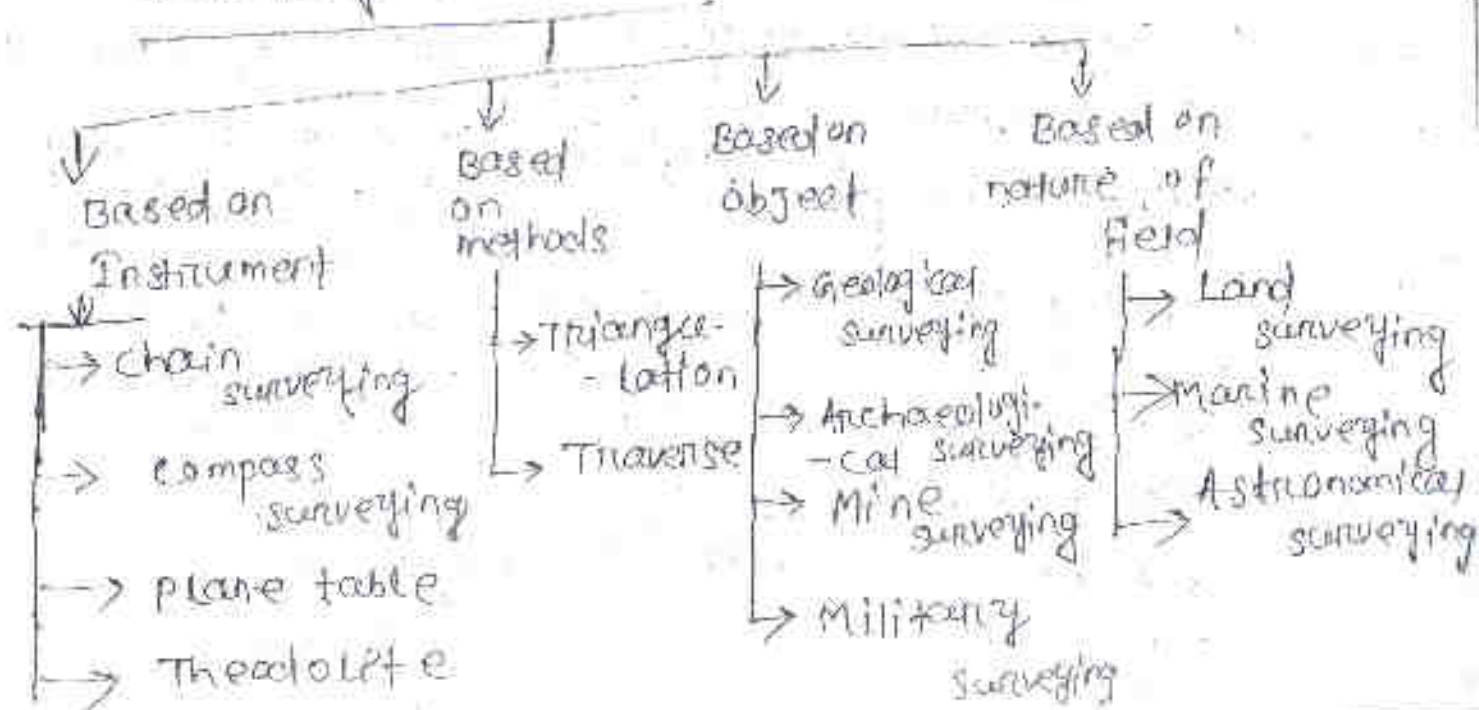
1.1.1 plane surveying

- The shape of earth is spheroidal. Thus the surface of the earth is curved.
- In plane surveying the curvature of the earth is neglected & it is assumed to be flat surface.
- In this surveying a line joining two points is considered to be straight.
- plane surveying is done on an area of less than 250 sqm.
- plane surveying conducted by state agencies like Irrigation department & railway department.

Geodetic Surveying

- In Geodetic surveying the curvature of the earth is considered.
- The line joining any two points is considered as curved line.
- It is used for large area i.e. greater than 250 sqm.
- This survey is conducted by the department of great trigonometrical survey (G.T.S) of India.

Secondary classification



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- Tacheometric
- Photographic

Based on methods:-

- (a) Triangulation surveying:- The lines form a system of triangles.
- (b) Traverse surveying:- The various stations form a polygon.

Based on object:-

- (a) Geological surveying:- The information about different strata of the earth's surface.
- (b) Mine surveying:- To find out the positions and volume of material in mines, bore holes for underground works.
- (c) Archaeological surveying:- To bring out the relics of antiquity.
- (d) Military surveying:- To determine the routes and points of strategic importance.

(ii) Based on nature of field:-

- (a) Topographical survey:- It is defined as the shape or configuration of the earth's surface it is used to locate the cities, hills, valleys, rivers, railway lines, roads, pipe line etc.

- (b) Cadastral survey:- To locate property boundaries of land.

- (c) City survey:- To locate layout of streets, buildings, towers, pipes etc within city limit.

- (d) Marine survey:- Survey conducted on or near

the body of water such as bay, lake, harbour, river etc. to estimate water flow and to determine shape of areas below the water surface.

- (iii) Astronomical survey:- Survey conducted to determine the latitudes, longitudes, azimuths, local time etc for various places on the earth by observing sun or stars.

1-19-8 Principles of surveying :-

- The principle of surveying are :-

- (a) To work from whole to the part.
- (b) To locate a new station by at least two measurements (linear or Angular) from fixed reference point.

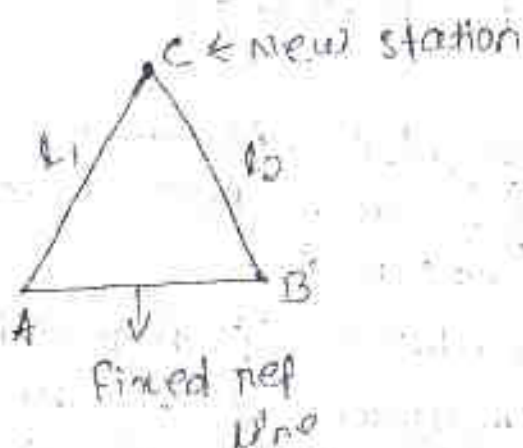
(a) To work from whole to the part :-

- The whole area is first enclosed by main stations & main survey line.
- The area is then divided into a number of well conditioned or equi-lateral triangle.
- The main survey line is measured very accurately. Then the side of triangle are measured.
- During this procedure if there is any error in measurement of any side of triangle, then it will not affect the whole work. The error can always be detected and eliminated.
- But if the reverse process (from part to the whole) is followed, then the minor error in measurement will get accumulated, magnified & become uncontrollable at the end of survey work.

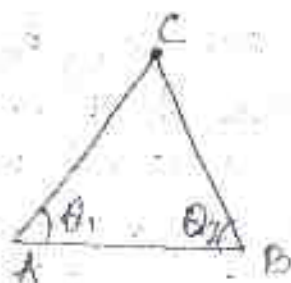
(b) To locate a new station :-

- The new station should always be fixed by at least two measurements from fixed reference point.
- The station can be located by taking
 - (a) Linear measurements
 - (b) Angular measurements
 - (c) Both Linear & Angular measurements

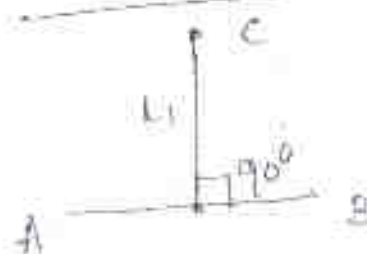
(a) Linear measurements



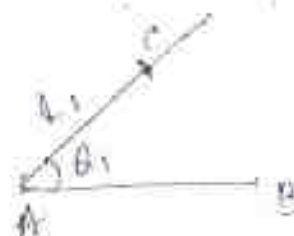
(b) Angular measurement



(c) Linear & Angular



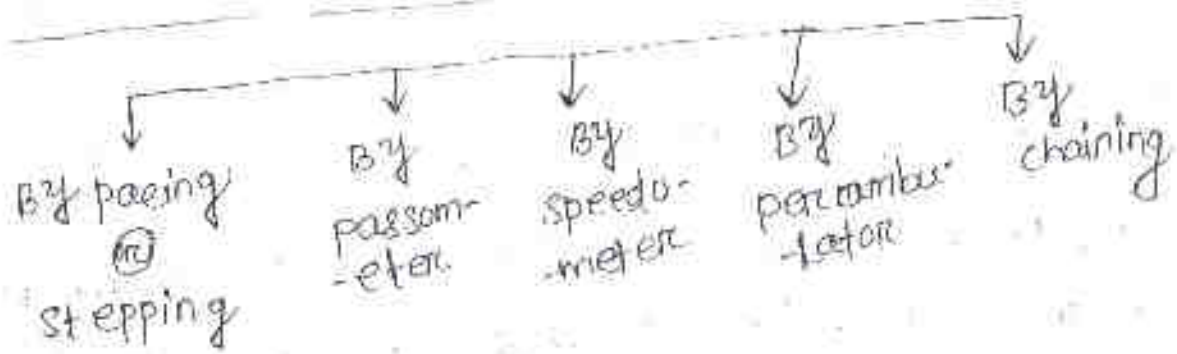
(OR)



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Methods of Linear measurement :-



By pacing ① stepping :-

⇒ For rough & speedy work, distances are measured by pacing, i.e. by counting the number of walking steps of a man.

⇒ The walking step of a man is considered 2.5 ft @ 80 cm.

⇒ This method is generally employed in the reconnaissance survey of any project.

By passometer :-

⇒ A small instrument just like a stop watch i.e. passometer which is used for counting the number of steps automatically which is some mechanical device.

⇒ It offers an improvement over the normal pacing method when a very long distance is to be measured & when it becomes very tedious to count & extremely difficult to remember to number of steps.

(iii) By speedometer:-

This is used in automobiles for recording distances.

(iv) By perambulation:-

- > It is a wheel fitted with a fork & handle.
- > The wheel is graduated & shows a distance per revolution.
- > There is a dial which records the no of revolution. Thus the distance can be measured.

(v) By chaining

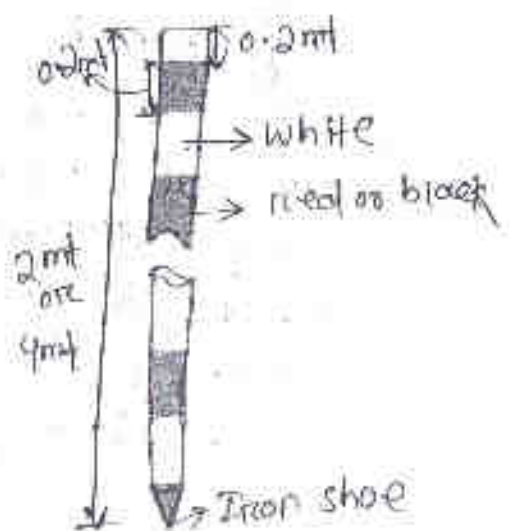
- > This is the accurate & common method for measuring the distance.
- > In this method for measurement chain or Tape is used.

Instruments used for Linear measurements:-

(1) Ranging rod:-

- > Rods which are used for ranging (i.e. the process of making a line straight) a line are known as ranging rods.

⇒ These are also used for making the main stations in chain surveying.



→ These rods are made of seasoned timber.

(a) seasoned bamboo.

→ Sometimes G.I pipes (Galvanised Iron) of 25 mm diameter are used as ranging rods.

→ They are generally circular in section & having length 2m & 4m.

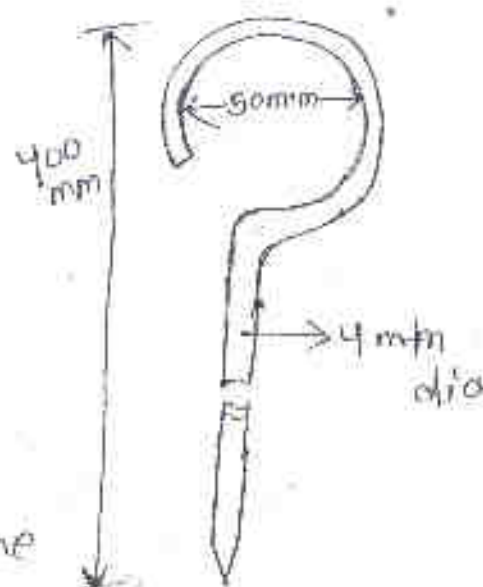
→ The rod is divided into equal parts of 20 cm each & the divisions are painted black & white (or) red & white so that the rod is visible from long distance. The lower end of the rod is pointed & it is called the iron shoe.

(2) Arrow :-

→ Arrows are made of steel wire of 4 mm diameter.

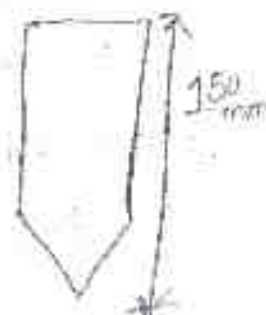
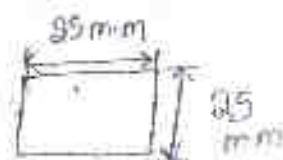
→ One end of the arrow is bent into a ring of 50 mm diameter & the other end is pointed.

→ It is used for counting the number of chains while doing chain surveying.



(3) peg :-

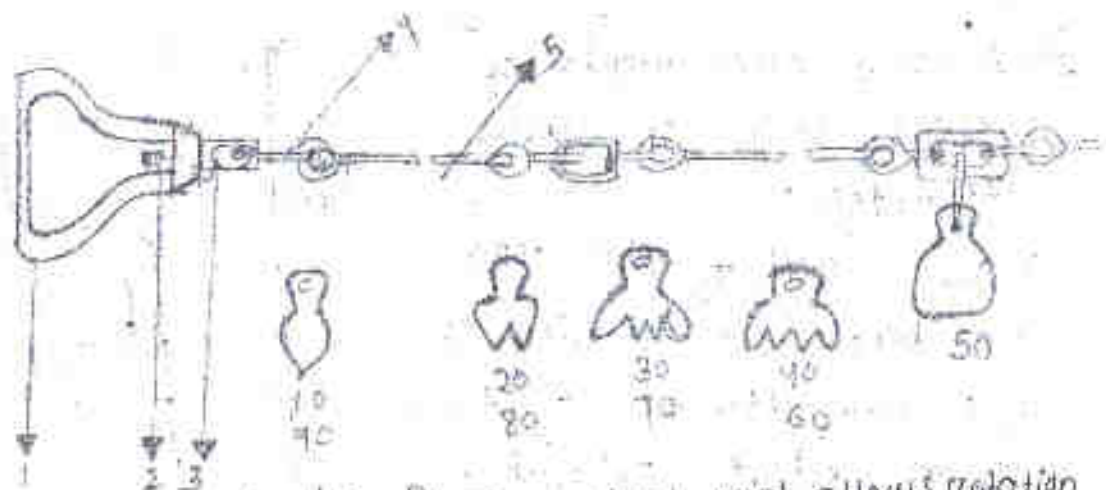
→ These are normally made of wood which having length 15 cm & 2.5 cm square at the top.



> These are used for marking the substation in surveying in survey line.

(4) chain

A chain is prepared with 100 or 150 pieces of galvanised mild steel wire of 4mm diameter. The ends of the pieces are bent to form loops. Then the pieces are connected together with the help of three oval rings, which make the chain flexible. Two brass handles are provided at the two ends of the chain. Tallies are provided at every 10 or 25 links for facility of counting. 'one link' means the distance between the centres of adjacent middle rings.



1. Brass handle
2. Collar
3. Eye bolt
4. Circuclawring
5. End link

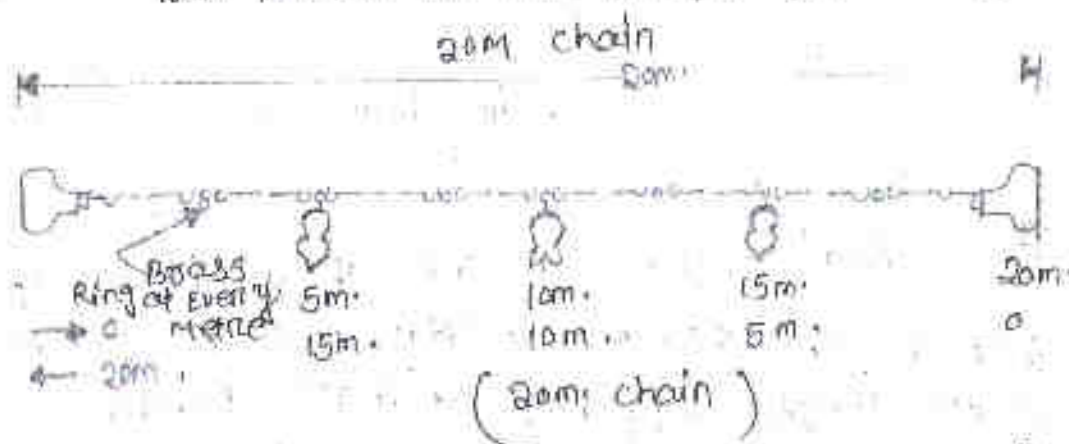
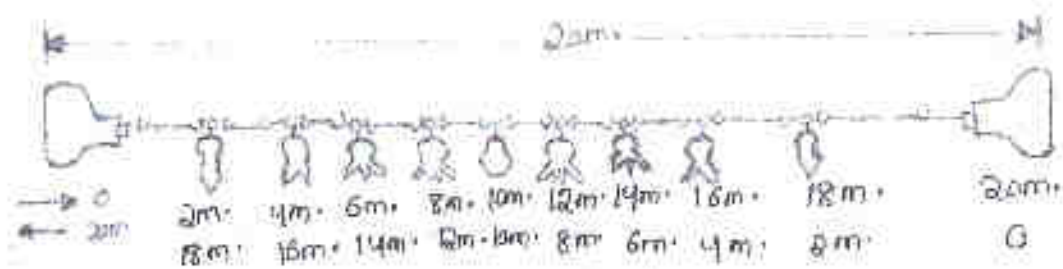
The swivel joint allows rotation of the handle preventing the deformation due to twist in the end link.

The following are the different types of chain.

- (a) Metric chain
- (b) Steel band
- (c) Engineers chain
- (d) Gunter's chain &
- (e) Revenue chain

(a) Metric chain :-

Metric chains are available in lengths of 20m. and 30m. The 20m. chain is divided into 100 links, each of 0.2m. tallies are provided at every 10 links (2m.). This chain is suitable for measuring distances along fairly level ground. The arrangement of tallies is shown :

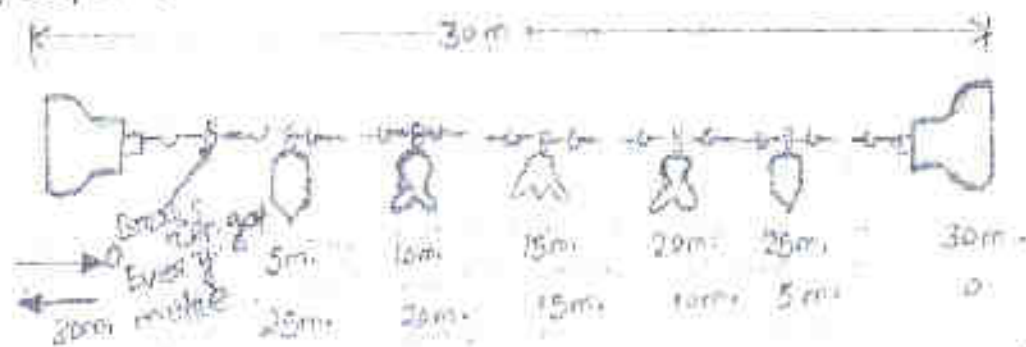


You may see from the arrangement of tallies that the central tally is round and that the other tallies have, one, two, three or four teeth. So each tooth may correspond to two different readings when considered from opposite ends. Therefore, during the measurement, the surveyor should bear in mind the position of the central tally.

As per IS: 1 recommendations, tallies should be provided after every 5m and brass rings after every 1m. The central tally has two teeth and the

tallies on opposite sides of it have one tooth each.

The 30m. chain is divided into 150 links. So, each link is of 0.2m. The tallies are provided after every 25 links. A round brass ring is fixed after every metre. This chain is heavy and is also suitable for measuring distances along fairly level ground. Here the central tally has three teeth.



(30m. chain)

(b) Steel band:- It consists of a ribbon of steel of 16mm. width and of 25mm. 30m. length. It has a brass handle at each end. It is graduated in metres, decimeters and centimeters on one side and has 0.2m link on the other. The steel band is used in projects where more accuracy is required.

(c) Engineer's chain:- The engineer's chain is 100 ft long and is divided into 100 links. So, each link is of 1 ft. Tallies are provided at every 10 links, the central tally being round. Such chains were previously

used for all engineering works.

(d) Quarters chain:- It is 66 ft long and divided into 100 links. So each link is of 0.66 ft. It was previously used for measuring distances in miles and furlongs.

(e) Revenue chain The revenue chain is 33 ft long and divided into 16 links. It is mainly used in cadastral survey.

Chains have the following advantages:-

- (i) They can be read easily and quickly.
- (ii) They can withstand wear and tear.
- (iii) They can be easily repaired or rectified in the field.

They have the following disadvantages:-

- (i) They are heavy and take too much time to open or fold.
- (ii) They become longer or shorter due to continuous use, the chain sags excessively.
- (iii) When the measurement is taken in suspension, the chain sags excessively.

Steel bands following advantages:-

- (i) They are very light and easy to open or fold.
- (ii) They maintain their standard length even after continuous use.
- (iii) When the measurement is taken in suspensions, they sag slightly.

Disadvantages :-

- (i) If handled carelessly, they break easily.
- (ii) They cannot be repaired in the field.
- (iii) They cannot be read easily.

Tapes :-

The following are the different types of tapes :

- (a) cloth or linen tape.
- (b) metallic tape.
- (c) steel tape &
- (d) Invar tape.

(a) cloth or linen tape :-

Such a tape is made of closely woven linen and is varnished to resist moisture. It is 15 mm wide and available in lengths of 10 and 15 m. This tape is generally used for measuring offsets and for ordinary work.

(b) Metallic Tape :- When linen tape is

reinforced with brass or copper wires to make it durable then it is called a metallic tape. This tape is available in lengths of 15, 20 and 30 m. It is wound on a leather case with a brass handle at the end. It is commonly used for all survey work.

(c) Steel Tape :- The steel tape is made of steel ribbon of width varying from 6 to 16 mm. The commonly available lengths are 10, 15, 20, 30 and 50 m. It is graduated in metres, decimetres and centimetres. It is not used in the field, but chiefly for standardizing chains and for measurements in constitutional works.

(d) Invar Tape :- Invar tape is made of an alloy of steel (64%) and nickel (36%). Its thermal coefficient is very low. Therefore, it is not affected by change of temperature. It is made in the form of a ribbon of 6 mm width and is available in length of 30, 50 and 100 m. It is used at places where maximum precision is required. It is generally used in the triangulation survey conducted by the Survey of India department.

RANGING :- The process of establishing intermediate points on a straight line between two end points is known as ranging. Ranging must be done before a survey line is chained. Ranging must be done by direct observation by the naked eye or by the ranger or by theodolite. Generally, ranging is done by the naked eye with the help of three ranging rods.

NOTE :- Line ranger is also used for ranging.

Ranging may be of two kinds:-

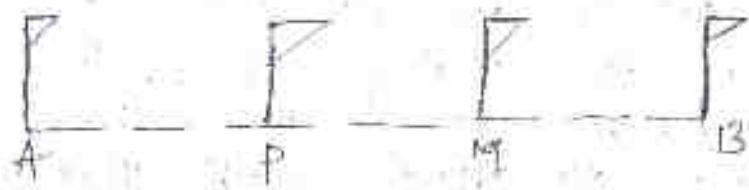
- (1) Direct, and
- (2) Indirect or reciprocal.

Direct Ranging - When intermediate ranging rods are fixed on a straight line by direct observation from end stations, the process is known as direct ranging.

Direct ranging is possible when the end stations are intervisible. The following procedure is adopted for direct ranging.

Assume that A and B are two end station 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. 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 slightly 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, the one exactly in the same straight line. To check the non-vertically 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 single 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.



(Direct Ranging)

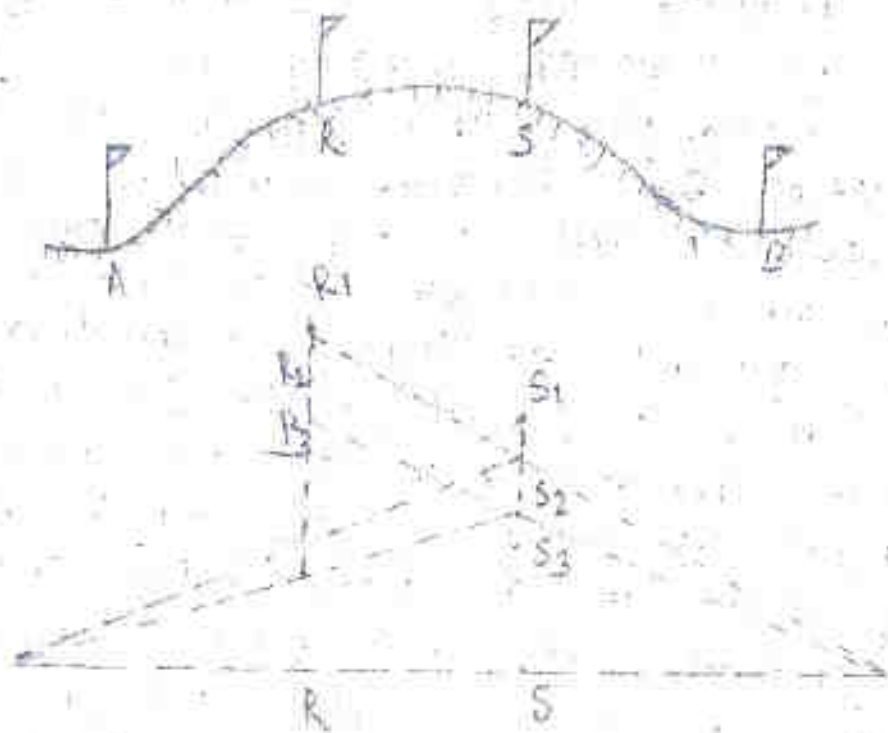
Indirect or Reciprocal Ranging -

When the end stations are not inter-visible due to there being high ground between them, intermediate ranging rods are fixed on the line in an indirect way. This method is known as indirect ranging or

reciprocal ranging. The following procedure is adopted for indirect ranging.

Suppose A and B are two end stations which are not inter-visible due to high ground existing between them. Suppose it is required to fix intermediate points between A and B. Two chainmen 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 chairman at R_1 directs the chairman at S_1 to come to the position S_0 so that R_1 , S_0 and B are in the same straight line. Again the chairman at S_0 direct the chairman at R_1 to move to the position at R_0 so that S_0 , R_0 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.



(Reciprocal Ranging)

UNFOLDING AND FOLDING A CHAIN

(1) unfolding :- To open a chain, the strap

is unfastened and the two brass handles are held in the left hand and the bunch is thrown forward with the right hand. Then one chainman stands at the starting station by holding one handle and another moves forward by holding the other handle until the chain is completely extended.

(2) folding :- To fold the chain, a chainman should move forward by pulling the chain at the middle. Then the two halves of the chain will come side by side. After this commencing from the central position of the chain, two pairs of links are taken at a time with the right hand and placed on the left hand alternately in both directions. Finally, the two brass handles will appear at the top. The bunch should be then fastened by the strap.

OBSTACLE IN CHAINING :- empty road

Conversion Table for units :-

Length

1 inch = 2.54 cm

12 inch = 1 foot

1 foot = 0.3048 m

3 foot = 1 yard

5 1/2 yard = 1 road @ pole

4 pole (66 ft) = 1 chain

10 chain = 1 furlong

8 furlong = 1 mile

6 feet = 1 fathom

100 fathoms = 1 cable

1 nautical mile - $\left\{ \begin{array}{l} \text{length} \\ \rightarrow 6,080 \text{ feet} \\ \rightarrow 1.152 \text{ mile} \\ \rightarrow 1.852 \text{ km} \end{array} \right.$

1 mile = 1,760 yard (or)

5,280 feet (or)

1.609 km.

1 dekametre = 10 decametre.

1 kilometre = 1000 metre

Area

1 acre = 48,400 square yards

(or)

→ 3.025 bighas

1 km² = 100 hectares

1 hectare = 10,000 m²

1 bigha = 1600 square yards

20 kathas = 1 bigha

LEADER AND FOLLOWER

The chainman at the forward end of the chain, who drags the chain forward, is known as the leader. The duties of the leader are as follows:—

- (i) To drag the chain forward with some arrows and a ranging rod,
- (ii) To fix arrows on the ground at the end of every chain, and
- (iii) To obey the instructions of the follower.

The chainman at the rear end of the chain, who holds the zero end of the chain at the station, is known as the

station, is known as the follower. The duties of the follower are as follows.

- (1) to direct the leader at the time of ranging.
- (2) to carry the rear handle of the chain
- (3) to pick up the arrows inserted by the leader.

METHOD OF CHAINING ON LEVEL GROUND

Before starting the chaining operation, two ranging rods should be fixed on the chain line, at the end stations. The other ranging rod, should be fixed near the end of each chain length, during the ranging operation.

To chain the line, the leader moves forward by dragging the chain and by taking with him a ranging rod and ten arrows. The follower stands at the starting station by holding the other end of the chain. When the chain is fully extended, the leader holds the ranging rod vertically at arm's length. The follower directs the leader to move his rod to the left or right, until the ranging rod is exactly in line. Then the follower holds the zero end of the chain by touching the station peg. The leader stretches the chain by moving it up and down with both hands, and finally places it on the line. He then inserts an arrow on the ground at the end of the chain and marks with a cross ('X').

Again, the leader moves forward by dragging the chain with nine arrows and the ranging rod. At the end of the chain he fixes another arrow as before. As the leader moves further, the follower picks up the arrows which were inserted by the leader. During chaining, the surveyor or an assistant should conduct the ranging operation.

In this way, chaining is continued. When all the arrows have been inserted and the leader has none left with him, the follower hands them over to the leader, this should be noted by the surveyor. To measure the remaining fractional length, the leader should hold the zero end of the chain at the last arrow. Then the odd links should be counted.

OBSTACLE IN CHAINING

A chain line may be interrupted in the following situations:

- (i) When chaining is free, but vision is obstructed,
- (ii) When chaining is obstructed, but vision is free.
- (iii) When chaining and vision are both obstructed.

Chaining free but vision obstructed

Such a problem arises when a rising ground or a jungle area interrupts the chain line. Here, the end

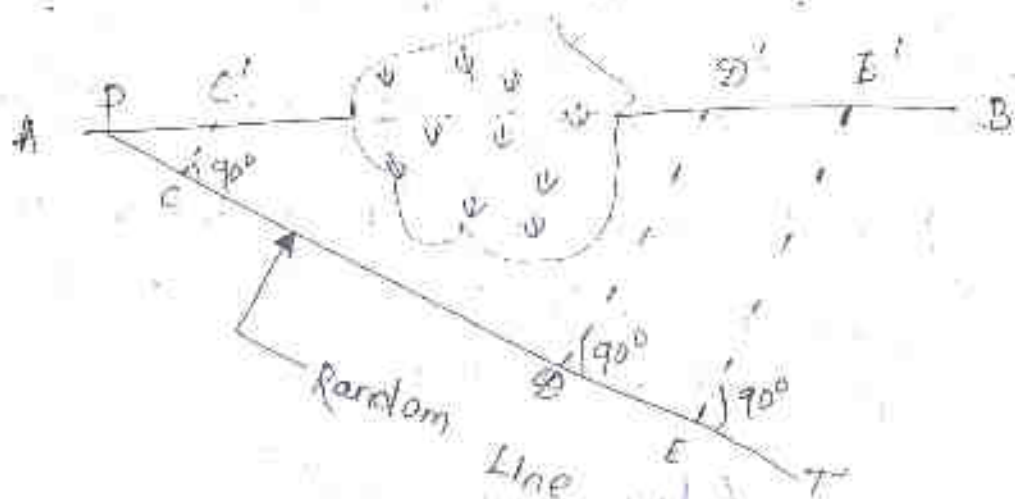
stations are not intervisible - There may be two cases -

case-1 The end stations may be visible from some intermediate points on the rising ground. In this case, reciprocal ranging is resorted to, and the chaining is done by the stepping method.

Case-2 The end stations are not visible from intermediate points when a jungle area comes across the chain line. In this case the obstacle may be crossed over using a random line as explained below.

Let AB the actual chain line which cannot be ranged and extended because of interruption by a jungle. Let the chain line be extended up to R . A point P is selected on the chain line and a random line, and perpendiculars are projected from them. The perpendicular at C meets the chain line at C_1 .

Theoretically, the perpendicular at D and E will meet the chain line at C_1 and E_1 now, the distances PC , PE , PC_1 and CE are measured.



From triangles POD , and PCE ,

$$\frac{DD'}{PD} = \frac{CC'}{PC}$$

$$DD' = \frac{CC'}{PC} \times PD \quad \text{--- (i)}$$

Again from triangles PEE' , and PCE'

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

$$EE' = \frac{CC'}{PC} \times PE \quad \text{--- (ii)}$$

From equation (i) and (ii) the lengths DD' , and EE' are calculated. These calculated distances are measured along the perpendiculars at D and E . points D' and E' should lie in the chain line AB , which can be extended accordingly.

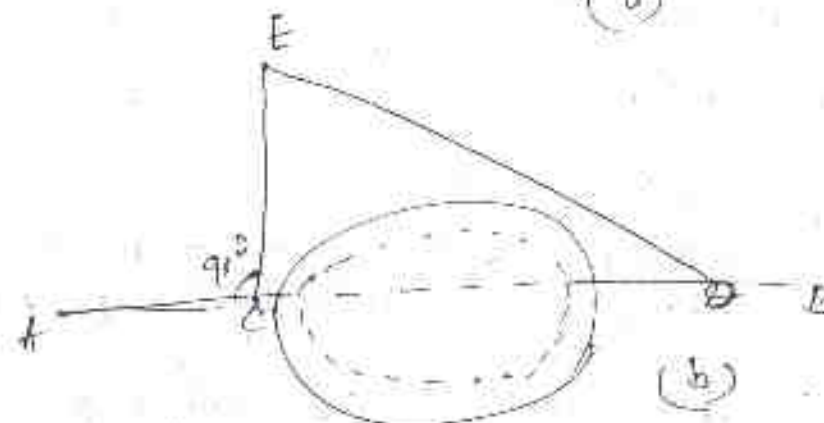
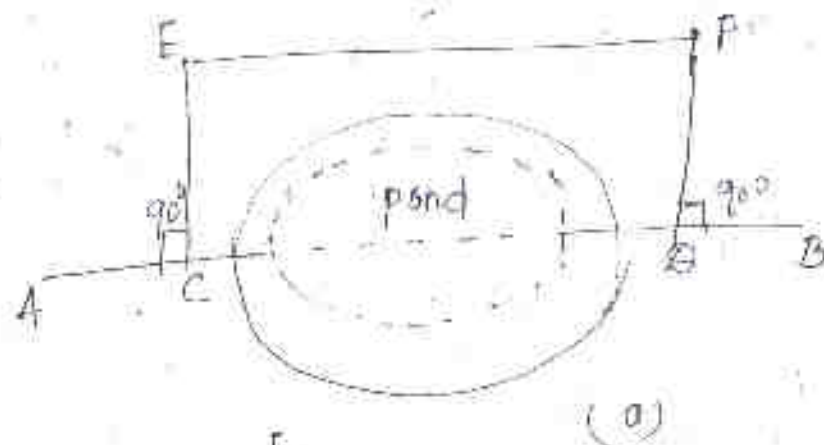
$$\text{Distance } PE_1 = \sqrt{PE^2 + EE'^2}$$

$$AB = AP + PE_1 + BE_1$$

Chaining obstructed but vision free.

Such a problem arises when a pond or a river comes across the chain line. The situations may be tackled in the following ways.

Case 1 When a pond interrupts the chain line, it is possible to go around the obstruction.



(chaining obstructed but vision free - pond)

Suppose AB is the chain line. Two points C and D are selected on it on opposite banks of the pond. Equal perpendiculars CE and DF are erected at C and D. The distance EF is measured. Here $CD = EF$.

The pond may be crossed by forming a triangle as shown. A point C is selected on the chain line. The perpendicular CE is set out at C and a line ED is suitably taken. The distances CE and ED are measured.

$$So \quad CD = \sqrt{ED^2 - CE^2}$$

In fig (a) ~~also~~ $AB = AC + CD + DB$

Case - 2 Sometimes it is not possible to go around the obstruction.

(a) Imagine a small river coming across the chain line. Suppose AB is

the chain line. Two points C and D are selected on this line on opposite banks of the river. At C a perpendicular CE is erected and bisected at F. A perpendicular is set out at E and a point G is so selected on it that D, F and G are in the same straight line.

From triangle DCF and GEF

$$GE = CD$$

The distance GE is measured, and thus the distance CD is obtained indirectly.

(b) Consider the case when a large river interrupts the chain line.

Let AB be the chain line. points C, D and E are selected on this line such that D and E are on opposite banks of the river. The perpendiculars DF and CG are erected on the chain line in such a way that E, F and G are on the same straight line. The line FH is taken parallel to CG.

Now, from triangles DEF and HFG.

$$\frac{ED}{DE} = \frac{FH}{HG} \quad \text{where } FH = CD$$

$$ED = \frac{FH}{HG} \times DF$$

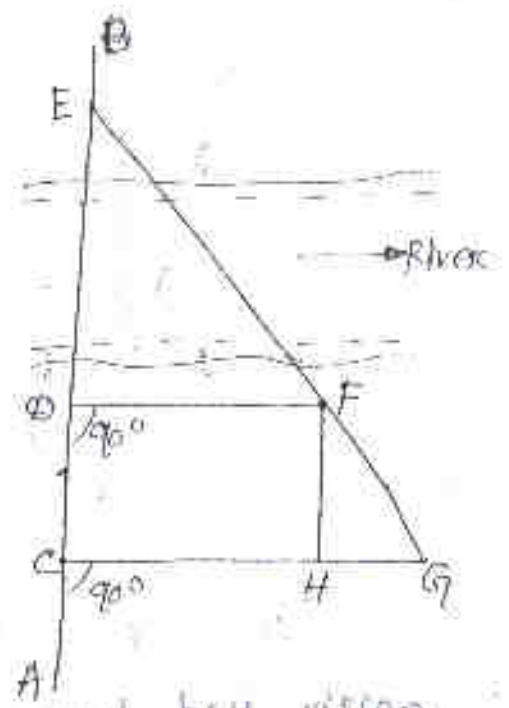
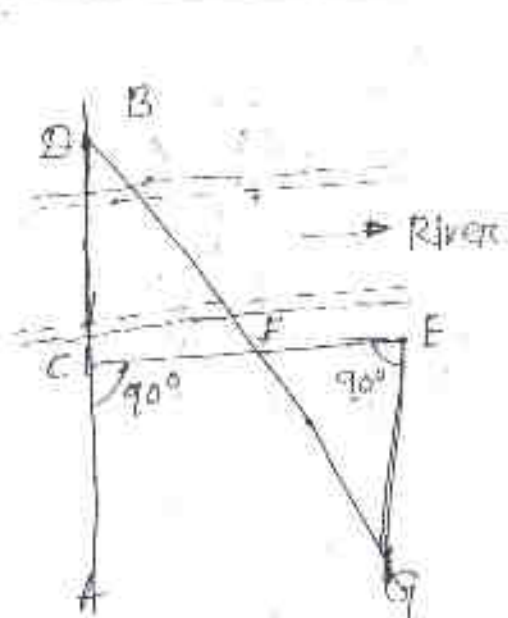
$$= \frac{CD}{CG - DF} \times DF$$

$$CH = DF$$

$$HG = CG - CH$$

$$\therefore HG = CG - DF$$

The distances CD, DF and CG are measured. Thus, the required distance ED can be calculated.



In fig (a) $AB = AC + CD + DB$

In fig (b) $AB = AC + CD + DE + EB$
(chaining obstructed but vision free - River)

Chaining and vision both obstructed:-

Such a problem arises when a building comes across the chain line. It is solved in the following manner.

Suppose AB is the chain line, two points C and D are selected on it on one side of the building. Equal perpendiculars CE and DF are erected. The line E'D' is extended until the building is crossed on the extended line, two points E' and F' are selected. Then perpendiculars E'E and F'F are so erected that $E'E = F'F = D'D = C'C$.

Thus, the points C, D, E and F will lie on the same straight line AB.
 $DE = D'E'$

Here the distance D'E' is measured, and is equal to the required distance.

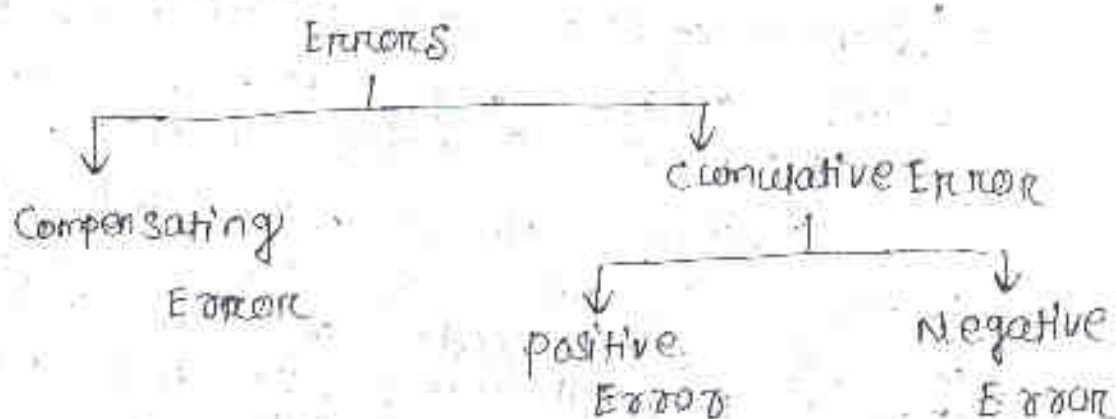


(chaining and vision both obstructed)

$$AB = AC + CD + DE + EF + FB$$

8 May 2021

Errors & mistakes in chaining :-



Compensating Error :-

Errors which may occur in both directions (i.e. both positive & negative) and which finally tend to compensate are known as compensating errors. These errors do not affect survey work seriously. They are proportional to $\sqrt{L}$, where L is the length of the line. Such errors may be caused by

- (a) Incorrect holding of the chain,
- (b) Horizontality and verticality of steps not being properly maintained during the stepping operation.
- (c) fractional parts of the chain or tape not being uniform throughout its length.
- (d) Inaccurate measurement of right angles with chain and tape.

Cumulative Errors :-

Errors which may occur in the same direction and which finally tend to accumulate are said to be cumulative. The seriously affect the accuracy of the work, and are proportional to the length of the line (L). The errors may be positive or negative.

Positive Errors :- when the measured

length is more than the actual length (i.e. when the chain is too short). The error is said to be positive. Such errors occur due to

- (a) The length of chain or tape being shorter than the standard length.
- (b) Slope correction not being applied.
- (c) Correction for sag not being made.
- (d) Measurement being taken with faulty alignment.
- (e) Measurement being taken in high winds with the tape in suspension.

Negative Errors - When the measured length of the line is less than the actual length (i.e. when the chain is too long) the error is said to be negative. These errors occur when the length of the chain or tape is greater than the standard length due to the following reasons -

- (a) The opening of ring joints.
- (b) The applied pull being much greater than the standard pull.
- (c) The temperature during measurement being much higher than the standard temperature.
- (d) Wearing of connective rings.
- (e) Elongation of the links due to heavy pull.

Mistakes Errors occurring due to the carelessness of the chainman are called mistakes. The following are a few common mistakes.

- (a) Displacement of arrows: once an arrow is withdrawn from the ground during chaining, it may not be replaced in proper position, if required due to some reason.
- (b) A full chain length may be omitted or added. This happens when arrows are lost or wrongly counted.
- (c) A reading may be taken from the end of the chain.

This happens when the bath of the tally is noted without observing the central tally (i.e. when the bath is noted from the wrong end)

- (d) The numbers may be read from the wrong direction: for instance, a '6' may be read as a '9'.
- (e) Some numbers may be called wrongly. For example, 50.2 may be called "fifty-two" without the decimal point being mentioned.

(f) While making entries in the field book, the figures may be interchanged due to carelessness: for instance, 245 may be entered instead of 254.

PRECAUTIONS AGAINST ERRORS AND MISTAKES:-

The following precautions should be taken to guard against errors and mistakes.

(1) The point where the arrows is fixed on the ground should be marked with a cross (X).

(2) The zero end of the chain or tape should be properly held.

(3) During chaining, the number of arrows carried by the follower and leader should always tally with the total numbers of arrows taken.

(4) While noting the measurement from the chain, the teeth of the tally should be verified with respect to the correct end.

(5) The chainman should call the measurement loudly and distinctly and the surveyor should repeat them while looking.

(6) Measurements should not be taken with the tape in suspension during high winds.

(7) In stopping operations, horizontally and vertically should be properly maintained.

(8) Ranging should be done accurately.

(9) No measurement should be taken with the chain in suspension.

(10) Care should be taken so that the chain is properly extended.

Chain & Tape Corrections :-

Tape

(i) Temperature Correction (Ct) :-

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

where α = Co-efficient of thermal expansion

C_t = in mt.

T_m = temperature during measurement in degree centigrade @ celcius.

T_0 = Temperature at which the tape was standardised in degree centigrade @ celcius.

L = Length of tape in mt.

NOTE

$$\begin{aligned} & \rightarrow (+ve) \rightarrow T_m > T_o \\ & \rightarrow (-ve) \rightarrow T_m < T_o \end{aligned}$$

* α (steel tape) $\rightarrow 11 \times 10^{-6}$ per degree centigrade @ celsius

2) Pull correction (C_p) — it may vary

$$C_p = \frac{(P_m - P_o) L}{A E}$$

where C_p = pull correction in mt
 P_m = pull applied during measure.
 in kg.

P_o = pull at which the tape was standardised, in kg

L = Length of tape, in mt

A = cross sectional area of tape, in cm^2

E = Modulus of elasticity
 (Young's modulus)

NOTE :-

$$\begin{aligned} & \rightarrow +ve \quad P_m > P_o \\ & \rightarrow -ve \quad P_m < P_o \end{aligned}$$

$$* E = 2.1 \times 10^6 \text{ kg/cm}^2$$

(3) Slope Correction (C_h) :-

$$C_h = l - \sqrt{l^2 - h^2}$$

NOTE:- This type of correction is always negative.

(*)

$$C_h = l (1 - \cos \theta)$$

(or)

$$C_h = \frac{h^2}{2l}$$

(4) Sag Correction (C_s) :-

$$C_s = \frac{L (wt)^2}{24n^2 P_m^2} \quad \text{and} \quad C_s = \frac{Lw^2}{24n^2 P_m^2}$$

Where C_s = sag correction in mt

L = Length of the tape @ chain in mt.

n = number of span

P_m = pull applied during measurement

w = weight of tape per unit length in kg per mt.

w = Total weight of tape in kg

NOTE:- This correction is always negative.

(5) Normal tension (P_n):-

⇒ The tension at which the effect of pull is neutralised by the effect of sag is known as normal tension.

$$P_n \rightarrow \begin{cases} \frac{(P_n - P_0)L}{AE} = \frac{L(wL)^2}{24P_n^2} \quad (\text{Assume}) \\ \frac{(P_n - P_0)L}{AE} = \frac{LW^2}{24P_n^2} \end{cases}$$

12 May 2021

(1) Chain:-

(1) correction applied to incorrect length:-

$$\boxed{\text{True length of the line (TL)} = \left(\frac{L'}{L}\right) \times ML}$$

where L = true length of chain

L' = True length $\pm$ error
= $L \pm e$

ML = measured length

NOTE :-

- * use (+ve) sign when the chain
- (a) tape is too long.
- * use (-ve) sign when it is too short.

(2) Correction of Incorrect Area :-

$$\text{True Area} = \left(\frac{L'}{L}\right)^2 \times \text{Measured Area}$$

(3) Hypotenusal Allowance :-

$$\text{Correction per tape length} = L (\sec \theta - 1)$$

L = length of tape

θ = slope of the ground

NOTE :-

It is always added to the chain length

16 - The distance between two points, measured with a 20 m chain was recorded as 327 m. It was afterwards found that the chain was 30 cm too long. What was the true distance between the points?

Data given :-

$$\text{True length} = \left(\frac{L'}{L} \right) \times ML$$

$$e = 30 \text{ m}$$

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

$$ML = 327 \text{ m}$$

$$L' = 20 + 0.03 = 20.03 \text{ m}$$

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

$$= 327.49 \text{ m}$$

$$\begin{aligned} \textcircled{10} \quad 20 \text{ m} &= 327 \text{ m} \\ 20.03 &= \frac{327}{20} \times (20.03) \\ &= \left(\frac{20.03}{20} \right) \times 327 \\ &= 327.49 \text{ m} \end{aligned}$$

20 The distance between two stations was 1200 m when measured with a 20 m chain. The chain was 0.05 m too long. The same distance when measured with a 30 m chain the measured length was found to be 1195 m. What was the error in 30 m chain?



20 m chain

$$e = +0.05 \text{ m}$$

$$L' = 20 + 0.05 = 20.05 \text{ m}$$

$$TL = \frac{L'}{L} \times ML$$

$$= \frac{20.05}{20} \times 1200$$

$$= 1203 \text{ m}$$

$$TL = 120.3 \text{ m}$$

$$L = 30 \text{ m}$$

$$ML = 119.5 \text{ m}$$

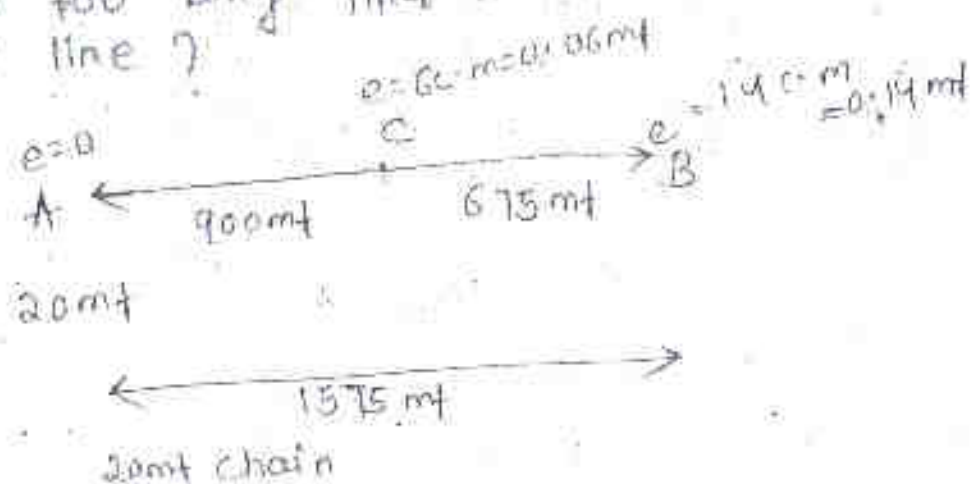
$$L' = 30 + e$$

$$TL = \frac{L'}{L} \times ML$$

$$\Rightarrow L' = \frac{TL \times L}{ML} = \frac{120.3}{119.5} \times 30 = 30.20 \text{ m}$$

$$e = L' - L = 30.20 - 30 = 0.20 \text{ m}$$

3 Q A line was measured by a 20m chain which was accurate before starting the day's work. After chaining, point the chain was found to be 6cm too long. After chaining a total distance of 1575m the chain was found to be 14cm too long. Find the true distance of the line?



$$AB(TL) = AC(TL) + CB(TL)$$

$$AC(TL) :-$$

$$L = 20 \text{ m}, ML = 900 \text{ m}, L' = 20 + e = 20 + 0.03 = 20.03 \text{ m}$$

$$e = 0 + 0.06 = 0.06 \text{ m}$$

$$AC(TL) = \frac{20 \cdot 03}{20} \times 900$$

$$= 901.35 \text{ mt}$$

$$CB(TL) :-$$

$$L = 20 \text{ mt}, \quad ML = 675 \text{ mt} \quad L' = 20 + e = 20.1 \text{ mt}$$

$$= 20 + 0.1 = 20.1 \text{ mt}$$

$$e = \frac{0.06 + 0.14}{2} = 0.1 \text{ mt}$$

$$CB(TL) = \frac{20.1}{20} \times 675 = 678.375 \text{ mt}$$

$$AB(TL) = 901.35 + 678.375 = 1579.72 \text{ mt}$$

(4) Q A 20 mt steel tape was standardised on flat ground, at a temperature of 20°C & under a pull of 15 kg. The tape was used at a temperature of 30°C & under a pull of 10 kg. The cross-sectional area of the tape is 0.22 cm^2 & its total weight is 400 gm. The young's modulus of elasticity is $2.1 \times 10^6 \text{ kg/cm}^2$ & $\alpha = 11 \times 10^{-6} \text{ per } ^\circ\text{C}$ find the correct horizontal distance.

Soln

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

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

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

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

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

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

$$\alpha = 11 \times 10^{-6} \text{ per } ^\circ\text{C}$$

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

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

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

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

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

$$\begin{aligned}
 (\delta p) &= \frac{(P_m - P_o) L}{AE} \\
 &= \frac{(10 - 15) 20}{0.22 \times 2.1 \times 10^6 \text{ kg/cm}^2} \\
 &= (-0.00238 \text{ m})
 \end{aligned}$$

$$\begin{aligned}
 C_s &= \frac{L w^2}{24 n^2 p m^2} = \frac{20 \times (0.04)^2}{24 \times 12 \times 10^2} \\
 &= 0.00133 \text{ m} (-ve)
 \end{aligned}$$

$$\text{Total correction} = +0.00220 - 0.00238 - 0.00133$$

$$\begin{aligned}
 \text{Correct horizontal distance} &= -1.5 \text{ m} \\
 &= 20 - 0.0015 \\
 &= 19.99849 \text{ m}
 \end{aligned}$$

50 A 30 m steel tape was standardised at a temperature of 20°C & under a pull of 5 kg. The tape was used at a temperature 25°C & under a pull of p kg. The cross-sectional area of tape is 0.02 cm^2 & its weight per unit length is 22 g/m . $E = 2 \times 10^6 \text{ kg/cm}^2$ & $\alpha = 11 \times 10^{-6} \text{ per } ^\circ\text{C}$. Find the correct distance if p is (a) 5 kg (b) 11 kg?

Solⁿ Given data:-

$$L = 30 \text{ m}$$

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

$$P_o = 5 \text{ kg}$$

$$T_m = 25^\circ\text{C}$$

$$A = 0.02 \text{ cm}^2$$

$$P_{m1} = 5 \text{ kg}, P_{m2} = 11 \text{ kg}$$

$$= 22 \text{ g/m}$$

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

$$\alpha = 11 \times 10^{-6} \text{ per } ^\circ\text{C}$$

$$n = 1$$

(a) $p = 5 \text{ kg}$

(i) $C_T = 11 \times 10^{-6} (25 - 20) \times 30$
 $= 0.00165 \text{ m} (\text{+ve})$

(ii) $C_P = \frac{(5 - 5) \times 30}{0.02 \times 2 \times 10^6} = 0$

(iii) $C_S = \frac{L(wL)^2}{24n^2 p^2 n} = \frac{30 \times (0.022 \times 30)^2}{24 \times 5^2}$
 $= 0.02178 (-\text{ve})$

$T_C = 0.00165 + 0.02178 = -0.02013$

Correct horizontal distance $= 3.0 - 0.0201$
 $= 29.979 \text{ m}$

(b) $p = 11 \text{ kg}$

(i) $C_T = 0.00165 \text{ m} (\text{+ve})$

(ii) $C_P = \frac{(11 - 5) \times 30}{0.02 \times 2 \times 10^6} = 0.0045 \text{ m} (\text{+ve})$

(iii) $C_S = \frac{L(wL)^2}{24n^2 p^2 n} = \frac{30 \times (0.022 \times 30)^2}{24 \times 11^2}$
 $= 0.0045 (-\text{ve})$

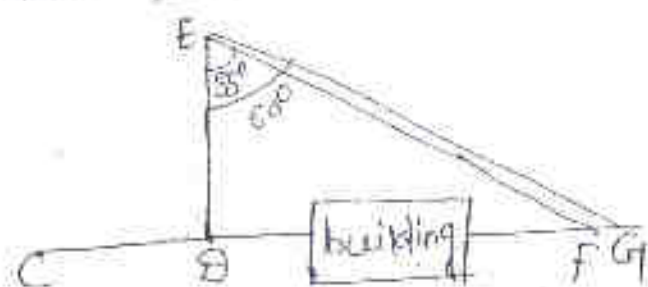
$T_C = +0.00165 + 0.0045 - 0.0045$
 $= 0.00165$

Correct HD $= 30 + 0.00165 = 30.00165 \text{ m}$

18 may 2021

18

A survey line CD intersects a building to overcome the obstacle a perpendicular DE, 85m long is set out at D from E, two lines EF & EG are set out at angles of 55° & 60° respectively with ED find the lengths EF & EG such that points F & G falls on the prolongation of CD. Also find the obstructed distance DF?



EF, EG, DF = ?

Solⁿ

$$\triangle DEF, \cos \theta = \frac{b}{h}$$

$$\cos 55^\circ = \frac{DE}{EF}$$

$$\Rightarrow EF = \frac{85}{\cos 55^\circ} = 148.19 \text{ m}$$

$$\triangle DEG, \cos \theta = \frac{b}{h}$$

$$\cos 60^\circ = \frac{DE}{EG}$$

$$EG = \frac{85}{\cos 60^\circ} = 170 \text{ m}$$

$$\triangle DEF, \tan \theta = \frac{p}{b}$$

$$\Rightarrow \tan 55^\circ = \frac{DF}{DE}$$

$$\Rightarrow DF = DE \times \tan 55^\circ$$

$$= 85 \times \tan(55^\circ) = 121.39 \text{ m}$$

26 An old map was plotted to a scale of 40m to 1cm over the years, this map has been shrinking & a line originally 20cm long is only 19.5cm at present. Again the 20m chain was 50m too long. If the present area of the map measured is 125.50 cm² find the true area of the land surveyed?

solⁿ

19.5cm on the map originally 20cm
 1cm on the map originally $= \frac{20}{19.5} = 1.0256$

$$1 \text{ cm}^2 \quad " \quad " \quad " = (1.0256)^2 \text{ cm}^2$$

$$125.50 \text{ cm}^2 \quad " \quad " \quad " = 125.50 \times 1.050625 \\ = 131.853 \text{ cm}^2$$

Scale on map 1cm = 40m ground

$$1 \text{ cm}^2 = (40)^2 \text{ m}^2 \text{ ground} \\ = 1600 \text{ m}^2$$

$$131.853 \text{ cm}^2 = 1600 \times 131.853 \text{ on ground} \\ = 210964.8 \text{ m}^2$$

$$\text{Correction for Area} = \left(\frac{L'}{L} \right)^2 \times M$$

$$= \left(\frac{20 + 0.05}{20} \right)^2 \times 210964.8$$

$$= 212020.94 \text{ m}^2$$

$$= 21.2020 \text{ hectare}$$

$$(1 \text{ hectare} = 10000 \text{ m}^2)$$

PRINCIPLE OF CHAIN SURVEYING

The principle of chain surveying is triangulation. This means that the area to be surveyed is divided into a number of small triangles which should be well conditioned. In chain surveying the sides of the triangles are measured directly on the field by check on tape, and no angular measurements are taken. Hence the tie lines and check lines control the accuracy of work.

It should be noted that plotting triangles requires no angular measurements to be made, if the three sides are known. Chain surveying is recommended when

- (1) The ground surface is more or less level.
- (2) A small area is to be surveyed.
- (3) A small-scale map is to be prepared
- (4) The formation of well-conditioned triangles is easy.

Chain surveying is unsuitable when

- (1) The area is crowded with many details.
- (2) The area consists of too many undulations.
- (3) The area is very large
- (4) The formation of well-conditioned triangles becomes difficult due to obstacles.

A Large - scale and Small - Scale Maps :-

When 1 cm of a map represents a small distance, it is said to be a large - scale map for example,

$$1 \text{ cm} = 1 \text{ m} \cdot \text{i.e. RF} = \frac{1}{100}$$

When 1 cm of the map represents a large distance, it is called a small - scale map.

EX:- $1 \text{ cm} = 100 \text{ m} \cdot \text{i.e. RF} = \frac{1}{10,000}$

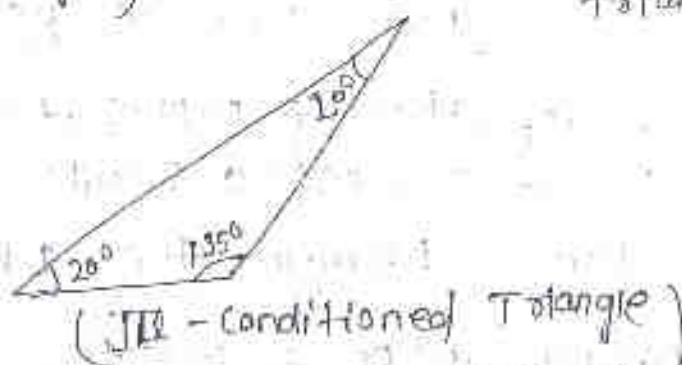
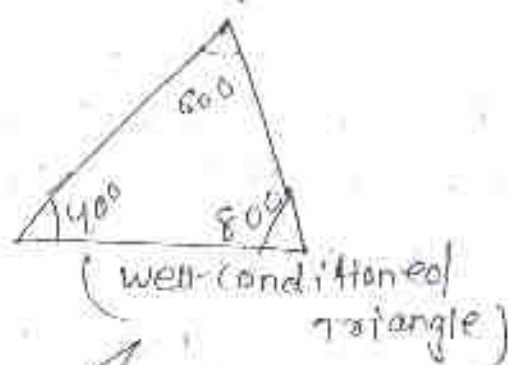
A map having an RF of less than $1/500$ is considered to be large - scale. A map of RF more than $1/500$ is said to be small - scale.

WELL - CONDITIONED AND ILL - CONDITIONED TRIANGLES

A triangle is said to be well conditioned when no angle is less than 30° or greater than 120° . An equilateral triangle is considered to be the best - condition or ideal triangle.

Well - conditioned triangles are preferred because their apex point are very sharp and can be located by a single 'dot'. In such a case, there is no possibility of relative displacement of the plotted point.

A triangle in which an angle is less than 30° or more than 120° is said to be ill conditioned.



Ill-conditioned triangles are not used in chain surveying. This is because their apex points are not sharp and well defined, which is why a slight displacement of these points may cause considerable error in plotting.

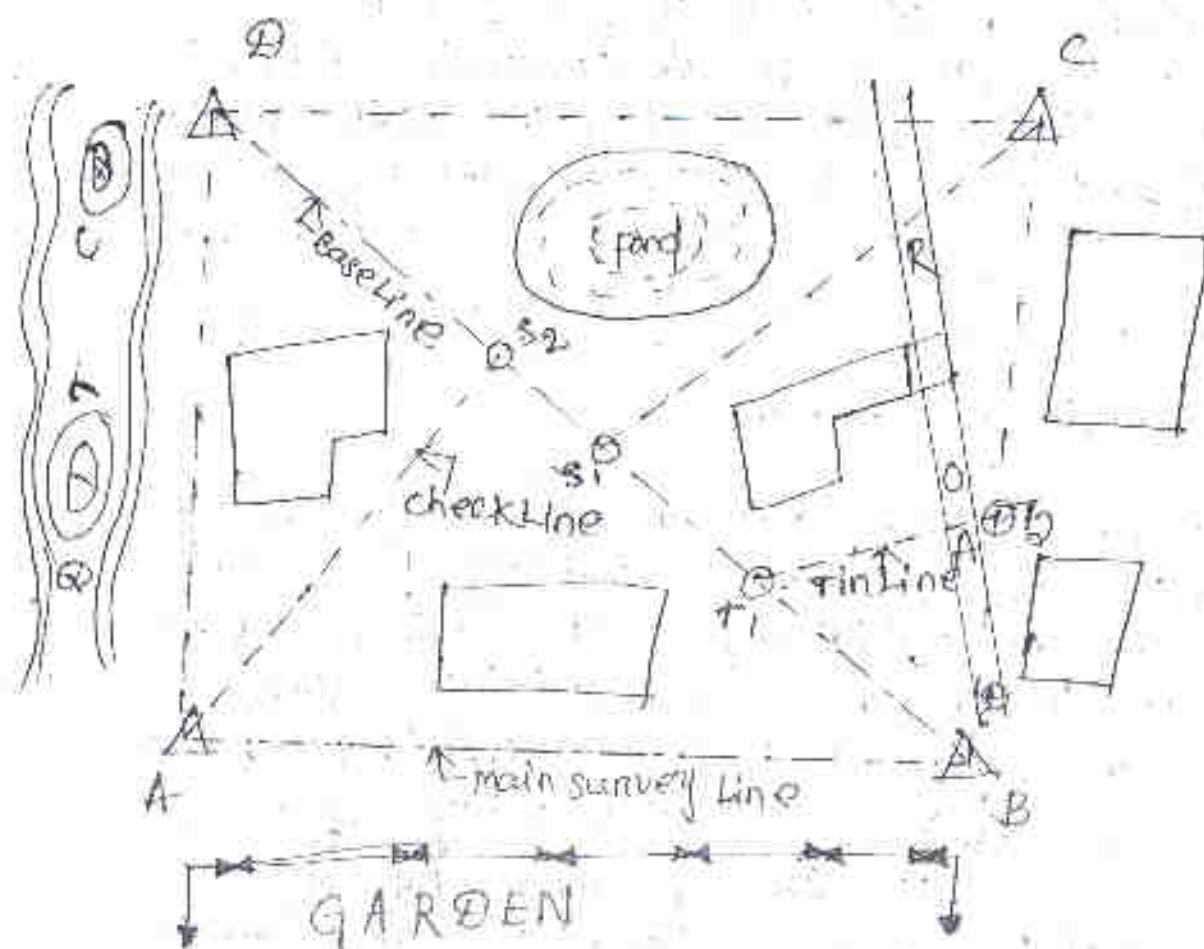
RECONNAISSANCE SURVEY AND INDEX SKETCH

Before the commencement of any survey work, the area to be surveyed is thoroughly examined by the surveyor who then thinks about the possible arrangement of the framework of survey. This preliminary investigation of the area is termed as reconnaissance survey or reconnaissance.

During reconnaissance survey work the surveyor should walk over the area and note the various obstacles and whether or not the selected stations are intervisible. The main stations should be so selected that they enclose whole area. The surveyor

should also take care the triangles formed are well not the various objects which are to be located.

The neat hand sketch of the area which is prepared during reconnaissance survey is known as the index sketch or key plan. The index sketch shows the skeleton of the survey work. It indicates the main survey stations, sub-stations, tie stations, base line arrangement for framework of triangles and the approximate positions of different objects. This sketch is an important document for the surveyor and for the person who will plot the map. It should be attached to the starting page of the field book.



(Index sketch)

Definitions and Illustrations

(a) Survey stations

Survey stations are the points at the beginning and the end of a chain line. They may also occur at any convenient points on the chain line. Such stations may be

- (i) main stations,
- (ii) subsidiary stations,
- (iii) tie stations.

Main stations stations taken along the

boundary of an area as controlling points are taken known as main stations. The lines joining the main stations are called main survey lines. The main survey lines should cover the whole area to be surveyed. The main stations are denoted by 'A' with letters A, B, C, D etc. The chain lines are denoted by

" "

Subsidiary stations :-

stations which are on the main survey lines or any other survey lines are known as subsidiary stations. These stations are taken to run subsidiary lines for dividing the area into triangles, for checking the accuracy of triangles and for locating interior details. These stations are denoted by (i) with letters S₁, S₂, S₃ etc.

Tie stations

These are also subsidiary stations taken on the main survey lines. Lines joining the tie stations are known as tie lines. Tie lines are mainly taken to fix the directions of adjacent sides of the chain survey map. These are also taken to form chain angles in chain traversing. When triangulation is not possible, chain angles are described and sometimes tie lines are taken to locate interior details. Tie stations are denoted by 'O' with letters T_1, T_2, T_3 etc.

② Base line:- The line on which the framework of the survey is built is known as the base line. It is the most important line of the survey. Generally, the longest of the main survey lines is considered the base line. This line should be taken through fairly level ground, and should be measured very carefully and accurately. The magnetic bearings of the base line are taken to fix the north line of the map.

3. Check line:- The line joining the apex point of a triangle to some fixed point on its base is known as the check line. It is taken to check the accuracy of the triangle. Sometimes this line helps to locate interior details.

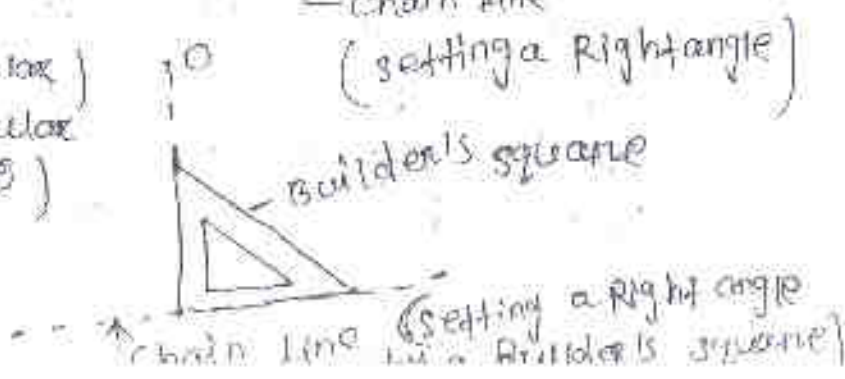
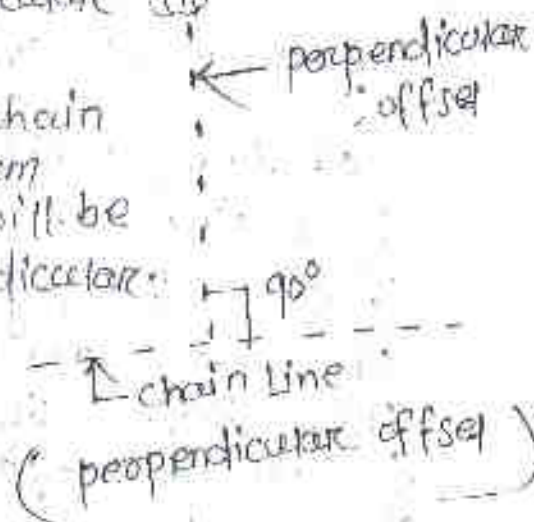
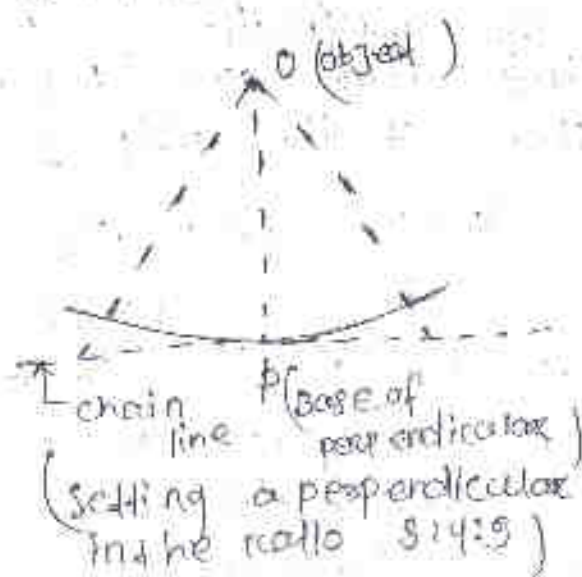
offset :- The lateral measurement taken from an object to the chain line is known as offset. Offsets are taken to locate objects with reference to the chain line. They may be of two kinds perpendicular and oblique.

perpendicular offsets

When the lateral measurements are taken perpendicular to the chain line, they are known as perpendicular offsets.

perpendicular offsets may be taken in the following ways:

- By 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 base of the perpendicular.
- By setting a right angle in the ratio 3:4:5.

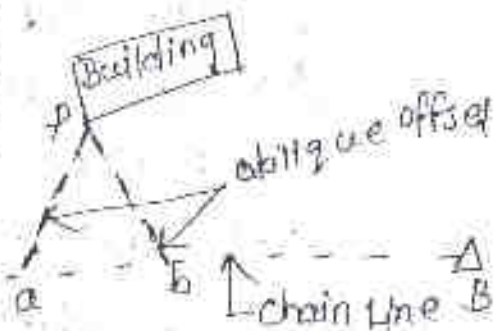


- (c) By setting a right angle with help of builders square or tri-square.
 (d) By setting a right angle by cross-staff or optical square.

Oblique offsets

Any offset not perpendicular to the chain line is said to be oblique. oblique offsets are taken when the objects are at a long distance from the chain line or when it is not possible to set up a right angle due to some difficulties. Such offsets are taken in the following manner:

Suppose AB is a chain line and P is the corner of a building. Two points a and b are taken on the chain line. The chainages of a and b are noted. The chainage ap and bp are measured and noted in the field book. Then ap and bp are the oblique offsets.



When the triangle abp is plotted, the apex point p will represent the position of the corner of the building. oblique offsets are preferred for the following reasons:-

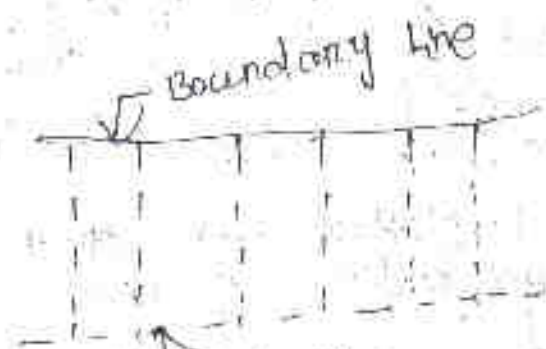
- They can be taken very quickly.
- The progress of survey is not hampered.
- The entry in the field book becomes easy.
- The plotting of the offsets also becomes easy.

number of offsets :-

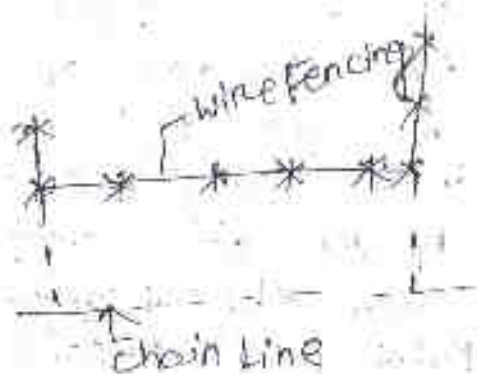
The offsets should be taken according to the nature of the object, so there is no hard-and-fast rule regarding the number of offsets. It should be remembered that the object's area to be correctly represented and hence the number of offsets should be decided on the field. Some guidelines are given below.

(a) When a boundary of the object is approximately parallel to the chain line, perpendicular offsets are taken at regular intervals.

(b) When the boundary is straight, perpendicular offsets are taken at both ends of it.



(Boundary parallel to chain line)

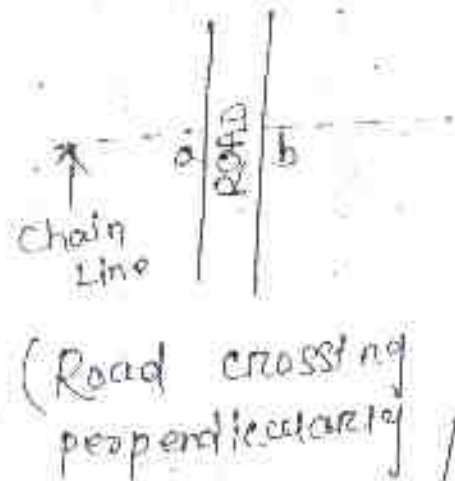
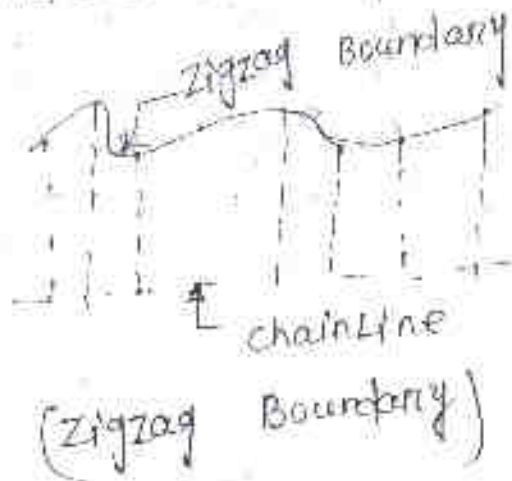


(straight Boundary)

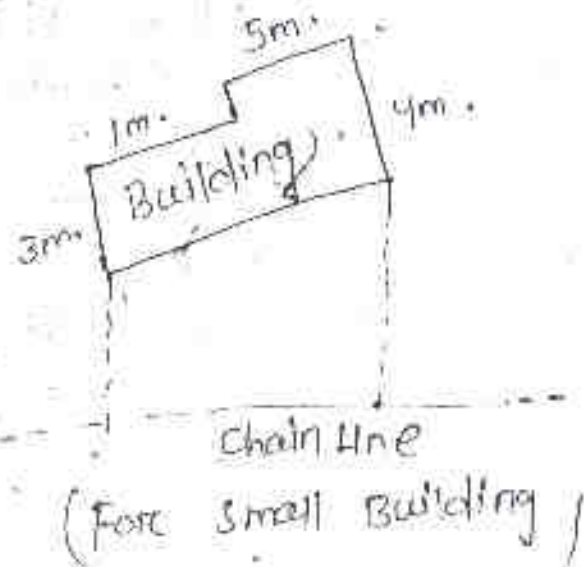
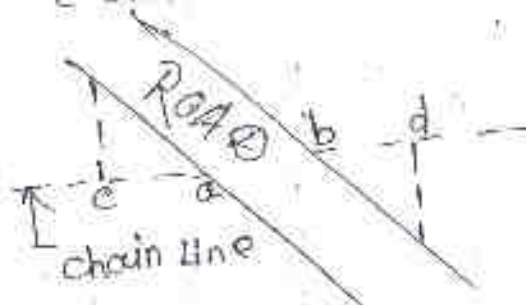
(c) When the boundary line is zigzag, perpendicular offsets are taken at every point of bend to represent the shape of the boundary accurately. In such a case, the interval of the offsets may be irregular.

(d) When a road crosses the chain line, the chainage of the

intersection point is to be noted.



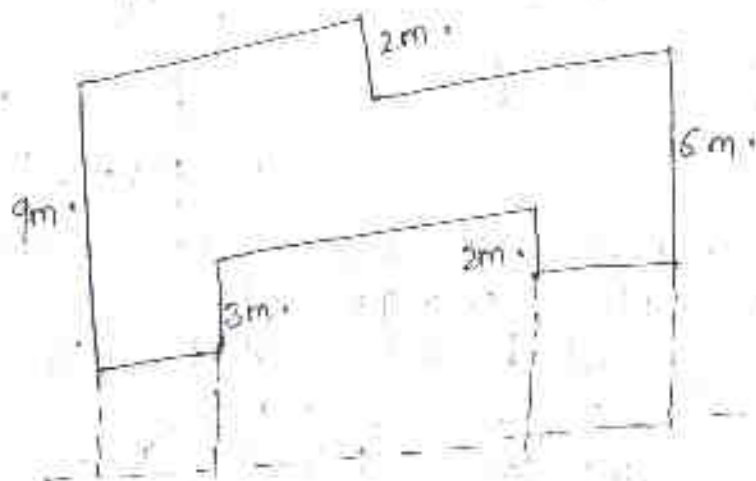
(e) When a road crosses a chain line obliquely, the changes of intersection points a and b are noted. Then at least one offset is taken on both sides of the intersection points. More offsets are taken on both sides of the intersection points. More offsets may be taken depending on the nature of the road. Here perpendicular offsets are taken at c and d.



(f) When the building is small, its corners are fixed by perpendicular offsets of oblique offsets and the other dimensions are taken directly on the field and noted in the field book.

g) When the building is large, zigzag in shape and oblique to the chain line

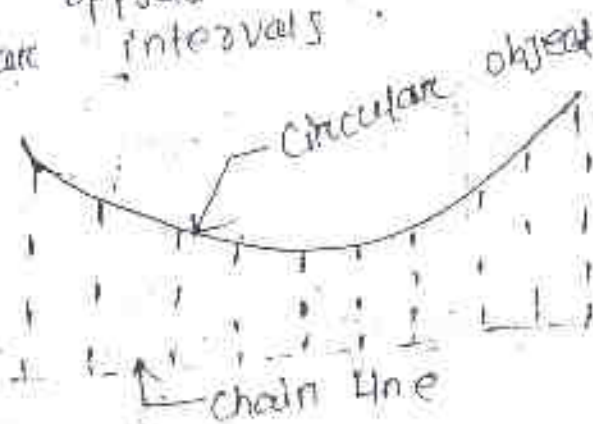
then the corners are fixed by perpendiculars or oblique offsets. Then the full plan of the building is drawn on a separate page along with all the dimensions. This page should be attached with the field book at the proper place.



chain line

(Large Building)

(h) When the object is circular, perpendicular offsets are taken at short and regular intervals.



(Circular object)

(i) Limiting length of offset

The maximum length of the offset should not be more than the length of the tape used in the survey. Generally, the maximum length of

offset is limited to 15 m. However, this length also depends upon the following factors.

- (i) The desired accuracy of the map
- (ii) The scale of the map
- (iii) The maximum allowable deflection of the offset from its true direction
- (iv) The nature of the ground.

SELECTION OF SURVEY STATIONS

The following points should be remembered during the selection of survey stations.

- (1) The stations should be so selected that the general principle of surveying may be strictly followed.
- (2) The stations should be intervisible.
- (3) The stations should be selected in such a way that well-conditioned triangles may be formed.
- (4) The base line should be the longest of the main survey lines.
- (5) The main survey lines should pass close to the boundary line of the area to be surveyed.
- (6) The survey lines should be taken through fairly level ground, as far as practicable.
- (7) The survey lines should be taken close to the objects so that they can be located by short offsets.
- (8) The tie stations should be suitably selected for taking check lines the directions of adjacent sides.
- (9) The subsidiary stations should be suitably selected for taking check lines.

- (15) stations should be so selected that obstacles to chaining are avoided as far as possible.
- (16) The survey lines should not be very close to main roads, as survey work may then be interrupted by traffic.

THE FIELD BOOK :-

The notebook in which field measurements are noted is known as the 'field book'. The size of the field book is 20 cm x 12 cm and it opens lengthwise. Field books may be of two types.

① Single-line

② Double-line

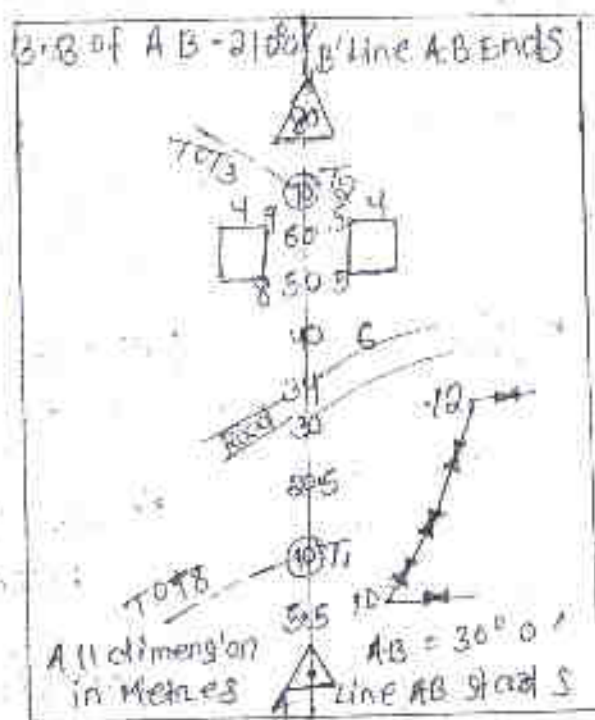
Single-line field book

In this type of field book, a single red line is drawn through the middle of each page. This line represents the chain line, and the changes are written on it. The offsets are recorded with sketch to the left or right of the chain line. The recording of the field book is started from the last page and continued towards the first page. The main stations are marked by Δ and subsidiary stations or the station are marked by $\odot$.

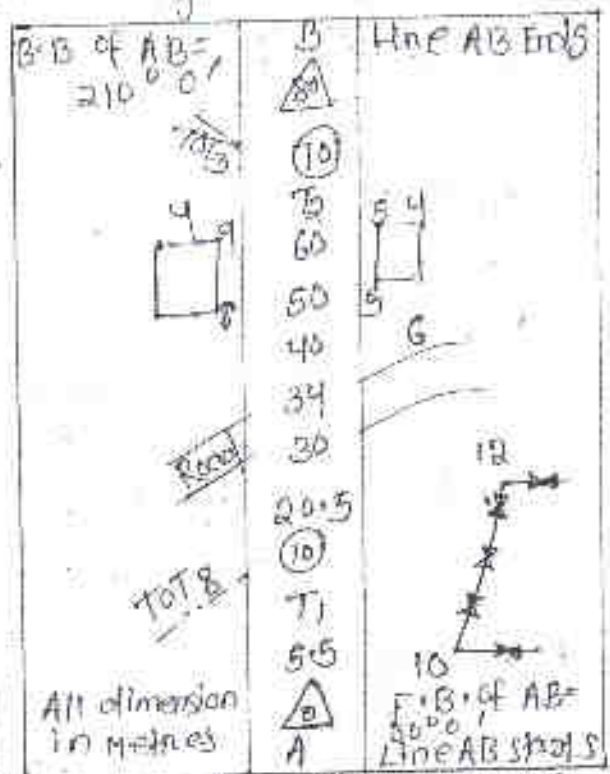
Double-line field book

In this type of field book, two red lines, 1.5 cm apart, are drawn through the middle of each page. This column represents the chain line, and the

chainages are written in 4. The offset are recorded, with sketches to the left or right, of this column. The recording is begun from the last page and continued towards the first. The main stations are marked by 'A' and subsidiary or tie by 'O'. This type of field book is commonly used.



(Single-Line field book)



(Double-Line Field book)

CONVENTIONAL SYMBOLS

In a map the objects are shown by symbols and not by names. So the surveyor should know the following standard conventional symbols for some common objects.

S.no	object	Symbol	Color
1	North line		Black
2	Main stations or triangulation station		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
7	Lake or pond		prussian blue
8	open well		prussian blue
9	Tubewell		Black
10	Foot path		Black
11	Metalled road		Burnt sienna
12	unmetalled road		Burnt sienna

S. no	object	Symbol	Color
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
20	Hedge		Green
21	Wire fencing		Black
22	Rope fencing		Prussian blue
23	Wood fencing		Yellow
24	Building (pukka)		Crimson lake
25	Building (katcha)		umber
26	Hut/s		Yellow
27	Temple		Crimson Lake
28	church		Crimson lake

Sl. no	object	symbol	Colour
29	Mosque		Crimson lake
30	Benchmark		Black
31	Tree		Green
32	Jungle		Green
33	Orchard		Green
34	Cultivated land		Black & 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

COMPASS TRAVERSING

⇒ The chain surveying the area to be surveyed is divided into a number of triangles.

⇒ This method is suitable for fairly level ground covering small areas.

⇒ But when the area is large undulating & crowded with many details, triangulation is not possible, in such an area traversing is adopted.

⇒ In traversing, the framework consist of a number of connected line.

⇒ The length are measured by chain (or) angle measuring instrument.

⇒ In one of the method, the angle measuring instrument is compass. Hence the process is compass traversing.

Definitions

1) True Meridian The line or plane passing through the geographical north pole, geographical south pole and any point on the surface of the earth is known as the 'true' meridian' or 'geographical meridian'. The true meridian at a station is constant. The true meridians passing through different points on the earth's surface are not parallel but converge.

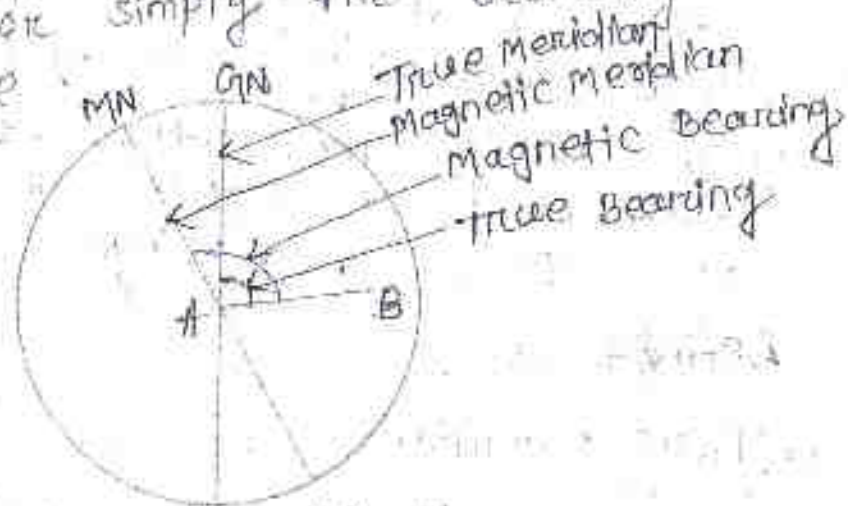
towards the poles. But for surveys in small areas, the true meridians passing through different points are assumed parallel.

The angle between the true meridian and a line is known as 'true bearing' of the line. It is also known as the 'azimuth'.

Magnetic Meridian :-

When a magnetic needle is suspended freely and balanced properly unaffected by magnetic substances, it indicates a direction. This direction is known as the 'magnetic meridian'.

The angle between the magnetic meridian and a line is known as the 'magnetic bearing' or simply the 'bearing' of the line.



(Meridians)

(3) Arbitrary meridian :- Sometimes for preparing a map, some state agencies assume several lines parallel to the true meridian for a particular zone. These lines are termed grid lines and the central line the 'grid meridian'.

The bearing of a line ~~are~~ termed with grid lines and respect to the grid meridian is known as the grid bearing of the line.

(4) Grid Meridian

Some times for preparing a map, some state agencies assume several lines parallel to the true meridian for a particular zone. These lines are termed grid lines and the central line the 'grid meridian'. The bearing of a line with respect to the grid meridian is known as the grid bearing of the line.

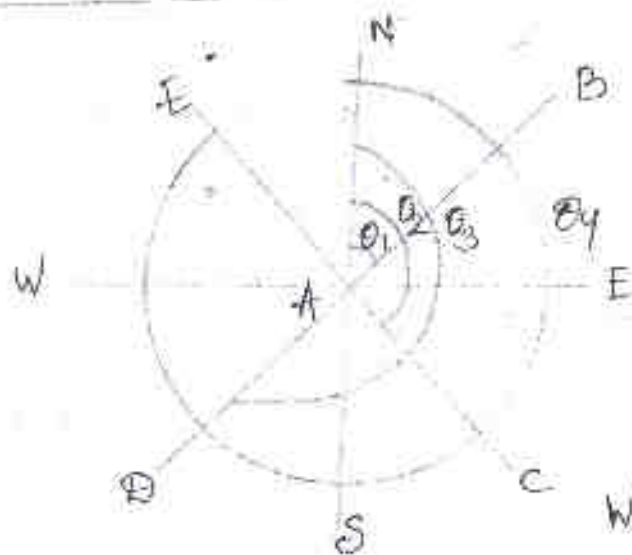
(5) Designation of Magnetic Bearings

Magnetic bearings are designated by two systems:

- (a) whole circle bearing
- (b) Quadrantal bearing (QB)

(a) Whole Circle Bearing (WCB)

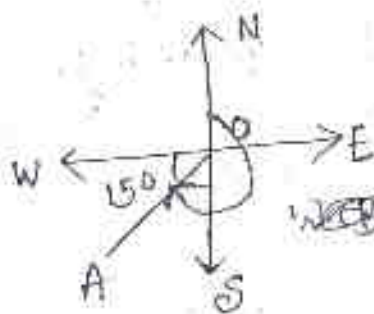
The magnetic bearing of a line measured clockwise from the north pole towards the line, is known as the 'whole circle bearing' of that line. Such a bearing may have any value between 0° and 360° . The whole circle bearing of a line is obtained by prismatic compass.



Whole circle Bearing (W.C.B)

Ex:-
W.C.B of AB = B_1
W.C.B of AC = B_2
W.C.B of AD = B_3
W.C.B of AE = B_4

1Q



W.C.B of OA = ?

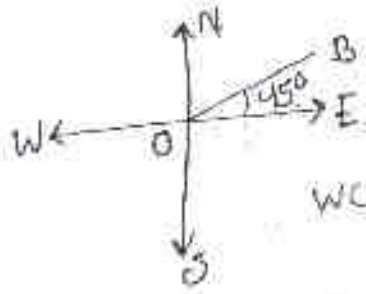
~~W.C.B = 255°~~

~~W.C.B = 255°~~

QB of OA = S 75° W

Ans

2Q

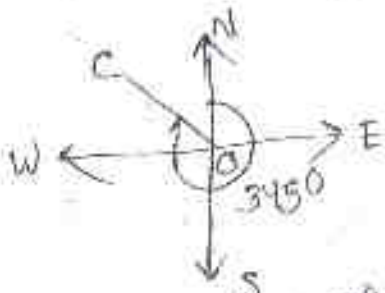


W.C.B of OB = ?

W.C.B = 45°

Ans

3Q



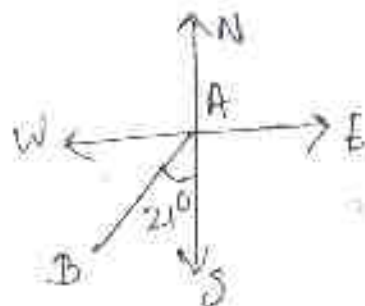
W.C.B of OC = ?

N.C.B = 345°

QB = N 15° W

Ans

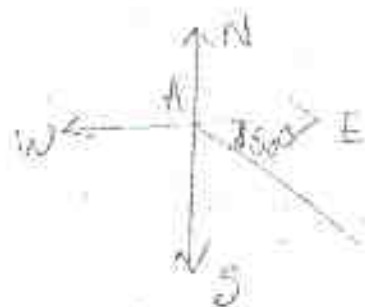
Q1



~~W.C.B. of AB = ?~~
 Q.B. of AB = $S 21^{\circ} W$

Ans

Q2



Q.B. of AB = ?

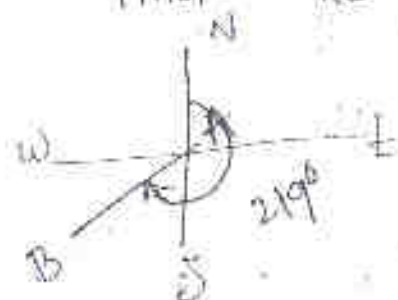
~~W.C.B. of AB = ?~~

Q.B. of AB = $90^{\circ} - 60^{\circ} = S 30^{\circ} E$

W.C.B. of AB = 150°

Ans

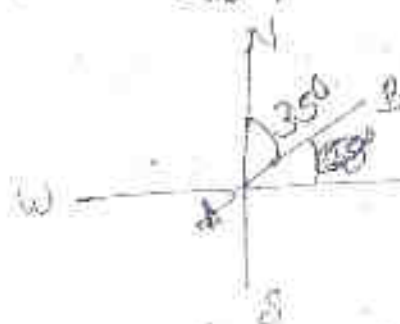
Q3 If the W.C.B. of a line AB = 219° . then find R.B. of AB = ?



R.B. of AB = $39^{\circ} (219 - 180^{\circ})$

Q4 If W.C.B. of AB = 350

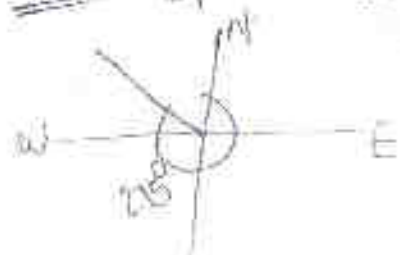
Q.B. of AB = ?



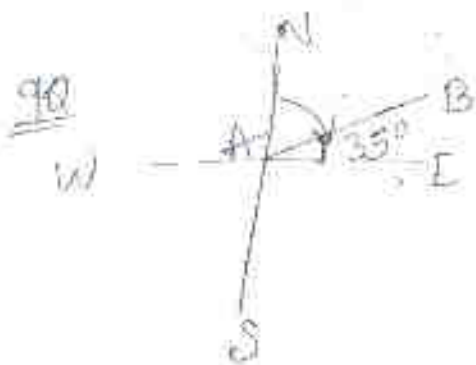
~~Q.B. of AB = ?~~ $90 - 350 = 0$

Q.B. of AB = $35^{\circ} E$

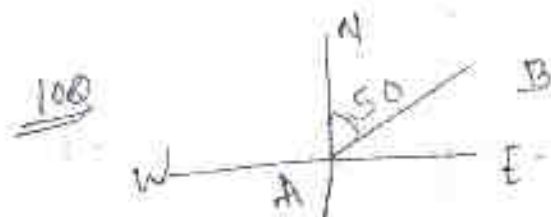
Q5 If W.C.B. of AB = 275° Q.B. of AB = ?



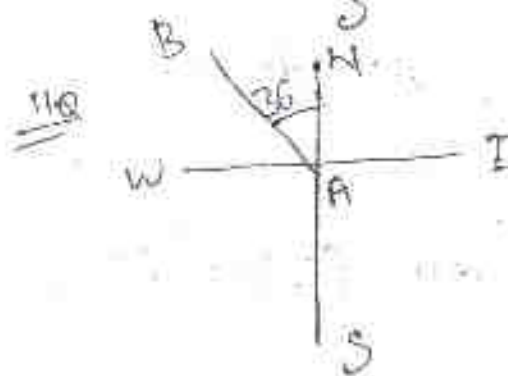
Q.B. of AB = $N 85^{\circ} W$



Ans W.C.B of AB = 55°

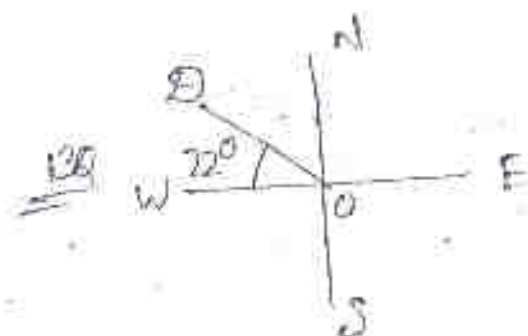
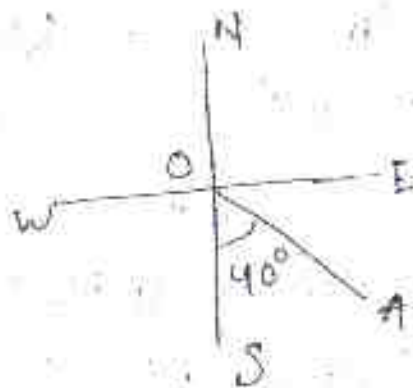


W.C.B of AB = 80°



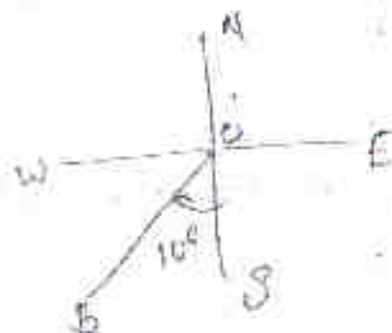
W.C.B of AB = $360^\circ - 36^\circ$
= 324°

120 W.C.B of OA = $180 - 40$
= 140°



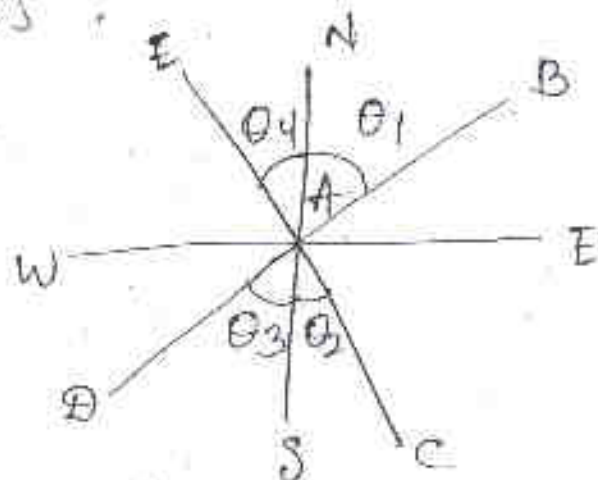
W.C.B of OD = $270 + 22$
= 292°

140 W.C.B of OB = $180 + 10$
= 190°



(b) Quadrantal Bearing (QB) :-

The magnetic bearing of a line measured clock wise or counterclockwise from the North pole or South pole (whichever is nearer the line) towards the East or West, is known as the 'quadrantal bearing' of the line. This system consists of four quadrants - NE, SE, SW and NW. The value of a quadrantal bearing lies between 0° and 90° , but the quadrants should always be mentioned. Quadrantal bearings are obtained by the surveyor's compass.



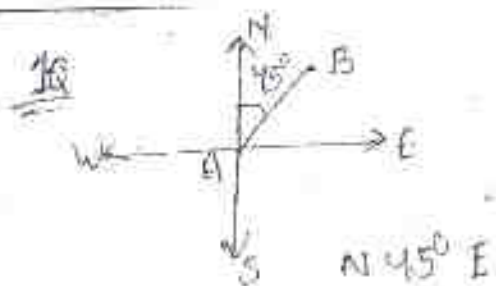
(Quadrantal Bearing 'QB')

ex- QB of AB = N θ_1 E

QB of AC = S θ_2 E

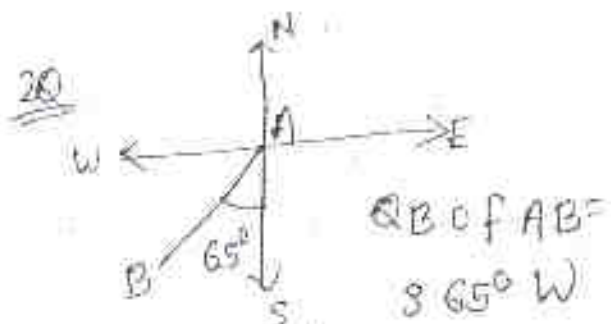
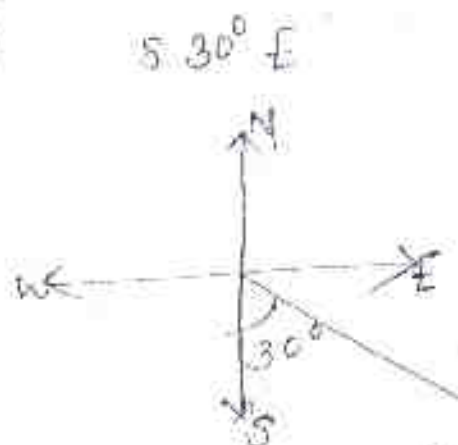
QB of AD = S θ_3 W

QB of AE = N θ_4 W



Q.B of AB =

76

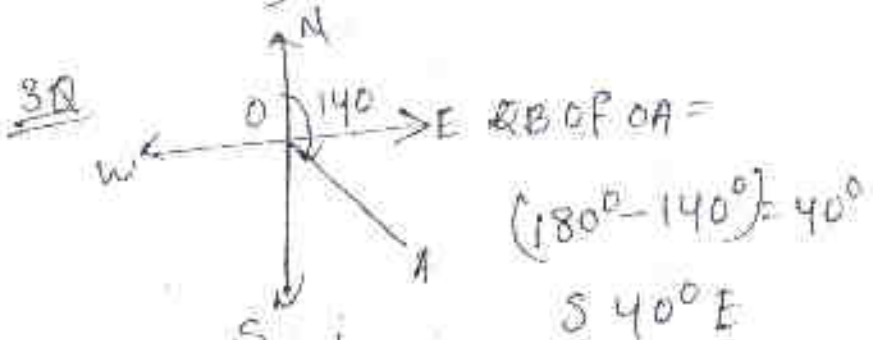


Q.B of AB =

80

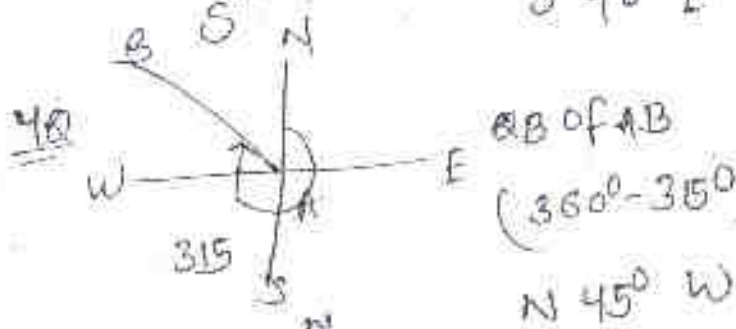
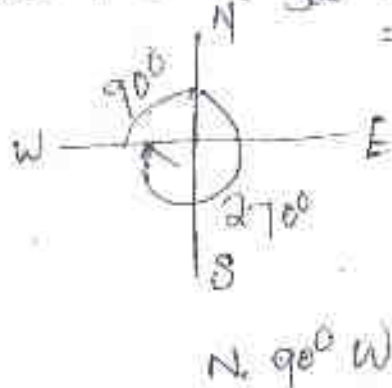
W.C.B of AB = 270°

Q.B of AB = ?
 $360 - 270 = 90°$



Q.B of OA =

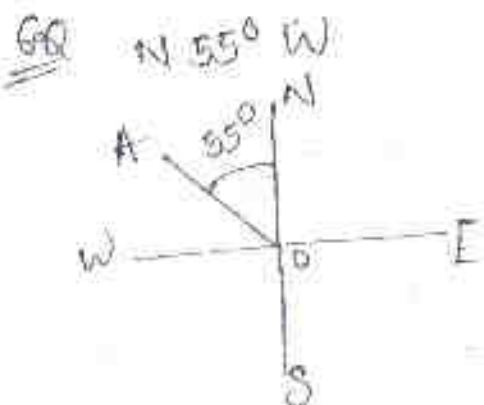
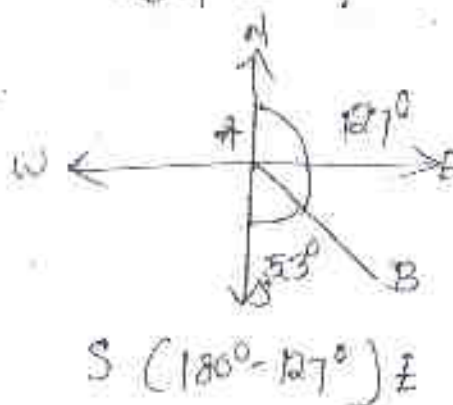
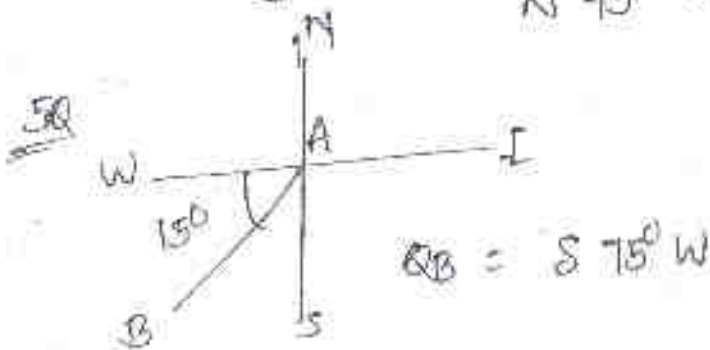
$$(180° - 140°) = 40°$$



Q.B of AB

$$(360° - 315°) = 45°$$

W.C.B of AB = 127°
 Q.B of AB = ?



(v) Reduced Bearing (RB) :-

When the whole circle bearing of a line is converted to quadrant bearing, it is termed the 'reduced bearing'. Thus the reduced bearing is similar to the quadrant bearing. Its value lies between 0° and 90° but the quadrant should be mentioned for proper designation.

The following table should be remembered for conversion of WCB to RB.

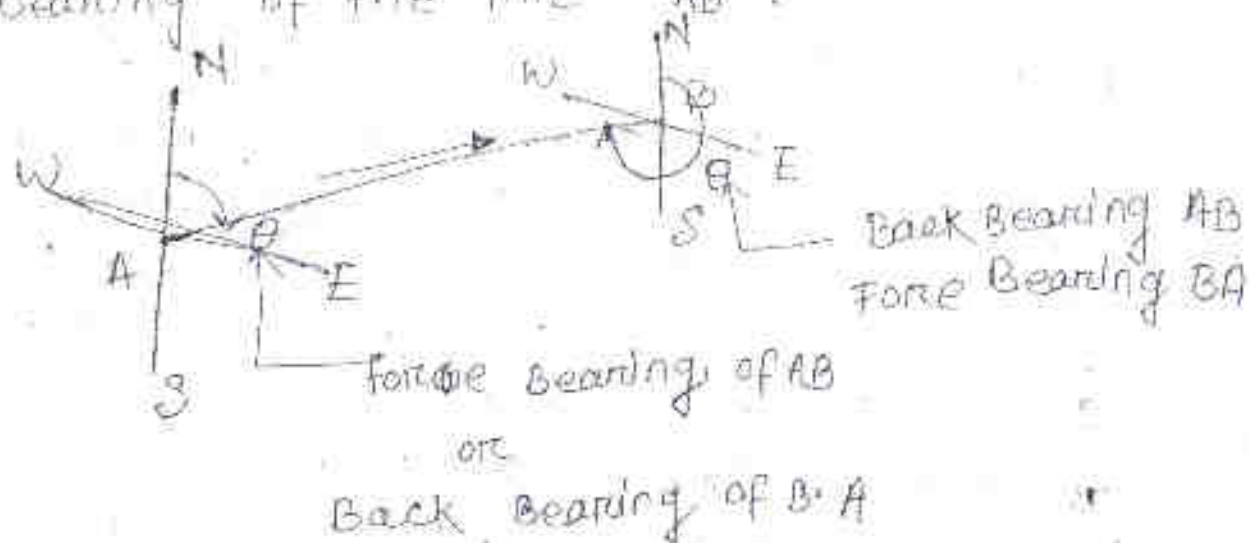
WCB between	Corresponding RB	Quadrant
$0^\circ - 90^\circ$	$RB = WCB$	NE
$90^\circ - 180^\circ$	$RB = 180^\circ - WCB$	SE
$180^\circ - 270^\circ$	$RB = WCB - 180^\circ$	SW
$270^\circ - 360^\circ$	$RB = 360^\circ - WCB$	NW

Fore and Back Bearing

Every line has two bearings one is observed along the progress of the survey or forward direction, and is called 'fore bearing' and the second is observed in the reverse or opposite direction and is called 'back bearing'.

Consider the line AB shown. Here, we consider the direction of meridian as upward and the bearing is measured clockwise from the meridian.

The bearing as measured at A along the progress of survey A to B is θ , so the angle or bearing θ is the fore bearing of the line $\overline{AB}$.



(Fore Bearing and Back Bearing)

Similarly, the bearing as measured at B in the opposite direction of the progress of the survey A to B, along clockwise direction is θ . The bearing θ is the back bearing of the line $\overline{AB}$.

It is clear that the fore bearing and back bearing of a line differ exactly by 180° .

i.e. $\text{Back bearing} = \text{Fore Bearing} \pm 180^\circ$

use positive sign(+) when fore bearing is less than 180° and (-ve) sign when it is more than 180° .

In case of quadrantal bearing system the numerical value of fore bearing and back bearing is equal but the quadrants are opposite.

ex:- If the fore bearing is $N30^{\circ}E$
 back bearing $S30^{\circ}W$
 then the fore bearing of the line
 AB is equal to back bearing the
 line BA. i.e. the opposite direction
 of the progress of survey.

1Q F.B of a line AB = 310°
 B.B = ?

Ans F.B = 310°

$$\begin{aligned} B.B &= FB - 180^{\circ} \\ &= 310^{\circ} - 180^{\circ} \\ &= 130^{\circ} \end{aligned}$$

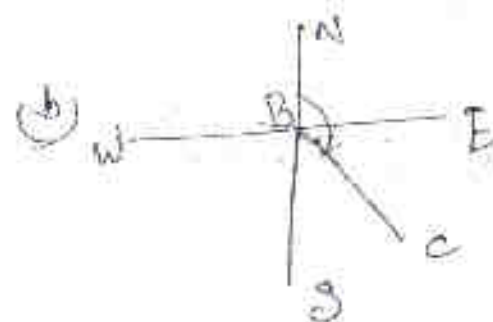
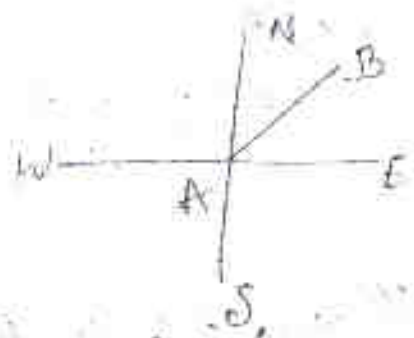
2Q F.B = 95°
 B.B = $95^{\circ} + 180^{\circ} = 275^{\circ}$

3Q F.B = 245°
 B.B = $245^{\circ} - 180^{\circ}$
 $= 65^{\circ}$

4Q F.B = 169°
 B.B = $169^{\circ} + 180^{\circ} = 349^{\circ}$

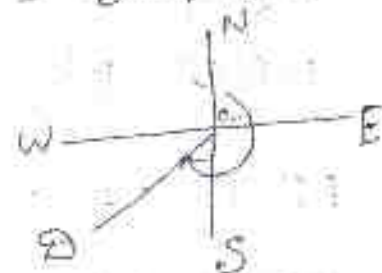
5Q F.B = 181°
 B.B = $181^{\circ} - 180^{\circ} = 1^{\circ}$

- 16 (a) WCB of AB = $95^{\circ} 30'$
 QB of AB = $N 45^{\circ} 30' E$



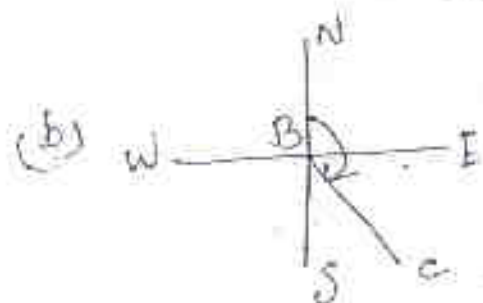
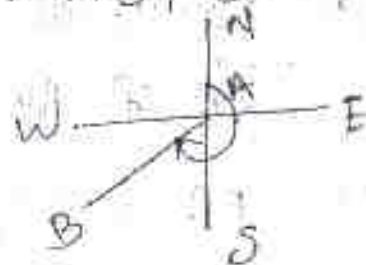
WCB of BC = $125^{\circ} 45'$
 QB of BC = $180^{\circ} - 125^{\circ} 45'$
 = $54^{\circ} 15' E$

- (c) WCB of CD = $222^{\circ} 15'$
 QB of CD = $222^{\circ} 15' - 180^{\circ}$
 = $42^{\circ} 15' W$



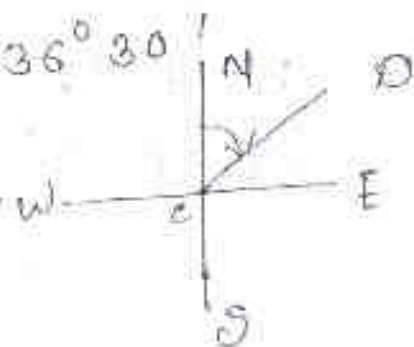
- (d)
-
- WCB of DE = $320^{\circ} 30'$
 QB of DE = $360^{\circ} - 320^{\circ} 30'$
 = $N 39^{\circ} 30' W$

- 20 (a) QB of AB = $S 36^{\circ} 30' W$
 WCB of AB = $180^{\circ} + 36^{\circ} 30'$
 = $216^{\circ} 30'$



QB of BC = $S 43^{\circ} 30' E$
 WCB = $180^{\circ} - 43^{\circ} 30'$
 = $136^{\circ} 30'$

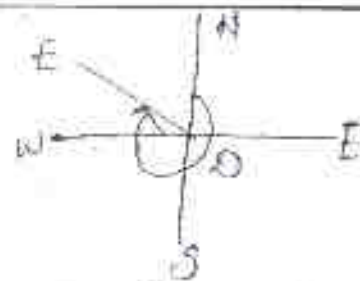
- (c) QB of CD = $N 26^{\circ} 45' E$
 WCB = $26^{\circ} 45'$



(d) FB of DE = $N 40^{\circ} 15' W$

WCB = $360^{\circ} - 40^{\circ} 15'$

= $319^{\circ} 45'$



30 (a) FB of AB = $310^{\circ} 30'$

BB of AB = $310^{\circ} 30' - 180^{\circ} = 130^{\circ} 30'$

(b) FB of BC = $145^{\circ} 15'$

BB of BC = $145^{\circ} 15' + 180^{\circ} = 325^{\circ} 15'$

(c) FB of CD = $210^{\circ} 30'$

BB of CD = $210^{\circ} 30' - 180^{\circ} = 30^{\circ} 30'$

(d) FB of DE = $60^{\circ} 45'$

BB of DE = $60^{\circ} 45' + 180^{\circ} = 240^{\circ} 45'$

40 (a) FB of AB = $S 30^{\circ} 30' E$

BB of AB = $N 30^{\circ} 30' W$

(b) FB of BC = $N 40^{\circ} 30' W$

BB of BC = $S 40^{\circ} 30' W$

(c) FB of CD = $S 60^{\circ} 15' W$

BB of CD = $N 60^{\circ} 15' E$

(d) FB of DE = $N 45^{\circ} 30' E$

BB of DE = $S 45^{\circ} 30' W$

5Q (a) BB of AB = 180°

$$FB \text{ of } AB = 40^\circ 30' + 180^\circ = 220^\circ 30'$$

$$(b) \text{ BB of } ABC = 310^\circ 45'$$

$$FB \text{ of } ABC = 310^\circ 45' - 180^\circ = 130^\circ 45'$$

$$(c) \text{ BB of } CD = 145^\circ 45'$$

$$FB \text{ of } CD = 145^\circ 45' + 180^\circ = 325^\circ 45'$$

$$(d) \text{ BB of } DE = 215^\circ 30'$$

$$FB \text{ of } DE = 215^\circ 30' - 180^\circ = 35^\circ 30'$$

6Q (a) BB of AB = N $30^\circ 30'$ W

$$FB \text{ of } AB = S $30^\circ 30'$ E$$

$$(b) \text{ BB of } BC = S $40^\circ 15'$ E$$

$$FB \text{ of } BC = N $40^\circ 15'$ W$$

$$(c) \text{ BB of } CD = N $60^\circ 45'$ E$$

$$FB \text{ of } CD = S $60^\circ 45'$ W$$

$$(d) \text{ BB of } DE = S $45^\circ 30'$ W$$

$$FB \text{ of } DE = N $45^\circ 30'$ E$$

Dip of the magnetic Needle

o o o

If a needle is perfectly balanced before magnetisation, it does not remain in the balanced position after it is magnetised. This is due to the magnetic influence of the earth. The needle is found to be inclined towards the pole. This inclination of the needle with the horizontal is known as the 'dip of magnetic needle'.

It is found that the north end of the needle is deflected downwards in the northern hemisphere and that its south end is deflected downwards in the southern hemisphere. The needle is just horizontal at the equator. To balance the dip of the needle, a rider (brass or silver coil) is provided along with it. The rider is placed over the needle at a suitable position to make it horizontal.

Local Attraction :-

o o o

A magnetic needle indicates the north direction when freely suspended or pivoted. But if the needle comes near some magnetic substances, such as iron ore, steel structures, electric cables conveying current; etc. it is found to be deflected from its true direction, and does not show the actual north. This disturbing influence of magnetic substances is known as 'local attraction'.

To detect the presence of local attraction the fore and back bearings of a line should be taken. If the difference of the fore and back bearings of the line is exactly 180° then there is no local attraction.

If the FB and BB of a line do not differ by 180° then the needle is said to be affected by local attraction, provided there is no instrumental error.

To compensate for the effect of local attraction, the amount of error is found out and is equally distributed between the fore and back bearings of the line for example, consider the case when,

$$\text{observed FB of AB} = 60^\circ 30'$$

$$\text{observed BB of AB} = 240^\circ 0'$$

$$\text{Calculated BB of AB} = 60^\circ 30' + 180^\circ 0' = 240^\circ 30'$$

$$\text{Corrected BB of AB} = 1/2 (240^\circ 0' + 240^\circ 30') \\ = 240^\circ 15'$$

$$\text{Hence, Corrected FB of AB} = 240^\circ 15' - 180^\circ 0' = 60^\circ 15'$$

Method of Application of Correction

(a) First Method:- The interior angles of a traverse are calculated from the observed bearings. Then an angular check is applied. The sum of the interior angles should be equal to $(2n-4) \times 90^\circ$ (n being the number of sides of the traverse). If it is not so, the total error is equally distributed among all the angles of the traverse.

Then, starting from the unaffected line, the bearings of all the lines may be corrected by using the corrected interior angles. This method is very laborious and is not generally employed.

(b) Second Method :- In this method, the interior angles are not calculated from the given table, the unaffected line is first detected. Then, commencing from the ~~amount~~ of unaffected line, the bearings of the other affected lines are corrected by finding the amount of correction at each station.

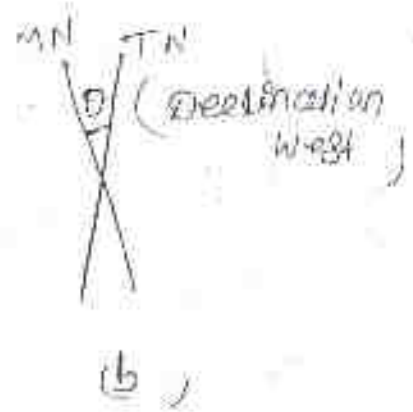
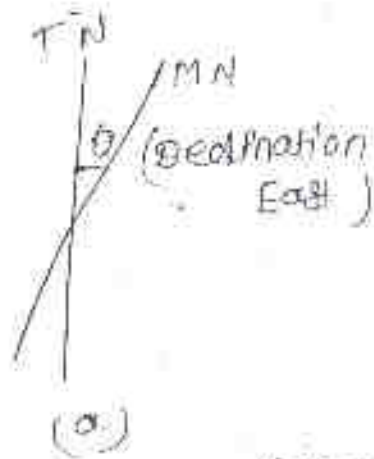
This is an easy method, and one which is generally employed.

Magnetic Declination :-

The horizontal angle between the magnetic meridian and true meridian is known as 'magnetic declination'.

When the north end of the magnetic needle is pointed towards the west side of the true meridian, the position is termed declination west (DW).

When the north end of the magnetic needle is pointed towards the east side of the true meridian, the position is termed declination East (DE).

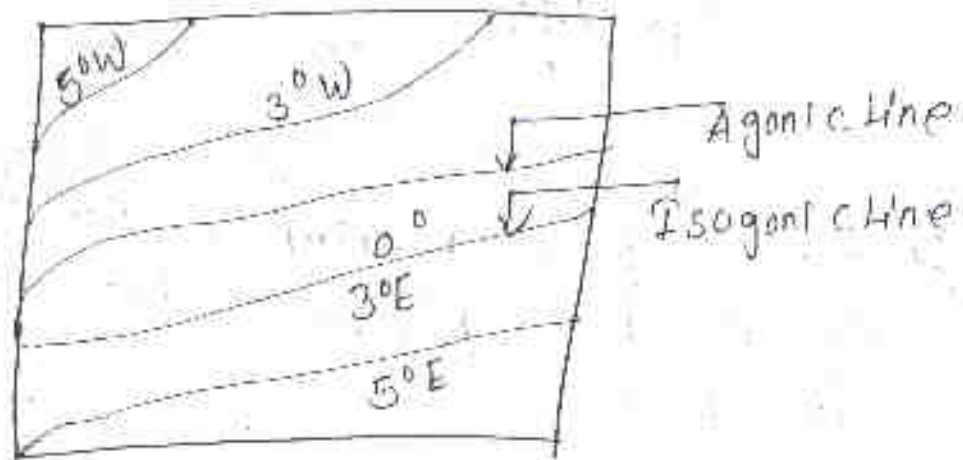


(Magnetic Declination)

Isogonic and Agonic Lines

Lines passing through points of equal declination are known as isogonic lines.

The line passing through points of zero declination is said to be the agonic line.



(Isogonic and Agonic Lines)

1 June 2021

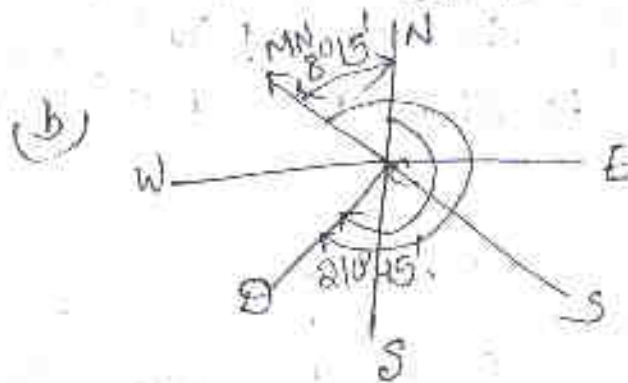
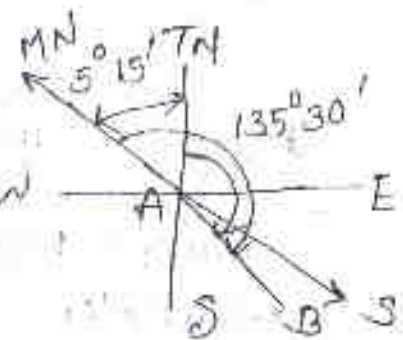
10 (a) The magnetic bearing of a line AB is $135^{\circ}30'$
what will be the true bearing, if the
declination is $5^{\circ}15'W$?

(b) The true bearing of a line CD is $210^{\circ}45'$
what will be its magnetic bearing if the
declination is $8^{\circ}15'W$?

Solⁿ (a) True Bearing = M.B. - M.D

$$= 135^{\circ}30' - 5^{\circ}15'$$

$$= 130^{\circ}15'$$



Magnetic Bearing

$$= \text{True Bearing} + \text{Magnetic Bearing}$$

$$= 210^{\circ}45' + 8^{\circ}15'$$

$$= 219^{\circ}00'$$

20 The magnetic bearing of a line CD is $53^{\circ}15'W$
find its true bearing if the declination is
 $10^{\circ}15'E$?

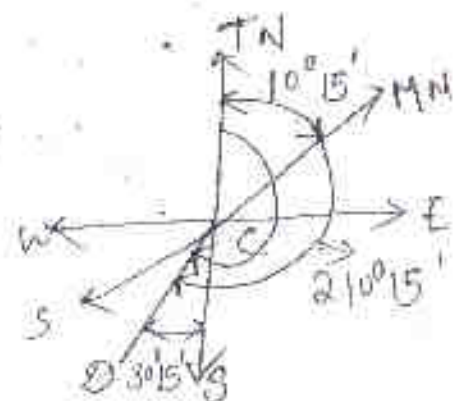
Solⁿ MB = $30^{\circ}15'$

$$W.C.B. = 180^{\circ} + 30^{\circ}15' = 210^{\circ}15'$$

$$\text{True Bearing} = M.B. + M.D$$

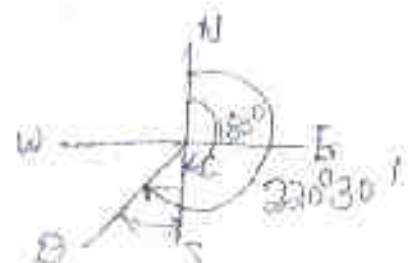
$$= 210^{\circ}15' + 10^{\circ}15'$$

$$= 220^{\circ}30'$$



$$\text{Required TB} = 220^{\circ}30' - 180^{\circ}$$

$$= 34^{\circ}30'W$$



3 June 2021

The FB of the lines AB, BC, CD & DE are $45^\circ 30'$, $120^\circ 15'$, $200^\circ 30'$ & $280^\circ 45'$ respectively.
Find angle $\angle B$, $\angle C$ & $\angle D$?

Solⁿ (i) BB of AB = FB of AB + 180°
 $= 45^\circ 30' + 180^\circ$
 $= 225^\circ 30'$

$\angle B = \text{BB of AB} - \text{FB of BC}$
 $= 225^\circ 30' - 120^\circ 15'$
 $= 105^\circ 15'$

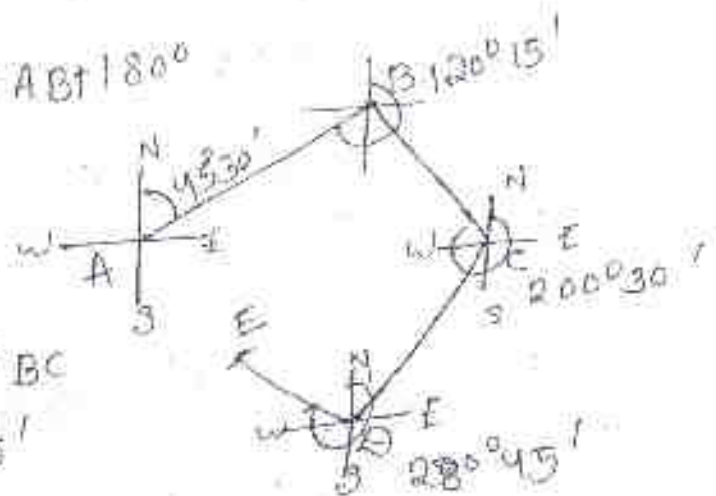
(ii) BB of BC = $120^\circ 15' + 180^\circ = 300^\circ 15'$

$\angle C = \text{BB of BC} - \text{FB of CD}$
 $= 300^\circ 15' - 200^\circ 30'$
 $= 99^\circ 45'$

(iii) BB of CD = FB of CD + 180°
 $= 200^\circ 30' + 180^\circ = 380^\circ 30'$

Exterior
Interior $\angle D = \text{FB of DE} - \text{BB of CD}$
 $= 280^\circ 45' - 380^\circ 30'$
 $= -99^\circ 45'$

Interior angle D = $360^\circ - \text{exterior } \angle D$
 $= 360^\circ - (-99^\circ 45')$
 $= 459^\circ 45'$



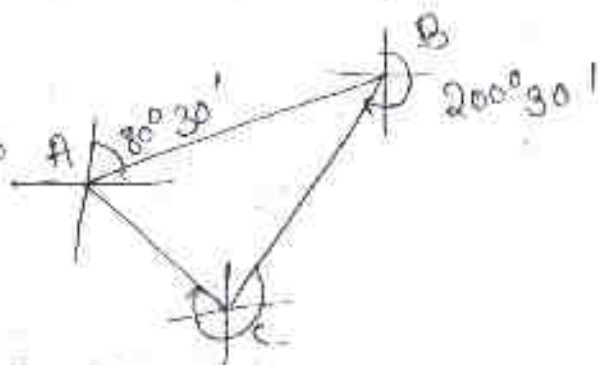
Q A traverse is above done by three stations A, B, C in clock wise order in the form of an equilateral triangle. If the fore bearings of other sides?

Solⁿ

$$(i) \text{ FB of BC} = \text{BB of AB} - \angle B$$

$$= (80^\circ 30' + 180^\circ) - 60^\circ$$

$$= 200^\circ 30'$$



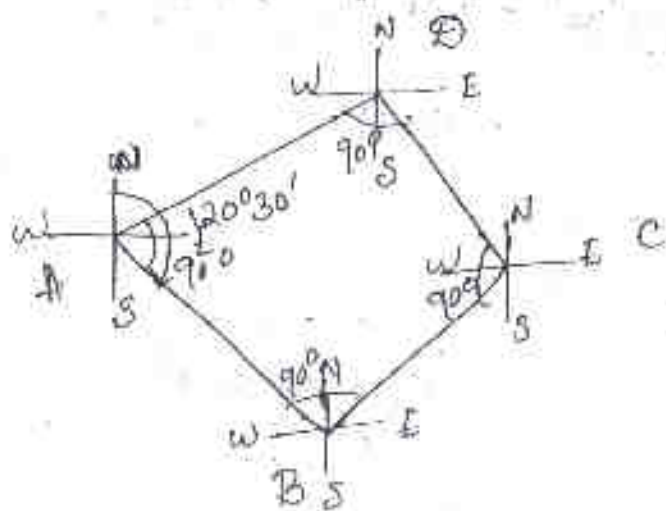
$$(ii) \text{ FB of AC} = \text{BB of BC} + \text{external angle at C}$$

$$= (200^\circ 30' - 180^\circ) + (360^\circ - 60^\circ)$$

$$= 20^\circ 30' + 300^\circ$$

$$= 320^\circ 30'$$

Q A traverse is made in the form of a square taking in clockwise order. If bearing of AB is $120^\circ 30'$, find the bearing other side?



Solⁿ

$$\text{FB of AB} = 120^\circ 30'$$

$$(i) \text{ External angle (B)} = 360^\circ - 90^\circ = 270^\circ$$

$$\begin{aligned}
 BB &= 120^\circ 30' + 180^\circ = 300^\circ 30' \\
 FB \text{ of } BC &= BB \text{ of } AB - \text{external } \angle B \\
 &= 300^\circ 30' - 270^\circ \\
 &= 30^\circ 30'
 \end{aligned}$$

$$\begin{aligned}
 \text{ii) } BB \text{ of } BC &= 180^\circ + 30^\circ 30' \\
 &= 210^\circ 30'
 \end{aligned}$$

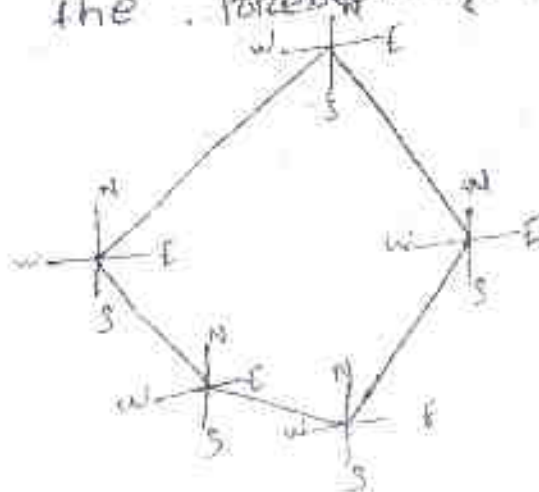
$$\begin{aligned}
 FB \text{ of } CD &= BB \text{ of } BC + \text{Internal angle } C \\
 &= 210^\circ 30' + 90^\circ = 300^\circ 30'
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) } FB \text{ of } DA &= BB \text{ of } CD + \text{Internal } \angle D \\
 &= (300^\circ 30' - 180^\circ) + 90^\circ \\
 &= 120^\circ 30' + 90^\circ = 210^\circ 30'
 \end{aligned}$$

checked:

$$\begin{aligned}
 FB \text{ of } AB &= BB \text{ of } DA + \text{Internal } \angle A \\
 &= (210^\circ 30' - 180^\circ) + 90^\circ \\
 &= 30^\circ 30' + 90^\circ \\
 &= 120^\circ 30'
 \end{aligned}$$

$\Rightarrow$ A closed traverse is conducted with five stations, A, B, C, D & E taken in anticlockwise direction in the form of regular pentagon of the FB of AB is $30^\circ 30'$. Find the forebearing of other side.



$$\text{ii) BB of AB} = 36^\circ + 180^\circ \\ = 216^\circ$$

$$\text{FB of BC} = \text{BB of AB} + \text{Internal } \angle A \\ = 216^\circ + 108^\circ = 324^\circ$$

$$\text{iii) FB of CD} = \text{BB of BC} + \text{Internal } \angle C \\ = (324^\circ - 180^\circ) + 108^\circ \\ = 246^\circ$$

$$\text{iv) FB of DE} = \text{BB of CD} + \text{Internal } \angle D \\ = (246^\circ - 180^\circ) + 108^\circ \\ = 174^\circ$$

$$\text{FB of EA} = \text{BB of DE} + \text{External } \angle B$$

$$= (174^\circ + 180^\circ) - (360^\circ - 108^\circ) \\ = 354^\circ - 252^\circ = 102^\circ$$

checked

$$\text{BB of EA} = 102^\circ + 180^\circ = 282^\circ$$

$$\text{FB of AB} = \text{BB of EA} - \text{external } \angle E$$

$$= 282^\circ - (360^\circ - 108^\circ) \\ = 282^\circ - 252^\circ = 30^\circ$$

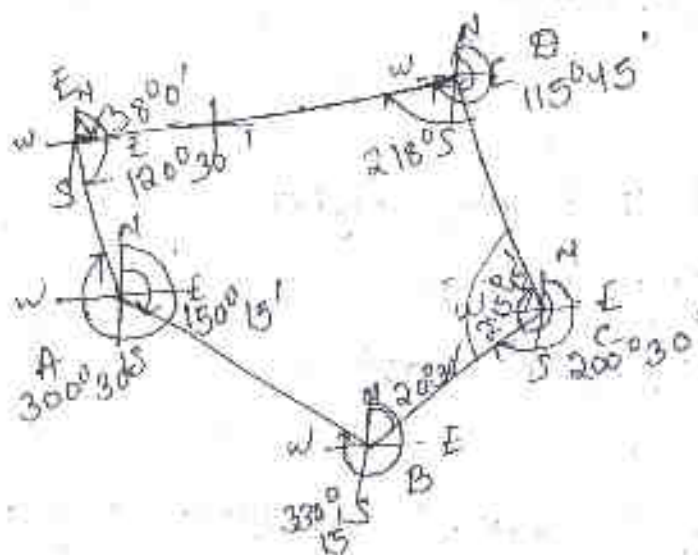
$$\begin{aligned} \text{Internal angle} \\ &= (2 \times 5 - 4) \times 90^\circ \\ &= 540^\circ \\ \text{5 angles} &= 540^\circ \\ \text{1 angle} &= 108^\circ \end{aligned}$$

Q The following are the FB & BB of a closed traverse.

side	FB	BB
AB	$150^{\circ} 15'$	$330^{\circ} 15'$
BC	$20^{\circ} 30'$	$200^{\circ} 30'$
CD	$295^{\circ} 45'$	$115^{\circ} 45'$
DE	$218^{\circ} 0'$	$38^{\circ} 0'$
EA	$120^{\circ} 30'$	$300^{\circ} 30'$

Calculate the interior angle of the traverse?

Soln



Internal Angle

$$\begin{aligned} \text{(i) Exterior } \angle A &= (\text{BB of EA} - \text{FB of AB}) \\ &= (300^{\circ} 30' - 150^{\circ} 15') \\ &= 150^{\circ} 15' \end{aligned}$$

$$\text{Interior } \angle A = 360^{\circ} - 150^{\circ} 15' = 209^{\circ} 45'$$

$$\begin{aligned} \text{(ii) Exterior } \angle B &= \text{BB of AB} - \text{FB of BC} \\ &= 330^{\circ} 15' - 20^{\circ} 30' \\ &= 309^{\circ} 45' \end{aligned}$$

$$\text{Interior } \angle B = 360^\circ - 309^\circ 45' = 50^\circ 15'$$

$$\begin{aligned} \text{(iii) Interior } \angle C &= \text{FB of } CD - \text{BB of } BC \\ &= 295^\circ 45' - 200^\circ 30' \\ &= 95^\circ 15' \end{aligned}$$

$$\begin{aligned} \text{(iv) Interior } \angle D &= \text{FB of } DE - \text{BB of } CD \\ &= 218^\circ - 115^\circ 45' \\ &= 102^\circ 15' \end{aligned}$$

$$\begin{aligned} \text{(v) Interior } \angle E &= \text{FB of } EA - \text{BB of } DE \\ &= 120^\circ 30' - 38^\circ 0' \\ &= 82^\circ 30' \end{aligned}$$

checked

Σ of all Interior angle

$$\begin{aligned} &= (2n-4) \times 90^\circ \\ &= (2 \times 5 - 4) \times 90^\circ \\ &= 540^\circ \end{aligned}$$

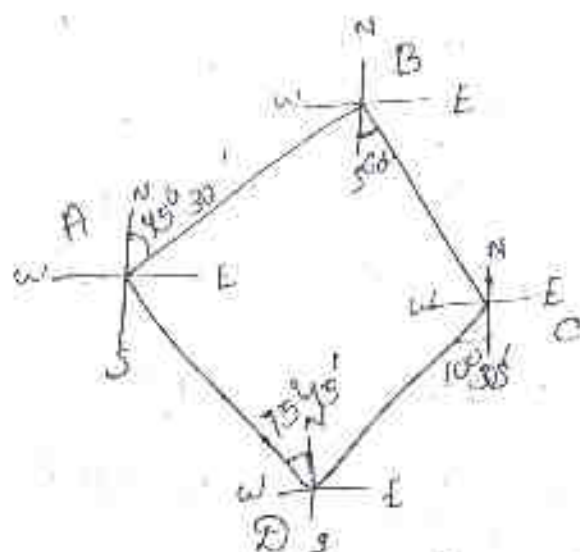
Sum of calculate Interior angle :-

$$\begin{aligned} &= \angle A + \angle B + \angle C + \angle D + \angle E \\ &= 209^\circ 45' + 50^\circ 45' + 95^\circ 15' + 102^\circ 15' + 82^\circ 30' \\ &= 540^\circ \end{aligned}$$

Ex The following are the bearing of a closed traverse

<u>side</u>	<u>FB</u>	<u>BB</u>
AB	N $45^\circ 30'$ E	S $48^\circ 30'$ N
BC	S $60^\circ 0'$ E	N $60^\circ 0'$ W
CD	S $10^\circ 30'$ E	N $10^\circ 30'$ W

DA N $15^{\circ}45'W$ $375^{\circ}45'E$
 calculate the interior angle of the traverse.



(i) Interior angle $\angle A = 180^{\circ} - (45^{\circ}30' + 75^{\circ}45')$
 $= 58^{\circ}45'$

(ii) Interior angle $\angle B = \text{BB of AB} + \text{FB of BC}$
 $= 45^{\circ}30' + 60^{\circ}0'$
 $= 105^{\circ}30'$

(iii) Interior angle $\angle C = \text{BB of BC} + \text{FB of CD}$
 $= 75^{\circ}45' + 10^{\circ}30' = 86^{\circ}15'$

(iv) Interior angle $\angle D = 180^{\circ} - (60^{\circ}0' + 10^{\circ}30')$
 $= 109^{\circ}30'$

Sum of Calculate interior angle:-

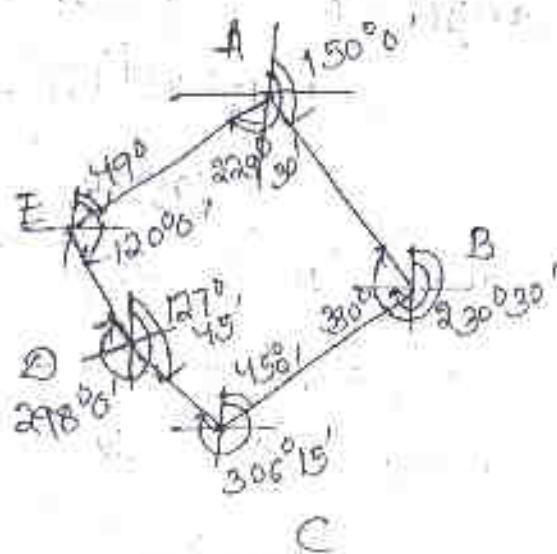
$$\begin{aligned} & \angle A + \angle B + \angle C + \angle D \\ &= 58^{\circ}45' + 105^{\circ}30' + 109^{\circ}30' + 86^{\circ}15' \\ &= 360^{\circ}0' \end{aligned}$$

Checking Σ of all interior angle $= (2 \times 4 - 4) \times 90^{\circ}$
 $= 360^{\circ}0'$

12 Jun 2021

Q The following are the bearings observed in traversing with a compass, an area where local attraction was suspected. calculate the interior angles & correct them if necessary.

<u>Line</u>	<u>FB</u>	<u>BB</u>
AB	$156^{\circ}0'$	$330^{\circ}0'$
BC	$230^{\circ}30'$	$48^{\circ}0'$
CD	$306^{\circ}15'$	$127^{\circ}45'$
DE	$298^{\circ}0'$	$120^{\circ}0'$
EA	$49^{\circ}30'$	$229^{\circ}30'$



Soln

Interior angle $\angle A = \text{BB of EA} - \text{FB of AB}$
 $= 229^{\circ}30' - 156^{\circ}0'$
 $= 73^{\circ}30'$

Interior angle $\angle B = \text{BB of AB} - \text{FB of BC}$
 $= 330^{\circ}0' - 230^{\circ}30'$
 $= 99^{\circ}30'$

$$\text{Exterior angle } L_C = \text{FB of } CD - \text{BB of } CB \\ = 306^\circ - 48^\circ 0' = 258^\circ 15'$$

$$\text{Interior angle } L_C = 360^\circ - 258^\circ 15' = 101^\circ 45'$$

$$(iv) \text{ Exterior angle } L_D = \text{FB of } DE - \text{BB of } DC \\ = 298^\circ 0' - 127^\circ 45' = 170^\circ 15'$$

$$\text{Interior angle } = 360^\circ - 170^\circ 15' = 189^\circ 45'$$

$$\text{Interior angle } L_E = \text{BB of } DE - \text{FB of } EA \\ = 120^\circ 0' - 49^\circ 0' = 71^\circ 0'$$

$$\Sigma \text{ of all interior angle} \\ = (2n - 4) \times 90^\circ = 540^\circ$$

Σ of all calculate interior angle

$$L_A + L_B + L_C + L_D + L_E$$

$$= 79^\circ 30' + 99^\circ 30' + 101^\circ 45' + 189^\circ 45' + 71^\circ 0' \\ = 541^\circ 0'$$

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

$$\text{Correction for angle} = \frac{-10}{-5} = \frac{-60^\circ}{-5} = -12'$$

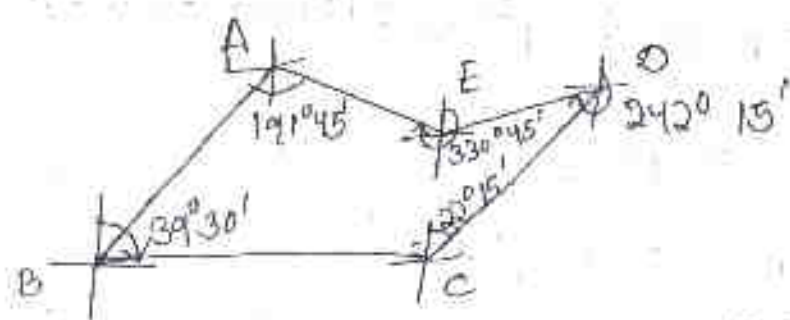
Angle	Calculate value	Correction	Corrected value
L_A	$79^\circ 30'$	$-12'$	$79^\circ 18'$
L_B	$99^\circ 30'$	$-12'$	$99^\circ 18'$
L_C	$101^\circ 45'$	$-12'$	$101^\circ 33'$
L_D	$189^\circ 45'$	$-12'$	$189^\circ 33'$

$$\begin{array}{rcl}
 LE & 70^{\circ}30' & -12^{\circ} & 70^{\circ}18' \\
 & & \hline
 \text{Total} & = & 540^{\circ}0'
 \end{array}$$

Q The following are the observed bearing of a traverse ABCDEA with a compass in a place where local attraction was suspected.

Line	FB	BB
AB	$191^{\circ}45'$	$13^{\circ}0'$
BC	$39^{\circ}30'$	$222^{\circ}30'$
CD	$22^{\circ}15'$	$200^{\circ}30'$
DE	$242^{\circ}45'$	$62^{\circ}45'$
EA	$330^{\circ}45'$	$147^{\circ}45'$

Find the correct bearings of the line?



sol Interior angle $\angle A = \text{FB of AB} - \text{BB of EA}$
 $= 191^{\circ}45' - 147^{\circ}45' = 44^{\circ}0'$

(ii) Interior angle $\angle B = \text{FB of BC} - \text{BB of AB}$
 $= 39^{\circ}30' - 13^{\circ}0' = 26^{\circ}30'$

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

$$= 222^{\circ} 30' - 22^{\circ} 15'$$

$$= 200^{\circ} 15'$$

$$\text{Interior angle} = 360^{\circ} - 200^{\circ} 15'$$

$$= 159^{\circ} 45'$$

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

$$= 242^{\circ} 45' - 200^{\circ} 30'$$

$$= 42^{\circ} 15'$$

$$(v) \text{ Interior angle } LE = \text{FB of EA} - \text{BB of DE}$$

$$= 330^{\circ} 15' - 62^{\circ} 45'$$

$$= 267^{\circ} 30'$$

Calculation for connected bearings:-

The line DE is free from local attraction

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

$$\text{FB of EA} = 330^{\circ} 15' \text{ (correct)}$$

Connected:-

$$\text{FB of AB} = \text{BB of EA} + \text{Interior } \angle A$$

$$= (330^{\circ} 15' - 180^{\circ}) + 44^{\circ}$$

$$= 150^{\circ} 15' + 44^{\circ} = 194^{\circ} 15'$$

$$\text{FB of BC} = \text{BB of AB} + \text{Interior } \angle B$$

$$= (194^{\circ} 15' - 180^{\circ}) + 26^{\circ} 30'$$

$$= 14^{\circ} 15' + 26^{\circ} 30' = 40^{\circ} 45'$$

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

$$= 220^{\circ} 45' - 200^{\circ} 15'$$

$$= 20^{\circ} 30'$$

$$\begin{aligned}
 \text{FB of DE} &= \text{BB of CD} + \text{Internal Angle} \\
 &= (180^\circ + 20^\circ 30') + 42^\circ 15' \\
 &= 200^\circ 30' + 42^\circ 15' \\
 &= 242^\circ 45'
 \end{aligned}$$

Line	Correct	
	FB	BB
AB	$194^\circ 15'$	$14^\circ 15'$
BC	$40^\circ 45'$	$200^\circ 45'$
CD	$20^\circ 30'$	$200^\circ 30'$
DE	$242^\circ 45'$	$62^\circ 45'$
EA	$330^\circ 45'$	$147^\circ 45'$

Type - Compass

There are two types of compasses:-

- (i) Prismatic compass
- (ii) Surveyor's compass

Prismatic Compass

In this compass the readings are taken with the help of a prism. The following are the essential parts of this compass.

(a) Compass Box:- The compass box is a circular metallic box (the metal should be non-magnetic) of 8 to 10 cm diameter. A pivot with a sharp point is provided at the centre of the box.

Magnetic Needle and Graduated Ring:-

The magnetic needle is made of a broad magnetised iron bar. The bar is pointed at both ends. The magnetic needle is attached to a graduated aluminium ring.

The ring is graduated from 0° to 360° clockwise, and the graduations begin from the south end of the needle. Thus 0° is marked at the south, 90° at the west, 180° at the north and 270° at the east.

The degrees are again subdivided into half degrees. The figures are written upside down. The arrangement of the needle and ring contains an agate cap pivoted on the central pivot point.

A rider of brass or silver call is used to counterbalance

45 dip.

(c) Sight vane and prism

The sight vane and the reflecting prism are fixed diametrically opposite to the box. The sight vane is hinged with the metal box and consists of a horseshoe at the centre. The prism consists of a sighting slit at the top and two small circular holes, one at the bottom of the prism and the other at the side of the observer's eye.

(d) Dark glasses:- Two dark glasses are provided with the prism. The red glass is meant for sighting luminous objects at night and the blue glass for reducing the strain on the observer's eye in bright daylight.

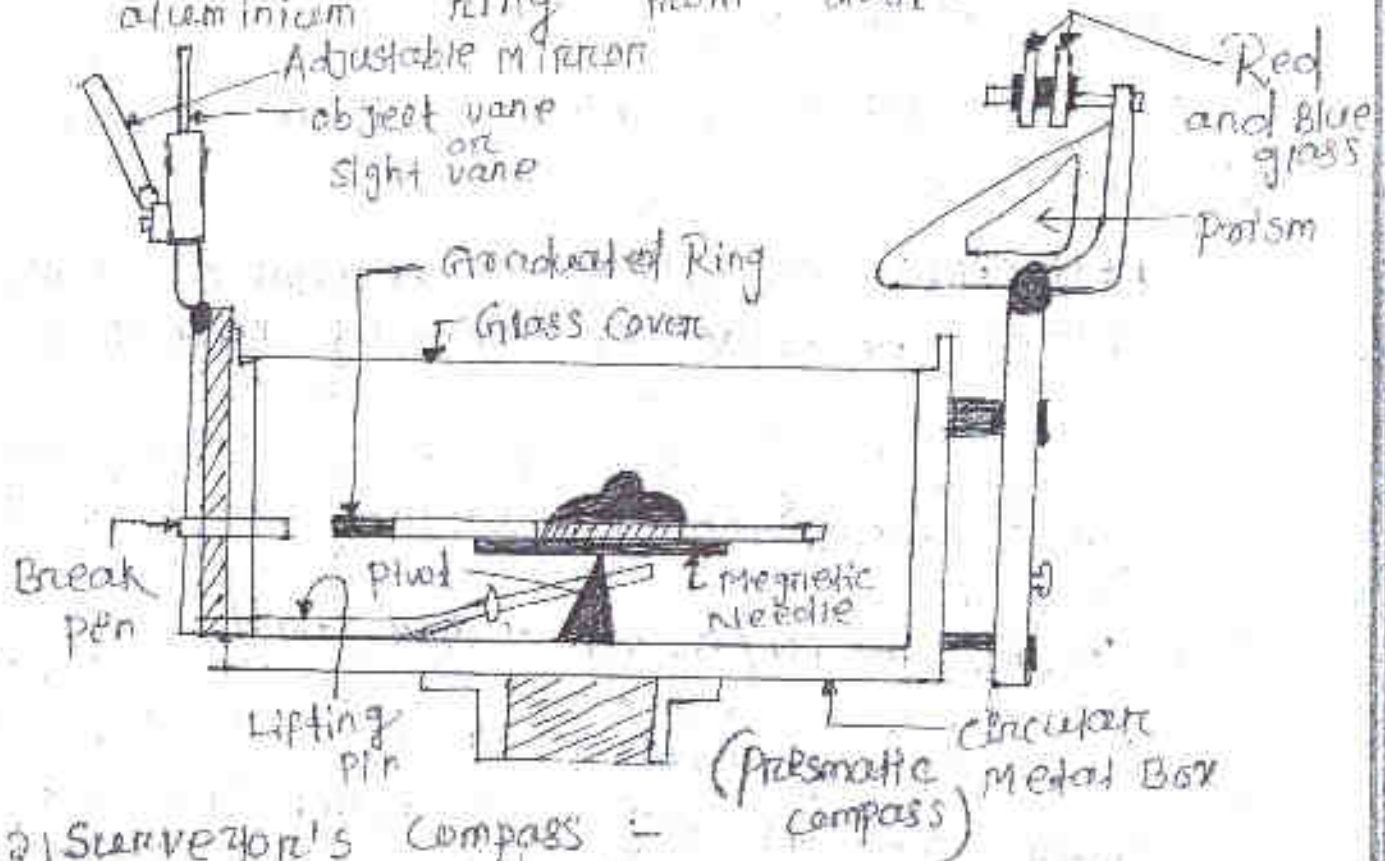
(e) Adjustable mirror:- A mirror is provided with the sight vane. The mirror can be lowered or raised, and can also be inclined. If any object is too low or too high with respect to the line of sight, the mirror can be adjusted to observe it through reflection.

(f) Brake pin:- A brake pin is provided just at the base of the sight vane. If pressed gently, it stops the oscillations of the ring.

(g) Lifting pin:- A lifting pin is provided just below the sight vane. When the sight vane is folded, it presses on the lifting pin.

The lifting pin then lifts the magnetic needle out of the pivot point to prevent damage to the pivot head.

Glass cover:- A glass cover is provided on top of the box to protect the aluminium ring from dust.



(2) Surveyor's Compass :-

The surveyor's compass is similar to the prismatic compass except for the following points.

- (i) There is no prism on it. Readings are taken with the naked eye.
- (ii) It consists of an eye-vane (in place of prism) with a fine sight-slit.
- (iii) The graduated aluminium ring is attached to the circular box. It is not fixed to the magnetic needle.
- (iv) The magnetic needle moves freely over the pivot. The needle shows the reading on the graduated ring.

- (v) The ring is graduated from 0° to 90° in four quadrants 0° is marked at the north and south, and 90° at the east and west. The letters E and W are interchanged from their true positions. The figures are written the right way up.
- (f) A mirror is attached to the object vane.

TEMPORARY ADJUSTMENT OF PRISMATIC COMPASS (Field procedure of observing bearing)

The following procedure should be adopted while measuring the bearing by prismatic compass.

- (1) Fixing the compass with tripod stand.

The tripod stand is placed at the required station with its legs well apart. Then the prismatic compass is held by the left hand and placed over the threaded top of the stand. After this, the compass box is fixed with the threaded top of the stand.

- (2) Centring Normally, the compass is centred by dropping a piece of stone from the bottom of the compass box. Centring may also be done with the aid of a plumb bob held centrally below the compass box.

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

This arrangement is loosened and the box is placed in such a way that the graduated ring rotates freely without touching either the bottom of the box or the glass cover on top.

(4) Adjustment of prism:-

The prism is moved up and down till the figures on the graduated ring are seen sharp and clear.

(5) Observation of Bearing:-

After centring and levelling the compass box over the station, the ranging rod at the required station is bisected perfectly by sighting through the slit of the prism and horizontal at the sight vane.

At this time, the graduated ring may rotate rapidly. The brake pin is pressed very gently to stop this rotation when the ring comes to rest, the box is struck very lightly to verify the horizontality of the ring and the frictional effect on the pivot point. Then the reading is taken from the graduated ring through the hole in the prism. This reading will be the magnetic bearing of the line.

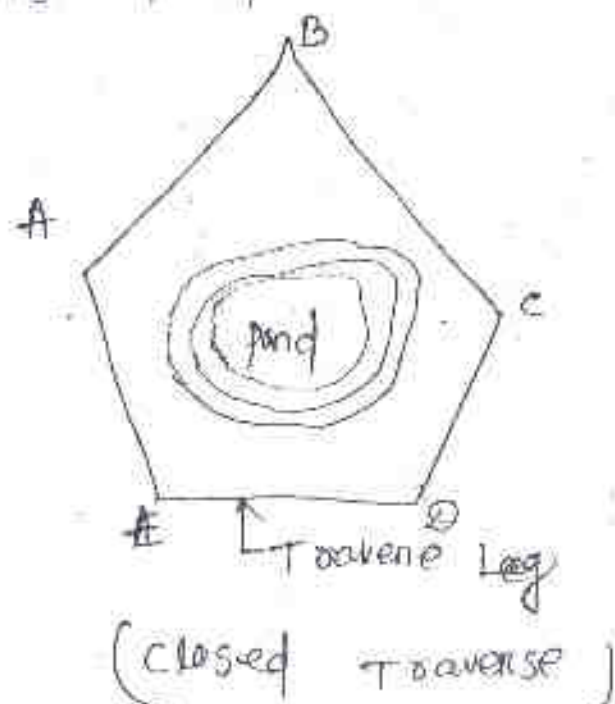
Traversing :- As already stated in the

last section, surveying which involves a series of connected lines is known as 'traversing'. The sides of the traverse are known as 'traverse legs'.

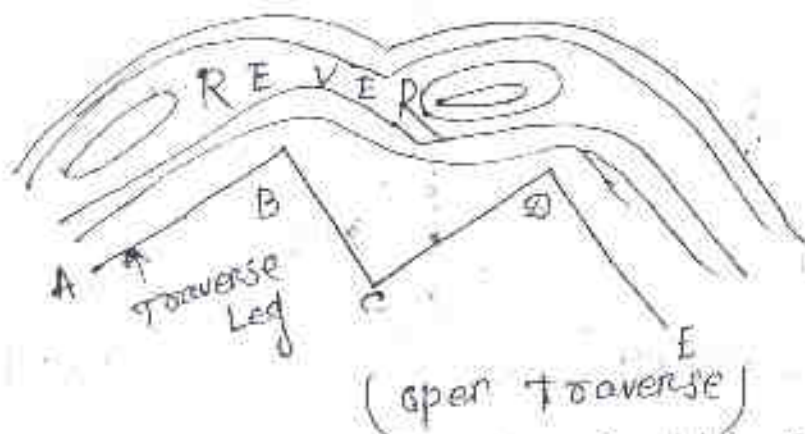
In traversing the lengths of the lines forms a closed circuit i.e. when the finishing point coincides with the starting point of a survey. It is called a 'closed traverse'. Here ABCDEA represents one measured by chain and the directions are fixed by compass or theodolite or by forming angles with chain and tape. A traverse may be of two types - closed and open.

(i) closed traverse when a series of a

connected lines forms a closed circuit. i.e. when the finishing point coincides with the starting point of a survey, it is called a 'closed traverse'. Here ABCDEA represents a closed traverse. closed traverse is suitable for the survey of boundaries of ponds, forests, estates, etc.



open traverse When a sequence of connected lines extends along a general direction and does not return to the starting point. It is known as 'open traverse' or 'unclosed traverse'. Here ABCDE represents an open traverse.



open traverse is suitable for the survey of roads, rivers, coast lines, etc.

METHODS OF TRAVERSING

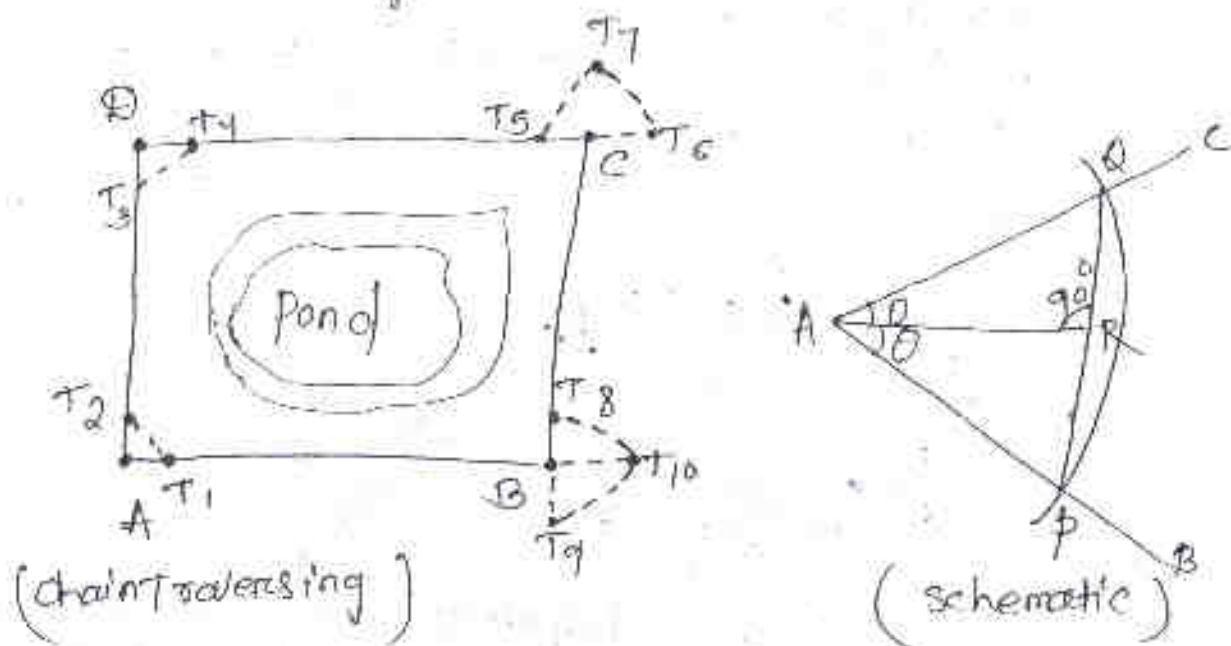
Traverse survey may be conducted by the following methods.

- ① chain traversing by (chain angle)
- ② compass traversing (by free needle)
- ③ theodolite traversing (by fast needle)
- ④ plane table traversing (by plane table)

Chain Traversing :-

chain traversing is mainly conducted when it is not possible to adopt triangulation. In this method, the angle between adjacent sides are fixed by 'chain angles'. The entire survey is conducted by chain and

tape only and no angular measurements are taken. When it is not possible to form triangles, as for example in a pond, chain traversing is conducted.



The formation of chain angles is explained below.

First Method :- Suppose a chain angle is to be formed to fix the direction of side AB and AD. Tie stations T_1 and T_2 are fixed on the lines AB and AD. The distances AT_1 , AT_2 and T_1T_2 are measured. Then the angle $\angle T_1AT_2$ is said to be the chain angle. So the chain angle is fixed by the tie line T_1T_2 .

Second Method Sometimes the chain angle is fixed by a chord. Suppose the angle betⁿ the lines AB and AC is to be fixed. Taking A as the centre and a radius equal to one tape

length (15m) an arc intersecting the line AB and AC at points P and Q, respectively is drawn. The chord PQ is measured and bisected at R.

$$\text{Let } \angle PAR = \theta$$

$$\angle BAC = 2\theta$$

$$AP = AQ = 15\text{m}$$

$$\text{In triangle PAR } \sin \theta = \frac{PR}{AP} = \frac{2PR}{2AP} = \frac{PQ}{30}$$

$$\therefore \theta = \sin^{-1} \frac{PQ}{30}$$

The angle θ can be calculated from the above equation, and the chain angle $\angle BAC$ can be determined accordingly.

(2) Compass Traversing:- In this method, the fore and back bearing of the traverse legs are measured by a prismatic compass and the sides of the traverse by chain or tape. Then the observed bearings are verified and necessary correction for local attraction are applied. In this method, closing error may occur when the traverse is plotted. This error is adjusted graphically by using Bowditch's rule.

(3) Theodolite Traversing

In such traversing, the horizontal angles between the traverse legs are measured by a theodolite. The length of the legs are measured by chain or by the stadia method.

The magnetic bearings of the starting leg is measured by a theodolite. Then the magnetic bearings of the other sides are calculated. The independent coordinates of all the traverse stations are then found out. This method is very accurate.

(v) plane table traversing

ooo
In this method, a plane table is set at every traverse station in the clockwise or anticlockwise direction, and the circuit is finally closed. During traversing, the sides of the traverse are plotted according to any suitable scale. At the end of the work, any closing error which may occur is adjusted graphically.

CHECK ON CLOSED TRAVERSE

oooo
Check on Angular measurements

- ~~~~~ o o ~~~~~ o o ~~~~~ o o ~~~~~
- (a) The sum of the measured interior angles should be equal to $(2N-4) \times 90^\circ$.
 - (b) The sum of the measured exterior angles should be equal to $(2N+4) \times 90^\circ$.
 - (c) The algebraic sum of the deflection angles should be equal to 360° .

Right-hand deflection is considered positive and left-hand deflection negative.

check on Linear Measurement

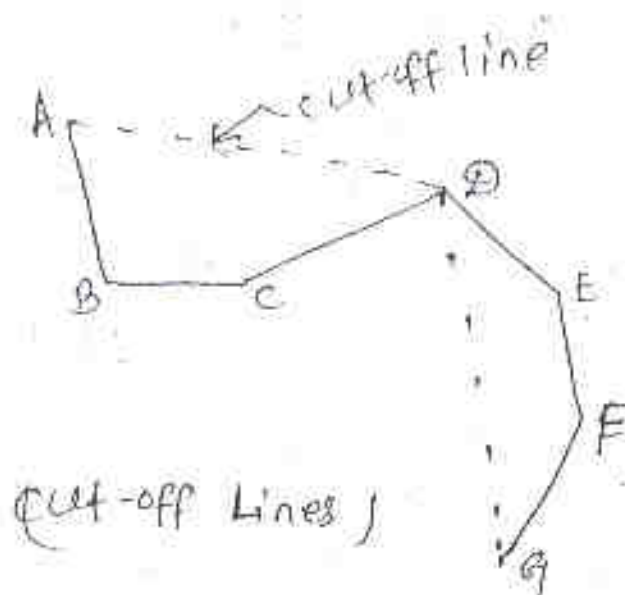
- (a) The lines should be measured once each on two different days (along opposite directions). Both measurements should tally.
- (b) Linear measurements should also be taken by the stadia method. The measurements by chaining and by the stadia method should tally.

CHECK ON OPEN TRAVERSE

In open traverse, the measurements cannot be checked directly. But sum field measurements can be taken to check the accuracy of the work. The methods are discussed below.

Taking cut-off lines

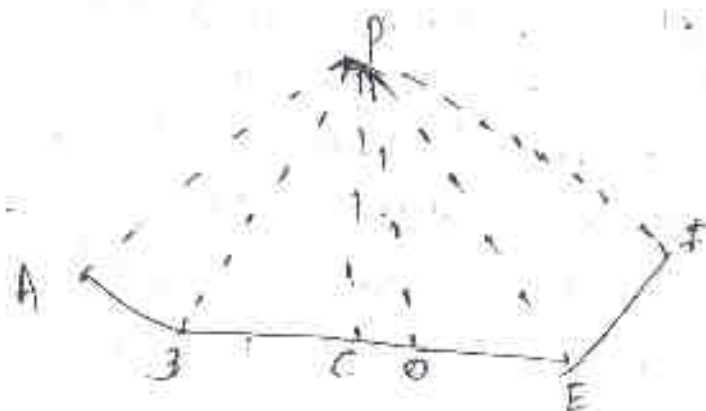
Cut-off lines are taken between some intermediate stations of the open traverse. Suppose ABCDEFG represents an open traverse. Let AG and EG be the cut-off lines. The lengths and magnetic bearings of the cut-off lines are measured accurately. After plotting the traverse, the distance and bearing are noted from the map. These distance and bearings should tally with the actual records obtained from the field.



(Cut-off Lines)

Taking an Auxiliary point :-

Suppose ABCDEF is an open traverse. A permanent point P is selected on one side of it. The magnetic bearings of this point are taken from the traverse stations - A, B, C, etc. If the survey is carried out accurately and so is the plotting, all the measured bearings of P when plotted should meet at the point P. The permanent point P is known as the auxiliary point.

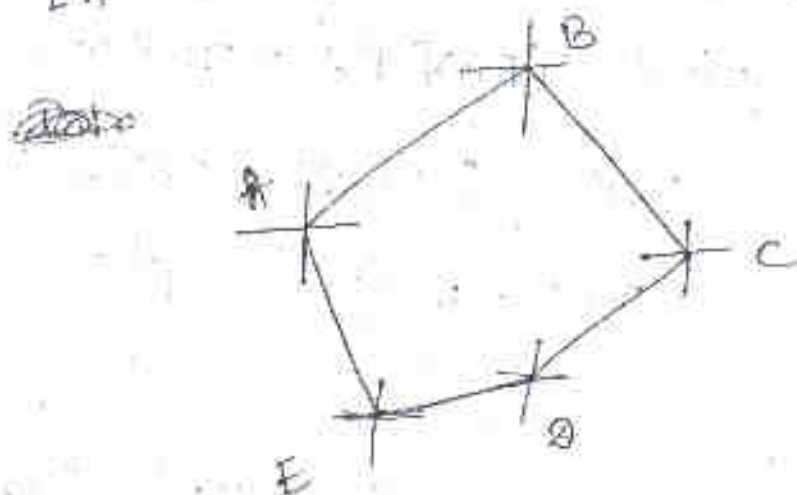


(Auxiliary point)

19 Jun 2021

Q The following bearings were observed in traversing with a compass, an error where local attraction was suspected find the amount of local attraction at different stations, the correct bearings of lines & the included angles.

Line	FB	BB
AB	$68^{\circ} 15'$	$248^{\circ} 15'$
BC	$148^{\circ} 45'$	$32^{\circ} 15'$
CD	$224^{\circ} 30'$	$46^{\circ} 00'$
DE	$217^{\circ} 13'$	$38^{\circ} 15'$
EA	$327^{\circ} 45'$	$147^{\circ} 45'$



$$\begin{aligned}
 \text{Interior } \angle A &= \text{BB of EA} - \text{FB of AB} \\
 &= 147^{\circ} 45' - 68^{\circ} 15' \\
 &= 79^{\circ} 30'
 \end{aligned}$$

$$\begin{aligned}
 \text{Interior } \angle B &= \text{BB of AB} - \text{FB of BC} \\
 &= 248^{\circ} 15' - 148^{\circ} 45' \\
 &= 99^{\circ} 30'
 \end{aligned}$$

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

$$= 326^{\circ}15' - 224^{\circ}30'$$

$$= 101^{\circ}45'$$

Internal $\angle D = 360^{\circ} - \text{external angle } \angle D$

$$= 360^{\circ} - (\text{FB of } DE - \text{BB of } CD)$$

$$= 360^{\circ} - (217^{\circ}15' - 46^{\circ}00')$$

$$= 360^{\circ} - 171^{\circ}15' = 188^{\circ}45'$$

Internal angle $\angle E = 360^{\circ} - \text{external } \angle E$

$$= 360^{\circ} - (\text{FB of } EA - \text{BB of } DE)$$

$$= 360^{\circ} - (327^{\circ}45' - 38^{\circ}15')$$

$$= 360^{\circ} - 289^{\circ}30' = 70^{\circ}30'$$

CHECKED

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

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

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

$$= 540^{\circ}$$

Calculation for connected bearings :-

The line EA & AB is free from local attraction.

$$\text{FB of EA} = 327^{\circ}45' \text{ (Correct)}$$

$$\text{FB of AB} = 68^{\circ}15' \text{ (Correct)}$$

$$\text{FB of BC} = 148^{\circ}45' \text{ (Correct)}$$

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

$$= (148^{\circ}45' + 180^{\circ}) - 101^{\circ}45'$$

$$= 328^{\circ}45' - 101^{\circ}45'$$

$$= 227^{\circ}0'$$

$$\text{FB of DE} = \text{BB of CD} + \text{external } \angle D$$

$$= (\text{FB of CD} + 180^{\circ}) + (360^{\circ} - \text{Internal } \angle D)$$

$$= (227^{\circ} - 180^{\circ}) + (360^{\circ} - 188^{\circ}45')$$

$$= 47^{\circ} + 171^{\circ}15'$$

$$= 218^{\circ}15'$$

$$\text{FB of EA} = \text{BB of DE} + \text{external } \angle E$$

$$= (218^{\circ}15' - 180^{\circ}) + (360^{\circ} - 70^{\circ}30')$$

$$= 38^{\circ}15' + 289^{\circ}30'$$

$$= 327^{\circ}45'$$

$$\text{FB of AB} = \text{BB of EA} - \text{Internal } \angle A$$

$$= (327^{\circ}45' - 180^{\circ}) - 79^{\circ}30'$$

$$= (147^{\circ}45') - 79^{\circ}30' = 68^{\circ}15'$$

$$\begin{aligned}
 \text{FB of BC} &= \text{BB of AB} - \text{Internal } \angle B \\
 &= (\text{FB of AB} + 180^\circ) - 99^\circ 30' \\
 &= (68^\circ 15' + 180^\circ) - 99^\circ 30' \\
 &= 248^\circ 15' - 99^\circ 30' \\
 &= 148^\circ 45'
 \end{aligned}$$

Line	Corrected	
	FB	BB
AB	68° 15'	248° 15'
BC	148° 15'	328° 45'
CD	227° 0'	47° 0'
DE	218° 15'	38° 15'
EA	327° 45'	147° 45'

2nd method

(i) The line AB & EA is free from local attraction. So station A, B & E are free from local attraction.

(ii) The FB of BC is also correct.

(iii) FB of BC = 148° 45'

$$\text{BB of BC} = 148^\circ 45' + 180^\circ = 328^\circ 45'$$

$$\text{observed BB of BC} = 326^\circ 15'$$

$$\text{Correction} = 328^\circ 45' - 326^\circ 15'$$

$$= +2^\circ 30' \text{ applied at station 'c'}$$

$$\begin{aligned}
 \text{iv) FB of CD} &= \text{observed FB of CD} + 2^{\circ}30' \\
 &= 224^{\circ}30' + 2^{\circ}30' \\
 &= 227^{\circ}
 \end{aligned}$$

$$\text{Connected BB of CD} = 227^{\circ} - 180^{\circ} = 47^{\circ}$$

$$\text{observed BB of CD} = 46^{\circ}$$

$$\text{Correction} = 47^{\circ} - 46^{\circ} = 1^{\circ} \text{ applied at station 'D'}$$

$$\text{v) FB of DE} = \text{observed FB of DE} + 1^{\circ}$$

$$= 217^{\circ}15' + 1^{\circ}$$

$$= 218^{\circ}15'$$

$$\text{Connected BB of DE} = 218^{\circ}15' - 180^{\circ}$$

$$= 38^{\circ}15'$$

$$\text{observed BB of DE} = 38^{\circ}15'$$

observed			Correction	Connected		Remarks
Line	FB	BB		FB	BB	
AB	68°15'	248°15'	0° at A	68°15'	248°15'	Station A is free from local attraction.
BC	148°45'	326°15'	0° at B	148°45'	326°45'	Station B is free from local attraction.
CD	224°30'	46°00'	+2°30' at C	227°	47°	
DE	217°15'	38°15'	+1° at D	218°15'	38°15'	
EA	327°45'	147°45'	0° at E	327°45'	147°45'	Station E is free from local attraction.

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Following are the bearings observed while traversing with a compass an area where local attraction was suspected find the correct bearings of the line & also true bearings if the magnetic declination is $10^{\circ}W$.

Line	FB	BB
AB	$59^{\circ}00'$	$239^{\circ}00'$
BC	$139^{\circ}30'$	$317^{\circ}00'$
CD	$215^{\circ}15'$	$36^{\circ}30'$
DE	$208^{\circ}00'$	$29^{\circ}00'$
EA	$318^{\circ}30'$	$138^{\circ}45'$

(i) The line AB is free local attraction station A & B free local attraction.

(ii) FB of BC is correct.

$$BB \text{ of } BC = 139^{\circ}30' + 180^{\circ} = 319^{\circ}30'$$

$$\text{Observed } BB \text{ of } BC = 317^{\circ}00'$$

$$\text{Correction} = 319^{\circ}30' - 317^{\circ}00' = +2^{\circ}30'$$

at 'C' station.

$$(iii) \text{ FB of } CD = 215^{\circ}15' + 2^{\circ}30' = 217^{\circ}45'$$

$$\text{Correct BB of } CD = 217^{\circ}45' - 180^{\circ} = 37^{\circ}45'$$

observed BB of CD = $360^{\circ}30'$

$$= 37^{\circ}45' - 36^{\circ}30' = +1^{\circ}15' \text{ station 'D'}$$

(iv) FB of DE = $208^{\circ} + 1^{\circ}15' = 209^{\circ}15'$

observed BB of DE = $29^{\circ}15'$

$$\text{Correction} = 29^{\circ}15' - 29^{\circ}0'$$

$$= +0^{\circ}15' \text{ applied station 'E'}$$

(v) FB of EA = $318^{\circ}30' + 0^{\circ}15' = 318^{\circ}45'$

$$\text{observed} = 138^{\circ}45'$$

$$\text{correct bearing of EA} = 138^{\circ}45'$$

Line	observed		Correction	Corrected		Remarks
	FB	BB		FB	BB	
AB	$59^{\circ}0'$	$289^{\circ}0'$	0° at 'A'	$59^{\circ}0'$	$239^{\circ}0'$	Station A is free from local attraction
BC	$139^{\circ}30'$	$317^{\circ}0'$	0° at 'B'	$139^{\circ}30'$	$319^{\circ}30'$	
CD	$215^{\circ}15'$	$36^{\circ}30'$	$+2^{\circ}30'$ at 'C'	$217^{\circ}45'$	$37^{\circ}45'$	Station B is free from local attraction
DE	$208^{\circ}0'$	$29^{\circ}0'$	$+1^{\circ}30'$ at 'D'	$209^{\circ}15'$	$29^{\circ}15'$	
EA	$318^{\circ}30'$	$138^{\circ}45'$	$+0^{\circ}15'$ at 'E'	$318^{\circ}45'$	$138^{\circ}45'$	

True Bearing

Line	Corrected bearing		declination -10°W	True Bearing	
	FB	BB		FB	BB
AB	59°0'	239°0'	-10°W	49°0'	229°0'
BC	139°30'	319°30'	-10°W	129°30'	309°30'
CD	217°45'	37°45'	-10°W	207°45'	27°45'
DE	209°15'	29°15'	-10°W	199°15'	19°15'
EA	318°45'	138°45'	-10°W	308°45'	128°45'

SOURCES OF ERROR IN A COMPASS :-

The following are the kinds of error which may occur while taking reading with a compass.

(1) Instrumental Errors :-

- The needle may not be perfectly straight and might not be balanced properly.
- The pivot point may be eccentric.
- The graduations of the ring may not be uniform.
- The ring may not rotate freely on account of the pivot point being blunt. This may occur due to the head of the pivot being broken because of careless handling.

- (e) The sight vane may not be vertical.
- (f) The horse hair may not be straight and vertical.

(2) Personal Errors

- (a) The centring may not be done perfectly over the station.
- (b) The graduated ring may not be levelled.
- (c) The object might not be bisected properly.
- (d) The readings may be taken or entered carelessly.
- (e) The observer may be carrying magnetic substances.

(3) Other Sources of Error

- (a) There may be local attraction due to the presence of magnetic substances near the station.
- (b) The magnetic field could vary on account of some natural causes.
- (c) The magnetic declination might vary.

PRECAUTIONS TO BE TAKEN IN COMPASS SURVEYING

The following precautions should be taken while conducting a compass traverse:

- (i) The centring should be done perfectly.
- (ii) To stop the rotation of the graduated ring, the brake pin should be pressed very gently and not suddenly.

- (3) Readings should be taken along the line of sight and not from any side.
- (4) When the compass has to be shifted from one station to another, the sight vane should be folded over the glass cover. This is done to lift the ring out of the pivot to avoid unnecessary wear of the pivot head.
- (5) The compass box should be tapped gently before taking the reading. This is done to find out whether the needle rotates freely.
- (6) The stations should not be selected near magnetic substances.
- (7) The observer should not be carrying magnetic substances.
- (8) The glass cover should not be dusted with a handkerchief, because the glass may be charged with electricity and the needle may be deflected from its true direction. The glass cover should be cleaned with a moist finger.

PLOTTING of COMPASS TRAVERSE :-

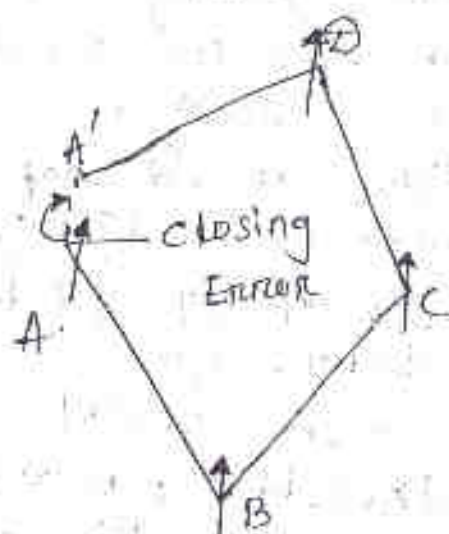
The following are the various methods of plotting compass traverse.

(1) By parallel Meridian Through Each station

The starting point A is suitably selected on the paper and a line representing the north line. The bearing of the line AB is plotted by protractor and its length is plotted to any suitable scale.

At station B, the north line is drawn parallel to the north line which was drawn at A. Then the bearing of the line BC is plotted and its length marked according to the previous scale.

Similarly, all the traverse legs are plotted. In case of closed traverse, there may be a closing error which should be adjusted graphically.

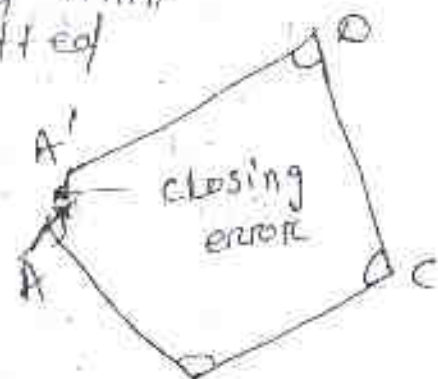


(Plotting Compass Traverse by parallel Meridian)

(2) By considering Included Angles :-

The starting station A is suitably selected on the sheet. A line representing the north line is drawn through the station A. The bearing of the line AB is plotted by a protractor and the distance AB marked to a suitable scale. At the station B, the angle B is plotted and the distance BC marked according to the previous scale. Angle C is plotted at the station C.

The process is continued until all the lines have been plotted. In this case also, there may be a closing error which has to be adjusted graphically.

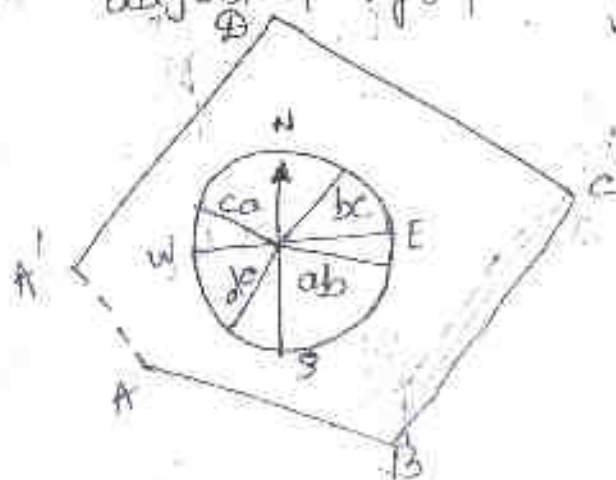


(3) By considering the central Meridian:-

A suitable point O is selected at the centre of the drawing sheet. A line representing the magnetic meridian is drawn through this point. Then a protractor is placed at O and all the lines, namely ab, bc, cd and da, are drawn according to their bearings.

Then a starting point A is suitably selected on the sheet. A line AB is drawn parallel to ab, and the length AB is plotted to a suitable scale. Again from B a line BC is drawn parallel to the line bc, and the distance BC is plotted to the previous scale.

The process is continued until all the lines have been drawn. In this case also there may be a closing error is adjusted graphically.



NOTE After adjustment of the closing error, the objects are plotted according to the offsets noted in the field book.

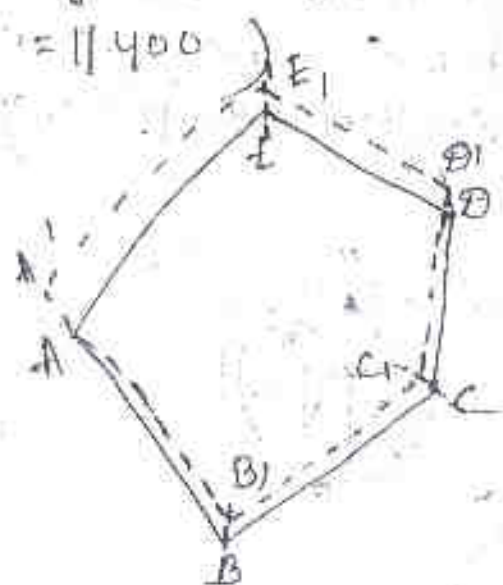
ADJUSTMENT OF CLOSING ERROR

When a closed traverse is plotted, the finishing and starting points may not coincide. The distance by which the traverse fails to close is said to be the closing error. Such an error may occur due to mistakes made in the measurement of lengths and bearings of the lines, or because of an error in plotting.

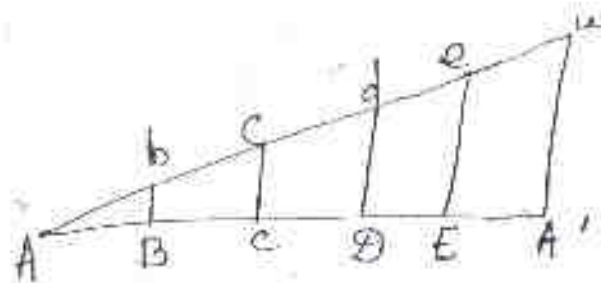
If the closing error exceeds a certain permissible limit, the field work should be repeated. But when the error is within the permissible limit, it is adjusted graphically by Bowditch's rule as explained below.

Suppose a traverse AB, C, D, E, A , is plotted according to any suitable scale.

($RF = 1/400$)



$DE = 1/400$



$$RF = \frac{1}{2000} \text{ (say)}$$

(Adjusting closing Error)

In this case, the traverse fails to close by a distance AA' , which is the closing error.

To adjust this error, a horizontal AA_1 is drawn to represent the perimeter of the traverse to another scale ($RF = 1/2,000$) on this line, distance AB_1 , B_1C_1 , C_1D_1 , D_1E_1 and E_1A_1 are set off according to the corresponding measured lengths of the traverse legs. A perpendicular A_1O is drawn equal to the amount of closing error, after which the line AO is drawn. From the points B_1 , C_1 , D_1 and E_1 the lines

B_1b , C_1c , D_1d and E_1e are drawn parallel to A_1O . These intercept represent the amount by which the respective stations are to be shifted.

Lines are drawn parallel to the closing error through stations B_1 , C_1 , D_1 and E_1 . Then the intercepts B_1b , C_1c , D_1d and E_1e are set off along the parallel lines drawn through the respective stations. In this manner, the adjusted traverse $ABCDEA$ is obtained.

OBJECT AND USE OF LEVELLING

Object

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

Uses

Levelling is done for the following purposes:

- (1) To prepare a contour map for fixing sites for reservoirs, dams, harbours, etc. and to fix the alignment of roads, railway, irrigation canals, and so on.
- (2) To determine the altitudes of different important points on a hill or to know the reduced levels of different points on or below the surface of the earth.
- (3) To prepare a longitudinal section and cross-section of a project (roads, railways, irrigation canals, etc) in order to determine the volume of earth work.
- (4) To prepare a layout map for water supply, sanitary or drainage schemes.

DEFINITIONS

(1) Levelling— The art of determining the relative heights of different points on or below the surface of the earth is known as levelling. Thus, levelling deals with measurements in the vertical plane.

(2) Level surface Any surface parallel to the mean spheroidal surface of the earth is said to be a level surface. Such a surface is obviously curved. The water surface of a still tank is also considered a level surface.

Level line :- Any line lying on a level surface is called a level line. This line is perpendicular to the plumb line (direction of gravity) at all points.



(4) Horizontal plane :- Any plane tangential to the level surface at any point is known as the horizontal plane. It is perpendicular to the plumb line which indicates the direction of gravity.

(5) Horizontal line :- Any line lying on the horizontal plane is said to be a horizontal line. It is a straight line tangential to the level line.

(6) Vertical line :- The direction indicated by a plumb line (the direction of gravity) is known as the vertical line. This line is perpendicular to the horizontal line.

(7) Vertical plane :- Any plane passing through the vertical line is known as the vertical plane. This plane is

(8) Datum surface or line :- This is an imaginary level line from which the vertical distance of different points (above or below this line) are measured. In India, the datum

adopted for the Great Trigonometrical Survey (GTS) is the mean Sea Level (MSL) at Karachi.
(9) Reduced Level (RL) - The vertical distance of a point above or below the datum line is known as the reduced level (RL) of that point. The RL of a point may be positive or negative according as the point is above or below the datum.

(10) Line of Collimation :- It is an imaginary line passing through the intersection of the cross-hair of the diaphragm and the optical centre of the object glass and its continuation. It is also known as the line of sight.

(11) Axis of the Telescope :- This axis is an imaginary line passing through the optical centre of the object glass and the optical centre of the eyepiece.

(12) Axis of Bubble Tube :- It is an imaginary line tangential to the longitudinal curve of the bubble tube at its middle point.

(13) Bench - marks (BM) - These are fixed points or marks of known RL determined with reference to the datum line. These are very important marks. They serve as reference points for finding the RL of new points or for conducting levelling operations in projects involving roads, railways etc.

Bench - marks may be of four types

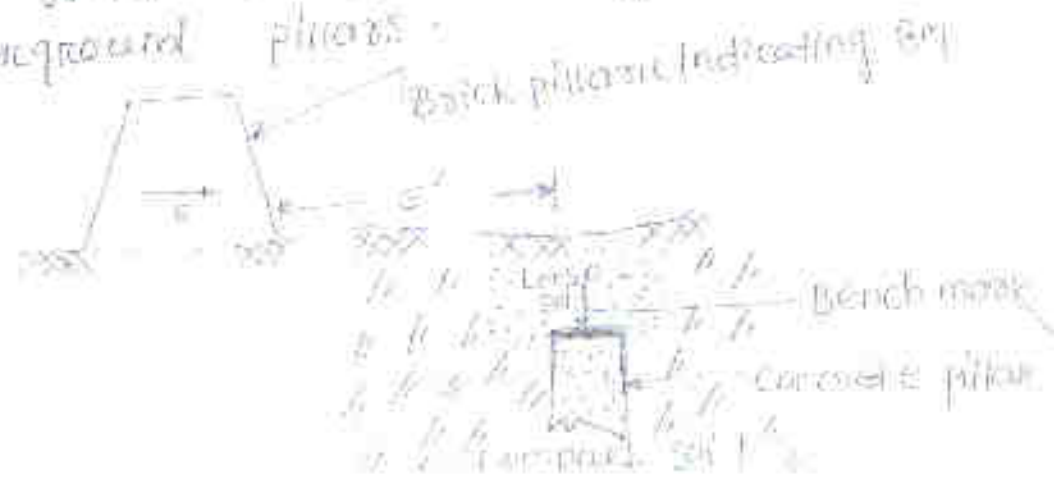
(a) GTS (b) permanent (c) temporary

(d) Arbitrary

(a) GTS Bench-Marks :- These bench-marks are established by the survey of India Department at large intervals all over the country. The values of reduced levels, the relevant positions and the number of bench-marks are given in a catalogue published by this department.



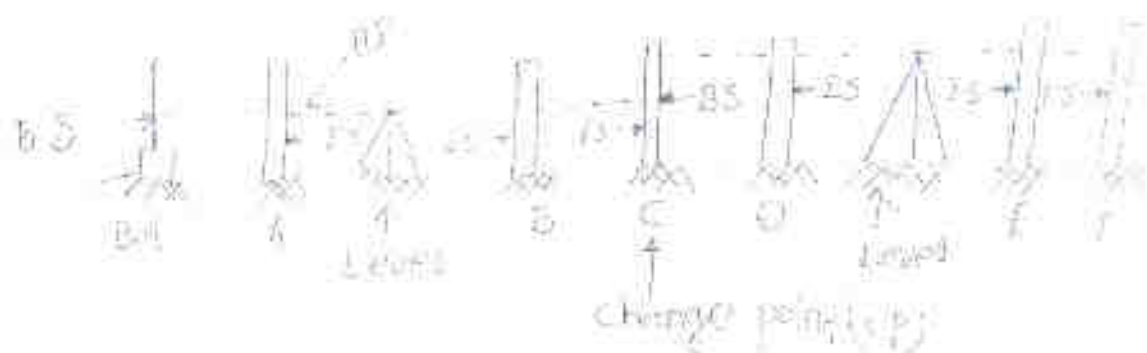
(b) Permanent Bench-Marks :- These are fixed points or marks established by different government departments like P.W.D. & Railway, Irrigation, etc. The RLs of these points are determined with reference to the GTS bench-mark, and one kept on permanent points like the pierth of a building, parapet of a bridge or a corner, and so on. Sometimes they are kept on underground pillars.



(c) Temporary Bench Marks :- when the bench marks are established temporarily at the end of a day's work, they are said to be temporary bench marks. They are generally made on the root of a tree, the parapet of a railway, a current, a furlong post, or in a similar place.

(d) Arbitrary Bench Marks :- when the RLs of some fixed points are assumed, they are termed arbitrary bench marks. These are adopted in small survey operations when only the undulation of the ground surface is required to be determined.

Backsight Reading (BS) This is the first staff reading taken in any set-up of the instrument after the levelling has been perfectly done. This reading is always taken on a point of known RL, i.e. on a bench mark or change point.



BS, IS, FS and CP Reading

Foresight Reading (FS) It is the last staff reading in any set-up of the instrument and indicates the shifting of the latter.

Intermediate Sight Reading (IS) It is any other staff between the BS and FS in the same set-up of the instrument.

change point (CP) The point indicates the shifting of the instrument. At this point, an FS is taken from one setting and a BS from the next setting.

Height of Instrument :- When the levelling instrument is properly levelled, the RL of the line of collimation is known as height of instrument. This is obtained by adding the BS reading to the RL of the BM or CP on which the staff reading was taken.

Focussing The operation of setting the eyepiece and the object glass a proper distance apart for clear vision of the object is known as focussing. This is done by turning the focussing screw clockwise or anticlockwise.

The function of the object glass is to bring the object into focus on the diaphragm and that of the eyepiece is to magnify the cross-hairs and objects.

Focussing is done in two steps as follows:

- a) focussing the eyepiece. A sheet of white paper is held in front of the telescope and the eyepiece is turned clockwise or anticlockwise slowly until the cross-hairs appear distinct and clear.
- b) focussing the object glass the telescope is directed to the object and the focussing screw is turned clockwise or

anticlockwise until the image is clear and sharp.

Parallax The apposition of the image with the cross-hairs is known as parallax. This occurs due to imperfect focussing when the image does not fall in the plane of the alidade.

The parallax is tested by moving the eye up and down. If the focussing is perfect, the image appearance is fixed to the cross-hairs. The parallax may be eliminated by properly focussing the telescope.

DIFFERENT TYPES OF LEVELS

(i) Dumpy Level - The telescope of the dumpy level is rigidly fixed to its support. It cannot be removed from its support. It can be rotated about its longitudinal axis. The instrument is stable and retains its permanent adjustment for a long time. This instrument is commonly used.

(ii) Leveling level The telescope is held in two 'y' supports. It can be removed from the supports and reversed from one end of the telescope to the other end. The 'y' supports consist of two curved clips which may be raised. Thus the telescope can be rotated about its longitudinal axis.

(iii) Cooke's Reversible Level - This is a combination of the dumpy level and the y-level. It is supported by two rigid sockets.

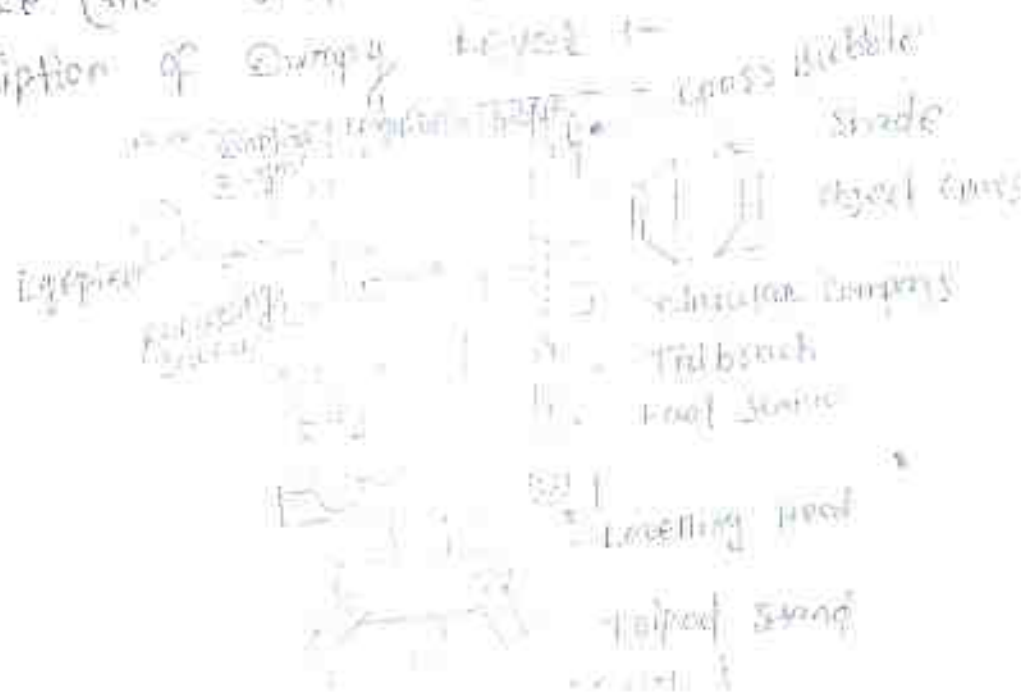
The telescope can be rotated about its longitudinal axis. withdrawn from the socket and replaced from one end of the telescope to the other end.

- (ii) caustically level :- The telescope cannot be removed from the sockets and rotated about its longitudinal axis. The eye-piece and object glass are removable and can be interchanged from one end of the telescope to the other end.

- (iii) Modern tilting level :- The telescope can be tilted slightly about its horizontal axis with the help of a tilting screw. In this instrument, the line of collimation is made horizontal for each observation by means of the tilting screw.

- (iv) Automatic level :- This is also known as the self-aligning level. This instrument is levelled automatically within a certain tilt range by means of a compensating device (the tilt compensator).

Description of Simple level :-



- (1) Tripod stand :- The tripod stand consists of three legs which may be solid or framed. The legs are made of light and hard wood. The lower ends of the legs are fitted with steel shoes.
- (2) Levelling head :- The levelling head consists of two parallel triangular plates having three grooves to support the foot screws.
- (3) Foot screws :- Three foot screws are provided between the tablet and tribrach. By turning the foot screws the tribrach can be raised or lowered to bring the bubbles to the centre of its run.
- (4) Telescope :- The telescope consists of two metal tubes, one moving within the other. It also consists of an object glass and an eyepiece at opposite ends. A diaphragm is fixed with the telescope just in front of the eyepiece. The diaphragm carries cross-hairs. The telescope is focussed by means of the focussing screw and may have either external focussing or internal focussing.

In the external focussing telescope, the diaphragm is fixed to the outer tube and the objective to the inner tube. By turning the focussing screw, the distance between the objective and diaphragm is altered to form a real image on the plane of cross-hairs.

In the internal focussing telescope the objective and eyepiece do not move when the focussing screw is turned. Hence

Leveling Staff :- The leveling staff is a graduated rod used for measuring the vertical distance betⁿ the points on the ground and the line of collimation. Leveling staffs are classified into two groups i.e. (a) the target staff and (b) The self reading staff.

(a) Target Staff :- The target staff consists of a movable target. The target is provided with a vernier which is adjusted by the staffman, according to directions from the levelman, so that the target coincides with the collimation line. After this, the reading is taken by either the staffman or the levelman. This staff is used for long sightings.

(b) Self reading staff

The following are the different types of self-reading staffs.

(i) Staff with telescope :- Such a staff

is arranged in three lengths placed one into the other. It can be extended to its full length by pulling the top portion. The top portion is solid and of 1.25 m length. The central box portion is hollow and of 1.25 m length, and the bottom box portion is hollow and 1.25 m long. The total length of the staff is 3.75 m. The top portions are held in rest on the left end. These instruments are marked in black vertical position by a brass spring catcher.

The staff is graduated in such a way that the smallest division is of 5 mm (0.005m). The values in meters are marked in red on the left and those in decimeters are marked in black on the right.

(b) Folding metric staff: This staff is made of well-seasoned timber and is of 75 mm width, 18 mm thickness, and 4m length. It is divided into two parts of 2m length having a locking arrangement. It can be folded or detached when required. It is graduated like the telescopic staff.

(c) One length staff: The one-length staff is solid and made of seasoned timber. It is 3m long and graduated in the same way as the telescopic staff.

(d) Invar staff: The invar staff is also 3m long. An invar band is fitted to a wooden staff. The band is graduated in millimetres. It is used for precise levelling work.

(e) Stadia: The diaphragm is a brass ring fitted inside the telescope, just in front of the eyepiece. It can be adjusted by four screws. The ring carries the cross-hairs, which get magnified when viewed through the eyepiece. The cross-hairs may be marked in the following ways:

- (1) with spider web stretched across the ring.
- (2) by very fine scratch marks in a glass fitted with the ring.
- (3) By means of platinum wires or silk threads stretched across the ring.



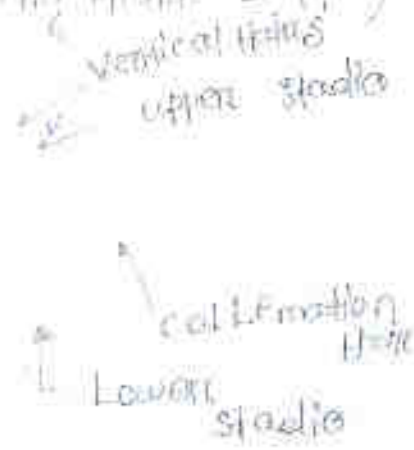
(Rigid Metal Staff)



(Folding Metal Staff)



(Graphometer)



Collimation
Lower stadia

- The cross-hair consists of the following lines:-
- (i) Two vertical hairs meant for maintaining the verticality of the staff.
 - (ii) Middle horizontal hair representing the line of collimation and
 - (iii) upper stadia hair and lower stadia hair. Both horizontal and short in length. The stadia hairs are meant for determining the horizontal distance between the position of level and that of the staff.

TEMPORARY ADJUSTMENT OF LEVEL :-

The adjustments made at every set-up of the level before the staff readings are taken are known as temporary adjustments. The following are the different steps to be followed in temporary adjustment.

- (1) Selection of suitable position :-

A suitable position is selected for setting the level. From this position, it should be possible to take the greatest number of observations without any difficulty. The ground should be fairly level and firm.

- (2) Fixing level with tripod stand :-

The tripod stand is placed at the required position with its legs well apart and pressed firmly into the ground.

The level is fixed on the top of the tripod stand according to the firing arrangement provided for that particular level. It should be remembered that the level is not to be set up at any station or point along the alignment.

(3) Approximate Levelling by leg of tripod stand

The foot screws are brought to the centre of their run. Two legs of the tripod stand are firmly fixed into the ground. Then the third leg is moved to the left or right in or out until the bubble is approximately at the centre of its run.

(4) Perfect Levelling by foot screws :-

As the longitudinal bubble is on the top of the telescope, the latter is placed parallel to any point of foot screws and the bubble is brought to the centre by turning the foot screws equally either both inwards or both outwards. The telescope is then turned through 90° and brought over the third foot screw and the bubble is brought to the centre by turning this foot screw clockwise or anticlockwise. The telescope is again brought to its original position (the first position) and the bubble is brought to the centre. The process is repeated several times until the bubble remains in the central position in the first as well as the second position. Then the telescope is turned through 90° .



third foot screw

first position of telescope

second foot screw

second position of telescope

third foot screw

(Leveling of foot screws)
180°. If the bubble still remains in the central position, the temporary adjustment is perfect and so is the permanent adjustment. But if the bubble is deflected from its central position, the permanent adjustment is not perfect and needs to be modified.

(b) Focussing the Eyepiece - A piece of white paper is held in front of the object glass and the eyepiece is moved in or out by turning it clockwise or anticlockwise until the cross-hairs can be seen clearly.

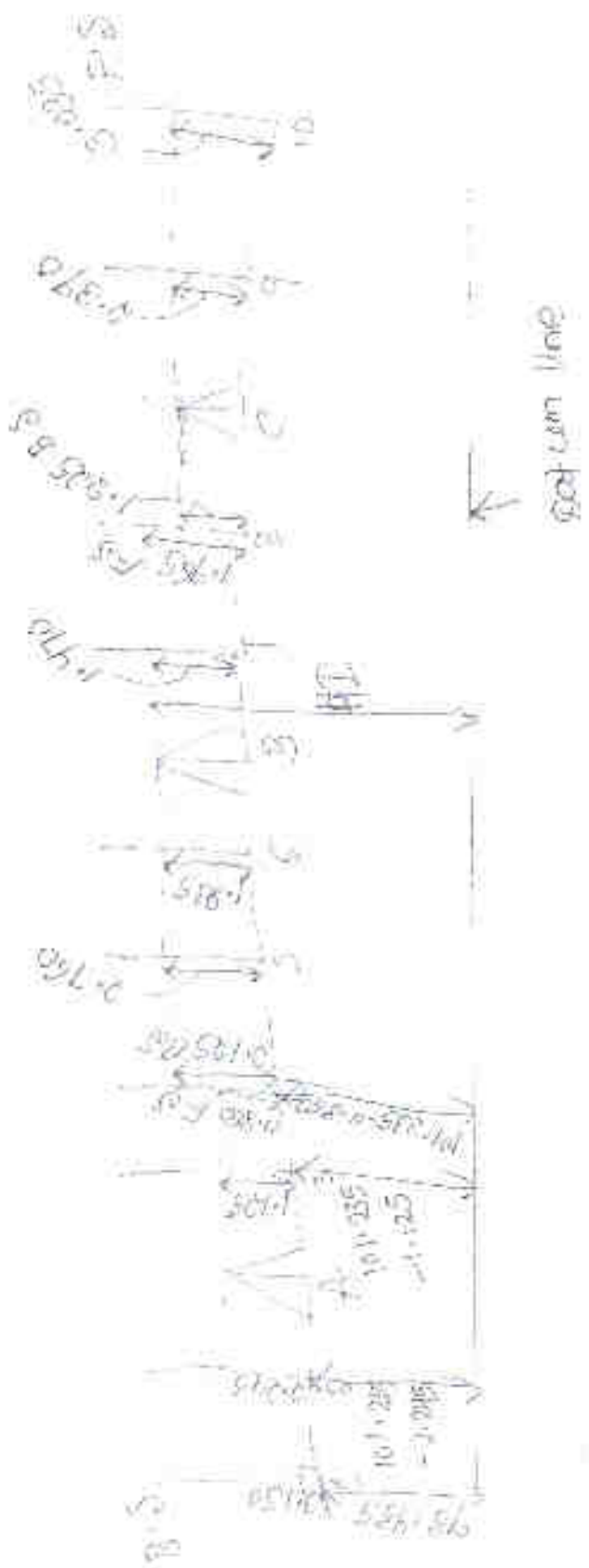
(c) Focussing the object glass -

The telescope is directed towards the leveling staff. Looking through the eyepiece, the focussing screws is turned clockwise or anticlockwise until the graduation of the staff is distinctly visible and the parallel is eliminated. To eliminate the parallel, the eye is moved up and down to verify whether whether the graduation of the staff remains fixed relative to the cross-hairs.

taking the staff Reading - Finally, the levelling of the instrument is verified by turning the telescope in any direction when the bubbles (the longitudinal bubble and cross-bubble) remain in the central position for any direction of the telescope the staff readings are taken.

16. The following consecutive readings were taken with a dumpy level along a chain line of a common interval of 15m. The first reading was taken at a change of 165 m when the RL is 95.085. The instrument was shifted after the fourth & ninth readings 3.150, 2.245, 1.125, 0.860, 5.125, 3.160, 1.835, 1.470, 1.955, 1.225, 3.390, 3.035 m. Find the RL of different points?





Station A :-

$$H.I. = RL \text{ of BM} + B.S. = 98.085 + 3.150 = 101.235$$

Station point	Chainage (m)	B.S.	I.S.	F.S.	H.I.	Remarks
1	100	3.150			101.235	B.M.
2	120		2.845		102.990	
3	175		1.125		100.00	2 nd P
4	210	3.725		3.860	103.50	C.P.
5	235		2.760		100.740	
6	240		1.855		101.200	
7	255		1.470		102.235	
8	270	4.220		1.760	100.350	C.P.
9	285		2.395		100.330	
10	300			3.035	97.100	
		T = 500		5.860		

Station B :- $RL \text{ of 6th P} + B.S. = 100.270 + 3.150 = 103.42$

Station C :- $H.I. = 102.07 + 3.150 = 105.22$

Arithmetic check

$$\sum B.S. + \sum F.S. = \text{Last RL} - \text{1st RL}$$

$$\begin{aligned} \Rightarrow 7.500 + 5.860 &= 97.100 - 98.085 \\ &= 1.610 \end{aligned}$$

∴ Hence it is ok.

2. The following consecutive readings were taken with a levelling instrument at intervals of 20 m:

2.275, 1.730, 2.615, 3.450, 2.835, 2.720, 2.835, 2.070, 1.515, 1.530, 2.255 & 3.680.

The instrument was shifted after the fourth & eight readings. The last reading was taken after 50 m of R.L. 100 m from the 1st at all the points.

Station point	Change	AS	IS	FS	HI	RL	Remark
1	0	2.375			112.575	110.200	B.M
2	20		1.130			110.875	
3	40		0.615			111.960	
4	60	2.835		3.450	111.960	109.125	C.P
5	80		2.070			109.890	
6	100		1.835			110.125	
7	120	0.435		0.985	111.410	110.975	
8	140		1.630			109.780	
9	160		2.055			109.155	
10	180			3.630		107.780	

total = 5.745

8.065

Arithmetical check :-

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

$$\Rightarrow 5.645 - 8.065 = 107.780 - 110.200$$

$$\Rightarrow -2.420 = -2.420$$

$\therefore$ Hence it is OK.

$$\text{B.M} + \text{I.S} = \text{HI}$$

$$110.200 + 2.375 = 112.575$$

$$\text{HI} - \text{FS or IS} = \text{RL of different point}$$

TYPES OF LEVELLING OPERATIONS

(1) Simple Levelling:-

When the difference of level between two points is determined by setting the levelling instrument midway between the points, the process is called simple levelling.

Suppose A and B are two points whose difference of level is to be determined. The level is set up at O, exactly midway between A and B. After proper temporary adjustment, the staff readings on A and B are taken. The difference of these readings gives the difference of level between A and B.



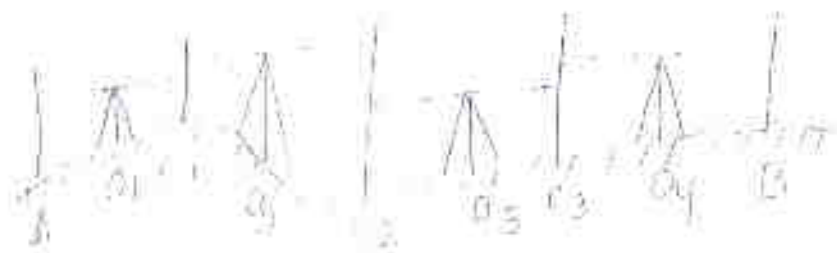
(2) Differential Levelling:-

Differential levelling is adopted when (i) the points are a great distance apart, (ii) the difference of elevation between the points is large, & (iii) there are obstacles between the points.

This method is also known as compound levelling or continuous levelling. In this method, the level is

set up at several suitable positions and staff readings are taken at all of these.

Suppose it is required to know the difference of level between A and B. The level is set up at points O_1, O_2, O_3 etc. After temporary adjustments, staff readings are taken at every set-up. The points C_1, C_2 and C_3 are known as change points. Then the difference of level between A and B is found out. If the difference is positive, A is lower than B. If it is negative, A is higher than B. Knowing the RL of A, that of B can be calculated.



(Differential Leveling)

(2) Fly Leveling :- When differential levelling is done in order to connect a bench mark to the starting point of the alignment of any project, it is called fly levelling. Fly levelling is also done to connect the BM for any intermediate point of the alignment for checking the accuracy of the work. In such levelling, only the backsight and foresight readings are taken at every set up of the level and no

distance are measured along the direction of levelling. The level should be set up just midway between the BS and the IS.

recharge rate
 $\text{LWR} = \frac{\text{vol. of } \text{H}_2\text{O}}{\text{area}}$



(1974-1975) (1976)

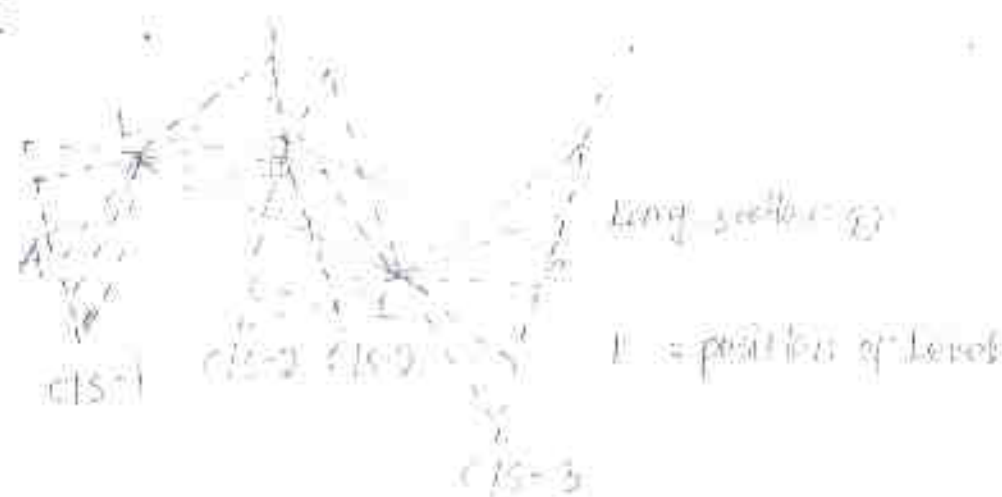
Q) Longitudinal or profile Levelling:-

The operation of taking levels along the centre line of any alignment (road, railway, etc.) at regular intervals is known as longitudinal levelling. In this operation, the backsight, intermediate sight and foresight readings are taken at regular intervals, at every set-up of the instrument. The chainages of the points are noted in the level book. This operation is undertaken in order to determine the undulations of the ground surface along the profile line.


$$E = \frac{1}{2}mv^2 = \frac{1}{2}m\lambda^2 f^2$$

5) Cross-sectional Levelling -

The operation of taking levels transverse to the direction of longitudinal levelling, is known as cross-sectional levelling. The cross-sections are taken at regular intervals (such as 20m, 40m, 50m etc.) along the alignment. Cross-sectional levelling is done in order to know the nature of the ground across the centre line of any alignment.



Cross-sectional levelling

(6) Check Levelling - The fly levelling done at the end of a day's work to connect the finishing point with the starting point on that particular day is known as check levelling. It is undertaken in order to check the accuracy of the day's work.



Q. The following consecutive readings were taken with a levelling instrument of interval of 2m :

2.315, 1.735, 0.615, 3.450, 2.835, 2.070, 1.835, 0.985, 0.435, 1.630, 2.255 and 3.630.

The instrument was shifted after the fourth and eighth readings. The last reading was taken on a B.M of RL 100.000. Find the RLs of all the points.

Station point	Change	BS	IS	FS	HI	RL	Remark
					114.975	112.65	
1	0	2.315				113.255	
2	20		1.730			114.380	
3	40		0.615			114.380	
4	60	2.835		3.450	114.380	11.545	c.p
5	80		2.070			112.310	
6	100		1.835			112.545	
7	120	0.435		0.985	113.530	113.395	c.p
8	140		1.630			112.500	
9	160		2.255			111.515	
10	180			3.630		110.200	B.M

total = 5.645

$$1^{st} HI = RL + BS = 110.300 + 3.630 = 113.930$$

$$RL \text{ of change point} = HI - BS = 113.930 - 0.495 \\ = 113.435$$

$$2^{nd} HI = RL + BS = 113.435 + 0.985 = 114.420$$

$$RL \text{ of C.P.} = HI - BS = 114.420 - 2.875 \\ = 111.545$$

$$3^{rd} HI = RL + BS = 111.545 + 3.450 = 114.995$$

$$RL \text{ of } = HI - BS = 114.995 - 2.375 \\ = 112.620$$

Mathematical check

$$\Sigma BC - \Sigma FS = 1^{st} RL - 2^{nd} RL$$

$$\Rightarrow 5.645 - 8.065 = 110.300 - 112.620$$

$$\Rightarrow -2.420 = -2.420$$

$\therefore$ Hence, it is OK.

23 July 2021 0.5.11

Q.2 The following consecutive readings were taken with a dumpy level along a chainline at constant interval of 5m. The first reading was taken on a change of 140 ft. The RL of the second change point was 107.215 m. The instrument was shifted after third & seventh readings calculate the RL of all the points.

3.150, 2.845, 1.125, 3.860, 2.125, 0.760, 2.235, 0.410, 1.935, 3.225, 3.890 m.

Station point	Chainage	BS	IS	FS	HI	RL	Remark
1	140	3.150			106.115	103.565	
2	160		2.245			104.470	
3	180	3.860	2.845	1.125	109.150	105.590	C.P
4	200		2.125			107.215	
5	220		0.760			108.690	
6	240	0.410		2.235	107.665	107.215	C.P
7	260		1.935			105.750	
8	280		3.225			104.460	
9	300			3.890		103.715	
10				7.25			
11		7.98					

Arithmetic check

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

$$\Rightarrow 9.48 - 7.25 = 103.705 - 103.563$$

$$\Rightarrow 0.23 = 0.23$$

$\therefore$ Hence it is OK.

16 July 2021 Rise and Fall Method

Q.10 The following consecutive readings were taken with a dumpy level along a chain line at a common interval of 15m. The first reading was 1.65 m when the

instrument was shifted after the fourth & ninth readings. 3.150, 2.245, 1.125, 0.860, 3.125, 0.760, 1.835, 1.470, 1.980, 1.225, 2.390, 0.035 m. Find the RL of different points?

Station point	Change	BS	FS	FS	Rise (+ve)	Fall (-ve)	RL	Remark
					0.035		98.085	B.M
1	1.65	3.150			0.0805		98.990	
2	1.80		2.245		0.1500		100.110	
3	1.95		1.125				100.375	
4	2.10	3.125		0.860	0.265		100.740	C.P
5	2.25		0.760		0.365			

6	240		1.1825	0.925	101.665	
7	235		1.470	0.365	102.030	
8	270	1.225		1.985	0.495	101.535 c.p
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	

Arithmetic check :-

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

$$\Rightarrow 7.500 - 5.860 = 99.725 - 98.085 = 3.795 - 2.305$$

$$\Rightarrow 1.640 = 1.640 = 1.640$$

$\therefore$ Hence it is OK.

26 The following consecutive readings were taken with a levelling instrument of interval of 20m.

2.55, 1.732, 0.615, 3.450, 2.835, 2.070, 1.835, 0.985, 0.435, 1.630, 2.455 & 3.630 m. The instrument

was shifted after the fourth & eighth readings. The 1st reading was taken

on a S.M of R.L 110.200 find the R.L of all the points.

Station Point	Change	I.S	F.S	I.S	Rise (+ve)	Fall (-ve)	R.L	Remark
1	0	2.375					110.200	B.M
2	20		1.730		0.645		110.845	
3	40		0.615		1.115		111.960	
4	60	2.835		3.450		2.835	109.125	C.P
5	80		2.070		0.680 765		109.890	
6	100		1.835		0.235		110.125	
7	120	0.435		0.985	0.950		110.975	C.P
8	140		1.630			1.195	109.780	
9	160		2.235			0.625	109.155	
10	180			3.630		3.375	107.780	
		5.645		8.065	3.610	8.610		

Arithmetic Check :-

$$\Sigma I.S - \Sigma F.S = \text{last R.L} - \text{1st R.L} = \Sigma \text{Rise} - \Sigma \text{Fall}$$

$$\Rightarrow 5.645 - 8.065 = 107.780 - 110.200 = 3.610 - 6.30$$

$$\Rightarrow -2.420 = -2.420 = -2.420$$

$\therefore$ Hence it is OK.

30 The following consecutive readings were taken with a levelling instrument of intervals of 20m.

2.375, 1.730, 0.615, 3.450, 2.835,
2.070, 1.835, 0.985, 5.425, 1.630,
2.255 and 2.630 m.

The instrument was shifted after the fourth and eighth readings. The last reading was taken on a BM of RL 110.200m. Find the RL of all the points.

Station point	Change	BS	IS	FS	Rise (+)	Fall (-)	RL	Remarks
1	0	2.375			0.615		112.620	
2	20	1.730	1.730		1.115		113.225	
3	40	0.615	0.615			2.835	111.380	
4	60	2.835		3.450	0.765		111.945	C.P
5	80		2.070		0.235		112.310	
6	100		1.835		0.850		112.545	
7	120	0.985		0.985		1.495	113.395	C.P
8	140		1.630			0.625	112.200	
9	160		2.255			1.315	115.515	
10	180		2.630				110.200	BM
Total = 5.645			8.065	3.640	6.230			

Arithmetic check

$$\begin{aligned} \sum BS - \sum FS &= \text{Last RL} - 1^{\text{st}} \text{RL} = \sum \text{rise} - \sum \text{fall} \\ \Rightarrow 5.845 - 8.065 &= 110.200 - 112.630 = 3.610 - 2.030 \\ &= 2.420 = 2.420 = 2.420 \end{aligned}$$

$\therefore$ Hence it is OK.

48

The following consecutive readings were taken with a dumpy level along a chainline at common interval of 20m the reading was taken on a chainage of 140m. The RL of the second change point was 107.215m. The instrument was shifted after third & seventh readings. Calculate the RL of all points.

3.150, 3.245, 1.125, 3.865, 2.125, 0.760, 2.235, 0.470, 1.935, 0.225, 3.890m.

Station point	Chainage	BS	IS	FS	Rise	Fall	RL	Remarks
1	140	3.150					103.655	
2	160		3.245		0.905		104.410	
3	180	3.865		1.125	1.150		105.560	C.P
4	200		2.125		1.735		107.295	
5	220		0.760		1.365		108.660	
6	240	0.470		2.235		1.475	107.235	C.P
7	260		1.935			1.945	105.290	

8	280		3.235		1.270	104.460
9	300		3.890		2.665	103.795
Total =		7.480	7.250	5.125	4.895	

Arithmetic check

$$2BS - 2FS = 2R - 2F = \text{Last RL} - \text{1st RL}$$

$$\therefore 7.480 - 7.250 = 5.125 - 4.895 = 103.795 - 103.565$$

$$= 0.23 = 0.23 = 0.23$$

$\therefore$ Hence it is OK.

27 July 2021

Q The following are the consecutive readings were taken with a level & a 4m. levelling staff on a continuously sloping ground at a common interval of 20m.

0.835 (on A) : 1.545, 2.335, 3.115, 3.825, 4.455, 1.380, 2.055, 2.855, 3.455 (on B). The RL of A was 580.500.

Find the RL of different point & carry out usual check & determine the gradient of AB.

Station point	Change	BS	IS	FS	Rise (ft)	Fall (ft)	RL	Remarks
							380.500	B.M.
1	0	0.855				0.690	379.810	
2	30		1.515			0.190	379.020	
3	60		2.335			0.780	318.240	
4	90		3.115					
5	120	0.455		3.825		0.110	377.930	C.P.
6	150		1.380			0.925	376.605	
7	180		2.055			0.615	375.990	
8	210		2.855			0.800	375.190	
9	240	0.585		3.455		0.600	374.590	C.P.
10	270		1.015			0.430	374.160	
11	300		1.850			0.835	373.325	
12	330		2.755			0.905	372.420	
13	360			3.845		0.090	371.770	
Total		1.895		11.125	9.23			

Arithmetic check:-

$$\sum BS - \sum FS = \text{Last RL} - \text{First RL} = \sum \text{Rise} - \sum \text{Fall}$$

$$\Rightarrow 1.895 - 11.125 = 371.770 - 380.500 = -9.230$$

$$\Rightarrow -9.230 = -9.230 = -9.230$$

Gradient

difference of level

Horizontal distance

$$= \frac{380.500 - 371.270}{360}$$

$$= \frac{9.23}{360} = \frac{1}{39} = \frac{1}{39} \text{ (1 in 39)}$$

Methods of calculation of Reduced level

The following are the two systems of calculating reduced level:

(i) The collimation system or height of instrument system (H.I.)

(ii) The rise and fall system

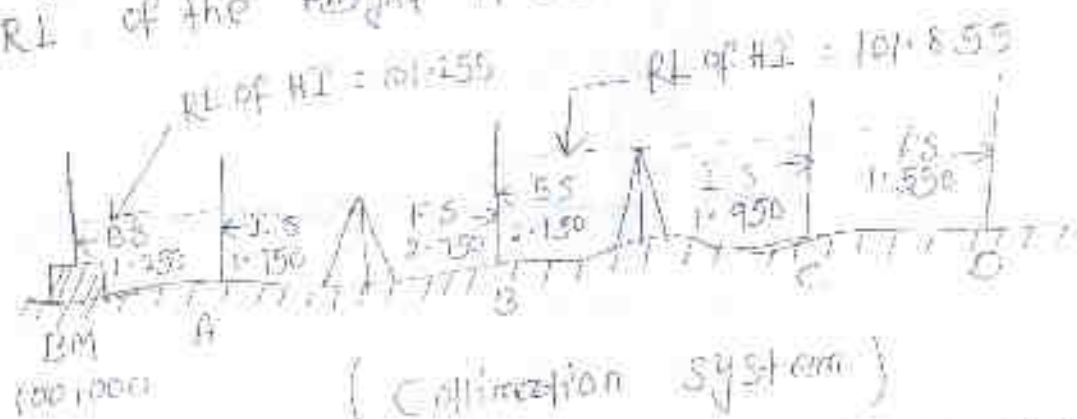
(i) The collimation system

The reduced level of the line of collimation is said to be the height of the instrument. In this system, the height of the line of collimation is found out by adding the backsight reading to the RL of the BM on which the IS is taken. Then the RL of the intermediate points and the change point are obtained by subtracting the respective staff readings from the height of the instrument (H.I.).

The level is then shifted for the next setup and again the height of the line of collimation is obtained by adding the backsight reading to the RL of the change point (which was calculated in the first set-up)

So, the height of the instrument is different in different setup of the level. Two adjacent planes of collimation are correlated at the change point by an FS reading from one setting and a BS reading from the next setting.

It should be remembered that in this system the RLs of unknown points are to be found out by deducting the staff readings from the RL of the height of the instrument.



$$(a) \text{ RL of HI in first setting} = 100.000 + 1.255 = 101.255$$

$$\text{RL of A} = 101.255 - 1.750 = 99.505$$

$$\text{RL of B} = 101.255 - 2.150 = 99.105$$

$$(b) \text{ RL of HI in second setting} = 99.105 + 2.750 = 101.855$$

$$\text{RL of C} = 101.855 - 1.950 = 99.905$$

$$\text{RL of D} = 101.855 - 1.550 = 100.305 \text{ and so on}$$

$$\text{Arithmetical check } \sum BS - \sum FS = \text{last RL} - \text{1st RL}$$

The difference between the sum of backsights and that of foresights must be the difference between the last RL

and the first RL. This check verifies the calculation of the RL of the HI and that of the change point. There is no check on the RLs of the intermediate points.

(a) Rise-and-fall system

In this system, the difference of level between two consecutive points is determined by comparing each forward staff reading with the staff reading of the immediately preceding points.

If the forward staff reading is smaller than the immediately preceding staff reading, a rise is said to have occurred. The rise is added to the RL of the preceding point to get the RL of the forward point.

If the forward staff reading is greater than the immediately preceding staff reading, it means there has been a fall. The fall is subtracted from the RL of preceding point to get the RL of the forward point.



$$\text{point A (with respect to BM)} = 100.00 - 1.25 = 98.75 \text{ fall}$$

$$\text{point B (with respect to A)} = 98.75 + 0.75 = 99.50 \text{ rise}$$

$$\text{point C (with respect to B)} = 99.50 - 1.50 = 98.00 \text{ fall}$$

point D (with respect to C) $= 1.50 - 1.75 = -0.25$ (fall)

RL of BM $= 100.00$

RL of A $= 100.00 - 0.50 = 99.50$

RL of B $= 99.50 - 1.50 = 98.00$

RL of C $= 98.00 + 0.25 = 99.25$

RL of D $= 99.25 - 0.25 = 99.00$

Arithmetical check: $\sum \text{BS} - \sum \text{IS} = \sum \text{rise} - \sum \text{fall} = \text{last RL} - \text{1st RL}$

In this method, the difference between the sum of BS and that of IS, the difference between the sum of rises and that of falls and the difference between the last RL and the first RL must be equal.

Comparison of the two systems :-

Collimation system

Rise and fall system

- | | |
|---|---|
| (i) It is rapid as it involves few calculations. | (i) It is laborious, involving several calculations. |
| (ii) There is no check on the RL of intermediate points. | (ii) There is a check on the RL of intermediate points. |
| (iii) Errors in intermediate RLs cannot be detected. | (iii) Errors in intermediate RLs can be detected as all the points are connected. |
| (iv) There are two checks on the accuracy of RL calculation. | (iv) There are three checks on the accuracy of RL calculation. |
| (v) This system is suitable for longitudinal levelling where there are a number of intermediate sights. | (v) This system is suitable for fly levelling where there are no intermediate sights. |

PRINCIPLE OF EQUALISING BACKSIGHT AND FORESIGHT DISTANCES.

In levelling, the line of collimation should be horizontal when the staff readings are taken. Again, the fundamental notion is that the line of collimation should be exactly parallel to the axis of the bubble, so when the bubble is at the centre of its run, the line of collimation is just horizontal. But sometimes the permanent adjustment of level may be disturbed and the line of collimation may not be parallel to the axis of the bubble. In such a case, due to the inclination of the line of collimation, error in levelling will likely to occur. But it is found that if the backsight and foresight distances are kept equal then the error due to the inclination of the collimation line is automatically eliminated, as illustrated below.

Case 1 - When the line of collimation is inclined upwards.

Let A and B be two points whose true difference of level is required. The level is set up at C, exactly midway between A and B.



Let α = angle of inclination of collimation line.

Aa = true reading

Aa_1 = observed staff reading on A

$$\therefore \text{Error} = Aa_1 - Aa = aa_1 = D \tan \alpha$$

So true reading $Aa = Aa_1 - aa_1 = Aa_1 - D \tan \alpha$

Similarly Bb = true reading

Bb_1 = observed staff reading on B

$$\therefore \text{Error} = Bb_1 - Bb = bb_1 = D \tan \alpha$$

So true reading $Bb = Bb_1 - bb_1 = Bb_1 - D \tan \alpha$

True difference of level between A and B

$$= Aa - Bb \text{ (Fall from B to A)}$$

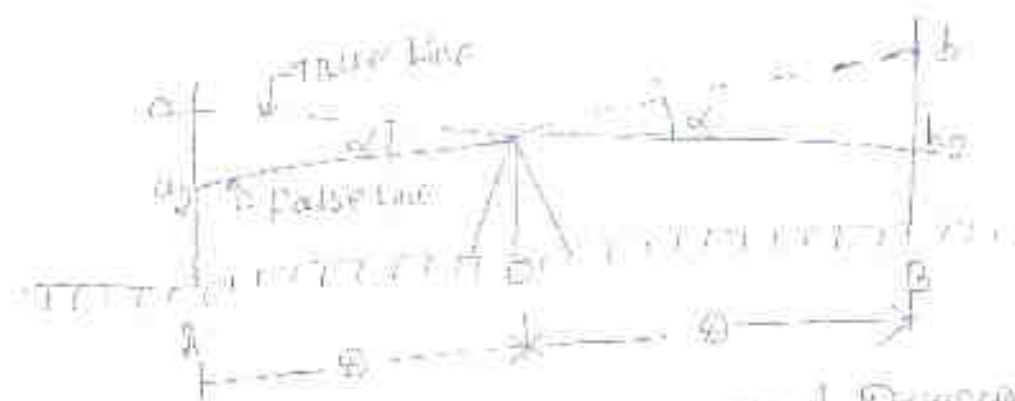
$$= Aa_1 - D \tan \alpha - Bb_1 + D \tan \alpha$$

$$= Aa_1 - Bb_1$$

Thus, it is seen that the error due to inclination of the collimation line is completely eliminated and the apparent difference is equal to the true difference.

Case - II -- When the line of collimation is inclined downwards

The staff readings on A and B are taken after setting the level at C. Suppose the readings are a_2 and b_2 .



Line of collimation inclined downwards

Here, Aa = true staff reading

Aa_2 = observed staff reading on A

$$\therefore \text{Error} = Aa - Aa_2 = aa_2 = 0 \text{ ft}$$

So true reading $Aa = Aa_2 + aa_2 = Aa_2 + 0 \text{ ft}$

Similarly, Bb = true reading

Bb_2 = observed staff reading on B

$$\therefore \text{Error} = Bb - Bb_2 = bb_2 = 0 \text{ ft}$$

So true reading $Bb = Bb_2 + bb_2 = Bb_2 + 0 \text{ ft}$

True difference to level between A and B

$$= Aa - Bb \text{ (fall from A to B)}$$

$$= Aa_2 + 0 \text{ ft} - Bb_2 - 0 \text{ ft}$$

$$= Aa_2 - Bb_2$$

Thus, it is seen that the error due to inclination of the collimation line is completely eliminated.

NOTE :-

So, always remember that the level should be placed exactly midway between backsight and foresight in order to eliminate any error.

CORRECTIONS TO BE APPLIED :-

1) Curvature correction - For long sights the curvature of the earth affects staff readings. The line of sight is horizontal, but the level line is curved on a spheroidal surface of the earth.



The vertical distance between the line of sight and the level line at a particular place is called the correction. Due to curvature, objects appear lower than they really are. Curvature correction is always subtractive (i.e. negative).

The formula for curvature correction is derived as follows:

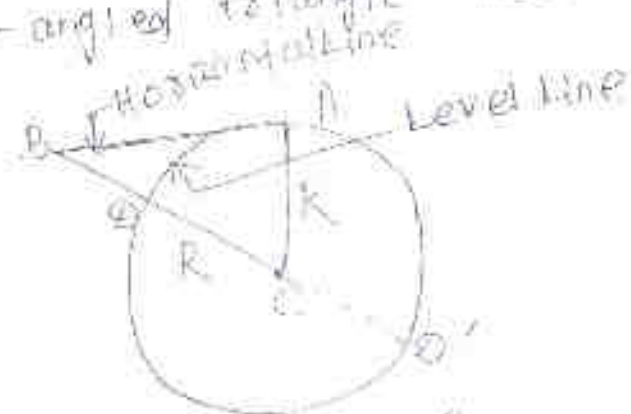
Let $A_3 = \mathbb{Q}$: horizontal and vertical connection

$$BD = CE = \text{curvature}$$

$BD = CE = \text{radius of earth}$
 $OC = AC = R = \text{radius of earth}$
 (considered 12)

$OC = AC = R = \text{radius of } \odot$
 $DD' = \text{diameter}$ Consider 19.792 km .
 $\angle AOC = \text{central angle}$

from right-angled triangle AOC



Deriving formula for curvature center

$$B^2C^2 = A^2C^2 + AB^2$$

$$(R+C_e)^2 = R^2 + 10^2$$

$$(R + Ce)^2 = R^2 + 2R + Ce^2 = R^2 + 2R + 0 = R^2 + 2R$$

$$\text{QR} \quad \text{C.C.} \neq \text{QR} \quad = \mathcal{Q}^2$$

Curvature correction

(C_c^2 is neglected as it is very small in comparison to the diameter of the earth)

$$C_c = \frac{S^2 \times 1,000}{12,740} = 0.0785 S^2 \text{ m (negative)}$$

Hence, True staff reading = observed staff reading - curvature correction.

(ii) Refraction correction

Rays of light are refracted when they pass through layers of air varying density. So, when long sights are taken, the line of sight is refracted towards the surface of the earth in a curved path. The radius of this curve is seven times that of the earth under normal atmospheric conditions. Due to the effect of refraction, objects appear higher than they really are. But the effect of curvature varies with atmospheric conditions.

However, on an average, the refraction correction is taken as one seventh of the curvature correction.

$$C_r = \frac{1}{7} \times \frac{C_c}{2}$$

Refraction correction: $C_r = \frac{1}{7} \times 0.0785 S^2 = 0.0112 S^2 \text{ m (positive)}$

Refraction correction is always additive
True staff reading = observed staff reading + refraction correction

(3) Combined correction :-

The combined effect of curvature and refraction is as follows :

combined correction = curvature correction + Refraction correction

$$= -0.0785 D^2 + 0.0118 D^2$$

$$= -0.0673 D^2 \text{ m}$$

So, combined correction is always subtractive (i.e. negative)

True staff reading = observed staff reading - combined correction

NOTE combined correction may also be expressed as

$$\frac{D^2}{2R} - \frac{1}{7} \times \frac{D^2}{2R} = \frac{6}{7} \times \frac{D^2}{2R} \text{ (negative)}$$

(g) visible horizon distance :-

Let $AB = D$ = visible horizon distance in kilometres.

h = height of the point above mean sea level in metres.



Considering curvature and refraction correction.

$$h = 0.0673 D^2$$

$$D = \sqrt{\frac{h}{0.0673}}$$

15) Dip of Horizon :-

$AB = R$ = tangent to the earth at A

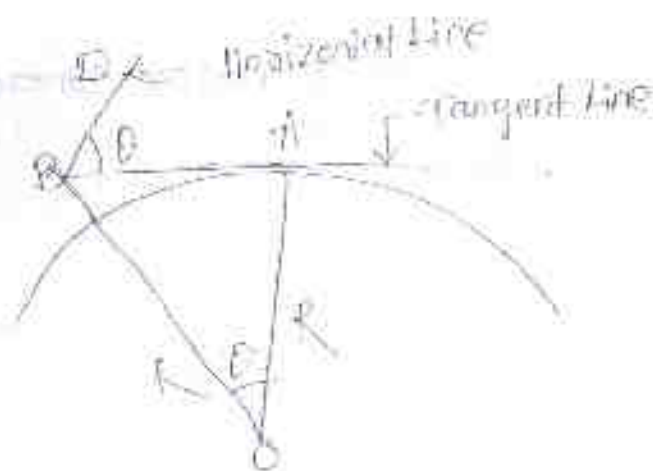
BD = horizontal line perpendicular to AB

θ = dip of horizon

The angle between the horizontal line and the tangent line is known as the dip of the horizon. It is equal to the angle subtended by the arc CA at the centre of the earth.

$$\text{Dip } \theta = \frac{\text{arc } CA}{\text{radius of the earth}} \text{ in radians}$$

$$\theta = \frac{D}{R} \text{ in radians (making } CA \text{ approx. equal to } AB)$$



(Dip of horizon)

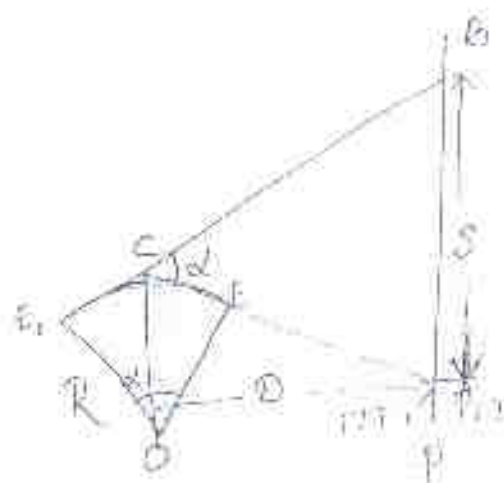
Here D and R must be expressed in the same units.

16) Sensitiveness of the bubble

The term sensitiveness in the context of a bubble means the effect caused by the deviation of the bubble per division of the graduation of the bubble tube.

Sensitiveness is expressed in terms of the radius of curvature of the upper surface of the bubble or by an angle through which the tube is tilted for the deflection of one division of the graduation.

Determining sensitiveness:- Suppose the level was set up at O at a distance S from the staff at P . The staff reading is taken with the bubble at the extreme left and. Let it be PS .



Determining sensitiveness of the bubble

Let S = distance between the level and staff.

s = intercept between the upper and lower sights.

n = number of division through which the bubble is deflected.

R = radius of curvature of the tube.

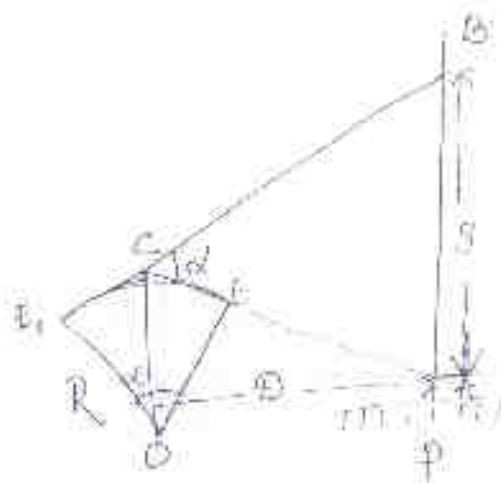
α = angle subtended by one EE_1 , and

d = length of one division of the graduation, expressed in the same units as S and s .

Movement of centre of bubble : $EE_1 = nd$.

Sensitiveness is expressed in terms of the radius of curvature of the upper surface of the tube or by an angle through which the axis is tilted for the deflection of one division of the graduation.

Determining Sensitiveness:- Suppose the level was set up at O at a distance S from the staff at P . The staff reading is taken with the bubble at the extreme left end. Let it be $P.E.$



Determining sensitivity of the bubble
measures the level and staff

Let g = distance between the upper and lower

s = distance between the upper and lower sights.

n = number of division through which the bubble is deflected.

$R =$ radius of curvature of the tube.

R = radius of
 α = angle subtended by arc EF , and
 division of the grade

d = length of one division of the graduation, expressed in the same units as θ and S

Movement of centre of bubble = $EE' = r \sin \theta$

Triangles OIE and ACB are similar
 Here $\angle \alpha = \angle EIE_1$

or

$$\alpha = \frac{IE_1}{R} = \frac{nd}{R}$$

Again $\frac{IE_1}{R} = \frac{s}{\theta}$ (height of AOE_1 may be considered as R)

$$\textcircled{or} \quad \frac{nd}{R} = \frac{s}{\theta}$$

$$\alpha = \frac{nd}{R} = \frac{s}{\theta}$$

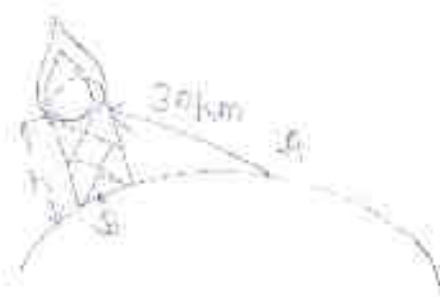
$$\therefore R = \frac{nd \times \theta}{s}$$

Let α' : angular value for one division in radians

$$\alpha' = \frac{\alpha}{n} = \frac{s}{\theta} \times \frac{1}{n} \text{ radians}$$

$$\textcircled{or} \quad \alpha = \frac{s}{\theta n} \times 206,265 \text{ seconds} \quad (1 \text{ radian} = 206,265 \text{ seconds})$$

Ex 1.1 A lamp at the top of a lighthouse is visible just above the horizon from a station at sea level. The distance of the lamp from the station is 30 km. Find the height of the lighthouse?



$$D = 30 \text{ km}$$

height = combined correction

$$h + c = 0.0673 D$$

$$= 0.0673 \times 30 = 2.019 \text{ m}$$

$\therefore$ Height of the lighthouse is 60.57 m.

Q. What is the visible horizon distance from a 50m high tower?

$$\text{Height} = 50 \text{ m (h)}$$

$$D = \sqrt{\frac{h}{0.0673}} = \sqrt{\frac{50}{0.0673}} = 27.25 \text{ km}$$

Q. What is the dip of horizon assuming the radius of the earth 6370 km take D from previous problem?

$$\text{Radius (R)} = 6370 \text{ km}$$

$$\text{Distance (D)} = 27.25 \text{ km}$$

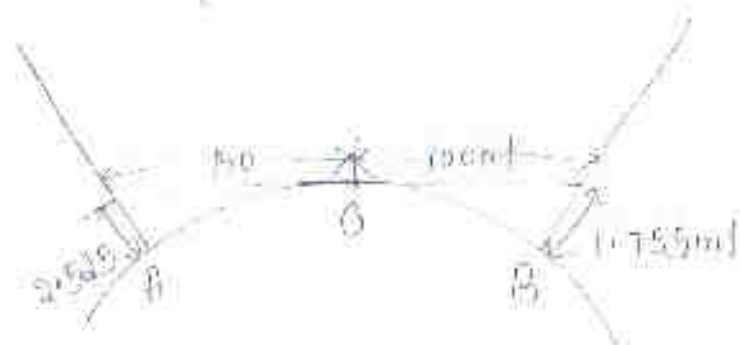
$$\text{Dip of horizon} = \frac{D}{R} \text{ radian}$$

$$\left[\begin{array}{l} 1 \text{ radian} = \frac{180}{\pi} \\ 1 \text{ degree} = \frac{\pi}{180} \text{ radian} \end{array} \right]$$

$$\frac{27.25}{6370} \times \frac{180}{\pi} = 0.24^\circ$$

$$= 0.24^\circ \times 60 \text{ min} = 14.4 \text{ min}$$

30 July 2021
 A level is set up at a point 150 m from A & 100 m from B. The observed staff readings of A & B are 2.525 & 1.755 find the true difference of level between A & B.



Soln $D_1 = 150 \text{ m}$
 $= \frac{150}{1000} \text{ km}$
 combined correction = C.C. = 0.0673 m

station A C.C. = ~~0.0673~~
 $0.0673 \times \left(\frac{150}{1000} \right)^2$
 $= 1.51 \times 10^{-4}$
 $= 0.00151 \text{ m} (-ve)$

true reading = $2.525 - 0.00151$
 $= 2.5235 \text{ m}$

station B C.C. = $0.0673 \times \left(\frac{100}{1000} \right)^2$
 $= 6.73 \times 10^{-4} = 0.000673 \text{ m}$

true reading = observed reading + C.C.
 $= 1.755 + 0.000673$
 $= 1.755673 \text{ m}$

Difference of level betⁿ A & B

$$2.5735 - 1.7543$$

$$= 0.7692 \text{ m}$$

$$\left[\begin{array}{l} \text{Rise from A to B} \\ \text{Fall from B to A} \end{array} \right]$$

30 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 betⁿ him & the object.

solⁿ height (h_1) = 50 m

height (h_2) = 10 m

$$Q_1 = \sqrt{\frac{h_1}{0.0673}} = \sqrt{\frac{50}{0.0673}} = 27.25 \text{ km}$$

$$Q_2 = \sqrt{\frac{h_2}{0.0673}} = \sqrt{\frac{10}{0.0673}} = 12.18 \text{ km}$$

$$\text{distance betⁿ him } Q_1 + Q_2 = 27.25 + 12.18$$

$$= 39.43 \text{ km}$$

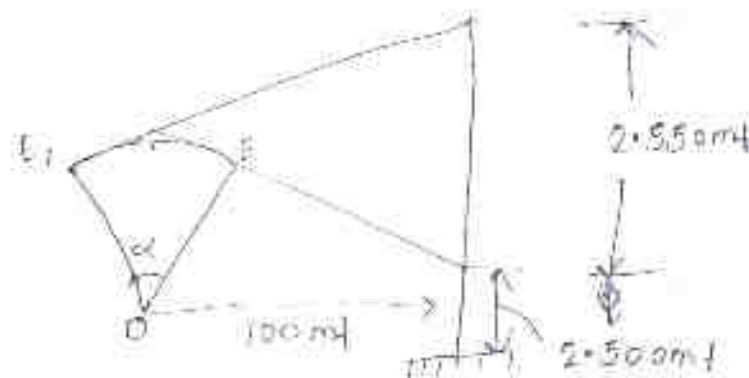
60 A man at a position 10 m above sea observes the peak of a hill. The angle betⁿ the man & a hill is found the height of the hill.

solⁿ $Q_1 = 10 \text{ m}$

$h_1 = 0.0673 Q_1^2$

$$= 0.0673 \times 10 = 0.673 \text{ m}$$

76) When the bubble is at the centre the reading on the staff is 100 cm. When the bubble is then deviated by height division 2, the staff reading is 2.550 m. If the length of one division of the bubble is 2 mm calculate the radius of curvature of the bubble tube & the angle of value of one division of the bubble.



Sol

$$L = 100 \text{ m}$$

$$d = 2 \text{ mm} = 0.002 \text{ m}$$

$$n = 5$$

$$R = ?$$

$$\alpha = ?$$

$$S = 2.550 - 2.500 = 0.050 \text{ m}$$

$$R = \frac{nl \times D}{S} = \frac{5 \times 0.002 \times 100}{0.050} = 20 \text{ m}$$

$$\alpha' = \frac{S}{R} \times 206,265 \text{ sec}$$

$$= \frac{0.050}{100 \times 5} \times 206,265 = 20.62 \text{ seconds}$$

∴ Hence the radius of curvature is 20 m
& the angle of 1 division is 20.62 seconds

RECIPROCAL LEVELLING

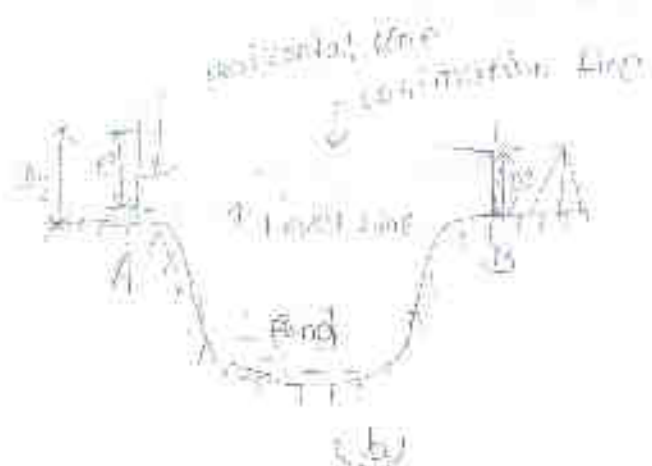
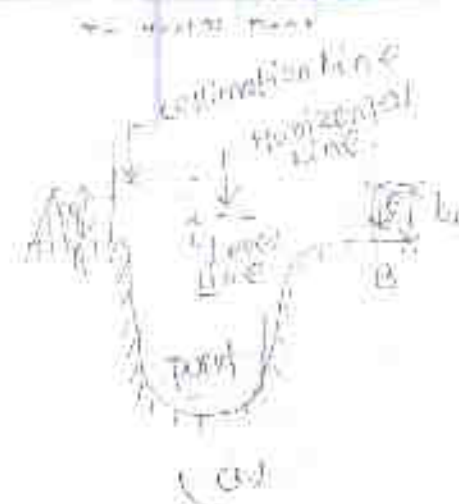
we have already found by the principle of equalising backsight and foresight distances that if the level is placed exactly midway betⁿ two points and staff readings are taken to determine the difference of level then the errors (due to inclined collimation line, curvature and refraction) are automatically eliminated. But in the case of a river or valley, it is not possible to set up the level midway betⁿ two points on opposite banks. In such cases, the method of reciprocal levelling is adopted which involves reciprocal observations from both banks of the river or valley.

In reciprocal levelling, the level is set up on both banks of the river or valley and two sets of staff readings are taken by holding the staff on both banks. In this case, it is found that the errors are completely eliminated and the true difference of level is equal to the mean of the two apparent differences of level.

The principle is explained as follows:
procedure

1. Suppose A and B are two points on the opposite banks of a river. The level is set up very near A and after proper temporary adjustment, staff readings are taken at A and B. Suppose the readings are a_1 and b_1 .

Let, h = true difference of level betⁿ A & B
 e = combined error due to curvature, refraction and collimation (The error may be positive or negative)



$$e = e_c$$

Case-1

true reading at A = a_1
 $B = b_1 - e$

$$\text{true diff (h)} = a_1 - (b_1 - e) \quad \text{--- (1)}$$

Case-2, true reading at B = b_2
 $B = a_2 - e$

$$\text{true diff (h)} = (a_2 - e) - b_2 \quad \text{--- (2)}$$

Solving eqn (1) & (2)

$$h = a_1 - (b_1 - e)$$

$$h = (a_2 - e) - b_2$$

$$\Rightarrow 2h = a_1 - b_1 + a_2 - b_2$$

$$\Rightarrow h = \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$$

Q2 In an operation including involving reciprocal leveling two points A & B are taken on opposite bank of a river, when the level was set up near A, the staff readings on A & B were 2.245 & 3.375 respectively. When the level was set up near B, the staff readings were 1.955 & 3.055. Find the true difference of level b/w A & B. What is the RL of the B if that of A is 125.500 m?

$$h = \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$$

$$a_1 = 2.245 \quad b_1 = 3.375$$

$$a_2 = 1.955 \quad b_2 = 3.055$$

$$h = \frac{(2.245 - 3.375) + (1.955 - 3.055)}{2}$$

$$= 1.115 \text{ m (-ve)} \quad (\text{fall from A to B})$$

$$\text{RL of B} = \text{RL of A} - h$$

$$= 125.500 - 1.115 = 124.385$$

Instrument at	readings		Remarks
	A	B	
A	2.245 a_1	3.375 b_1	distance AB = 500 m
B	1.955 a_2	3.055 b_2	
			RL of A = 125.500

Find (i) true RL of B

(ii) combined correction

Qp

$$h = \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$$

$$= \frac{(1.155 - 2.595) + (0.955 - 2.415)}{2}$$

$$= 1.435 \text{ m}$$

$$\text{RL of B} = \text{RL of A} - h$$

$$= 525.500 - 1.435$$

$$= 524.065 \text{ m}$$

$$\begin{aligned} \textcircled{1} C_a &= 0.06738^2 \\ &= 0.06738 \times \left(\frac{500}{1000} \right)^2 \\ &= 0.016 (\%) \end{aligned}$$

SOURCES OF ERROR IN LEVELLING

The following are the different sources of error in levelling:

(i) Instrumental errors :-

(a) The permanent adjustment of the instrument may not be perfect that is the line of collimation may not be parallel to the axis of the bubble tube.

(b) The internal arrangement of the focussing tube is not perfect.

(iii) The graduation of the levelling staff may not be perfect.

1) personal errors :-

- (i) The instrument may not be levelled perfectly.
 - (ii) The focussing of the eyepiece and object glass may not be perfect and the parallax may not be eliminated entirely.
 - (iii) The position of the staff may be displaced at the change point at the time of taking FS and BS readings.
 - (iv) The staff may appear inverted when viewed through the telescope. By mistake the staff readings may be taken upwards instead of downwards.
 - (v) The reading of the stadia hair rather than the central collimation hair may be taken by mistake.
 - (vi) A wrong entry may be made in the level book.
 - (vii) The staff may not be properly and fully extended.
- ## 2) Errors due to natural causes

- (i) When the distance of sight is long, the curvature of the earth may affect the staff reading.
- (ii) The effect of refraction may cause a wrong staff reading to be taken.
- (iii) The effect of high winds and a shining sun may result in a wrong staff reading.

CONTOURING

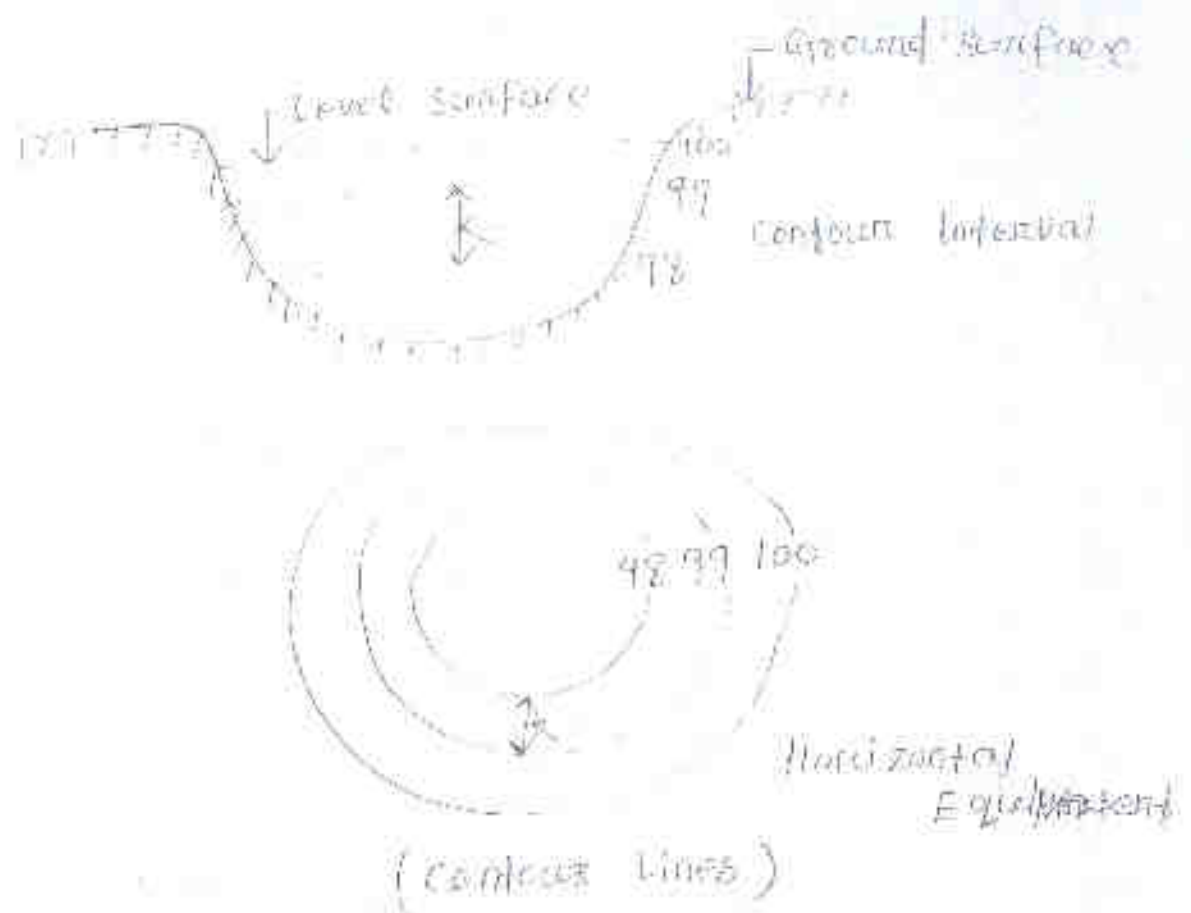
Contouring is, basically, a levelling operation. The equipment and the same for levelling and contouring. The main objective of contouring is to determine the points on the ground having the same reduced level (RL). The contour lines join the point of same elevation directly or by interpolation technique. It gives the topographical features of the ground, comparing different contour lines of different elevations for a closed area. Based on the topographical features, calculations for engineering projects can be carried out.

DEFINITIONS

- (i) Contour Line :- The line of intersection of a level surface with the ground surface is known as the contour line or simply the contour. It can also be defined as a line passing through points of equal reduced levels.

For example, a contour of 100m indicates that all the points on this line have an RL of 100m. Similarly in a contour of 99m, all points have an RL of 99m, and so on.

A map showing only the contour lines of an area is called a contour map.



(ii) Contour Interval - The vertical distance between any two consecutive contours is known as a contour interval. Suppose a map includes contour lines of 100m, 98m, 96m, and so on. The contour interval here is 2m. This ~~map~~ interval depends upon (i) the nature of the ground (i.e. whether flat or steep) (ii) the scale of the map, and (iii) the purpose of the survey. Contour intervals for flat country are generally small, e.g. 0.25m, 0.15m, etc. The contour interval for a steep slope in a hilly area is generally greater, e.g. 5m, 10m, 15m, etc.

Again for a small-scale map, the interval may be of 1m, 2m, 3m, etc. and for large scale map, it may be 0.25m, 0.50m, 1m, 1.5m, etc.

It should be remembered that the contour interval for a particular map is constant.

(3) Horizontal Equivalent :-

The horizontal distance between any two consecutive contours is known as horizontal equivalent. It is not constant. It varies according to the steepness of the ground.

For steep slopes, the contour lines run close together, and for flatter slopes they are widely spaced.

Object of preparing contour map

The general map of country includes the locations of roads, railways, rivers, villages, towns, and so on. But the nature of the ground surface cannot be realised from such a map. However for all engineering projects involving roads, railways, and so on a knowledge of the nature of ground surface is required for locating suitable alignments and estimating the volume of earth work. Therefore, the contour map is essential for all engineering projects. This is why contour maps are prepared.

Uses of contour map :-

The following are the specific uses of the contour map.

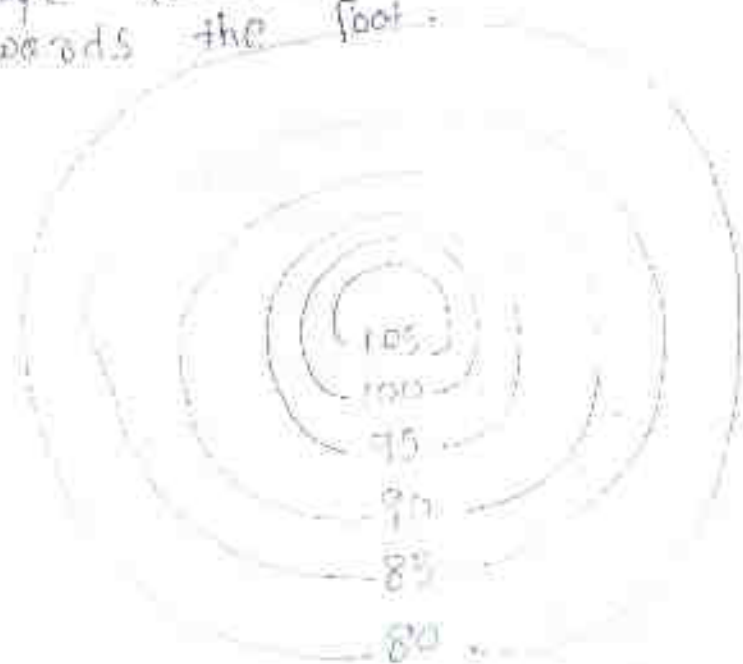
- (1) The nature of the ground surface of a country can be understood by a contour map. Hence, the

possible route of communication between different places can be demarcated.

- (iv) A suitable site or an economical alignment can be selected for any engineering project.
- (v) The capacity of a reservoir in the area of a catchment can be approximately computed.
- (vi) The intervisibility or otherwise of different points can be established.
- (vii) A suitable route for a given gradient can be marked on the map.
- (viii) A section of the ground surface can be drawn in any direction from the contour map.
- (ix) Quantities of earth work can be approximately computed.

CHARACTERISTICS OF CONTOURS

- ① The contour lines are closer near the top of a hill or high ground and wide apart near the foot. This indicates a very steep slope towards the peak and a flatter slope towards the foot.

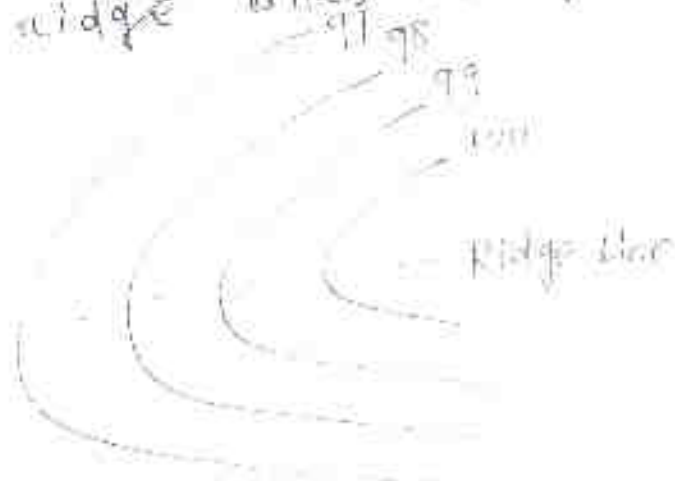


(Hill)

- (5) Contour lines cannot cross one another, except in the case of an overhanging cliff, but the overlapping portion must be shown by a dotted line.



- (6) when the higher values are inside the loop, it indicates a ridge line or a contour line. A ridge line is a line of high angles, and a valley line is a line of low angles.



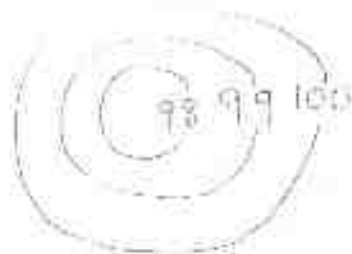
(Ridge line)

- (7) when the lower values are inside the loop, it indicates a valley line or a contour line. A valley line is a line of low angles, and a ridge line is a line of high angles.

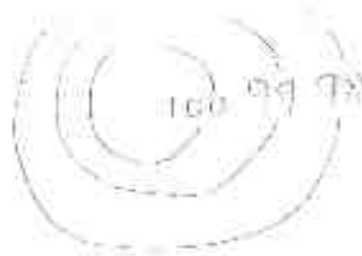


(Valley line)

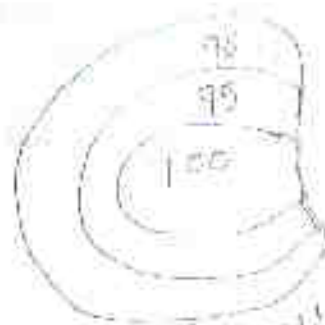
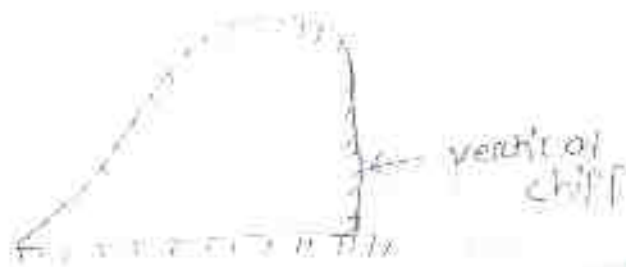
- (2) A series of closed contours always indicates a depression or summit. The lower value being inside the loop indicates a depression and the higher values being inside the loop indicates a summit.



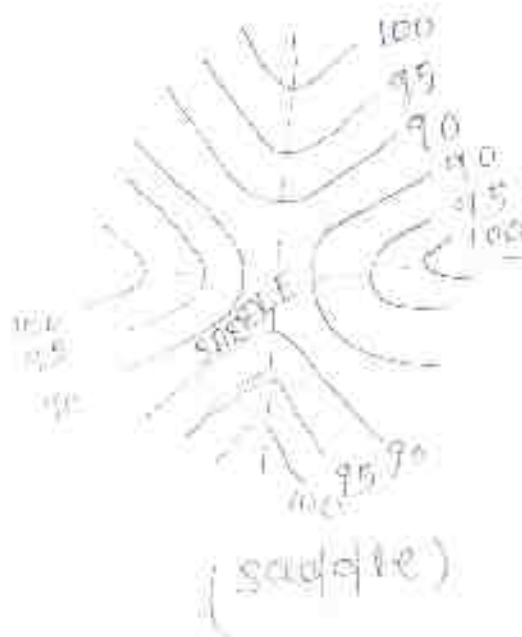
(a) (Depression)



(b) (Summit)



(vertical cliff)



(saddle)