Introduction to surveying, linear Mg - 07
(Chapter - 1) Measurement :— Date - 02/01/20

Defⁿ of surveying :—

It is defined as of determination of relative position of point on or below surface of earth by means of linear & angular measurement i.e. distance, elevation & direction.

The purpose of surveying essentially the measurement of point on surface of earth angle both horizontal & vertical.

Aims of surveying :—

The object of surveying is the preparation of plans & maps of the areas.

The practical importance of surveying can't be over-estimated. The absence of accurate maps, it is impossible to lay out the alignment of roads, railways, canals, tunnels, transmission power lines, and microwave or television relaying towers.

Surveying is the first step for the execution of any project.

Objective of surveying :—

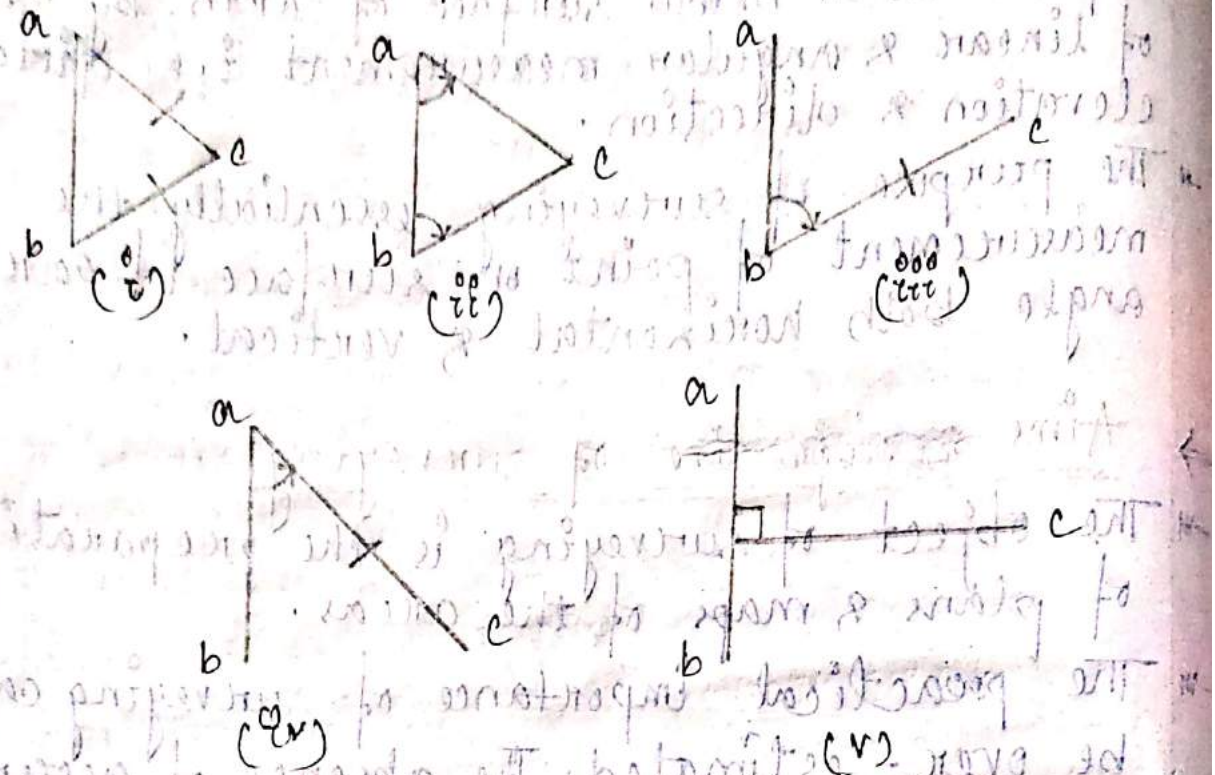
To take measurements for determining the locations of existing ground features.

To make the positions of objects wrt assumed datum.

To calculate the related quantities like areas & volumes.

→ Principles of surveying :-

(1) To locate the point wrt two known points;



(2) Working from whole to the part but not from part to a whole

→ Plane surveying :-

- Neglect the curvature of earth;
- Distances less than 18.5 km and areas less than 250 km^2.
- Less accurate

→ Geodetic surveying :-

- Consider the curvature of earth
- Large areas & more accurate.
- Fixing the control points and boundary

points of a field. → (greater than 250 unit area)

→ Incremental surveying :—

(1) chain surveying
(2) Compass surveying
(3) plane table surveying
(4) Levelling surveying
(5) Theodolite surveying
(6) Photogrammetry
(7) EDM's (Electronic Distance Measurement equipment).

→ Trailateration :—

→ It is the process of measuring the side triangle with the help of EDM's.

→ Precision :—

→ It is closeness to the some other measured quantity.

→ Accuracy :—

Measurement of accuracy :—

→ It is the ratio between unit of error to the unit of measured quantity.

→ Measurement of accuracy = 1 in n

1 unit of error in n units of measured value.

→ Measurement of distance :—

(i) Horizontal Distance :—

→ Done by chain, tape, tacheometer, total

station.

(ii) Vertical Distance :—

→ level, total station, tacheometer & seatant, Abney level (minor instrument).

(iii) Horizontal Angle :—

→ compass, theodolite, clinometer (minor instrument) total station.

(iv) Vertical Angle :—

→ Theodolite, seatant & total station.

Q5

→ Scale of a Map : ratio bet^n

→ It is the distance on the map to the distance on the ground.

$$\text{Scale} = \frac{\text{distance on the map}}{\text{distance on the ground}}$$

or

1 : 1000 → 1 unit on map = 1000 units on ground.

(i) Large scale 1 cm = 10 m

(ii) Medium scale 1 cm = 100 m

(iii) Small scale 1 cm > 100 m

(iv) Engineer's scale 1 cm = 50 m

→ Error due to shrinkage of a Map :—

Shrinkage factor, $SF = \frac{\text{distance on the Map}}{\text{corresponding distance on ground}}$

$= \frac{\text{distance during measurement}}{\text{corresponding actual distance}}$

formula: [SF < 1]

(i) Shrunk scale = Original scale × SF.

(ii) Shrunk RF = Original RF × SF.

(iii) Corrected distance, CD = $\frac{MD}{SF}$

(iv) Corrected area, CA = $\frac{MA}{(SF)^2}$

(v) Corrected volume, CV = $\frac{MV}{(SF)^3}$

→ Error due to wrong scale :—

(i) $CD = MD\left[\frac{RF \text{ of } WS}{RF \text{ of } CS}\right]$

(ii) $CA = MA\left[\frac{RF \text{ of } WS}{RF \text{ of } CS}\right]^2$

(iii) $CV = MV\left[\frac{RF \text{ of } WS}{RF \text{ of } CS}\right]^3$

→ Types of Errors :—

(i) Mistakes.
(ii) Systematic errors.
(iii) Accidental or Random error.

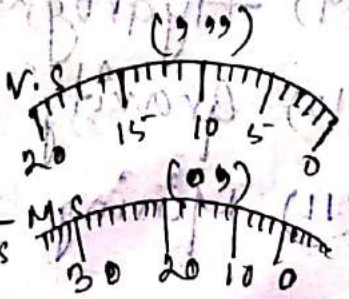
→ Random errors are directly proportional to square root of 'n', where n is total no. of observations.

$$\text{Random error} \propto \sqrt{n}$$

→ Vernier Scale :—

Least Count, LC = $\frac{S}{n}$ = $\frac{1 \text{ MSD}}{\text{No. of VSD's}}$

→ Its invented a device for the purpose of measuring a fractional part of a graduated scale.



→ Types of verniers :—

(i) Direct vernier :—

→ 'n' divisions of vernier = (n-1) divisions of MS.

(ii) Retrograde vernier :—

→ 'n' divisions of vernier = (n+1) divisions of MS.

(iii) Extended vernier :—

→ 'n' divisions of vernier = (2n-1) divisions of MS.

→ Classification of survey :—

→ Based on function :—

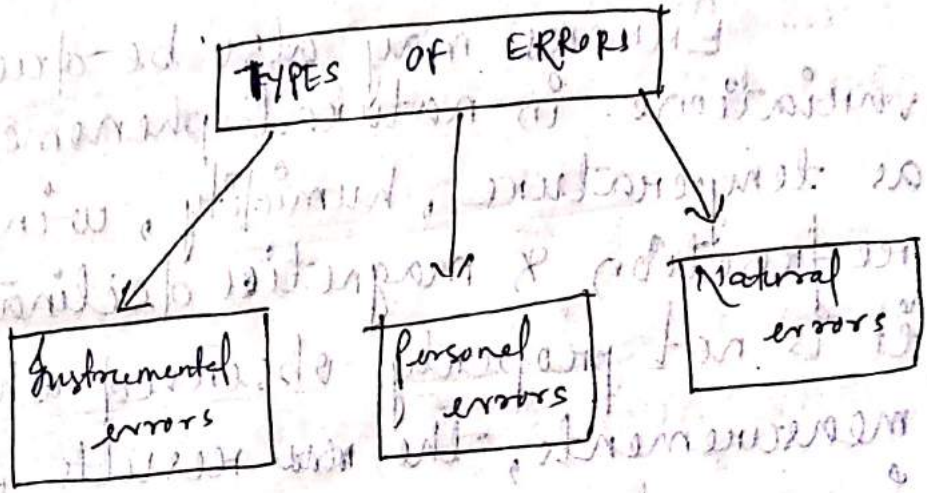
(1) Control survey.
(2) Land survey.
(3) City survey.
(4) Engineering survey.
(5) Topographic survey.
(6) Geological survey.
(7) Archaeological survey.
(8) Astronomical survey.
(9) Hydrographic survey.
(10) Gravity survey.
(11) Mining survey.

(12) Military survey
(13) Satellite survey.

→ Sources of Errors :-

(i) Instrumental errors :- When instrument is not calibrated at regular intervals by permanent adjustments.
(ii) Personal errors.
(iii) Natural errors.

→



(1) Instrumental errors :-

→ Errors may arise due to imperfection or faulty adjustment of the instrument with which measurement is being taken.

Eg:-
→ tape may be too long or an angle measuring instrument may be out of adjustment Such errors are known as Instrumental errors.

(2) Personal Errors :-

→ Errors may also arise due to want of perfection of human sight in observing

and of touch in manipulating instruments.

Eg :-

An error may be taking the level readings or reading an angle on a circle of theodolite. Such errors are known as Personal Errors.

(3) Natural Errors :-

→ Errors may also be due to variations in natural phenomenon such as temperature, humidity, wind, refraction & magnetic declination. If it is not properly observed while taking measurements, the results will be incorrect.

→ Classification of survey :—

(1) Control Survey :—

→

(2) Land Survey :—

→ (i) Topographic survey, (ii) Cadastral survey, (iii) City survey these are called land survey.

(3) City Survey :—

→ Roads, parks, water supply system, sewer & other constructional work for any developing township are called city surveys.

(4) Engineering Survey :—

→ Roads, reservoirs, sewage disposal, water supply, etc. are called Engineering surveys.

(5) Topographic Survey :—

→ The mountainous terrain, rivers, water bodies, wooded areas and other cultural details such as roads, railways, township etc. are called Topographic surveys.

(6) Geological Survey :—

→ The surveys which are carried out to ascertain the composition of the earth crust & different strata of rock of the earth crust are called Geological surveys.

(7) Archaeological Survey :—

→ The surveys which are ~~carried~~ carried out to prepare maps of ancient culture, antiquities are called Archaeological surveys.

(8) Astronomical survey :—

→ Stars & sun are called Astronomical Surveys.

(9) Hydrographic survey :—

→ The survey which deal with the mapping of large water bodies for the purpose of navigation, construction of harbour works, prediction of tides & determination of mean sea-level are called Hydrographic Surveys.

(10) Gravity survey :—

→

(11) Mining survey :—

→ Coal, copper, gold, iron ores etc are called Mining Surveys.

(12) Military survey :—

→ The surveys which are carried out for preparation of maps of the areas of military importance are called military surveys.

(13) Satellite survey :—

Problems

Pg - 08/08/2017
Date - 06/01/20

Q1) Assuming that a man can plot a distance as small as 0.25 mm & the scale of plotting is 1:1000. The representative fraction of the scale is ____ ?

Sol:- Scale = 1 : 1000

$\Rightarrow$ 1 mm = 1000

$\Rightarrow$ 0.25 mm = $\frac{0.25}{1} \times 1000$

= 250 mm = 0.25 m.

Q2) A Distance of 10m on ground is plotted on a map as 0.5 cm. The representative fraction of the scale is ____ ?

Sol:- $\Rightarrow RF = \frac{0.5\text{ cm}}{10\text{ m}}$

$= \frac{0.5}{10 \times 100}$

$= \frac{1}{2000}$

Q3) The RF 1/2500 means that the scale is 1cm equal to ____ ?

Sol:- $\Rightarrow RF = 1/2500$

$\Rightarrow$ 1cm = 2500 cm

$\Rightarrow$ 1cm = 25m.

Q4) The plan of a map was photo copied to a reduced size such that a line originally 100mm, measures 90mm. The original scale of the plan was 1:1000. The reduced scale is ____ ?

Sol:- ⇒ SF = $\frac{90}{100} - 0.9$

⇒ SRF = Original of RF x SF

= 1/1000 x 0.9

= 9×10^{-4}

= 1/1111

= 1 : 1111

Q5) Shrinkage of an old map is 24/25 & the RF is 1/2500 then the corrected scale for the map is equal to ____ ?

Sol:- ⇒ SRF = (1/25000) x (24/25)

= 1/2604.16

= 1 : 2600

Note:- More the R.F. value, larger the scale.

Eg- (1) 1cm = 50m = 1/5000 (larger scales)

(2) 1cm = 100m = 1/10000

Types of Tapes :-

(1) Cloth or linen tape :-

→ Length - 10m, 30m

→ Width - 15mm, 20mm

(2) Metallic Tape :-

→ Survey work, construction work.

→ length - 2mm, 30m

Dt - 06/01/20

(3) Steel tape :-

→ Length - 10m, 20m, 30m, 50m

→ Width - 2mm, 5mm, 15mm.

(4) Invar tape :-

→ Steel - 64% ✗

→ Nickel - 36%

→ Invar tape is used for base line measurement

$$\alpha = 1.2 \times 10^{-6}/^{\circ}C$$

$$\Rightarrow \alpha = 1/10\ \alpha_s$$

Dt - 09/01/20

Types of chain :-

(1) Metric chain :-

→ 20m, 30m

→ 150 ft, 100 links

→ each link = 20 cm

(2) Gunter's chain :-

→ 66 ft, 100 links

→ each link = 0.66 ft

(3) Engineer's chain :-

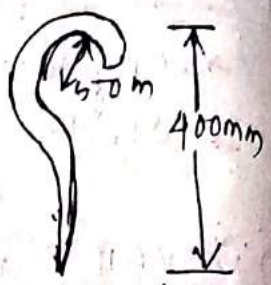
→ 100 ft, 100 links

→ each link = 1 ft

Dt - 09/01/20

Arrows :-

→ At the end of every chain length, an arrow is fixed.



Ranging Rods :-

→ Purpose of ranging rod is to range a line.
→ They are available at 2m & 3m length.

Offset Rods :-

→ Medium length is 5m.

C/s staff :-

→
(1) Open type = 90°
(2) French type = 45°

Plumb bob :-

→ To check the verticality of ranging rods c/s staff.

Wooden Pegs :-

→ To mark the terminal stations.

Ranging out survey lines :-

→ Ranging is reqd. when the length of a line to be measured is greater than the chain length.

→ Linear Measurement :-

(1) Direct Method :-

→ Chain or tape.

Dt - 09/01/20

(A) Computation or Optical Method :-

→ EDM (Electronic distance Measurement).

→ EDM are classified are :-

(1) Light waves.

(2) Microwaves.

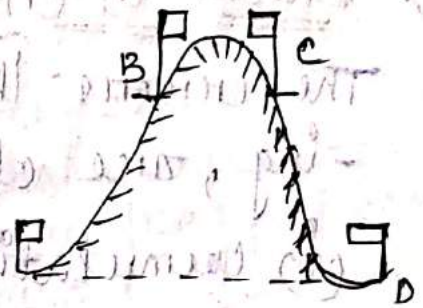
→ Methods of Ranging :-

(1) Direct Ranging :-

Its possible when 2 stations are intervisible

(A) By eye Judgement.

(B) By using line ranger.



(2) Indirect Ranging :-

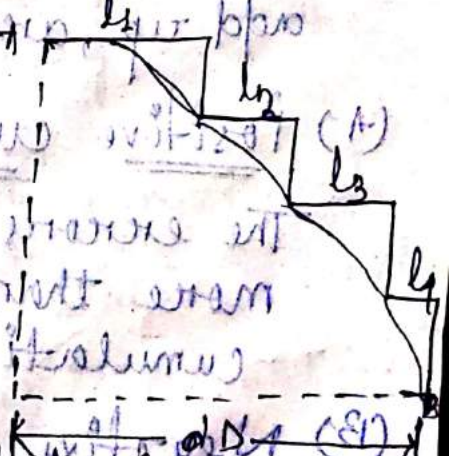
(A) When stations are not visible.

(B) Random methods is used to establish intermediate stations by reciprocal ranging.

→ Chaining on uneven / sloping ground :-

(1) Direct Methods :-

$$D = \sum_{i=1}^{n} l_i$$



→ Measuring down the hill is easier than up the hill.

→ Full length of a chain or tape is not generally used.

→ Depending upon the steepness of the slope, a portion of the chain or tape is used. Direct

method is also sometimes known as 'stepping method.'

(2) Indirect Method :—

The horizontal distance betn two stations on a sloping ground may be obtained by any one of the following methods :—

(i) By measuring along the slope & the angle of slope of the ground.

(ii) By applying the hypotenusal allowance to each chain length laid along the slope.

→ Error in chain :—

The errors that generally occur in chaining, are classified under two categories :—

(i) cumulative Errors.

(ii) Compensating Errors.

(i) Cumulative Errors :—

The errors which occur in the same direction & tend to accumulate, or to add up, are called cumulative Errors.

(A) Positive cumulative errors :—

The errors which make the measured length more than the actual, is known as positive cumulative errors.

(B) Negative cumulative errors :—

The errors which makes the measured

length less than the actual, it is known as Negative cumulative Error.

(ii) Compensating Errors:-

The errors which are liable to occur in either direction & tend to compensate, are called compensating errors.

Dt ↓ 12/01/20

→ Chaining a line :-

Leader	Follower
(1) To drag the chain forwarded.	(1) To direct the leader to be in line with the ranging rod at the end station.
(2) To insert an arrow at the end of every chain.	(2) To survey the near end of the chain ensuring that it is dragged above the ground.
(3) To obey the instructions of the follower	(3) To pick up the arrows inserted by the leader.

Q:- The length of a survey line measured with a 30m chain was found to be 631.5m. When the chain was compared with a standard chain, it was found to be 0.10m too long. find the true length of the survey line.

Sol:- True length of the line = $\frac{L'}{L}$ × measured length of the line

Here measured length of survey line = 631.5m

∴ True length of the survey line = $\frac{30.10}{30}$ × 631.5

method is also, sometimes known as stepping method.

= 633.603 m.

Q:- The area of a certain field was measured with a 30 m chain and found to be 5000 sq. m. It was after wards detected that the chain used was 10cm too short. What is the true area of the field.

Sol:- True area $= \left(\frac{L'}{L}\right)^2 \times$ measured area.

Here, $L' = 29.9$ m ; $L = 30$ m; measured area = 5000 sq. m.

True area $= \left(\frac{29.9}{30}\right)^2 \times 5000$ sq. m.

$= 4966.72$ sq. m.

Tape corrections :-

(1) Correction for temp :

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

where, L = measured length of the line.

T_m = mean temp^n during measurement

T_0 = normal temp^n at standardisation.

α = co-efficient of thermal expansion of the tape material.

temp^n correction.

Q:- A steel tape 20m long standardized at 15°C was used for measuring a base line. The temp^n during measurement was

300f. If co-efficient of linear expansion of steel = 6×10^{-6} /°f, correction for temp^{n}, per tape length is ——— ?

(A) +0.003m (B) −0.003m (C) −0.003m (D) +0.003m

Ans:- Correction for temp^{n}, $C_t = L \alpha (T_m - T_0)$

$= 20 \times (6 \times 10^{-6}) \times (30 - 15)$

$= -0.003$ m.

Q:- A 30m steel tape is subjected to pull of 10kg in 3 equal spans of 10m length. Area of C/s & density of tape are 0.08 sq.cm & 7.86 g/cc resp. The correction for sag in 'm' is ——— ?

Ans:- $W = V_V = (7.86 \times 0.08 \times 3000) \times 10^{-3} = 1.8864$ kg.

Correction for sag, $\text{sag} = \frac{W^2 L}{24 n^2 p^2}$

$= \frac{(1.86)^2 \times 30}{24 \times (3)^2 \times (10)^2}$

$= 0.0049$ m

Q:- A line was measured with a steel tape which was exactly 30 metres at 20°C at a pull of 100N (or 10 kgf), the measured length being 1650.00 metres. The temperature during measurement was 30°C and the pull applied was 150N (or 15 kgf). Find the length of the line, if the cross-sectional area of

the tape was 0.025 sq. cm. The co-efficient of expansion of the material of the tape per 1°C = 3.5×10^{-6} and the modulus of elasticity of the material of the tape = 2.1×10^5 N/mm² (2.1×10^6 kg/cm²).

Sol:-

(i) Correction of temp^{n} per tape length.

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

$$= 0.0000035 (30 - 20) \times 30$$

$$= 0.00105 \text{ m (+ve)}$$

(ii) Correction for pull per tape length.

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

$$= \frac{(150 - 100) \times 30}{2.5 \times 2.1 \times 10^5}$$

$$= 0.00286 \text{ m (+ve)}.$$

Combined correction = 0.00105 + 0.00286

= 0.00391 m.

∴ True length of the tape = 30 + 0.0039

= 30.0039 m

∴ True length of the line = $\frac{30.0039 \times 1650.100}{30}$

= 1650.21 m

Q: A tape 100m long, 6.35 mm wide, 0.5 mm

-thick was used to measure a line, the apparent length of which was found to be 1986.96 m. The tape was standardized under a pull of 67.5 N (or 6.75 kgf), but after the line was measured, it was found that the pull actually used during the measurement was 77.5 N (or 7.75 kgf). What was the true length of the line if the tape was standardized as used on the flat? Take young's modulus, E = 200000 N/mm² (or 20,00,000 kg/cm²).

Sol:- Correction for pull per tape length

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

$$= \frac{(77.5 - 67.5)\,100}{(6.35 \times 0.5) \times 200000}$$

$$= \frac{1000}{3.175 \times 200000}$$

$$= 0.001575 \text{ m (+ve)}$$

∴ True length of the tape

$$= 100 + 0.001575$$

$$= 100.001575 \text{ m}$$

∴ True length of the line

$$= \frac{100.001575}{100} \times 1986.96$$

$$= 1986.991 \text{ m}$$

Q: A base line AC was measured in two parts along two straight drains AB & BC of length 1650 m & 1819.5 m with a steel tape which was exactly 30 m at 25°C at a pull of 9 N (or 10 kgf). The applied pull during

measurement of both ends was 200N (0.20 kgf). The applied pull during measurement of both ends was 200N (0.20 kgf) whereas respective temp^{n} were 45°C & 25°C. The slopes of drains AB & BC were 3° & 3°30' & the deflection angle of BC was 10° right. find the correct length of the base line if the cross-section area of the tape was 2.5mm^2. The co-efficient of expansion & modulus of elasticity of tape material were 3.5×10^{-6} per on 1°C & 21×10^5 N/mm^2 respectively.

Sol:- (i) correction for temperature per tape length.

for length AB $= \alpha (T_m - T_0) L$

$= 0.0000035 (45 - 25) \times 30$

$= 0.00210$ m (+ve).

for length BC $= 0.0000035 (40 - 25) \times 30$

$= 0.001575$ m (+ve).

(ii) correction for pull per tape length

$= \frac{(P_m - P_0) L}{A E}$

$= \frac{(200 - 100) \times 30}{2.5 \times 21 \times 10^5}$

$= \pm 0.00057$ m (+ve)

∴ Combined correction for the length AB

$= 0.0021 \pm 0.00057$

$= 0.0078$ m.

& combined correction for the length BC $= 0.001575 + 0.00057$

$= 0.002145$ m.

∴ True length of the tape for measuring AB = 30.0078 m

and True length of the tape for measuring BC = 30.007275 m.

∴ True length of AB = $\frac{30.0078}{30} \times 1650$

= 1650.429 m

and True length of BC = $\frac{30.007275}{30} \times 1819.5$

= 1819.941 m.

Length of AB corrected for slope

= 1650.429 cos 3°

= 1648.168 m.

Length of BC corrected for slope

= 1819.941 cos 3° 30'

= 1816.547 m.

∴ Length of the base AC

$= \sqrt{(1648.168)^2 + (1816.547)^2 - 2 \times 1648.168 \times 1816.547 \cos 170°}$

= 3451.562 m.

— 0 —

Chapter - 02 | Dt - 15 | 01 | 20

Chaining & Chain Surveying :

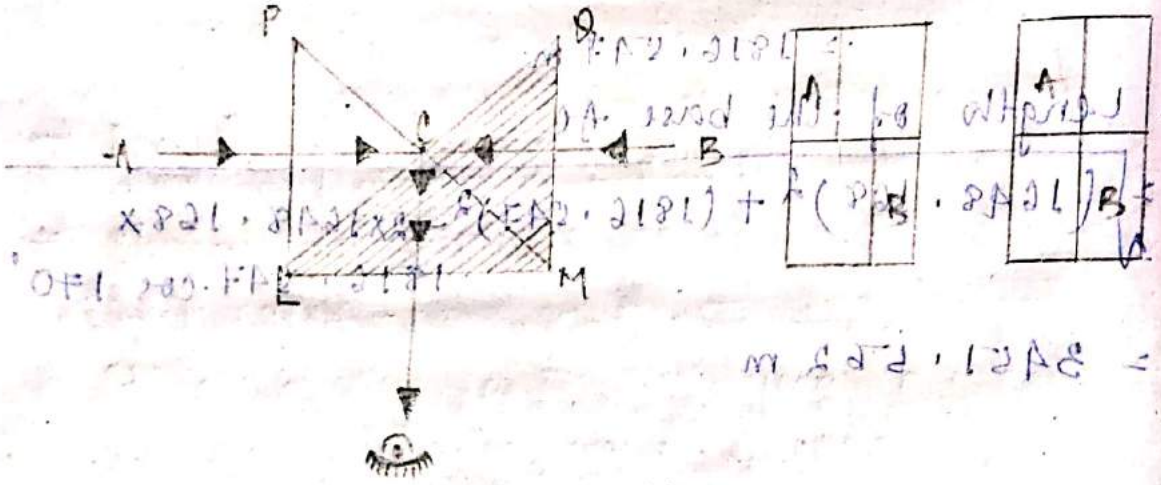
→ Types of chain :

The chains used in surveying. There are 3 types of chains.

(i) Gunter's chain.
(ii) Metric chain.
(iii) Engineer's chain.

→ Line Ranger :

It is a small reflecting instrument used for fixing intermediate points on a chain line. It consists of two right angled isosceles triangular prism.



→ Method of chaining :

To chain a line, the follower holds the handle of the chain in contact with the peg at the beginning of the line & direct the leader to be in line with the ranging rod fixed at the end of the chain line. The leader, taking 10 arrows in one hand and the other handle of the chain in other hand, walks along the line

dragging the chain.

→ Unfolding a chain :—

Unfolding a chain must be done with great care. After removing the leather strap, both the handles should be held in the left hand & the chain should be thrown well forward with the right hand. The leader, then should take one handle of the chain & move forward until the chain is extended to its full length. The chain then examined to see if there are any kinds or bent links. This operation is called unfolding the chain.

→ folding the chain :—

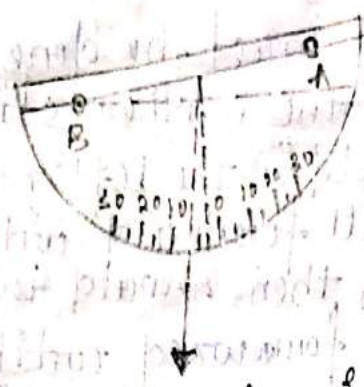
After the day's work the chain should be folded into a bundle & fastened with a leather strap. The handles of the chain should be brought together by pulling the chain at the middle. commencing from the middle, take two pairs of links at a time with the right hand & placed them obliquely across the other in the left hand. When the chain is collected in a bundle which somewhat resembles a sheaf of corn, it is tied with a leather strap. This operation is called folding the chain.

→ Chaining on sloping Ground :—

Chaining on the surface of a sloping ground gives the sloping distance. For plotting the surveys, horizontal distances are required. There are two methods for getting the horizontal distance between two stations on a sloping ground:

D-1 - 16/01/20

→ Measuring the slope Angle with a clinometer:-



The type of clinometer is most commonly used for measuring the angles of slope. It consists of :-

(i) A graduated semi-circle similar to a protractor.
(ii) Two pins A & B for sighting.
(iii) A light plumb-bob with a long thread suspended from the centre.

→ Defn of chain surveying :-

- Chain surveying is one of the methods of land surveying.
- It is the system of surveying in which sides of various triangles are measured directly in the field & no angular measurements are taken.
- It is the simplest but accurate method of land surveying.

D-1 - 21/01/20

→ Technical terms and their definitions :-

(1) Main survey station :-

The point where two sides of a main triangle meet is called a main survey

station. Main survey station is a point at either end of a chain line.

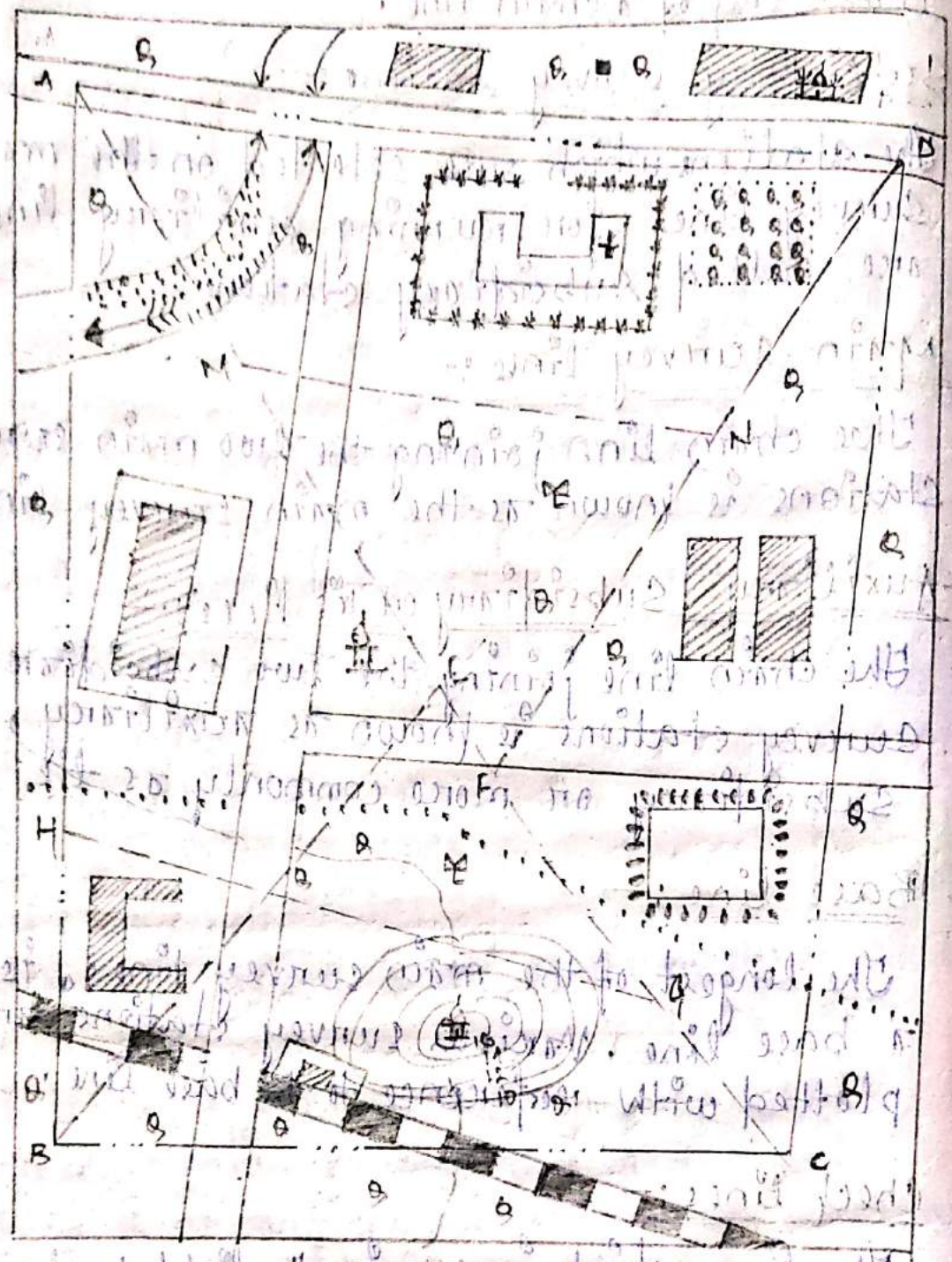
(2) Subsidiary survey stations :-
The stations which are selected on the main survey lines for running auxiliary lines, are called subsidiary stations.

(3) Main survey lines :-
The chain line joining the two main survey stations is known as the main survey lines.

(4) Auxiliary, Subsidiary or tie lines :-
The chain line joining the two subsidiary survey stations is known as auxiliary, subsidiary or more commonly as tie line.

(5) Base line :-
The longest of the main survey lines, is called a base line. Various survey stations are plotted with reference to the base line.

(6) Check lines :-
The line which is run in the field to check the accuracy of the field work is called the check lines.



(1) Base line = AC

(2) Main surveying lines = AB, BC, CD & DA.

(3) Subsidiary / tie lines = BE & FD.

(4) Check lines = HG & MN.

(5) Main surveying stations = A, B, C & D

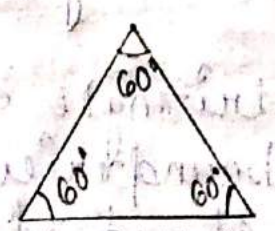
(6) Subsidiary stations = E & F.

Purpose of chain surveying :—

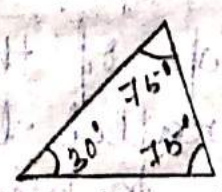
(1) To secure necessary data for exact description of the boundaries of a plot of land.
(2) To determine the area of a plot of land.
(3) To prepare an accurate plan of a plot of land.
(4) To demarcate the boundaries of a plot of land in a previously surveyed area.
(5) To divide a plot of land into a number of smaller units.
(6) To secure data for executing engineering projects, alignment of roads, railway lines, canals, etc.

→ Principle of chain surveying :—

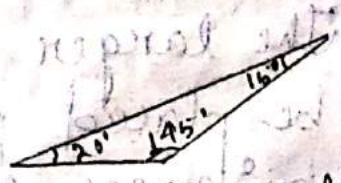
The principle of chain surveying is to divide the area into a number of triangles of suitable sides. As a triangle is the only simple plane geometrical figure which can be plotted with its sides alone, a network of triangles is preferred to in chain surveying.



An ideal triangle



A well conditioned triangle



An ill conditioned triangle.

→ field book :—

The note book in which chainages, offset measurements & rough sketches of detail points are recorded is generally called as field book. It is an oblong book of size about 20 cm x 12 cm & opens length wise.

→ Selection of survey stations :—

(1) Main survey stations at the ends of chain lines, should be intervisible.

(2) Survey lines should be minimum possible

(3) The main principle of surveying viz, working from the whole to the part, & not from the parts to the whole, should be strictly observed.

(4) Survey stations should form well conditioned triangles.

(5) Every triangle should be provided with a check line.

(6) Tie lines should be provided to avoid too long offsets.

(7) Obstacles to ranging & chaining, if any, should be avoided.

(8) The larger side of the triangle should be placed parallel to boundaries, roads, buildings, etc. to have short offsets.

→ Offsets :—

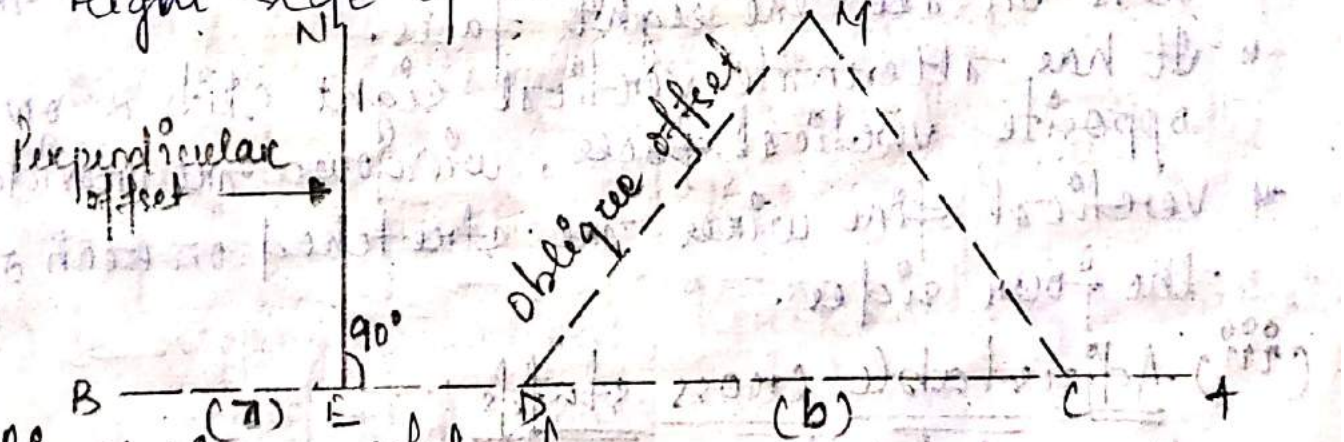
In chain surveying, the positions of details boundaries, culverts, roads stream bends, etc. are located with respect to the chain line by measuring their distances right or left of the chain lines. Such lateral measurements are called offsets. There are 2 types of offsets.

(i) Perpendicular offsets.

(ii) Oblique offsets.

(i) Perpendicular offsets :—

When the lateral measurements for fixing detail points, are made perpendicular to a chain line, the offsets are known as perpendicular offsets or right angled offsets. EN is a perpendicular offset on the right side of the chain line AB.



(ii) Oblique offsets :—

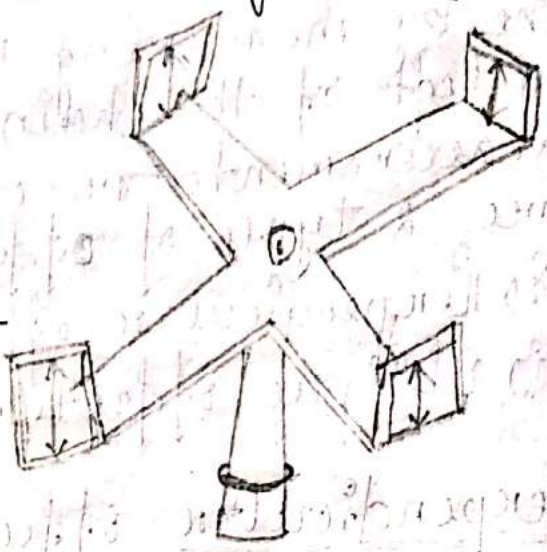
When the lateral measurements for fixing detail points, are made at any angle to the chain line, the offsets are known as oblique offsets. CM & DM are oblique offsets

on the right side of the chain line AB.

→ Instruments for setting offsets :—

For setting ~~ordinates~~ in chain surveying, the following instruments are generally used.

(i) Open cross staff.
(ii) French " "
(iii) Adjustable " "



(i) Open cross staff :—

- It is the simplest type of cross staff which is commonly used.
- It consists of a head & a leg.
- The head is a wooden block octagonal or round about 15 cm side or 20 cm dia. & 4 cm deep.

(ii) French cross staff :—

- It consists of an octagonal brass tube with slots on all the eight faces.
- It has alternate vertical sight slits & on opposite vertical faces, windows are provided.
- Vertical fine wires are stretched on each of the four sides.

(iii) Adjustable cross staff :—

- It consists of a brass cylindrical tube about 8 cm in dia. & 10 cm deep, divided at the middle.
- The lower portion remains fixed & the upper portion can be rotated relative to the lower one by a circular rack & pinion arrangement

~~[illegible]~~ actuated by a milled headed screw.
Sighting clots are provided in both the parts.

Dt - 22/01/20

Chain surveying precaution against Errors & Mistakes :-

(1) The point where the arrow 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 & 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 & distinctly & the surveyors should repeat them while booking.
(6) Measurements should not be taken with the tape in suspension in high winds.
(7) In slopping operations, horizontality & verticality 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.

→ Chaining when 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 & D are selected on either one side of the building. Equal perpendiculars CC1 & DD1 are erected. The line C1D1 is extended until the building is crossed. On the extended line, two points E1 & F1 are selected. Then perpendiculars E1E & F1F are so erected that,

$$E_1E = F_1F = D_1D = C_1C$$

Thus, the points C, D, E & F will lie on the same straight line AB.

Here,

$$\triangle D_1E_1E \cong \triangle D_1F_1F$$

The distance D1E1 is measured, & is equal to the required distance DE.

———— 0 ————

Chapter 2 : COMPASS SURVEYING : Dt → 27/01/20

→ Defn of compass surveying :—

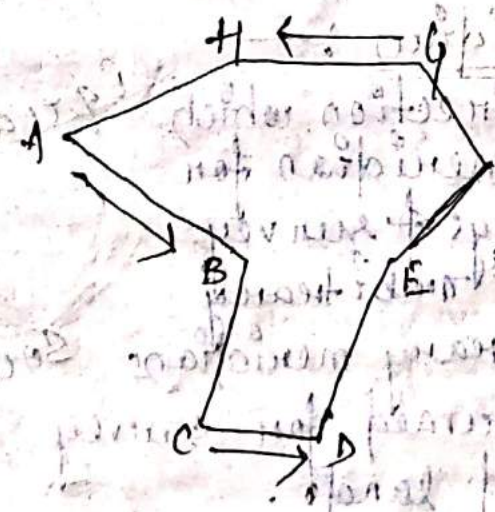
The branch of surveying in which directions of survey lines are determined by a compass & their lengths by chaining or taping directly on the surface of the earth is called compass surveying.

→ Traverse :—

A series of connected straight lines, each joining two points on the ground, is called as traverse. Traverse may be either a closed traverse or an open traverse.

(1) Closed traverse :—

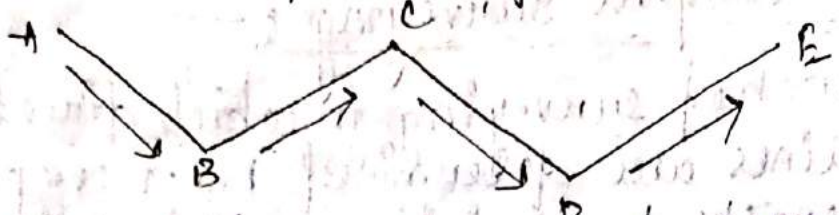
The traverse which either originates from a station & returns to the same station completing a circuit, or runs bet^n two known stations is called a closed traverse. The closed circuit of the traverse legs is known as traverse circuit.



(2) Open traverse :—

The traverse which neither returns to its starting station nor closes on any other known

station, is called an open traverse.



→ Meridians :—

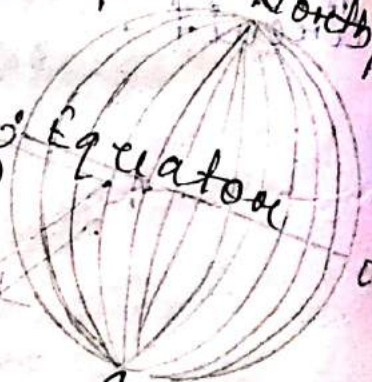
The fixed direction on the surface of the earth with reference to which, bearings of survey lines are expressed is called a 'meridian'.

(1) Magnetic Meridian :—

The longitudinal axis of a freely suspended & properly balanced magnetic needle, unaffected by local attractive forces, defines the magnetic north-south line which is called the 'magnetic meridian'.

(2) True Meridian :—

The line of intersection of the earth surface by a plane containing north pole, south pole & the observer's position is called 'true meridian' & 'geographical meridian'.

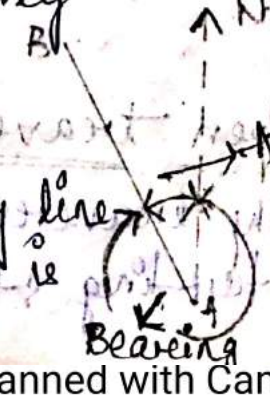


(3) Arbitrary Meridian :—

The convenient direction which is assumed as a meridian for measuring bearings of survey lines is known as 'arbitrary meridian'. Arbitrary meridians are generally assumed for survey of small plots of land.

→ Azimuth :—

The smaller angle which a survey line makes with the true meridian is called 'azimuth'.

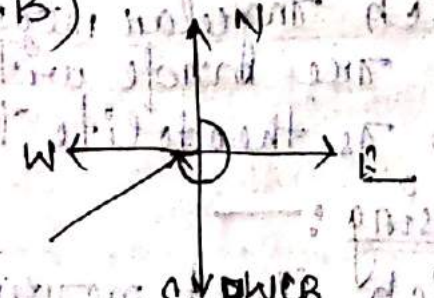


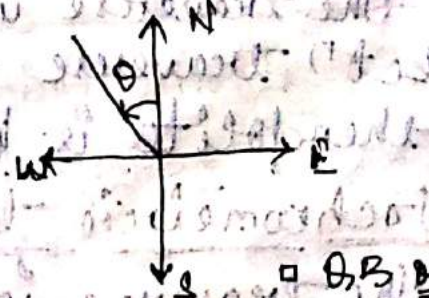
→ Bearing :—
The horizontal angle bet? the reference meridian and the survey line measured in a clockwise direction is called "bearing".

→ Designation of Bearings :—
Bearings of survey lines are designated in the following systems :—
(i) The whole circle bearing system (W.C.B)
(ii) The quadrental bearing system (Q.B).

(i) Whole circle bearing (W.C.B) :—
The whole circle bearing system is also sometimes known as 'Azimuthal system'. In this system bearing of a line is measured from the true north or magnetic north in clockwise direction. The value of a bearing may vary from 0° to 360°, utilising the whole circle of graduation.

(ii) Quadrental bearing (Q.B) :—
In quadrantal bearing system, bearings of survey lines are measured eastward or westward from North & south, whichever is nearer. In this system, both north & south directions are used as reference meridians & bearings are reckoned either clockwise or anticlockwise depending upon the position of the line. It is also called Reduced Bearing (R.B).





□ WCB
□ QB or RB

→ Methods of traversing :—

The classification of traverses based upon the instruments used is as under :—

(i) Chain traversing.
(ii) Compass traversing.
(iii) Plane table traversing.
(iv) Theodolite traversing.
(v) Tacheometric traversing.

(i) Chain traversing :—

In chain traversing the entire work is done by a chain or tape & no angle measuring instrument is needed. The angle computed by the measurement is known as 'chain traversing' or 'chain angle'.

(ii) Compass traversing :—

The traverse in which angular measurements are made with a surveying compass, is known as compass traversing.

(iii) Plane table traversing :—

The traverse in which angular measurements bet^n the traverse sides are plotted graphically on a plane table with the help of an alidade, is known as plane table traversing.

(iv) Theodolite traversing :—

The traverse in which angular measurements bet^n traverse sides are made with a theodolite is known as theodolite traversing.

(v) Tacheometric traversing :—

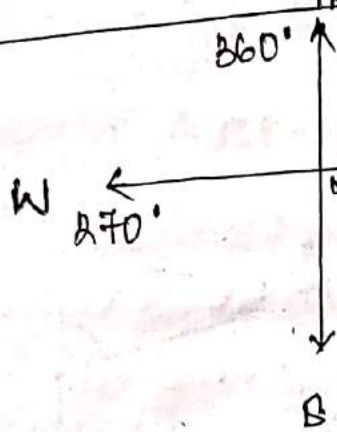
The traverse in which direct measurements

of traverse sides by chaining is dispensed with & these are obtained by making observation with a theodolite is known as tacheometric traversing.

Dt - 28/01/20

→ Conversion of W.C.B. into Q.B. :—

Case	W.C.B. betn	Rule of Q.B	Quadrant
(1)	0° and 90°	W.C.B	N.E.
(2)	90° & 180°	180° − W.C.B	S.E.
(3)	180° & 270°	W.C.B − 180°	S.W.
(4)	270° & 360°	360° − W.C.B	N.W.



→ Conversion of Q.B into W.C.B :—

Case	R.B	Rule for W.C.B	W.C.B betn
(1)	N & E	R.B	0° & 90°
(2)	S & E	180° − R.B	90° & 180°
(3)	S & W	180° + R.B	180° & 270°
(4)	N & W	360° − R.B	270° & 360°

Q:- (a) Convert the following whole circle bearings:-
(i) 12° 45' (ii) 160° 10' (iii) 210° 30' (iv) 285° 50',
(b) Convert the following Q.B. to W.C.B :-

(i) N 30° 30' E (ii) S 70° 42' E
(iii) S 36° 35' W (iv) N 82° 10' W.

Sol: (a) (i) Reduced Bearing = W.C.B.
= 12° 45'
= N 12° 45' E.

(ii) R.B. = 180° - W.C.B.
= 180° - 160° 10'
= 19° 50'
= S 19° 50' E.

(iii) R.B. = W.C.B - 180°
= 210° 30' - 180°
= 30° 30'
= S 30° 30' W.

(iv) R.B. = 360° - W.C.B
= 360° - 285° 50'
= 74° 10'
= N 74° 10' W.

(b) (i) W.C.B = R.B.
= 30° 30'

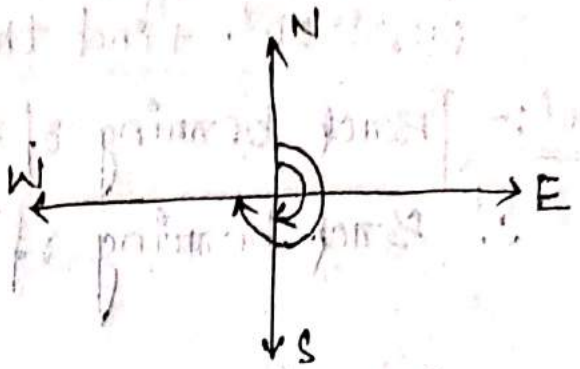
(ii) W.C.B = 180° - R.B
= 180° - 70° 42'
= 109° 18'

(iii) W.C.B = 180° + R.B
= 180° + 36° 35'
= 216° 35'

(iv) W.C.B = 360° - R.B.
= 360° - 85° 10'
= 274° 50'.

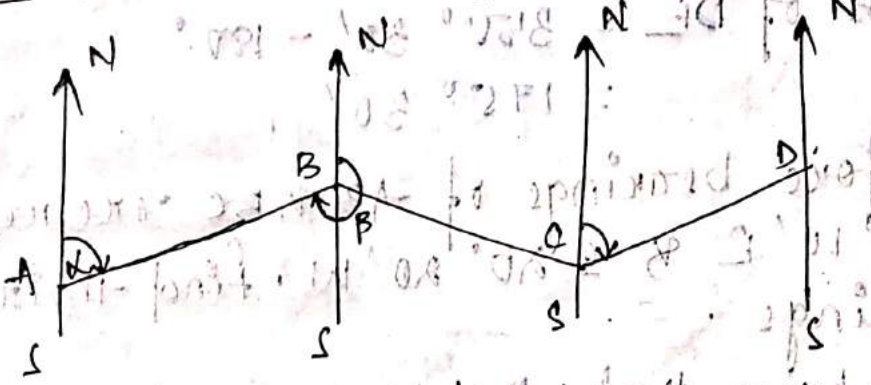
Q:- The whole circle bearing of a line is (i) 180° (ii) 270°. What will be its reduced bearing in each case?

Sol:- (i) R.B. = 180° - W.C.B
= 180° - 180°
= 0°
= S



(ii) R.B. = 360° - W.C.B
= 360° - 270°
= 90°
= W90°

→ Fore & Back Bearing :-



Every line may be defined by two bearings, one observed at either end of the line. Both the bearings expressed in W.C.B system differ each other by 180°. The bearing of a line in the direction of the progress of survey is called fore or forward Bearing (F.B.) while the bearing in the opposite direction of the progress of survey is known as back or reverse bearing (B.B).

Imp
more than 180°, deduct 180°.
more than 540°, deduct 540°.
less than 180°, add 180°, to get the bearing of the next line".

Q:- The fore bearings of traverse sides are as follow:-
AB 85° 10'; BC 155° 30'; CD = 265° 05' & DE 355° 30'. Find their back bearings.

Sol:- Back bearing of line = fore bearing of the line ± 180°.

∴ Back bearing of AB = 85° 10' + 180°
= 265° 10'.

B.B of BC = 155° 30' + 180°
= 335° 30'.

B.B. of CD = 265° 05' - 180°
= 85° 05'.

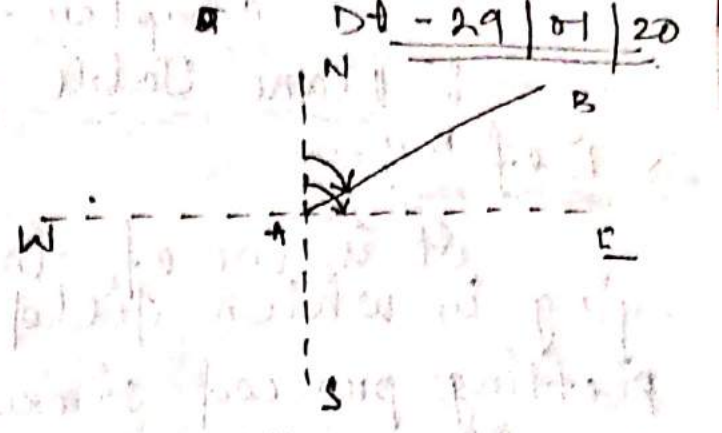
B.B. of DE = 355° 30' - 180°
= 175° 30'.

Q:- The fore bearings of AB & BC are respectively N 30° 10' E & S 20° 20' W. find their back bearings.

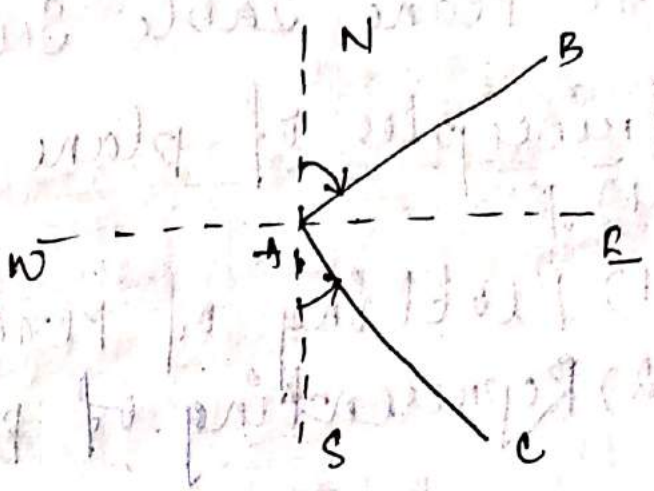
Sol:- We know that the back bearing of a line in Q.B. is obtained by simply replacing N by S & E by W & vice versa.

∴ Back bearing of AB = S 30° 10' W
Back bearing of BC = N 20° 20' E

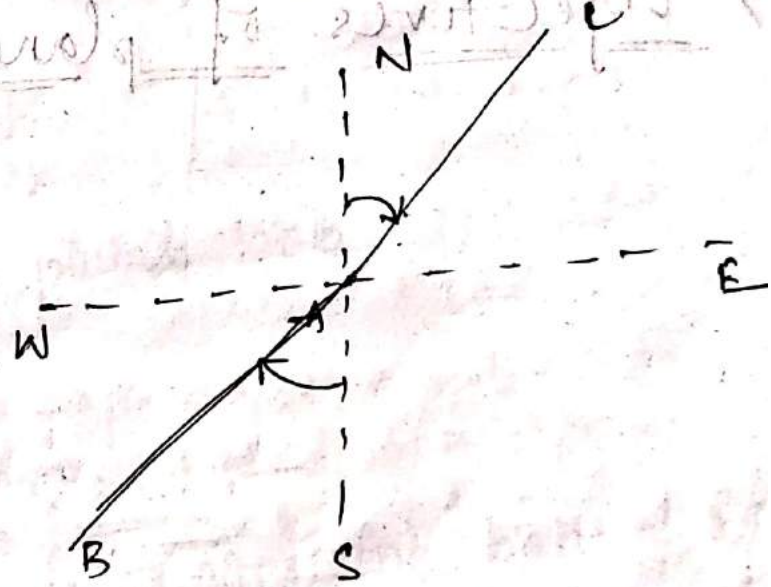
(1) AB N 40° 10' E
AC N 89° 45' E
= 89° 45' − 40° 10'
= 49° 35'.



(2) AB N 10° 50' E
AC S 40° 40' E
= 40° 40' + 10° 50'
= 51° 30'
= 180° − 57° 30'
= 128° 30'.



(3) AB S 35° 45' W
AC N 45° 20' E
= 45° 20' − 35° 45'
= 9° 35'
= 180° − 9° 35'
= 170° 25'



— 0 —

Chapter - 05

: Plane Table Surveying :

→ Defn :-

It is one of the methods of surveying in which field observations & plotting proceed simultaneously is known as Plane Table Surveying.

→ Principles of plane table surveying :-

(1) Plotting of plane table surveying
(2) Representing of plane table surveying.

→ Objectives of plane table surveying :-

Dt → 12/02/20

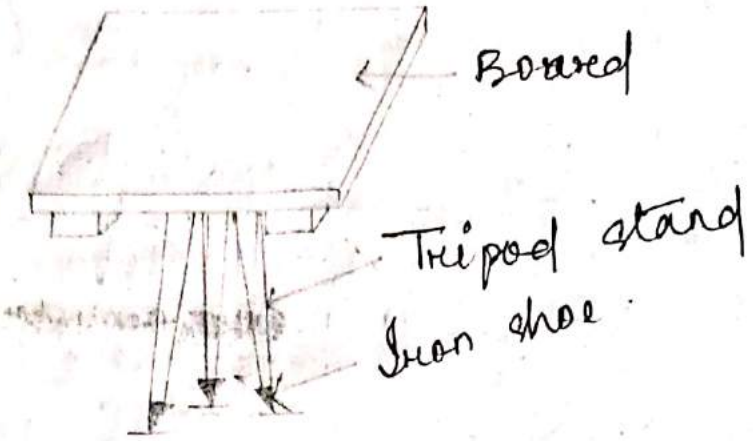
→ Instruments & Accessories used in plane table surveying :—

The instruments required for plane tabling are ;—

(1) Plane table with stand.
(2) Alidade or sight rule.
(3) Spirit level.
(4) Magnetic compass.
(5) Plumbing fork with plumb bob.
(6) Drawing paper.

(1) Plane table with stand :—

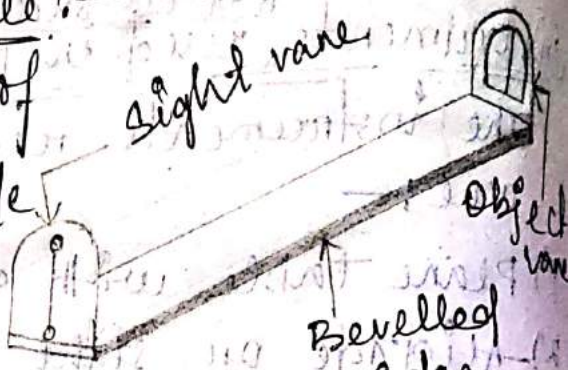
The plane table is a drawing board of size 750mm x 600mm made of well-seasoned wood like teak, pine, etc. The top surface of the table is well levelled. The bottom surface consists of a threaded circular plate for fixing the table on the tripod stand by a wing nut.



(2) Alidade or sight rule :—

There are two types of alidade :—

(i) plain alidade
(ii) telescopic "



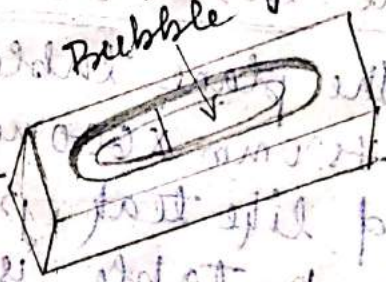
(i) Plain alidade :—

The plain alidade consists of a metal or wooden ruler of length about 5.0 cm.

(ii) Telescopic alidade :—

The telescopic alidade consists of a telescope meant for inclined sight or sighting distant objects clearly.

(3) Spirit level :—



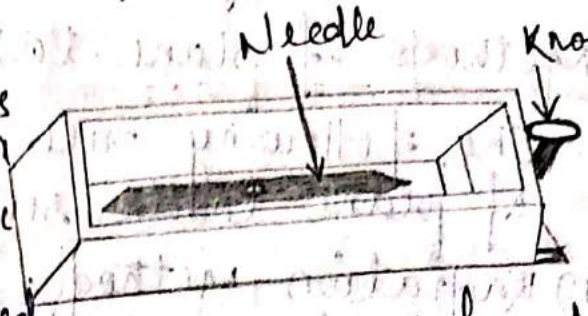
The spirit level is a small metal tube containing a small bubble of spirit. The bubble is visible on the top along a graduated glass tube. The spirit level is meant for levelling the plane table.

(4) Magnetic compass :—

There are two kinds of compass :—

(a) Through compass
(b) Circular box compass.

(a) Through compass :—



The through compass is a rectangular box made of non-magnetic metal containing a magnetic needle pivoted at the centre. This compass consists of 'O' mark at both ends to locate the N-S direction.

(b) Circular box compass :—

It carries a pivoted magnetic needle at the centre. The circular box is fitted on a square base plate. Sometimes two bubble tubes are fixed at right angles to each other on the base plate. The compass is meant for marking the north direction of the map.

(5) Plumbing fork with plumb bob :

The V-fork is a metal strip bent in the shape of 'V' (hair pin) having equal arm lengths. The top arm is pointed & the bottom arm carries a hook for suspending plumb bob.

(6) Drawing Paper :—

The drawing paper used for plane tabling must of be superior quality so that it can stand erasing. It may experience

minimum effect of distortion due to climatic changes.

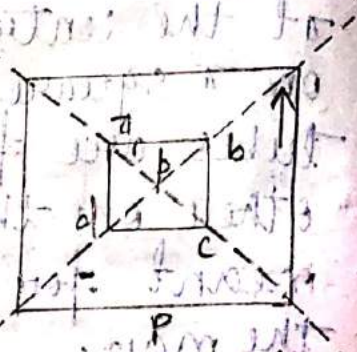
→ Methods of plane table surveying :-

The following are the four methods of plane-table surveying.

(1) Radiation method.
(2) Intersection "
(3) Traversing "
(4) Resection "

(1) Radiation Method :-

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



Procedure :-

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

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

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

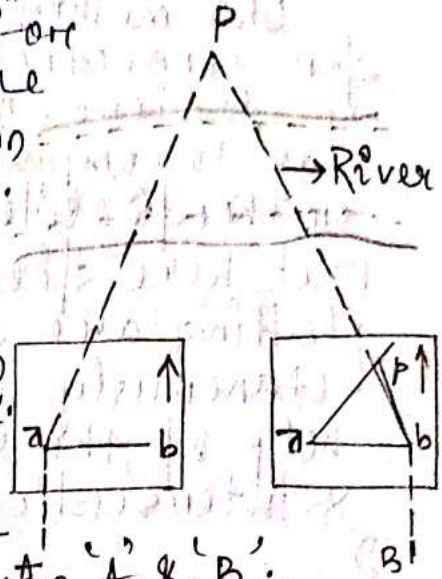
(d) The alidade touching p, the ranging rods at A, B, C & D are bisected & the rays drawn.

(e) The distances PA, PB, PC & PD are measured & plotted to any suitable scale to obtain

the pts a, b, c & d, representing the objects A, B, C & D on paper.

(2) Intersection Method :—

This method is suitable for locating inaccessible pts by the intersection of the rays drawn from two instrument stations.



Procedure :—

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

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

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

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

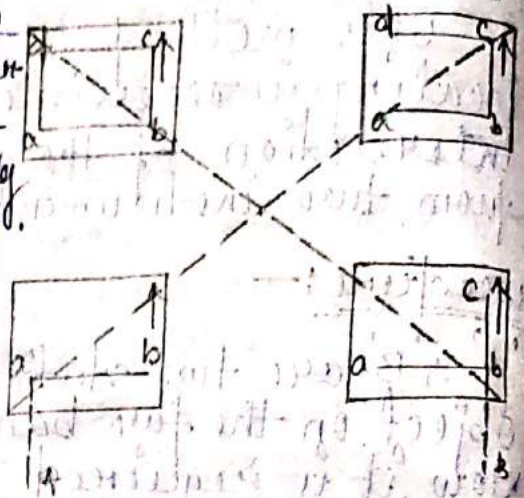
(e) The table is shifted & centred over 'B' & levelled properly. Now the alidade is placed along the line 'ba' & orientation is done by backsighting. At this time it should be remembered that the centering, levelling & orientation must be perfect simultaneously.

(f) The alidade touching b, the object P is bisected & a ray is drawn. Suppose this ray intersects the previous ray at a point 'p'. This point

'p' is the required plotted position of 'p'.

(3) Traversing method :—

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



Procedure :—

(1) Suppose A, B, C & D are the traverse stations.

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

(c) The alidade touching pt. 'a' the ranging rod at 'B' is bisected & a ray is drawn. The distance 'AB' is measured & plotted to any suitable scale.

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

(e) The alidade, touching pt. 'b', the ranging rod at C is bisected & a ray is drawn. The

distance BC is measured & plotted to the same scale.

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

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

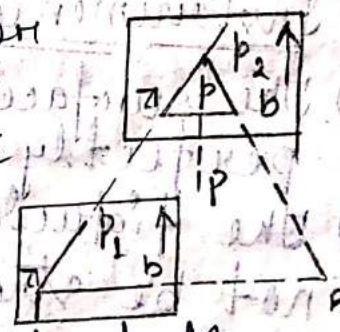
(h) At the end, the finishing point may not coincide with the starting pt. & there may be some closing error. This error is adjusted graphically by Bowditch's rule.

(i) After making the corrections for closing error, the table is again set up at 'A'. After centering, levelling & orientation, the surrounding details are located by radiation.

(j) The table is then shifted and set up at all the stations of the traverse & after proper adjustments the details are located by the radiation & intersection methods.

(4) The Resection Method :—

This method is suitable for establishing new stations at a place in order to locate missing details.



Procedure :—

(a) It is required to establish a station at position 'P'. Let us select two pt.s A & B on the ground. The distance AB is measured & plotted to any suitable scale. This line is known as the "base line".

(b) The table is set up at A, is levelled, centred and oriented by resection the

ranging rod at B. The table is then clam
(c) The alidade touching pt. 'a', the ranging rod at 'P' is bisected & a ray is drawn. Then a pt. P_1 is marked on this ray by estimating with the eye.
(d) The table is shifted & centred is such a way that P_1 is just over P. It is then oriented by backsighting the ranging rod at A.
(e) The alidade touching pt. b, the ranging rod at B is bisected & a ray is drawn. Suppose this ray intersects the previous ra at a pt. p. This point represents the position of the station P on the sheet. Then the actual position of the station P is marked on the ground by U-fork & plumb bob.

→ Errors in plane table surveying:—
The following are the common errors in plane table surveying.

(a) Instrumental Errors:—
(1) The surface of the table may not be perfectly level.
(2) The fiducial edge of the alidade might not be straight.
(3) The vanes may not be vertical.
(4) The horse hair may be loose and inclined.
(5) The table may be loosely joined with the tripod stand.
(6) The needle of the trough compass may not be perfectly balanced. Also it may not be able to move freely due to

sluggishness of the pivot pt.
The above errors are adjustable or avoidable.

(b) Personal Errors :—

(1) The levelling of the table may not be perfect.
(2) The table may not be centered properly.
(3) The orientation of the table may not be proper.
(4) The table might not be perfectly clamped.
(5) The objects may not be bisected perfectly.
(6) The alidade may not be correctly centred on the station pt.
(7) The rays might not be drawn accurately.
(8) The alidade may not be centred on the same side of the station pt. throughout the work.

(c) Plotting Errors :—

(1) A good quality pencil with a very fine pointed end may not have been used.
(2) An incorrect scale may be used by mistake.
(3) Errors may result from failure to observe the correct measurement from the scale.
(4) Unnecessary hurry at the time of plotting may lead to plotting errors.

→ Precautions in plane table surveying :-

(1) Before starting the work the equipments for survey work should be verified. Defective accessories should be replaced by perfect equipment.

(2) The centring should be perfect.

(3) The levelling should be proper.

(4) The orientation should be accurate.

(5) The alidade should be centred on the same side of the station pin until the work is completed.

(6) While shifting the plane table from one station to another, the tripod stand should be kept vertical to avoid damage to the fixing arrangement.

(7) Several accessories have to be carried. So care should be taken to ensure that nothing is missing.

(8) The pencil should have a sharp point.

(9) The distances of the objects or lines should be written temporarily along the respective rays until the plotting is completed.

(10) Only the selected scale should be on the table.

(11) Measurements should be taken carefully from the scale while plotting.

(12) The stations on the ground are marked A, B, C, D, etc. while the station pt. on the map are marked a, b, c, d, etc.

→ Advantages of plane table surveying:-

(1) It is the most rapid method of surveying.
(2) There is no need for a field book as plotting is done along with the field work. So, the problem of mistakes in booking field notes does not arise.
(3) Plotted work can be compared with actual object regardless of whether or not they are properly represented.
(4) There is no possibility of overlooking any important object.
(5) There is no possibility of overlooking any measurement as plotting is done in the field.
(6) Irregular objects may be represented accurately.
(7) It is suitable in magnetic areas.
(8) The map can be prepared easily, and does not require any great skill.
(9) Errors in measurement & plotting can be detected by check lines.
(10) Inaccessible points can be easily located by intersection.

→ Disadvantages of plane table surveying:-

(1) The plane table is not suitable for accurate work as the fitting arrangement is not perfect.
(2) Plane table surveying is not suitable in wet climate, in the rainy season, on foggy mornings & in windy weather.
(3) The number of accessories required is

such survey is large, & they are likely to be lost.

(4) The instrument is very heavy & difficult to carry.

(5) The map cannot be replotted to a different scale as there is no field book.

Dt → 18/02/20

→ Two-point problem :—

In this problem, two well-defined points whose positions have already been plotted on the plan are selected. Then, by perfectly bisecting these points, a new station is established at the required position.

Procedure :—

(a) Suppose, P & Q are two well-defined points whose positions are plotted on map as p & q. It is required to locate a new station at A by perfectly bisecting P & Q.

(b) An auxiliary station B is selected at a suitable position. The table is set up at B, & levelled & oriented by eye estimation. It is then clamped.

(c) The alidade touching p & q, the pts. P & Q are bisected and rays are drawn. Suppose these rays intersect at b.

(d) The alidade centered on b, the ranging rod at A is bisected & ray is drawn

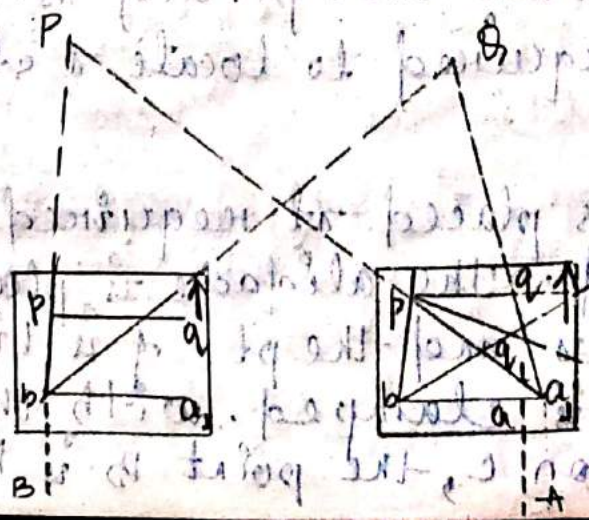
Then, by eye estimation, a pt. 1, is marked on this ray.

(e) The table is shifted & centered on 1, with 1, just over A. It is levelled & oriented by backsighting with the alidade touching b, the pt. P is bisected & a ray is drawn. Suppose this ray intersects the line b1 at point 1, as was assumed previously.

(f) The alidade centered on 1, the pt. B is bisected & a ray is drawn. Suppose this ray intersects the ray bq at a pt. q, The triangle, pqq, is known as the triangle of error, & is to be eliminated.

(g) The alidade is placed along the line pq, & a ranging rod R is fixed at some distance from the table. Then, the alidade is placed along the line pq & the table is turned to bisect R. At this position the table is said to be perfectly oriented.

(h) Finally, with the alidade centred on p & q, the pt. P & Q are bisected & rays are drawn. Suppose these rays intersect at a pt. 1. This would represent the exact position of the required station A. Then the station A is marked on the ground.

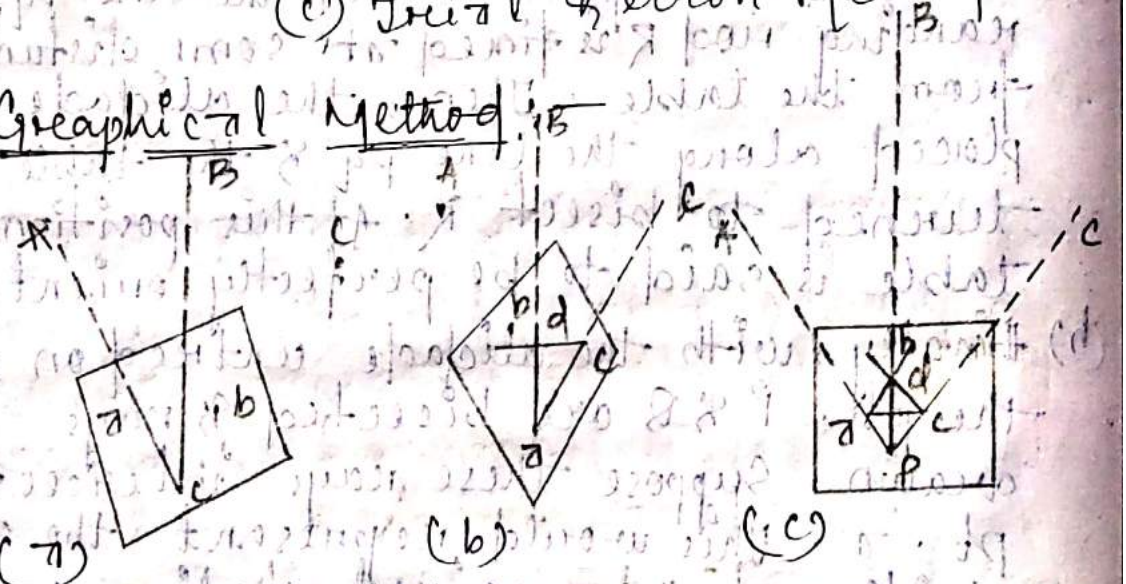


→ Three-point problem :—

In this problem, three well-defined points are selected whose positions have already been plotted on the map. Then, by properly perfectly bisecting these three well-defined pts., a new station is established at the required position.

No auxiliary station is required in order to solve this problem. The table is directly placed at the required position. The problem may be solved by three methods :- (a) Graphical or Bessel's method.
(b) Mechanical method.
(c) Trial & error method.

(a) Graphical Method :-



(i) Suppose A, B & C are three well-defined pts. which have been plotted as a, b & c. Now it is required to locate a station at P.

(ii) The table is placed at required station P & levelled. The alidade is placed along the line ca and the pt. A is bisected. The table is clamped. with the alidade centered on c, the point B is bisected &

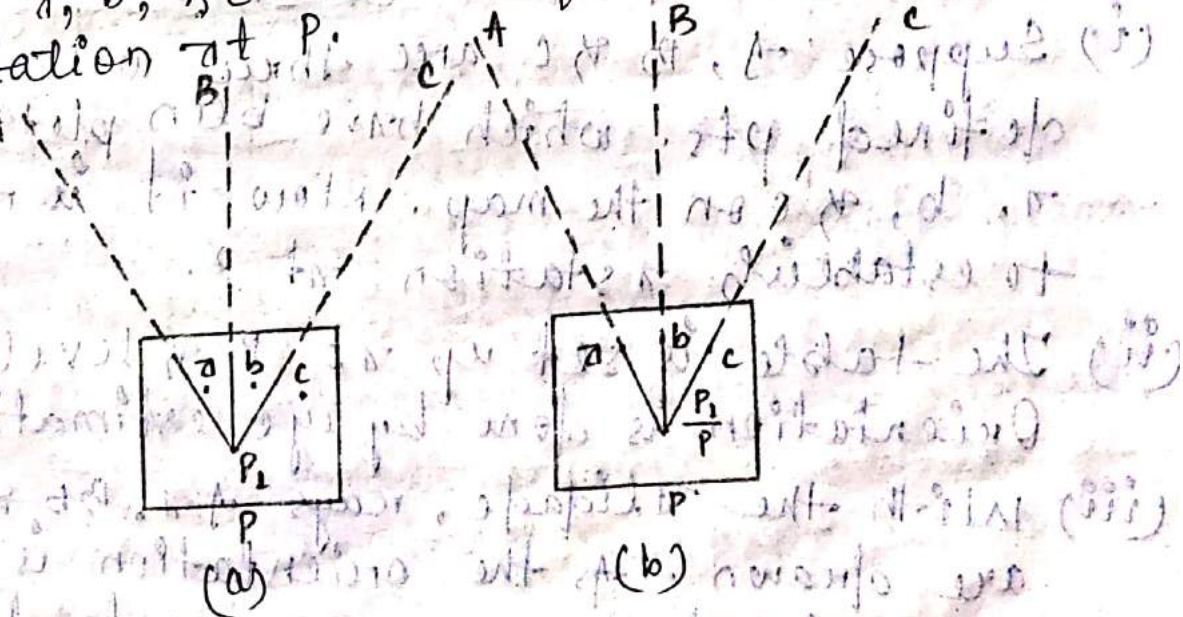
ray is drawn in fig.(a).

(iii) Again the alidade is placed along the line ac & the pt. c is bisected & the table is clamped. With the alidade touching a, the point B is bisected and a ray is drawn. Suppose this ray intersects the previous ray at a point d in fig.(b).

(iv) The alidade is placed along db & the pt. B is bisected. At this position the table is said to be perfectly oriented in fig.(c). Now the rays Aa, Bb & Cc are drawn. These three rays must meet at a pt. P which is the required pt. on the map. This pt. is transferred to the ground by U-fork & plumb bob.

(b) Mechanical Method:—

(i) Suppose A, B & C are three well-defined pts. which have been plotted on the map; a is a, b, & c. It is required to locate a station at P.



(ii) The table is placed at P & levelled. A tracing paper is fixed on the map & a pt. p is marked on it.

(iii) With the alidade centred on p the pts. A,

B, & C are bisected and rays are drawn. The rays may not pass through the pts. a, b & c as the orientation is done approximately in fig.(a).

(iv) Now the tracing paper is unfastened & moved over the map, in such a way that three rays simultaneously pass through the plotted positions a, b, & c. Then the pt. P is pricked with a pin to give an impression p on the map. p is the required point on the map.

(v) Then the alidade is centred on p & the rays are drawn towards A, B & C. These rays must pass through the pts. a, b & c.

(c) The Method of Trial & Error :—

(i) Suppose A, B & C are three well defined pts. which have been plotted as a, b, & c on the map. Now it is required to establish a station at P.

(ii) The table is set up, at P & levelled. Orientation is done by eye estimation.

(iii) With the alidade, rays Aa, Bb, & Cc are drawn. As the orientation is approximate, the rays may not intersect at a pt., but may form a small triangle the triangle of error.

(iv) To get the actual pt., this triangle of error is to be eliminated. By repeated

turning the table clockwise or anticlock wise. The triangle is eliminated in such a way that the rays 1a, 1b & cc finally meet at 1 at pt. 1'. This is the required pt. on the map. This pt. is transferred to the ground by U-fork & plumb bob.

— 0 —

Dt-

Chapter - 06

Theodolite surveying & Traversing :-

→ Defn :-

- An instrument used for measuring horizontal & vertical angles accurately is known as theodolite surveying'.

- The traversing in which traverse legs are measured by direct chaining on the ground & the traverse angle at every traver station is measured with a theodolite is known as theodolite traversing'.

→ Purpose of theodolite :-

(1) To provide control pts. for main surveying, plane tabling & photo-gramm-etric surveys in flat country.

(2) To fix the alignment of roads, canals, rivers, boundaries, etc. when better accuracy is required as compared to plane tabling.

(3) To ascertain the co-ordinates of boundary pillars in numerical terms that can be preserved for future reference such as cantonment boundary pillars, forest

boundary pillars, international boundary pillars, etc. In case the pillars get disturbed, their positions can be relaid with the help of their co-ordinates.

→ Classification of Theodolite :—

(i) Transit Theodolite :—

The theodolite whose telescope can be transited, is called a transit theodolite. A transit telescope can be revolved through a complete revolution about its horizontal axis in a vertical plane.

(ii) Non-Transit Theodolite :—

The theodolite whose telescope can't be transited, is called non-transit theodolite. A non-transit telescope can't be revolved through a complete revolution about its horizontal axis in vertical plane. Theodolites are also classified as :-

(i) Vernier theodolite.
(ii) Glass arc theodolite.

→ Reading a vernier theodolite :—

The least count of the vernier is to be determined first. Let it be 20". The main division of the main scale is of one degree. Suppose it is divided into three parts. Then each part accounts for 20' (i.e. d = 20')

The vernier scale has 20 big & 60 small division.

∴, least count $= \frac{d}{n}$

$= \frac{20}{60} \times 60$

$= 20''$.

Here, least count for one small division $= 20''$

∴ Least count for one big division

$= (20'' \times 3)$

$= 60'' = 1'$.

After making the final adjustment for measuring the angle, the position of the arrow of the vernier scale is noted. Suppose the arrow crosses 10° & 20', which is the direct reading obtained from the main scale. Suppose again that the first small division after 12 big divisions exactly coincides with any of the main scale divisions. Then, the vernier reading $12'20''$.

∴ final angle $= 10°20' + 12'20''$

$= 10°32'20'$.

→ Temporary adjustment of theodolite :—

The adjustments which are required to be made at every instrument station before making observations are known as temporary adjustments. The temporary adjustments of a theodolite include the following :—

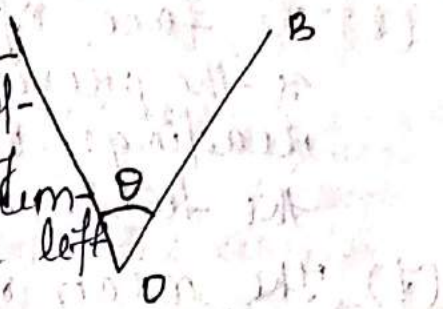
(i) setting up the theodolite over the station.
(ii) Levelling of the theodolite.
(iii) Elimination of the parallax.

(1) Setting up :—
The operation of setting up a theodolite includes the centering of the theodolite over the ground mark & its approximate levelling with the help of tripod legs.

(2) Centering :—
The operation with which vertical axis of the theodolite, represented by a plumb line, is made to pass through the ground station mark, is called centering.
The operation of centering is carried out in following steps :—
(i) Suspend the plumb bob with a string attached to the hook fitted to the bottom of the instrument to define the vertical axis.
(ii) Place the theodolite over the station mark by spreading the legs well apart so that telescope is at a convenient height.
(iii) The centering may be done by moving the legs radially & circumferentially till the plumb bob hangs within 1 cm horizontally of the station mark.
(iv) By unclamping the centre-shifting arrangement, the finer centering may now be made.

→ Measurement of Horizontal Angle :-

Suppose an angle ∠AOB is to be measured. The following procedures is adopted :-



(1) The instrument is set up over A. It is centred & levelled perfectly according to the procedure described for temporary adjustment. Suppose the instrument was initially in the face left position.

(2) The lower clamp is kept fixed. The upper clamp is loosened & by turning the telescope clockwise vernier A is set to 0° & vernier B to approximately 180°. The upper clamp is then tightened. Now by turning the upper tangent screw, vernier A & B are set to exactly 0° & 180° by looking through the magnifying glass.

(3) The upper clamp is tightly fixed. The lower one is loosened & the telescope approximately by properly focussing the telescope & eliminating parallax. The lower clamp is tightened & by turning the lower tangent screw the ranging rod at A is accurately bisected.

(4) The lower clamp is kept fixed. The upper clamp is loosened & the telescope is turned clockwise to approximately bisect the ranging rod at B by properly focussing the telescope. The upper clamp is tightened, & the ranging rod at B is bisected accurately by turning the upper tangent screw.

(5) The readings on vernier A & B are noted. Vernier A gives the angle directly. But in the case of vernier B.

- the angle is obtained by subtracting the initial reading from the final reading. The readings are noted in tabular form.

(6) The face of the instrument is changed & the previous procedure is followed. The readings of the verniers are noted in the table.

(7) The mean of the observations (i.e. face left & face right) is the actual angle ∠AOB. The two observations are taken to eliminate any possible error due to imperfect adjustment of the instrument.

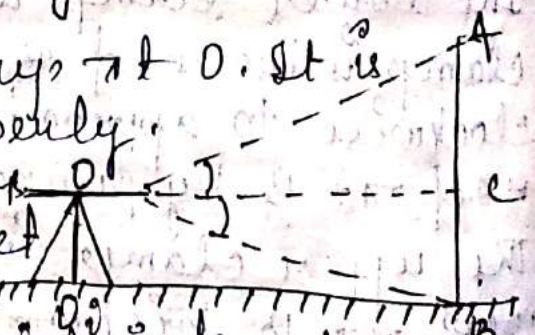
There are two methods of measuring horizontal angles :-

(i) repetition method.
(ii) reiteration method.

→ Measurement of vertical Angle :—

Suppose the angle of elevation ∠AOC & that of depression ∠BOC are to be measured. The following procedure is adopted :—

(1) The theodolite is set up at O. It is centred & levelled properly. The zeros of the verniers (generally C & D) are set at the 0°-0° mark of the vertical circle (which is fixed to the telescope). The telescope is then clamped.



(2) The plate bubble is brought to the

centre with the help of foot screws. Then the altitude bubble is brought to the centre by means of a clip screw. At this position the lines of collimation is exactly horizontal.

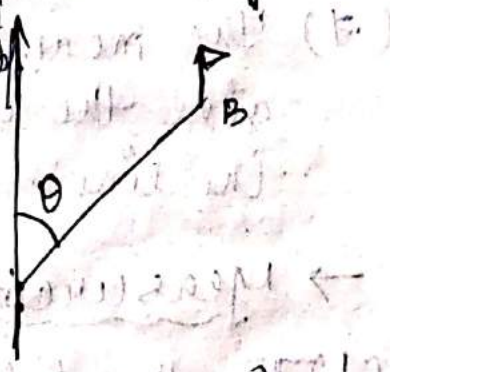
(3) To measure the angle of elevation, the telescope is raised slowly to bisect the pt. A accurately. The readings on both the verniers are noted, & the angle of elevation recorded

(4) The face of the instrument is changed & the point A is again bisected. The readings on the verniers are noted. The mean of the angles of the observed is assumed to be the correct angle of elevation.

(5) To measure the angle of depression, the telescope is lowered slowly & the pt. B is bisected. The readings on the verniers are noted for the two observations. The mean angle of the observation is taken to be the correct angle of depression.

→ Measurement of Magnetic bearing :—

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



(1) The theodolite is set up at A. & centred & levelled properly. Vernier A is set at 0° & vernier B at 180°. The upper clamp is fixed.

(2) Now a trough compass or tubular compass is fixed on the left hand standard (A-

became) with a fixing screw. In some theodolites, a circular compass is provided over the vernier scale bar. The standard however, the needle of the compass is released.

(3) By loosening the lower clamp, the telescope is rotated until it is to the north. At this time, the position of the telescope is said to be perfectly oriented along the magnetic meridian.

(4) The lower clamp is fixed & the upper clamp loosened. Then by turning the telescope clockwise, the ranging rod at B is bisected with the help of the upper tangent screw.

(5) The readings on both the verniers are taken. The mean of these readings is the magnetic bearing of AB.

(6) The face of the instrument is changed, & the magnetic bearing of AB is measured in a similar manner.

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

→ Measurement of Deflection Angle :-

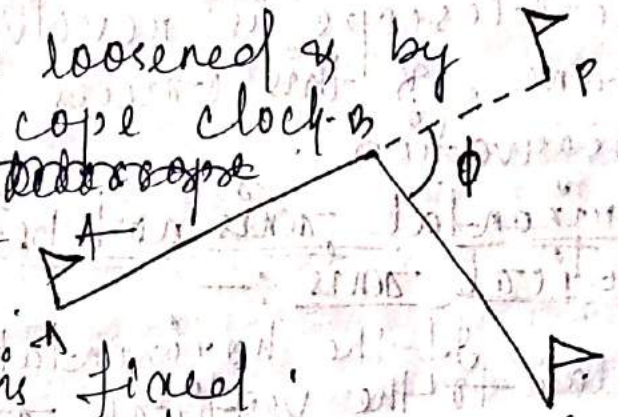
(1) The theodolite is set up at B, & centred & levelled properly. Vernier A is set to 0. & B is 180°. The upper clamp is tightened & the lower one loosened. By turning the telescope is transited & a ranging rod

→ A is perfectly bisected. The lower clamp is then fixed.

(2) The telescope is transited & a ranging rod → P is fixed along the prolongation of → AB.

(3) The upper clamp is loosened. By turning the telescope clockwise, the ranging rod → C is properly bisected. The readings on both the verniers are taken. The upper clamp is then tightened. Now, the verniers give the deflection angle ϕ.

(4) The lower clamp is loosened & by turning the telescope clockwise the ranging rod → P is again bisected. The lower clamp is fixed.



(5) The telescope is transited. The upper clamp is loosened & by turning the telescope clockwise the ranging rod → C is bisected once more. The readings on the verniers are taken.

(6) Thus the deflection angle is doubled. The average of the two verniers is taken. One half of this average value will give the correct value of the deflection angle. The deflection angle is doubled in order to eliminate errors, owing to wrong adjustment of the instrument, as those due to eccentricity of the centre.

→ Errors in Theodolite observation :—

(A) Instrumental Errors :—

The following are the major causes of instrumental error :—

(1) Non-adjustment of plate bubble :—

The axis of the plate bubble may be perpendicular to vertical axis, so when the plate levels are centred, the vertical axis may not be truly vertical.

(2) Line of collimation not being perpendicular to horizontal axis :—

In this case, a cone is formed when the telescope is revolved in the vertical plane, & this causes an error in the observation.

(3) Horizontal axis not being perpendicular to vertical axis :—

If the horizontal axis is not perpendicular to the vertical axis, there is an angular error. This is eliminated by reading the angle from both faces.

(4) Line of collimation not being parallel to axis of telescope :—

If the line of collimation is not parallel to the axis of the telescope, there is an error in the observed vertical angles. This error is ~~obtained~~ eliminated by taking readings from both faces.

(5) Eccentricity of inner & outer axis :—

This condition causes an error in vernier reading. This error is eliminated by taking readings from both verniers & considering the average of the readings.

(6) Graduations not being uniform :—
The error due to this condition is eliminated by measuring the angles several times on different parts of the circle.

(7) Verniers being eccentric :—
The zeroes of the verniers should be diametrically opposite to each other. When vernier A is set at 0°, vernier B should be at 180°. But in some cases, this condition may not exist.

(B) Personal Errors :—
(1) The centering may not be done perfectly, due to carelessness.
(2) The levelling may not be done carefully according to usual procedure.
(3) If the clamp screws are not properly fixed the instrument may slip.
(4) The proper tangent screw may not be operated by mistake.
(5) The focusing in order to avoid parallax may not be perfectly done.
(6) The object or ranging rod may not be bisected accurately.
(7) The verniers may not be set in proper place.
(8) Errors would also result if the verniers are not read because of oversight.

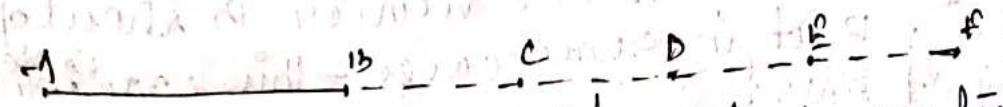
(C) Natural Errors :—
(1) High temp^{n} causes error due to irregular refraction.
(2) High winds cause vibration in the instrument.

& this may lead to wrong reading on the vernier.

→ **Prolonging of a straight line :—**

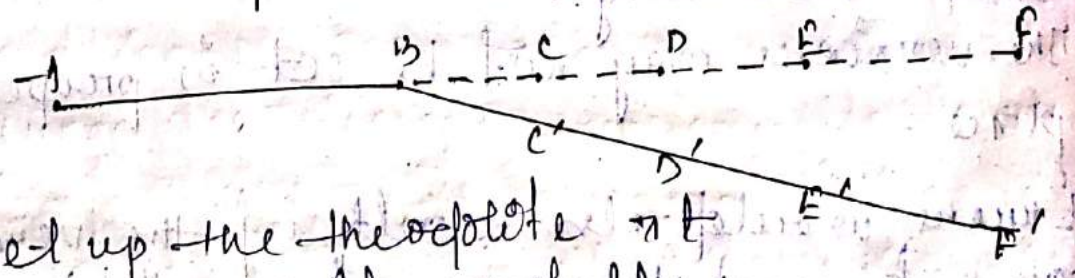
Prolonging of any straight line AB to a pt. F may be done by any one of the following methods :—

1st method :—



(1) Set up the theodolite at A, centre & level it accurately.
(2) Bisect B accurately.
(3) Establish a point C in the line of sight at a convenient distance.
(4) Shift the instrument to B.
(5) Centre the theodolite over B, level it & sight C. Establish another pt. D.
(6) Proceed in a similar manner until the desired point F is established.

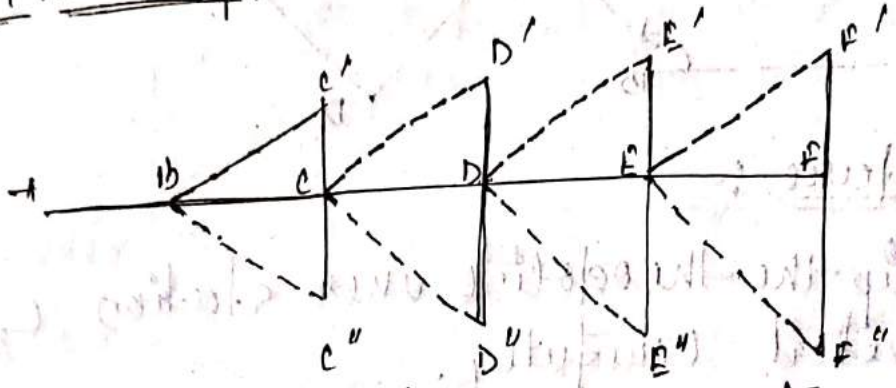
2nd method :—



(1) Set up the theodolite at B & centre it carefully.
(2) Bisect A accurately & clamp both the plates.
(3) Plunge the telescope & establish a point C in the line of sight.

(4) Shift the instrument to C & centre it carefully.
(5) Bisect B & clamp both the plates.
(6) Plunge the telescope & establish a point D in the line of sight.
(7) Continue the process till the last point E is established.

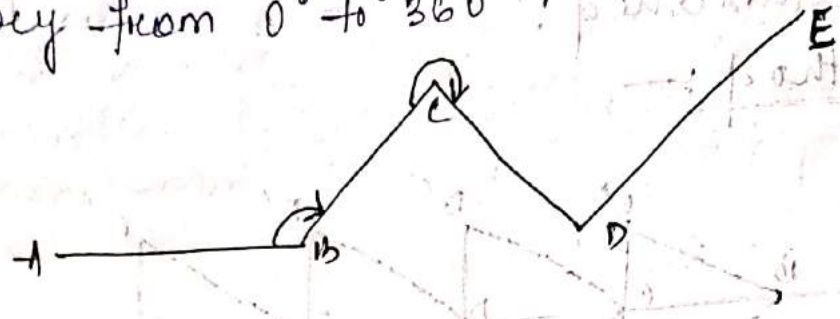
3rd method :—



(1) Set up the theodolite at B & centre it carefully.
(2) Bisect A on face left & clamp both the plates.
(3) Plunge the telescope & establish a point C'.
(4) Change the face, & bisect A again.
(5) Plunge the telescope & establish a point C'' at the same distance as C' from B.
(6) If the instruments is in adjustment, the point C' & C'' will coincide.
(7) If not, establish a point C midway betn C' & C''.
(8) Shift the instrument to C & repeat the process to establish a point D.
(9) Repeat the process until the required pt. E is established.

→ Direct angles :—

The angle measured clockwise from the preceding line to the following line is called a direct angle. These angles are also sometimes known as azimuths from back line, or angles to the right and may vary from 0° to 360°.



Procedure :—

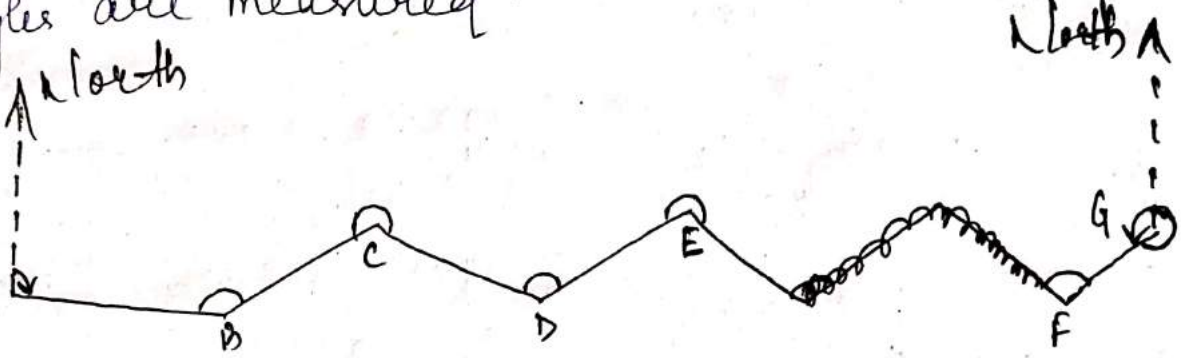
(1) Set up the theodolite over station C, centre & level it carefully.
(2) Keeping the face of the instrument left, set the vernier to read zero degree by turning the upper plate.
(3) Unclamp lower clamp & bisect the station B accurately using the lower tangent screw clamp the lower plate.
(4) Unclamp the upper plate swing the telescope clockwise & bisect the forward station D. Read both the vernieres.
(5) Plunge the telescope, unclamp the lower clamp & bisect the preceding station B without disturbing the vernier readings.
(6) Unclamp the upper plate, swing the telescope clockwise & bisect the station B accurately. Read both the vernier again.
(7) Take the mean of the final vernier readings. Now, the angles is doubled & hence the

average values gives the value of the direct angle BCD.

→ Methods of theodolite traversing :—

(i) Included angle method :—

In this method, bearings of the initial traverse leg & other traverse legs at frequent intervals as well as that of the last traverse leg, are generally observed from astronomical observations. The included angles are those angles which are measured on the left side of the direction of the traverse. In closed traverses included angles may either be exterior angles or interior angles. It is customary to run a closed traverse in an anti-clockwise direction in which only interior angles are measured.



Procedure :—

(i) Set up a theodolite on the face left at station B. centre it over the ground station mark & level it accurately with levelling screws.

(ii) Sight the telescope towards station A, clamp the upper & lower plates & sight the signal at A accurately, using either upper or lower tangent screw.

(iii) Read both the verniers & calculate the mean value.