Mining Surveying - II

(Unit :- 01) * Theodolite Surveying *

1. Theodolite Surveying & types of theodolite.
2. Description of various parts of a vernier theodolite
3. Requirement of mining type theodolite.
4. Measurement of height and distance of accessible and inaccessible points.
5. Traversing & theodolite on surface & underground
6. Checks on closed and open traverse.
7. Balancing of traverse.
8. Temporary & permanent adjustments of theodolite.
9. Sources of errors and their prevention.

- Theodolite Surveying :-

Theodolite Surveying is the branch of Surveying in which theodolite is used to measure the horizontal & vertical angles.

A theodolite is a very precise instrument mainly used for determining the horizontal & vertical distance between two points. it can also be used for prolonging a line, measuring distance indirectly, as a level, like a tachometer. due to its wide range of applications, it is also termed as "universal intrument."

Types of theodolite :-

There are generally two types of theodolite :-

1). **Transit Theodolite :-**
A transit theodolite is the one in which the telescope mounted in the instrument can be revolved through a complete revolution about its horizontal axis, in a vertical plane.

2). **Non-Transit theodolite :-**
it is the opposite of transit theodolite. in this type of theodolite, the telescope can not be revolved through a complete revolution about its horizontal axis in vertical plane. it can be rotated to a certain extent to take vertical angles.

Theodolites can also be classified into 2 categories on the basis of the scale used in theodolite as:

1). **Vernier Theodolite :-** it is fitted with a vernier scale. Vernier theodolite are most commonly used in normal surveying operations.

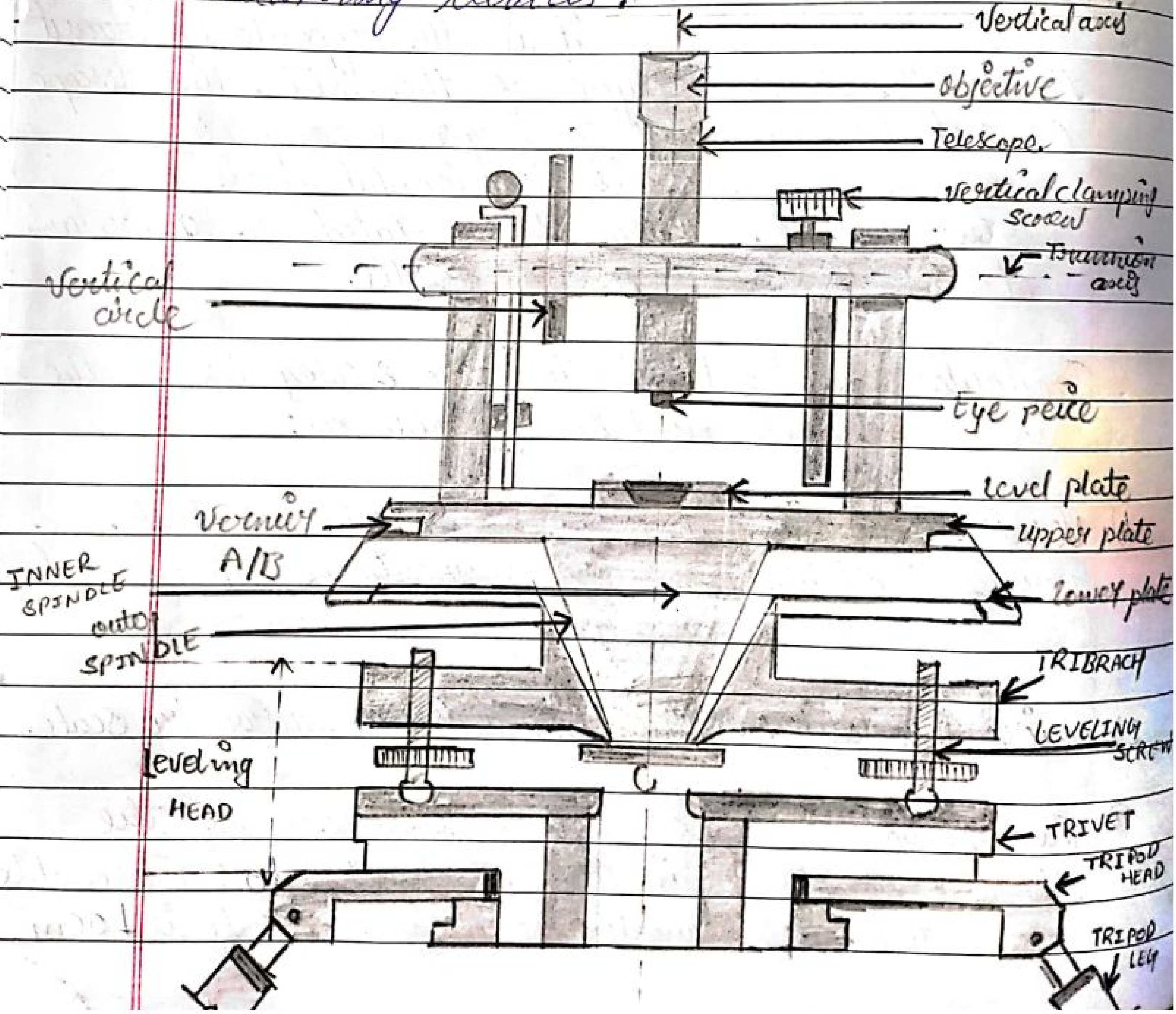
2). **Micro Theodolite :-** Fitted with a micro micrometre scale.

@ The size of theodolites is defined according to the diameter of its main scale. such as a 10 cm theodolite means that the diameter of its main scale is 10cm

(I) In a survey, 8 cm to 12 cm theodolites is generally used.

- **Vernier theodolite :-**

The vernier is an auxiliary graduation, placed alongside the main one with the purpose of determining fractions of the graduation unit. the vernier is typically used with theodolite of medium or low accuracy, as well as for simple angle measuring devices.



To understand the instrument. it is necessary to know about the parts. the instrument is composed of these parts are given as follows:-

1). Telescope:- the telescope of theodolite is mounted on the horizontal spindle it can be rotated about the horizontal axis to sight the objects. the Telescope is internal focusing type i.e. the object lens is fixed in the position and an additional double concave (focusing lens) is moved between the diaphragm and the objective.

2). vertical circle:- The vertical circle is rigidly fixed Screws, lower clamp Screws generally used for rotating the whole instrument, and upper clamp Screw, which is used to fix the vernier A and vernier B to certain degree (mostly 0° and 180°) by rotating the upper part of the instrument.

3). plate Bubble:- Two plate bubbles are mounted at the upper surface of the vernier plate at right angles. one plate bubble is kept parallel to the horizontal axis of the theodolite and is used for horizontal levelling of the instrument another plate bubble is mounted about the vertical axis of the theodolite and is used for vertical levelling of the instrument.

4). Trivet :- Trivet is the lowermost part of the instrument. it consists of a circular plate having a central, threaded hole in its centre, to properly fix the instrument with tripod stand. this plate is also termed as Base plate. the foot screws are attached over this plate with a ball and socket arrangement.

5). Foot Screw :- These are also termed as levelling screws, and are used to properly level the instrument in the ground. there is three number of foot screws, which are rotated in a certain direction, to level the instrument.

6). Tangent Screws :- The instrument consist of two tangent screws, one of which is placed in the lower plate, and another one is placed in the upper plate.
the lower tangent screw is used for very slight movement of the crosshairs to accurately bisect the ranging rod placed at the point, and the upper tangent screw is used for very slight movement of the scale reading. both screws are ~~for~~ accurate measurement purpose.

7). Vernier Scales:- Two vernier scales are naming, horizontal scale & vertical scale. the horizontal scale is used for taking horizontal angles and is mounted on the lower plate of the instrument, and the vertical scale is used for taking vertical angles, fixed on the vertical circle.

• Mining Vernier Theodolite:-

This is a Mining "Suspension" theodolite consisting of a vernier reading system for the horizontal and vertical circles. the theodolite is typically used in mining surveying. the interesting design allows the instrument to be hung upside-down in mines and tunnels. the two major components of this mining theodolite include the base section (the socket component), and the upper section (the ball component).

this ball and socket joint allows free and frictionless movement of the thedolite relative to the base, permitting the user to level the instrument approximately with minimum difficulty. the horizontal and vertical circles are completely enclosed, and magnifying glasses are attached at opposite ends of each circle for more comfortable vernier reading.

• Determination of height and distance of an object :-

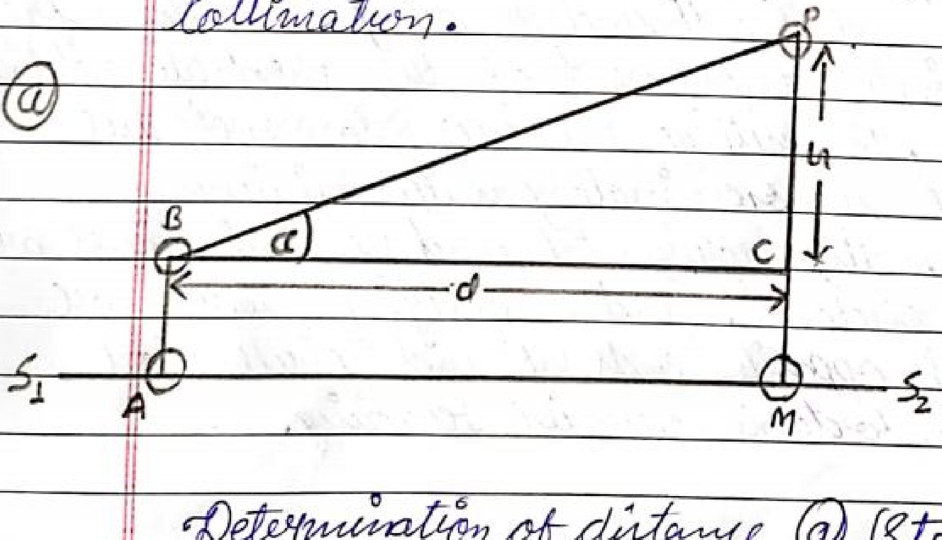
i). Level ground and base Accessible.
ii). Sloping ground and base accessible.
iii). level ground and base Inaccessible (Same Instrument height)
iv). level ground and base inaccessible (Different instrument height).

• To find the height and distance of an object :-

① Level ground and base accessible :-

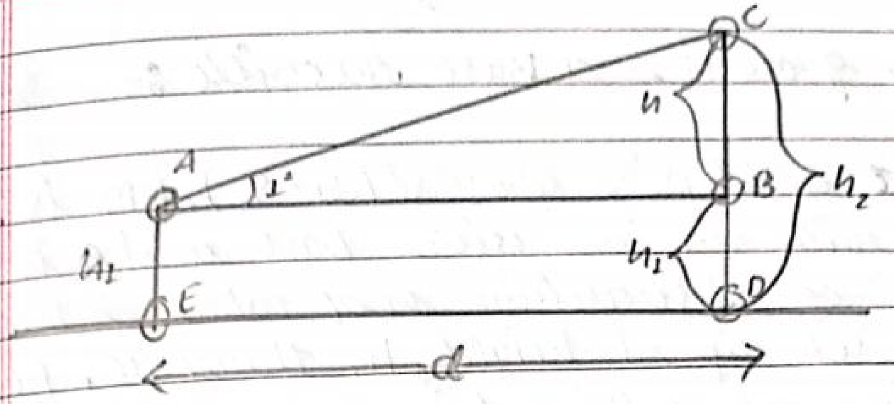
On a flat ground ($S_1 - S_2$), PM is the object with accessible base and A is the station of observation over which a theodolite (AB) has been set at a height (h) above the ground. therefore, BC is the line of collimation.

ⓐ



Determination of distance ⓐ Stadia method
ⓑ One degree method

(b)



Procedure :-

(1). After proper centering and levelling of the theodolite at A, its height (h) is measured with a tape or a graduated staff.

(2) The horizontal distance, AM (d), is then measured either directly with a tape or by computations from observation of the stadia reading on a staff held vertically at the base of the object.

Computation:-

From fig. a, b

AM || BC and AB || PM

Therefore,

CM = AB = h and BC = AM = d.

d = (USR ~ LSR) x stadia constant

from the rt Δ ΔPBC,

$PC(h_2) = BC \tan \alpha$

$= d \tan \alpha.$

2). Sloping ground and Base Accessible :-

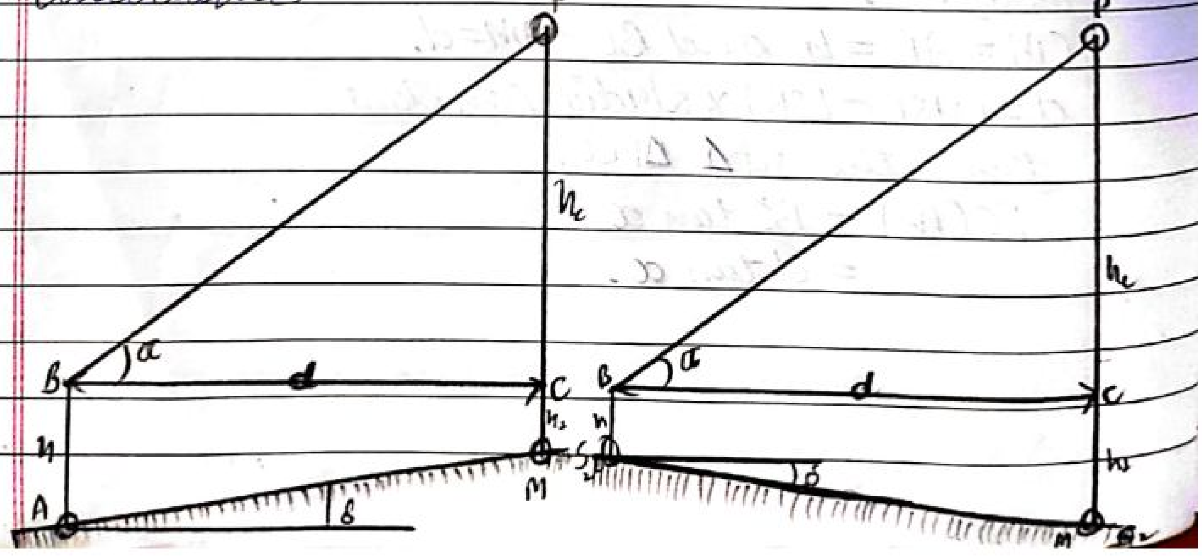
On a sloping ground ($S_1 - S_2$), PM is the object with an accessible base and A is the station of observation over which a theodolite AB is set up at height, h. therefore, BC is the line of collimation.

Procedure :-

i). After proper centering and levelling of the theodolite at A, its height is measured with a tape or a graduated staff.

ii). The horizontal distance, BC (d), is then measured by observations of the stadia reading on a staff held vertically at the base of the object.

iii) The angle of elevation (α) of the top of the object (P) is then found from the observation of the vertical circle readings by a theodolite



Computation:-

Horizontal distance

$d = (USR \sim LSR) \times$ Stadia constant

from fig, ΔPBC is rt∠Δ, therefore,

$$PC = BC \cdot \tan \alpha$$
$$= d \cdot \tan \alpha$$

again, $$\tan \delta = \frac{(h_1 - h)}{d}$$

$$\delta = \tan^{-1}\left[\frac{(h_1 - h)}{d}\right]$$ where, δ = slope

hence,

1. The horizontal distance of the object from A = d.
2. The height of the object above collimation h = PC.
3. The height of the object above its base = $(h_1 + h)$
4. The height of the object above A = $(h_c + h)$.
5. The slope of the ground = $\delta°$

3). Level Ground and base inaccessible; object and stations - collinear and coplaner; instrument heights same at both stations.

On a flat ground $(S_1 - S_1)$, PM is the object with inaccessible base. A and B are the two stations at d distance apart such that A, B and M are collinear on the ground. therefore the instruments a A and B and the object lie on the same vertical plane.

at both the stations, instruments are setup at the same height (h) therefore, DEC represents the common and fixed line of collimation

procedure :-

1. After proper centering and levelling of the theodolite a A, its height (h) is measured with a tape or a graduated staff.

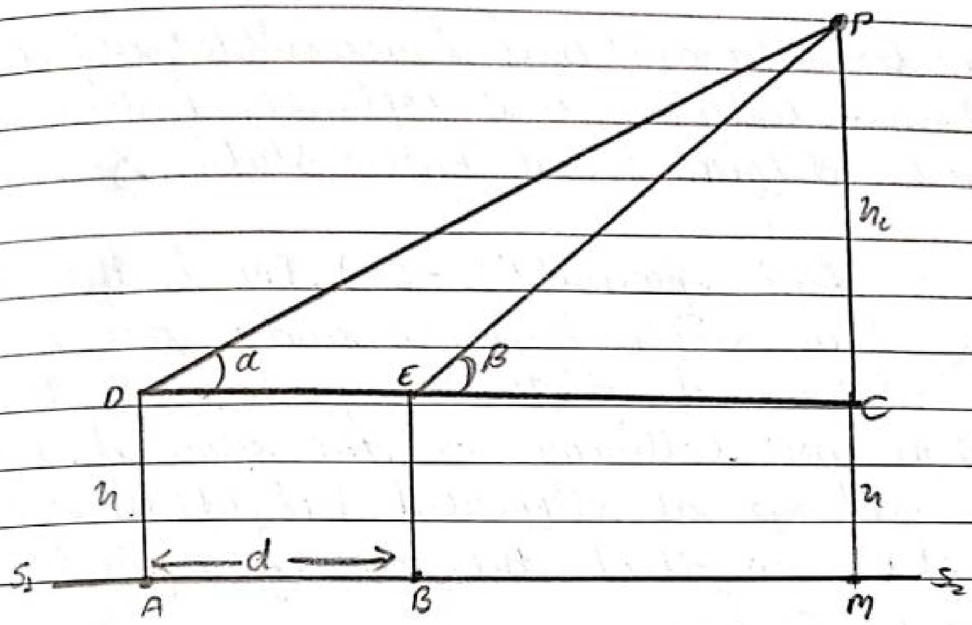
2. The angle of elevation (α) of the top of the object (P) at A is measured from the observations of the vertical circle reading of a theodolite.

3. With the horizontal plate fixed, another station of observation (B) is selected on the ground by looking through the telescope such that d or AB ≥ 5m.

4. The distance AB (d), is measured with a tape.

5. The instrument is then shifted to B, setup at height (h), carefully centred and levelled

6. The angle of elevation (β) of the top of the object (P) at B is then found from the vertical circle reading by a theodolite.



Computation :-

From fig.

AM ∥ DC and AB ∥ BE ∥ MC
therefore, AD = BE = MC = h and AB = DE = d.
from the rt △ △PDC, DC = PC . cot α ....①
from the rt △ △PEC, EC = PC . cot β ....②

as D, E and C are collinear and coplaner

$$DC - EC = DE$$

$$\text{or, } PC.\cot\alpha - PC.\cot\beta = d$$

$$\therefore PC(h_c) = \frac{d}{\cot\alpha - \cot\beta}$$

once PC is found, EC can be determined from the equation (ii)

4). Level Ground and base inaccessible; object and stations - collinear and coplaner, instrument height different at both station.

On a flat ground ($S_1 - S_2$), PM is the object with inaccessible base. A and B are in the two stations d distance apart such that A, B and M are collinear on the ground. Instruments are set up at different height (h_1 at A and h_2 at B) so that the survey operation become easier.

Procedure :-

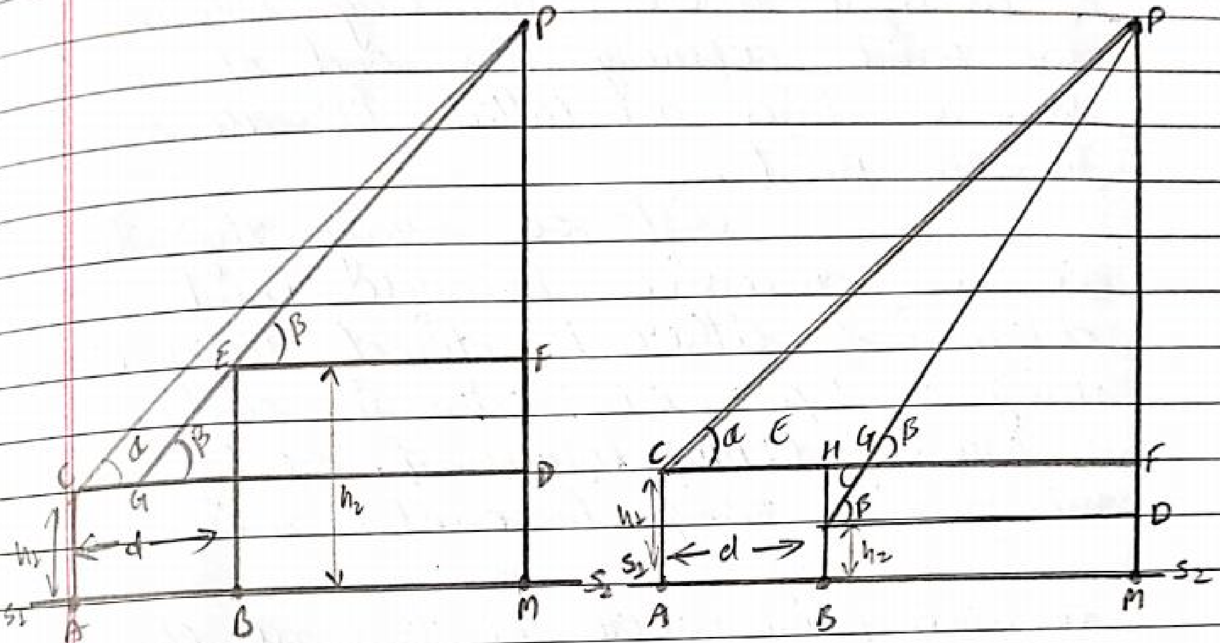
① after proper centering and levelling of the instrument at A, its height (h_1) is measured with a tape or a graduated staff.

② The angle of elevation (α) of the top of the object (P) at A is measured from the observations of the vertical circle readings.

③ With the horizontal plate fixed, station B is selective on the ground by looking through the telescope such that AB (d) $\geq$ 5m.

④ The distance, d is measured with a tape; the instrument is then set up at B, at height, h_2, carefully centred and properly levelled.

(5) The angle of elevation (β) of the top of the object (P) at B is then measured from the vertical circle readings by a theodolite.



Computation:-

From fig.

$AC \parallel BE \parallel PM$ and $AM \parallel CD \parallel EF$.

therefore, $AC = BH = MD = h_1$,

$BE = MF = h_2$, $AB = CH = d$, $\angle EGH = \angle PEF = \alpha$ and $EH = EB - HB = h_2 - h_1$

from the rt $\angle \Delta PCD$, $CD = PD.\cot\alpha$ — (1)

from the rt $\angle \Delta PGD$, $GD = PD.\cot\beta$ — (2)

and from the rt $\angle \Delta EGH$,

$GH = EH.\cot\beta \Rightarrow (h_2 - h_1).\cot\beta$ — (3)

As G lies on the collimation line CD,

$$CD - GD = CG$$

or, $PD.\cot\alpha - PD.\cot\beta = CH \pm GH$

[$-$ if $h_2 > h_1$ and $+$ if $h_1 > h_2$]

or, $PD = \dfrac{CH \mp GH}{\cot\alpha - \cot\beta} = \dfrac{d \mp (h_2 - h_1)\cot\beta}{\cot\alpha - \cot\beta}$

- **Traversing :-**

A traverse consists of a series of straight lines connecting successive points. The points defining the ends of the traverse lines are called traverse stations or traverse points.

Distance along the line between successive traverse points is determined either by direct measurement using a tape or electronic distance measuring (EDM) equipment, or by indirect measurement using tachometric methods.

At each point where the traverse changes direction, an angular measurement is taken using a theodolite.

- **Purpose of traverse :-**

It is a convenient, rapid method for establishing horizontal control particularly when the lines of sights are short due to heavily built up areas where triangulation and trilateration are not applicable. The purpose includes:-

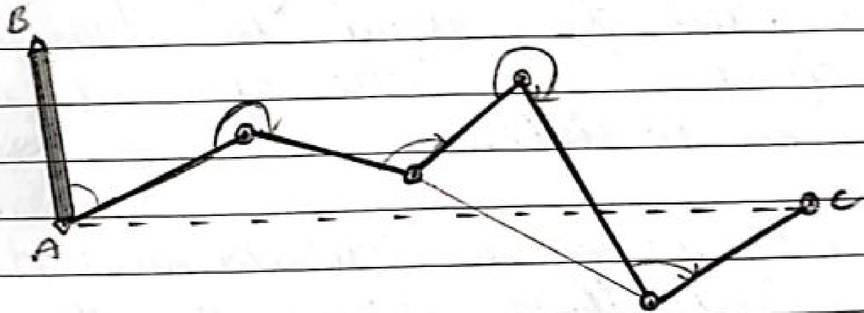
1. Property surveying to locate or establish boundaries.
2. Supplementary horizontal control for topographic mapping surveys.

③ Location and construction layout surveys for high-ways, railways and other private & public works.

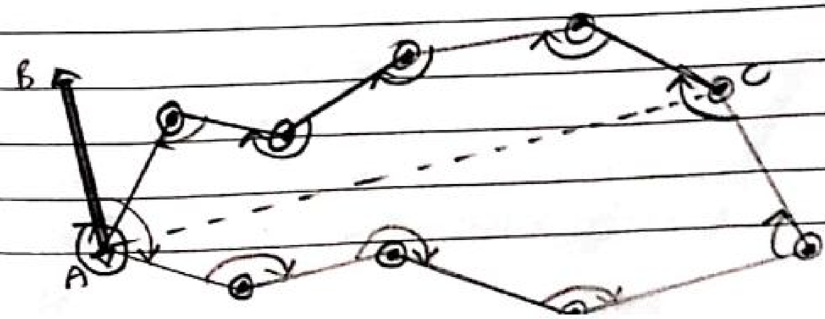
④ Ground control surveys for photogrammetric mapping.

• Types of traverse :-

Open traverse :- it starts at a point of known position and terminates at a point of unknown position.



Closed traverse :- it originates at a point of known position and close on another point of known horizontal position.



- **Balancing of traverse :-**

- A traverse is balanced by applying corrections to latitudes and departures. This is called balancing a traverse.

- In case of a closed traverse, the algebraic sum of latitudes and departures must be equal to zero.

- In other words, the sum of the northings should be exactly equal to the sum of the southing and the sum of easting should be exactly equal to the westings.

- It is clear that the closing error should be so distributed throughout the traverse that its effect is as little apparent on the plan as possible.

- The total error in latitudes and departures are determined these errors are then distributed among the traverse stations proportionally.

- This can be accomplished mathematically, by applying some rules.

- The following methods are generally used for balancing a traverse:-

- **Bowditch's method :-**

The bowditch's rule, also termed as the compass rule, is mostly used to balance traverse when linear and angular measurements are equally precise. by this rule, the total error in latitude or departure is distributed in proportion to the lengths of the traverse legs. this is the most common method of traverse adjustment.

(1) Correction to latitude of any line:
= length of that line / perimeter of the traverse × total error in latitude.

(2) correction to Departure of any of any line:
= length of that line / perimeter of the traverse × total error in departure.

- **Transit Rule :-**

The transit rule is used to balance a traverse in which the angular measurements are more precise than the linear measurements. (Theodolite traversing).

(1) Correction to latitude of any line:
= length of that line / arithmetic sum of all latitudes × total error in latitude.

⊙ Correction to departure of any line:
= departure of that line/arithmetic sum of all departure × total error in departure.

◉ Temporary adjustment:-

Temporary adjustment are a set of operations necessary in order to make a theodolite ready for taking observations at a station. these include its setting up, centering, levelling up and elimination of parallax, and are achieved in four steps:-

- **Setting up:-**
  fixing the theodolite onto a tripod along with approximate levelling and centering over the station mark.

- **Centering:-**
  bringing the vertical axis of theodolite immediately over station mark using a centering plate also known as a tribrach.

- **Levelling:-**
  levelling of the base of the instrument to make the vertical axis vertical usually with an in-built bubble-level.

- **Focusing:-**
Removing parallax error by proper focusing of objective and eye-piece. the eye-piece only requires adjustment once at a station. the objective will be refocusing for each subsequent sightings from this station because of the different distance to the target.

Permanent adjustments:-

- **Adjustment of horizontal plate levels:-**
The axis of the plate levels must be perpendicular to the vertical axis.

- **Collimation adjustment:-**
The line of the collimation should coincide with the axis of the telescope and the axis of the objective slide and should be at right angles to the horizontal axis.

- **Horizontal axis adjustment:-**
the horizontal axis must be perpendicular to the vertical axis.

- **Adjustment of telescope level or the altitude level plate levels:-**
the axis of the telescope levels or the altitude level must be parallel to the line of collimation.

- Vertical circle index adjustment :- The vertical circle vernier must read zero when the line of collimation is horizontal.

Sources of errors in theodolite :-

The common sources of errors in a theodolite traversing are instrumental, observational and natural.

- Instrumental errors :-

- Due to imperfect adjustment of the plate levels.
- collimation error :- the collimation line not being perpendicular to the horizontal axis.
- Horizontal axis error :- the horizontal axis not being perpendicular to the vertical axis.
- Non parallelism of the axis of the telescope & the collimation line.
- Eccentricity of centres (Inner & outer axis).

- **Observation Error :-**

- Inaccurate centering.
- Imperfect levelling.
- wrong manipulation of the tangent screw.
- wrong setting of the vernier parallax.
- Mistake in reading and recording the values in proper columns of the field book.

- **Field or on Site errors :- ground & wetther conditions.**

- Setting the instrument up on soft ground must be avoided.
- The instrument must be shade when working in hot sunshine.
- if refraction is a problem reading must not be taken
- Instrument must be left to adjust to atmospheric conditions
- observations and setting out angles must not be taken in windly conditions

(Unit :- 02) * Tacheometry *

1. Principle of Stadia Methods.
2. Determination of constants.
3. Theory of anallactic lens.
4. Distance and elevation formulae.
5. Subtense and Tangential Methods.
6. Auto - Reduction Tacheometer.

Tacheometry Survey :-

Tacheometry is a system of rapid surveying, by which the horizontal and vertical positions of points on the earth's surface relative to one another are determined without using a chain or tape, or a separate levelling instrument.

it's used for preparation of topographic map where both horizontal & vertical distances are required to be measured.

- Survey work in difficult terrain where direct methods of measurements are inconvenient.
- Reconnaissance survey for highways & railways etc.
- Establishment of secondary control points.

• Principle of stadia method:-

The stadia technique of tacheometry is a popular method adopted for calculating horizontal distance and vertical elevation.

the horizontal distance between the staff station and the instrument station and the elevation of the staff station along the instruments line of sight is computed using this approach with only one observation from the instrument station.

This method of surveying can be further classified into the following two types:-

a). Fixed hair method.

The device used for taking observations in this form of surveying is a telescope with two extra cross-hairs, one above and one below the center hair.

thus, stadia hairs are ones that are equally spaced from the center hair.

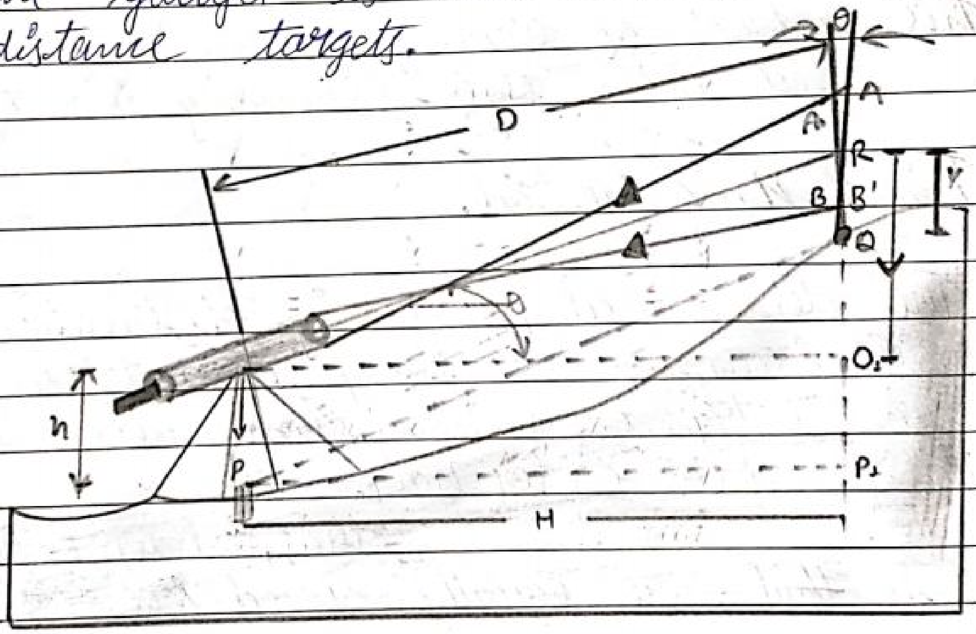
when observed via the instruments telescope, the stadia hairs are seen to intercept a specific length of the staff.

this is the most often used tacheometric surveying approach.

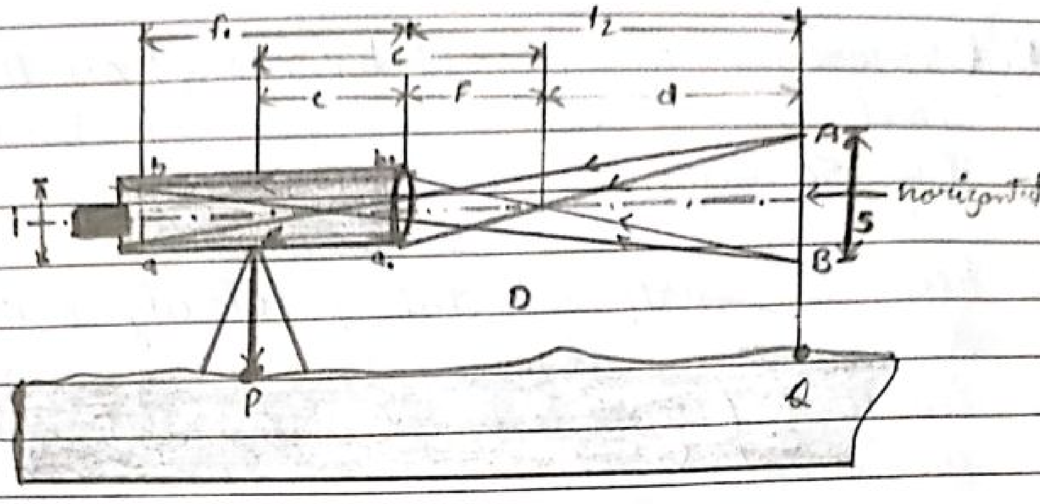
B). Movable hair Method.

In contrast to the stadia hair technique, the telescope connected to the instrument in the movable hair method comprises moveable cross-hairs.
the center hair can also be used to fixe the moveable cross-hairs.

the stadia interval is customizable in this manner for different staff positions. the horizontal distance is then calculated. the gadget is used with two fixed-distance targets.

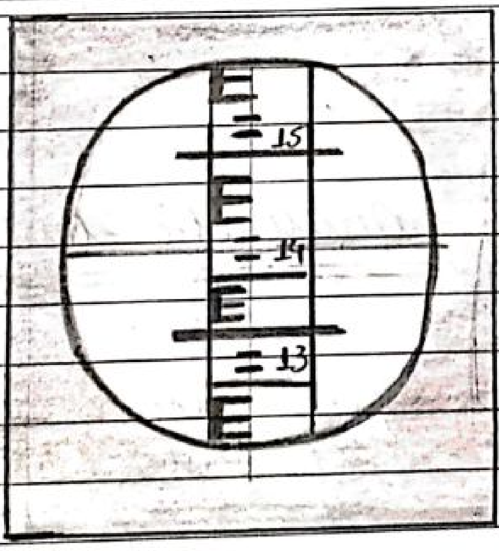


Movable hair Method



* Fixed hair Method *

- **Determination Tacheometric constants on field:-**



In most cases, we do not really know the value of F (focal length of the objective) so we have to determine the constant K & C on the field with a different approach as below :-

1). Measure a line (about 100m long) on the fairly level ground and drives pegs at some interval, say 50 meters.

2). Keep the staff on the previously determined station and observe the corresponding staff intercepts (upper & lower stadia reading) with horizontal sight.

3). Knowing the values of D and s for different points, a number of simultaneous equations can be formed by substituting the value of D and s in equation $D = K.s + C$. the simultaneous solution of successive pairs will give the values of K and C, and the average of these can be found.

- Theory of Anallactic lens:-

it is a special convex lens, fitted in between the object glass & eyepiece, at a fixed distance from the object glass, inside the telescope of a tacheometer.

The function of the anallactic lens is to reduce the stadia constant to zero. thus, when tacheometer is fitted with anallactic lens, the distance measured between instrument station and staff position (for line of sight perpendicular to the staff intercept) becomes directly proportional to the staff intercept. anallactic lens is provided in external focusing type telescopes only.

- **Advantages :-**

① For calculation of horizontal & vertical distances constant $(f+c)=0$, if tacheometer is provided with anallatic lens.

② Calculation becomes simple.

- **Disadvantages :-**

① The anallatic lens absorbs some of the incident light which consequently result in reduction of the brightness of the image.

② it also adds to the initial cost of the instrument because of one extra lens.

⊙ The Stadia method - (Fixed hair method).

(a). Distance and elevation formula for horizontal Sights :-

- Horizontal distances of the Staff position:-

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

where, D = horizontal distance from the axis of theodolite to staff.
f = Focal length of the object lens.
s = staff Intercept., i = stadia hair interval.
d = the distance between the optical centre of the object glass and the axis of the theodolite

- Elevation of the staff station:

Elevation of staff station = elevation of the instrument axis - central hair reading.

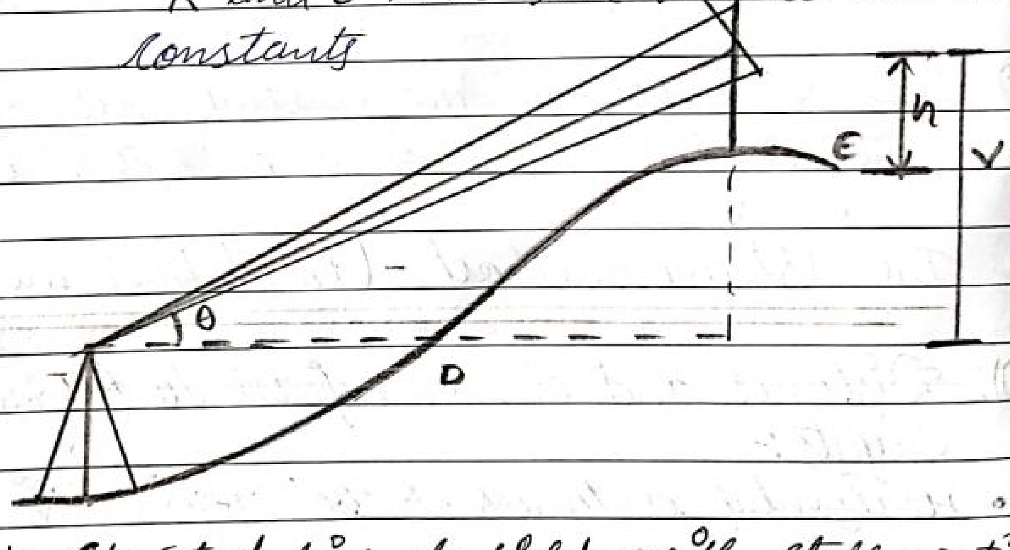
(ii). Distance and elevation formulae for inclined sights with staff vertical:

1). Horizontal distance formula:

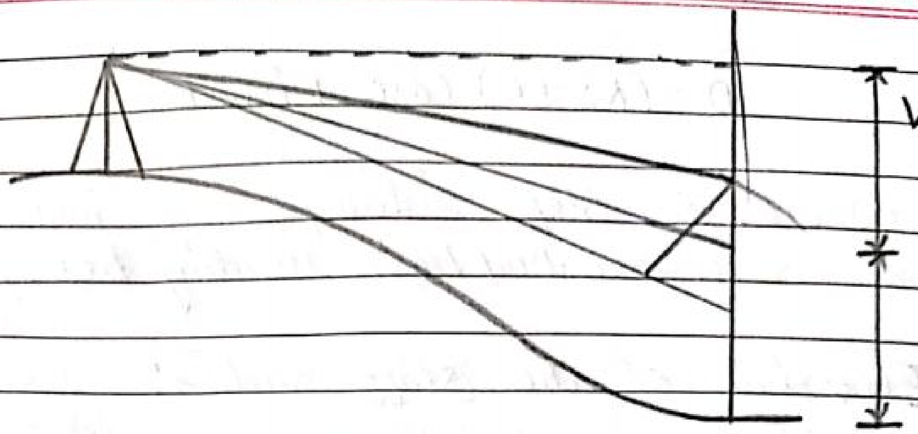
$$D = KS\cos^2\theta + C\cos\theta$$

where, θ = Angle of elevation or depression of the line of sight from the horizontal.

K and C are the tacheometric constants



* Elevated line of sight with staff vertical *



2). Elevation formula

- For angle of elevation

  Elevation of point E = H.I + V − h

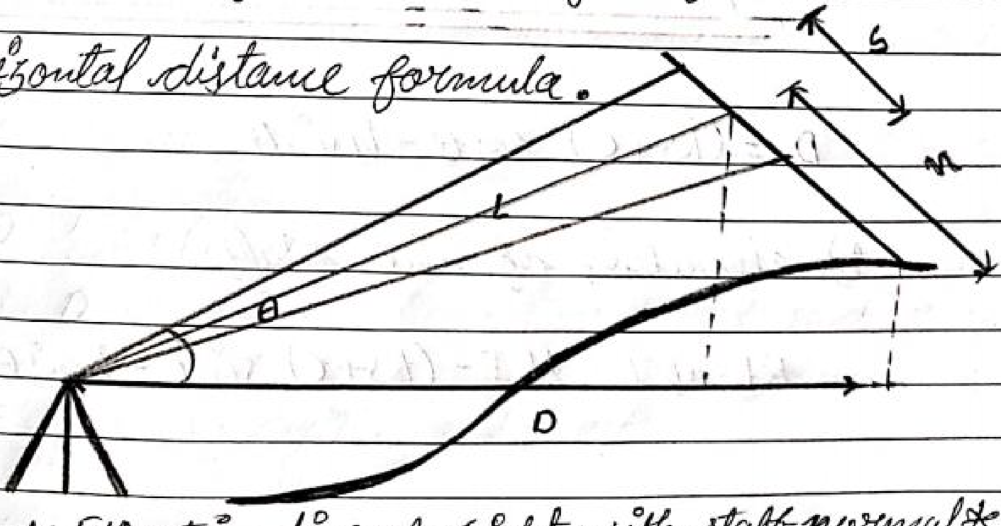
- For angle of depression

  R.L of point E = H.I − V − h

Q. Distance and elevation formula for inclined sight with staff normal:

Case(1). Line of sight at an angle of elevation.

- Horizontal distance formula.



* Elevation line of sight with staff normal *

$$D = (KS + C)\cos\theta + h\sin\theta$$

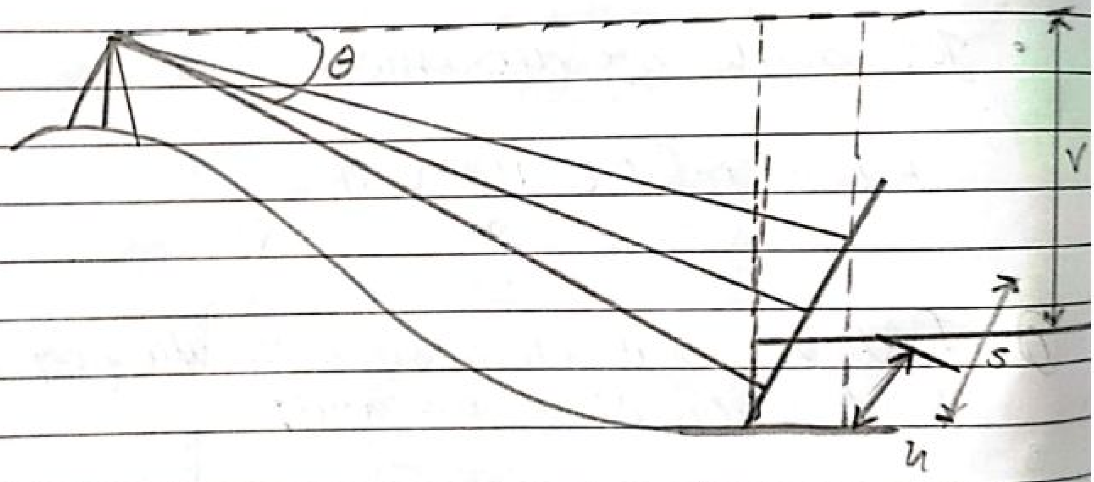
where, S = Staff intercept
h = Central hair reading

- Elevation of the staff station:

$$RL \text{ of } E = H.I + V - h\cos$$

Case (2). Line of sight at an angle of depression:

- Horizontal distance formula:



* Depressed line of sight with staff normal *

$$D = (KS + C)\cos\theta - h\sin\theta$$

b). elevation of the staff.

$$RL \text{ of } E = H.I - (KS + C)\sin\theta - h\cos\theta$$

Tangential Method :-

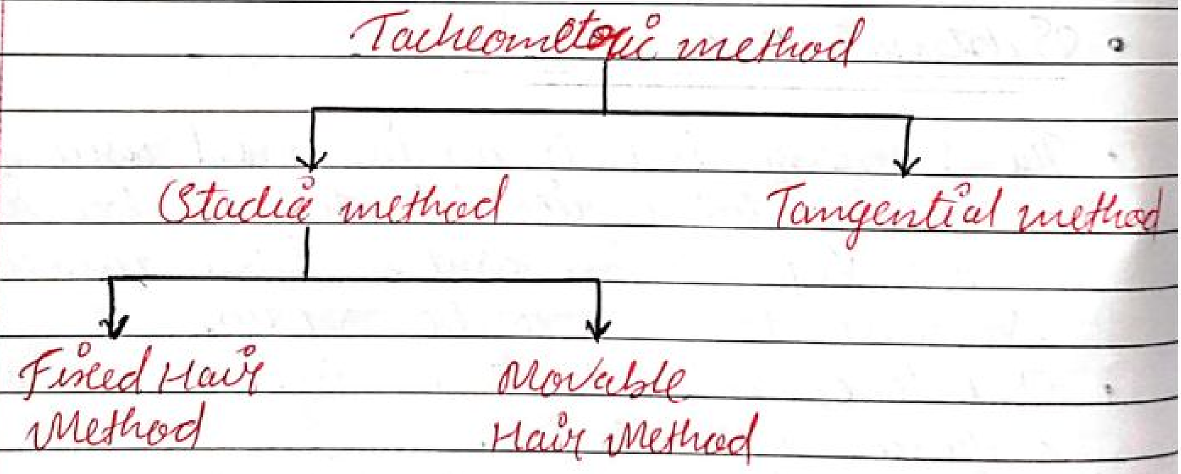
- No stadia hairs.
- levelling staff with vanes or targets of known distance.
- Horizontal and vertical distances are measured by measuring the angles of elevation or depression.
- Some cases are discussed in this method distance between hairs is fixed.
- The Intercept on levelling staff is variable and stadia hair interval is fixed.
- The staff intercept value varies with its distance from the instrument, this is most commonly used in tacheometry.

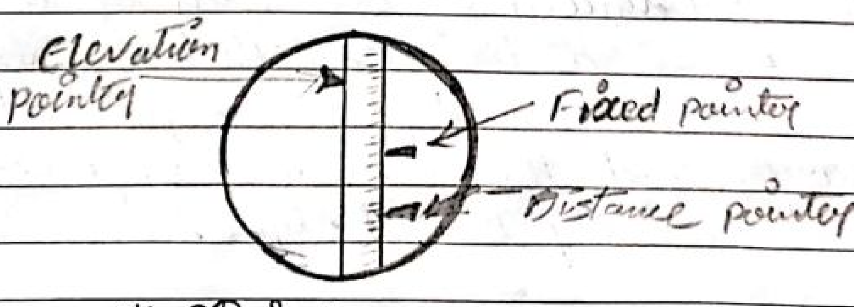
Subtense Bar Method :-

- The Subtense bar is an instrument used for measuring the horizontal distance between the instrument station and a station where the subtense bar is to be set up.
- Subtense method is an indirect method of distance determination.
- This method essentially consists of measuring the angle subtended by two ends of a horizontal rod of fixed length, called a subtense bar.
- In this method a staff or target rod is not necessary, and the theodolite required is also of the ordinary transit type.

- The Subtense bar is a metal bar of length varying from 3 to 4m.
- There are two discs of diameter about 20cm at both ends of the bar.
- The discs are painted black or red in front and white on the other side.
- The alidade is made perpendicular to the axis of the bar.
- A spirit level is included for levelling. The bar is mounted on a tripod stand which contains a ball and socket arrangement for levelling.

- **Auto Reduction Tacheometer :-**





* Diaphragm *

This type of tacheometer is provided with a special auto-Reduction device and gives both the horizontal and vertical distance by a single reading of a vertically held staff.

(Unit :- 03), * Setting out *

① Setting out simple curves on surface & in underground.
② Elementary knowledge of compound and transition curves.
③ Joint boundary survey.
④ Equalization of boundaries.
⑤ Maintenance of direction and gradient of roadways i.e. marking and checking of center line and grade line, transfer of point from roof to floor and floor to roof.

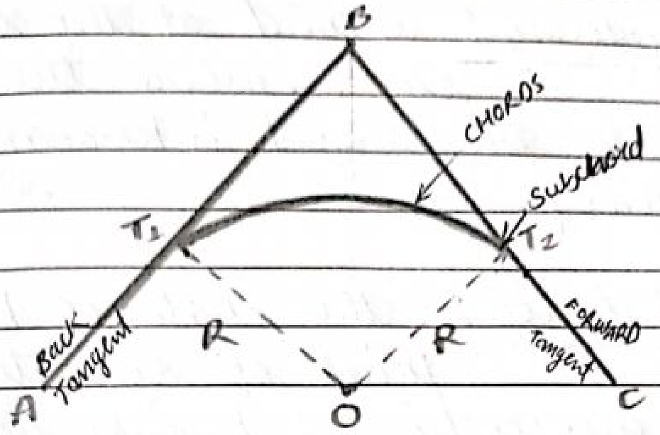
• Setting out :-

The setting out is done by taking measurements from the base line. it consist of establishment of reference marks of known elevation relative to some specified datum. all levels of the site are normally reduced to a nearby bench mark, usually known as Master Bench mark (MBM).

Setting out a curve means locating various points at equal and convenient distances along the length of a curve.

Simple curve :-

A simple curve consists of a single arc of a circle connecting two straights it has radius of the same magnitude throughout



* Simple Curve *

- **Back Tangent :-** The line of a tangent before the beginning of the curve is Known as a back tangent.
- **Forward Tangent :-** The tangent line after the finishing of the curve is Known as the forward tangent.
- **Point of intersection :-** A point where the back tangent and the forward tangent intersects, is Known as the point of intersection.
- **Intersection angle :-** The angle between the back & the forward tangent is Known tangent deflects is Known as angle of deflection.
- **point of curvature :-** A point at the beginning of the curve, where the alignment changes the tangent into a curve, is Known as point of curvature.

- Point of Tangency:- A point at the end of the curve, where the curve changes into the tangent, is known as point of tangency.

- Tangent distance:- the distance between the point of curvature and point of intersection is known as the tangent distance.

- Length of curve:- the total length of curve from the point of curvature to the point of intersection is known as the length of curve.

- Long chord:- A chord joining the point of curvature and the point of tangency, is known as the long chord.

- Normal Chord:- A chord between two successive pegs on the curve, is known as a normal chord.

- Sub-Chord:- A chord shorter than the normal chord is known as a sub-chord.

- Mid-ordinate:- The distance between the midpoint of curve and the midpoint of the long chord, is known as mid-ordinate.

- External Distance:- The distance between the point of intersection and the midpoint of the curve, is the external distance.

The various method used for setting curve may be broadly classified as follows:-

1). Linear Method.
2). Angular Method.

- **Linear Methods:-**

The following are some of the linear methods used for setting out simple curves:-

1). Offsets from long chord.
2). Successive bisection of chord.
3). Offset from the tangents perpendicular or radial.
4). Offset from the chords produced.

- **Angular Methods:-**

The following are the angular methods that can be used for setting curves:-

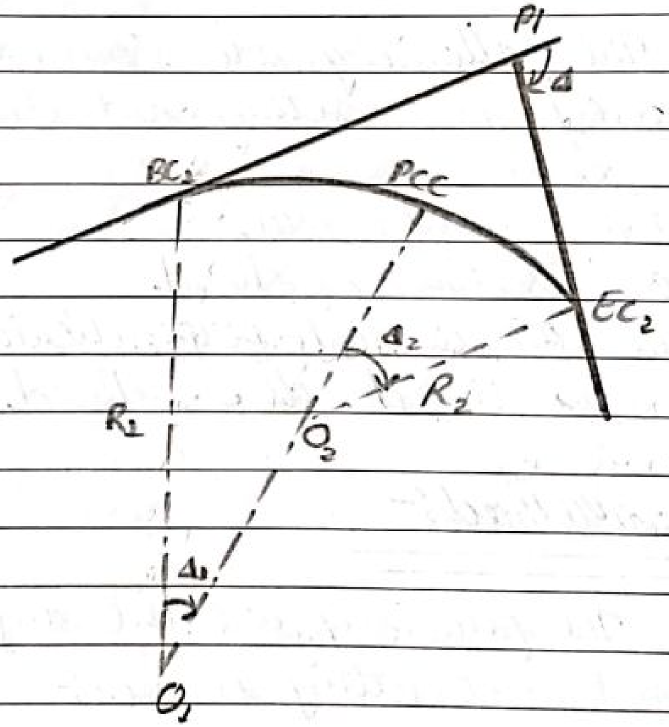
1). Rankine method of tangential (deflection) angles.
2). Two - theodolite method.
3). Tacheometric method.

Hence, by moving average of arc radius methods is not. Linear method of setting out simple circular curves.

- ## Compound curve:-

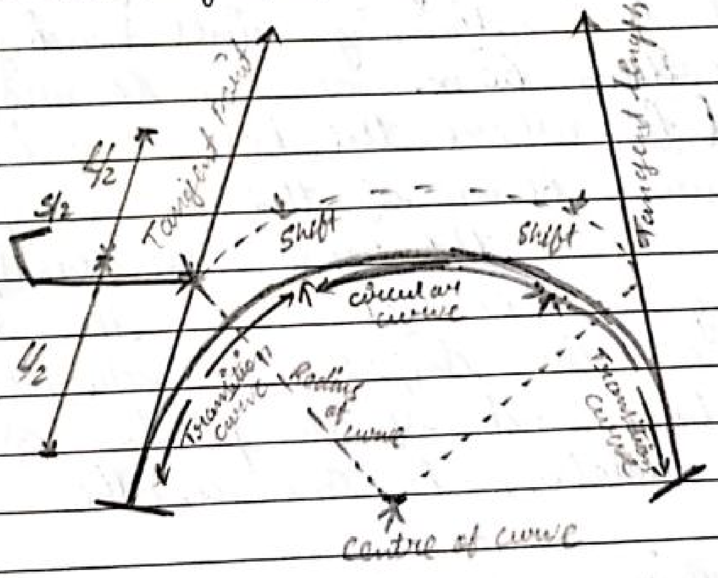
A compound curve comprises two or more circular arcs of different radii with their centers of curvature on the same side of the common tangent. it is where the cutting and filling of soil is to be avoided.

Compound curves are necessary whenever the space restriction rule out a signal circular curve and when there are property boundaries.



- ## Transition Curve :-

It is a curve of varying radius. the value of the radius of this type of curve varies from infinity to a certain fixed value. it provides a gradual change from the straight line to the circular curve and again from the circular curve to a straight line. it is usually provided on both ends of a circular curve. the transition curves are provided on roads and railways to lessen the discomfort at the sudden change in curvature at the junction of a straight line and a curve.



A transition curve has the following advantages:-

1). Transition Curve reduces the probability of overturning vehicles at the junction of the straight and the curve.

2). It gives comfort to the passengers.

3). It allows higher speeds for vehicles at the curves.

4). Transition curve reduces the wear and tear of the rail section, occurring due to unusu friction at point of curve.

• **Joint boundary Survey :-**

In compliance with the provision of Reg. 58(3), be signed by the Surveyor and the manager of the adjoining mines having workings within 60 m. of the Common boundary (for where the boundary is in dispute, within 60 m of the boundary claimed by the owner of the mine concerned) signifying the correctness of the common boundary, or the disputed boundaries, as the case may be, and of the position of the working in relation to one another

• Showing working and features of any adjacent mines with in 60m measured on any plane of the boundary claimed by the owners of the mine.

(Unit :- 04), * Error & problems *

1). Computation of areas and volumes.
2). Earthwork calculation.
3). Problems based on coordinates, fault, Dip-strike and boreholes.
4). Classification and Ralative importance of errors, Their prevention and elimination, theory of errors, adjustment of errors, Sources of error.

• Computation of areas and volumes :-

The main objective of the surveying is to compute the area and volumes. generally, the land will be of irregular shaped polygons. there are formulae readily available for regular polygons like, triangle, rectangle, square and other polygons.

But for determining the areas of irregular polygons, different methods are used.

Earthwork computation is involved in the excavation of channels, digging of trenches for laying underground pipelines, formation of bunds, earthen embankments, digging farm ponds, land levelling and smoothening.

In most of the computation the cross sectional areas at different intervals along the length of the channels and embankments are first calculated and the volume of the prismoids are obtained between successive cross section either by trapezoidal or prismoidal formula.

Calculation of area is carried out by anyone of the following methods:-

(a) Mid-ordinate method.
(b) Average ordinate method.
(c) Trapezoidal rule.
(d) Simpson's rule.

Computation of area:-

The term area in the context of surveying refers to the area of a tract of land projected upon the horizontal plane, and not to the actual area of the land surface.

Computation of area from field notes is done in two steps:-

Step.1) In cross staff survey the area of the field can be directly calculated from field notes, during survey work the whole area is divided into some geometrical figures such as triangles, rectangles, square & trapezium & the area is calculated.

Step.2) - Consider the fig. The area along the boundary is calculated as fallow:-

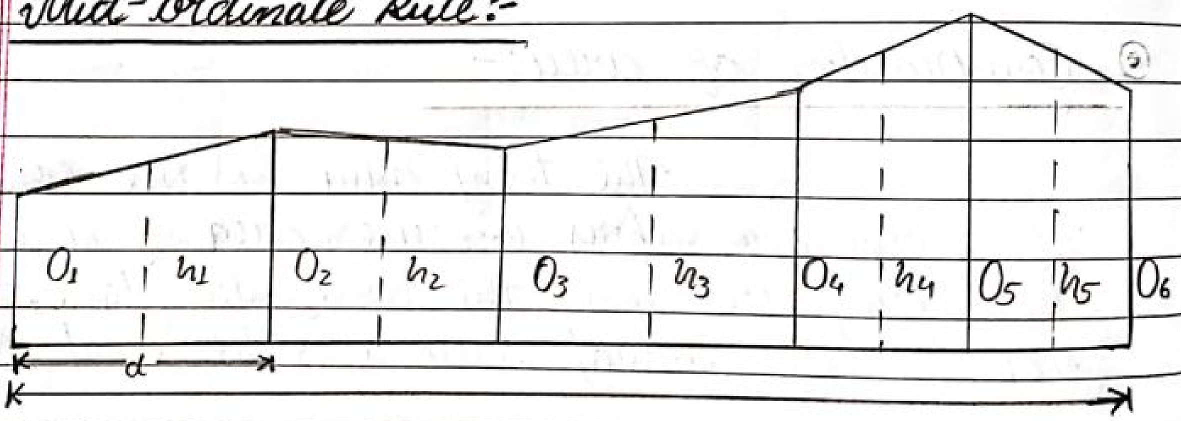
O_1, O_2 = ordinates
X_1, x_2 = Chainages

Area of the shaded portion $= (O_1 + O_2)/2 \times (X_1 - x_2)$

Similarly areas between all points of ordinates are calculated and added to the total boundary area.

- The boundary are is calculated according to the one of the fallowing rules:-

1). **Mid-ordinate Rule:-**



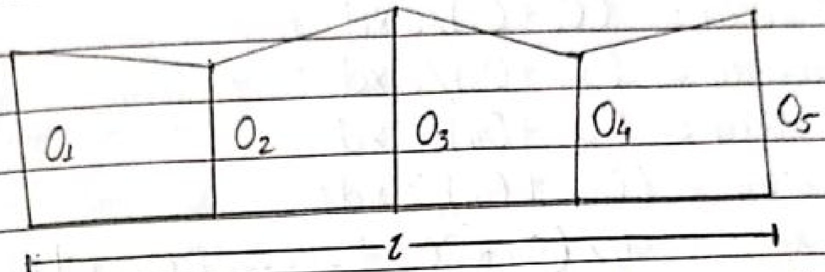
Let $O_1, O_2, O_3 ---- O_n$ = Ordinate at equal intervals

L = Length of base line.
d = common distance between ordinates.
$h_1, h_2, ---- h_n$ = mid-ordinates

Area of plot $= h_1 \times d + h_2 \times d + ----- h_n \times d$
$= d(h_1 + h_2 + ------- h_n)$

i.e. Area = common distance sum of mid-ordinates.

2). Average ordinate Rule :-



let $O_1, O_2, O_3 ---- O_n$ = ordinates or offsets at regular intervals

L = length of base line.

n = number of divisions.

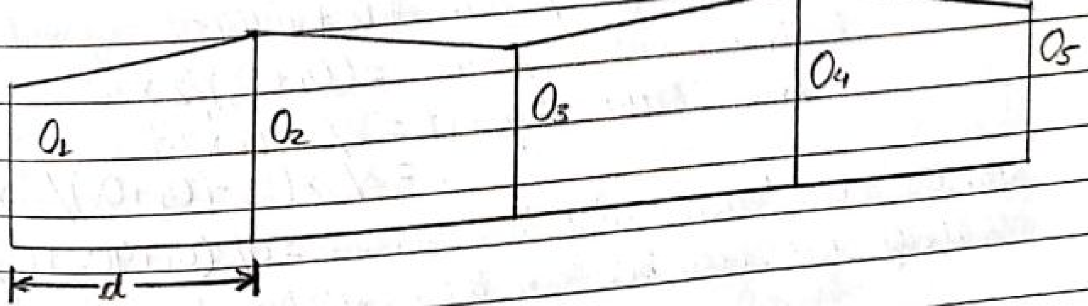
n+1 = number of ordinates.

$\text{Area} = (O_1 + O_2 + O_3 ---- O_n) / O_{n+1} \times l$

i.e. area = Sum of ordinates/no. of ordinates x length of base line.

3). Trapezoidal Rule :-

while applying the trapezoidal rule, the boundaries between the end of ordinates are assumed to be straight. thus the area enclosed between the base line and irregular boundary lines are considered as trapezoids.

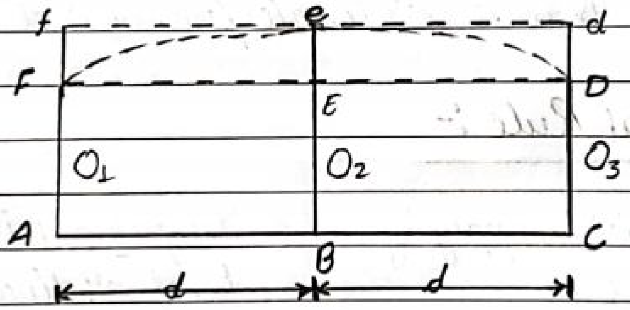


let $O_1, O_2, O_3 ---- O_n$ = ordinates at equal intervals
d = common distance

First area = $(O_1 + O_2)/2 \times d$
Second area = $(O_2 + O_3)/2 \times d$
Third area = $(O_3 + O_4)/2 \times d$
Last area = $(O_{n-1} + O_n)/2 \times d$
Total area = $d/2 (O_1 + 2O_2 + ----- 2O_{n-1} + O_n)$

4). Simpson's Rule :-

In this Rule the boundaries between the end of ordinates are assumed to form arc of a parabola. hence Simpson's rule is sometimes called the parabolic rule.



let O_1, O_2, O_3 = three consecutive ordinates
d = common distance between the ordinates.

Area AFeDC = area of trapezium AFDC + area of segment FeDEF
here, area of trapezium $= (O_1 + O_3)/2 \times 2d$
Area of the segment $= 2/3 \times Ee \times 2d$
$= 2/3 \times (O_2 - (O_1 + O_3)/2) \times 2d$

So, the area between first two division $= d/3(O_1 + 4O_2 + O_3)$
Similarly the area between the next two division $= d/3(O_3 + 4O_4 + O_5)$

So, total area $= d/3(O_1+4O_2+2O_3+4O_4+----+O_n)$
$= d/3(O_1+O_n+4(O_2+O_4+---)+2(O_3+O_5+---))$

- **Computation of Volume :**

For computation of the volume of the earthwork, the sectional areas of the cross-section which are taken transverse to the longitudinal section during profile levelling are first calculated. again the cross-sections may be of different types namely

1). level.
2). two-level.
3). three-level.
4). Side-hill-two-level.
5). multi-level.

- **Earthwork calculated :-**

After calculation of cross-sectional area the vol. of earthwork is calculated.

by the i). trapezoidal Rule.
ii). Prismoidal Rule.

(a). Trapezoidal Rule (average - end-area rule)
volume (cutting or filling), $V = D/2((A_1+A_n+2(A_2+A_3+----+A_{n-1}))$
i.e. volume = Common distance/2((area of first section + area of last section + 2 (Sum of area of other section))

(B). Prismoidal Rule (formula):-

Volume (cutting or filling), $V = D/3((A_1 + A_n + 4(A_2 + A_4 + A_{n-1}) + 2(A_3 + A_5 + --- + A_{n-2}))$

Volume = Common distance/2((area of first section + area of last + 4(sum of areas of even section) + 2(sum of areas of other sections))

- **Errors of measurement:-**

A discrepancy is defined as the difference between two or more measured values of same quantity.

However, measurement are never exact and there will always be a degree of variance regardless of survey instrument or method used.

The variances are known as errors & will need to be reduced or eliminated to maintain specific survey standards. even when carefully measured, observations may still contain errors. errors, by definition are difference between a measured value and its true value.

The true value of a measurement is determined by taking the mean value of a series of repeated measurements.

Surveyors must possess skill in instrument operation & knowledge of surveying methods to minimize the amount of error in each measurement.

• Sources of errors:-

1). **Natural:-** These are caused due to variations in nature i.e. variations in wind, temperature, humidity, refraction, gravity and magnetic field of the earth.

2). **Instrumental:-** These result from imperfection in the construction or adjustment of surveying instruments, and movement of their individual parts.

3). **Personal/Surveyor:-** These arise from limitation of the human senses of sight, touch and hearing.

• Classification of Errors:-

ⓐ. **Blunder/Mistake:-** A blunder is a significant, unpredictable mistake caused by human error that often leads to large discrepancies.
Blunders are typically the result of carelessness, miscommunication, fatigue, or poor judgment.

(B). Systematic errors:- the error is reproducible and can be discovered & corrected.

1). Instrument errors:- Failure to calibrate degradation of parts in the instrument, power fluctuations, variation in temperature etc.
Can be corrected by calibration or proper instrumentation maintenance.

2). Method errors:- Errors due to no ideal physical or chemical behavior - completeness and speed of reaction, interfering side reactions, sampling problems.
Can be corrected with proper method development

3). Personal errors:- occur where measurements require judgement, result from prejudice, color acuity problems.
Can be minimized or eliminated with proper training and experience.

(C). Random (Indeterminate) errors:-

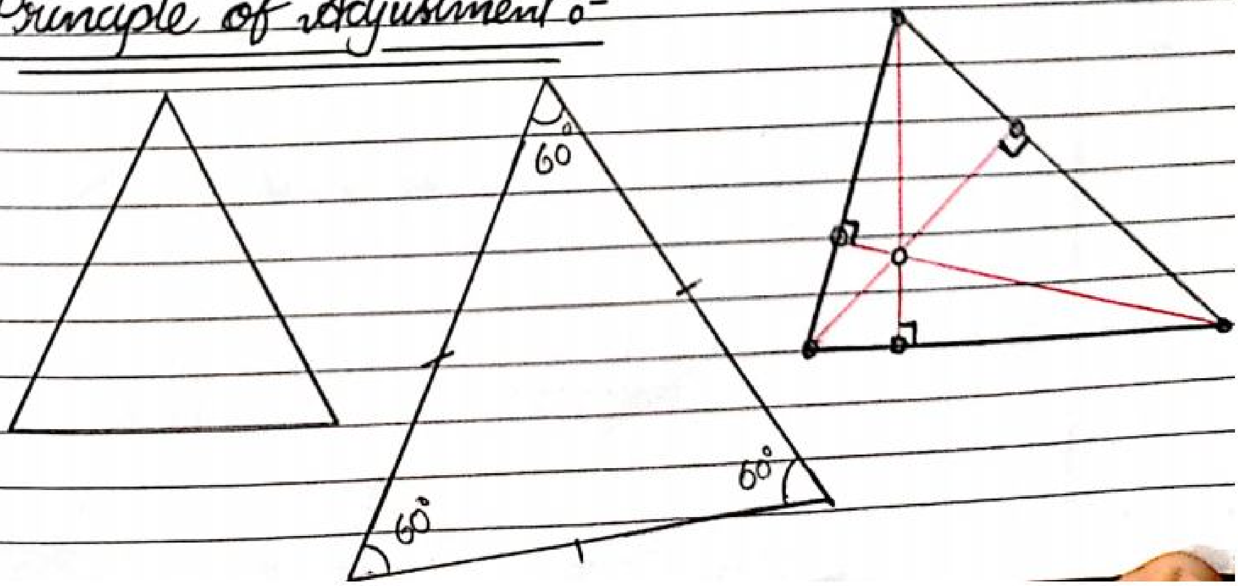
caused by uncontrollable variables, which can not be defined/eliminated. no identifiable cause; always present, cannot be eliminated; the ultimate limitation on the determination of a quantity.

Example:- Reading a scale on an instrument caused by finite thickness of the lines on the scale; electrical noise, magnetic field.

∴ Classification of errors by flowchart:-

- Types of error in measurements
  - Gross errors
  - Measurement errors
    - Systematic error
      - Instrumental errors
      - Environmental errors
      - Observational errors
      - Theoretical errors
    - Random errors
  - Blunders

- **Principle of Adjustment:-**



Terms

- **True Error:-** A true error (E_t) is defined as the difference between the true (exact) value and an approx. value.

True error (E_t) = True value − Approximate value.

- **Relative Error:-** Relative true error (E_t) is defined as the ratio between the true error and the true value.

Relative error (E_t) = True error / true value.

(Unit :- 05), * Plans & Sections *

1). General requirements of mine plans.
2). Types of plans.
3). Symbols used in mine plans.
4). preparation of plans & sections.
5). plotting of traverse.
6). Checking accuracy of old mine plans.
7). planimeter and its uses.
8). Enlargement & reduction of plans.

• General requirements of mine plans :-

1). The plan shall be accurately measured by or under the personal supervision of a competent surveyor of the mine. the surveyor will sign the plan to certify the correctness and the manager will countersign it.

2). The name of the mine and the owner & the purpose of the map will be mentioned on the map.

3). True north and 'Scale' of the map shown on the map. ~~and go~~ the scale shall be 25 cm long and properly divided.

4). the map will be drawn on 1:2000 scale (earlier there was a provision of 1:200).

5). Every map will be numbered. the list of all maps will be kept in writing in a register.

6). The map will be made on stong paper, tracing cloth or polyester sheet.

7). Only the symbols given in the regulation will be used on the map.

8). Map will be updated in such a way that it is not more than 3 months old. ~~so must~~ every time map is updated, the surveyor and the manager will sign.

9). if any part of the mine or mine is to be closed. then update his map before closed it.

10). if the map is copied, the surveyor's signature should ~~be~~ also be there on and will also show the number of the original map on copy of the map.

11). All original maps and relevant field books shall be preserved in the mines office at the charge of the surveyor, they will be available for inspection.

• Types of plans.

1). Surface plan :-

Showing every feature such as telephone, railway, road river, opencast workings, subsidence, shaft and incline opening, benchmark with its R.L., contours interval not exceeding 5m.

2). Underground plan :-

a. The position of working belowground, every borehole and shaft with depth, drift, incline, pumping stations, etc.

b. Every important features with in the boundaries such as railways track, river, reservoir and building within 200m of any part of the strata.

c. Dip direction with the rate and strike direction

d. Section of the seam.

e. Position of every dyke, fault with amount of throw and its direction.

f. Spot levels on the floor of working along all haulage roadways.

(g). A permanent on the surface with its R.L.

(h). The workings and other features, both above and below ground of all adjacent mines situated within 60m.

(i). working lines indicating the outlines of bodies of water.

(j). An abstract of all statutory restrictions in respect of any specified workings.

3). **Vertical mine Section :-**

Showing a vertical projection of the mine workings, where a seam has an average dip of more than 30° from the horizontal.

4). **Ventilation plan & Section :-**

Showing the system of ventilation in mine and in particular the general direction of air, air crossings, ventilation door, stopping, the position of fire-fighting equipment and stone dust barrier (with type and date of construction) every water dam with dimension etc.

5). **Combined Section/Section :-**

In case of contiguous seams, each other showing the workings of different seams in different colours.

6) Combine / composite plan :-

Showing the extent of working of all the seams lying within, the boundary of the mine, in different colours.

7). Geological plan :-

Showing area of the lease hole in 1:5000 R.F. Showing outcrops, dip direction dykes, faults, burnt coal or any other geological feature in the area.

8). Rescue plan / Tracing :-

At least three in nos. Showing all details required on ventilation plan and escape route.

9). Water danger plan :-

Showing existing danger due to flooding. Showing highest known flood level, low lying lands to be affected by the floods, water bearing strata, unconsolidated strata.

10). Abandoned Mine Plan :-

Showing all details of abandoned mine required for underground plan.

11). Stone dusting plan :-

Showing underground workings, divided into zones for stone dusting purposes, plan on a R.F. of 1:2400.

12). Sampling Plan :-

In underground workings clearly indicating zones for sampling purposes, each not longer than 150m, and sections in each zone not longer than 50m each.

13). Fire-Fighting plan :-

Showing the location of the fire fighting station in underground, layout of the firefighting pipeline and tapping point and there should be available in sufficient nos, both at the surface and underground.

14). Joint Survey plan :-

Showing workings and features of any adjacent mines with in 60m measured on any plane of the boundary claimed by the owners of the mine.

15). Electrical plan :-

Showing position of electrical equipment together with their specifications, the position of cables gate end box (GEB) together with their construction and capacities.

16). Subsidence plan and Sections :-

Showing observation points on the test line, depillared area, geological discontinuities and

ⓐ The thickness and nature of overlying strata.
ⓑ The conditions of overlying strata.
ⓒ Angle of draw.
ⓓ Amount of Subsidence from time to time.

17). Sketch plan for Systematic Support Rules :-

In respect of areas, where Systematic Support rules are enforced, giving details of the Support rules.

18). Accident plan :-

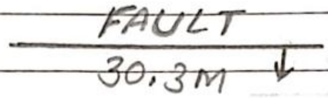
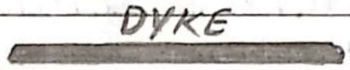
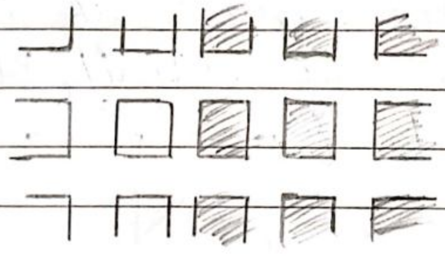
Accident site plan, any accident occurs in a mine resulting in loss of life or serious bodily injury to any person, cause of the accident, indicating the name of the district, place, date & time of accident in brief.

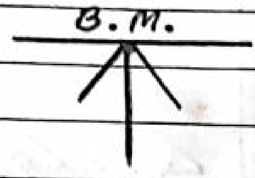
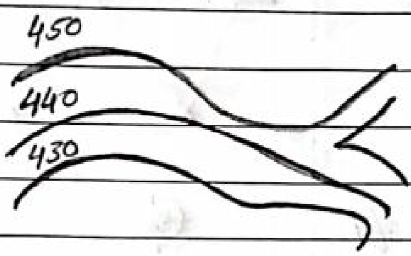
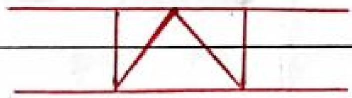
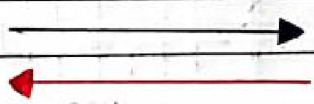
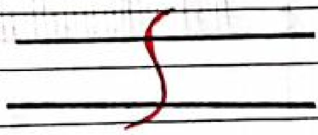
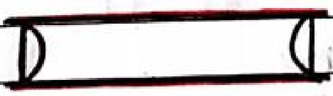
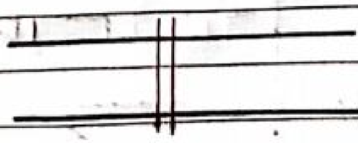
19). Manpower distribution Plan :-

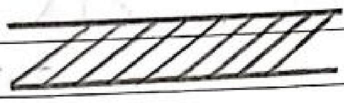
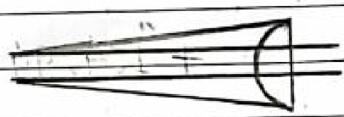
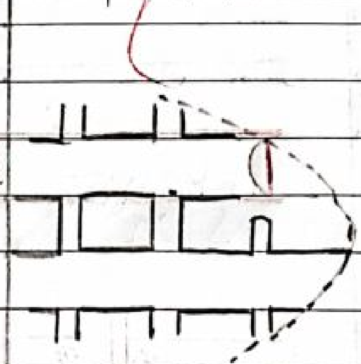
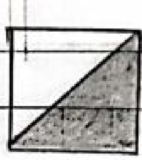
The number of persons employed in every district and other places belowground on any one day of the month shown on the plan. it should also indicate :-

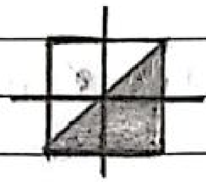
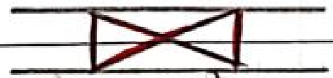
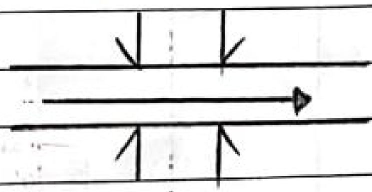
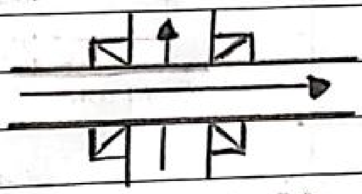
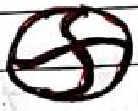
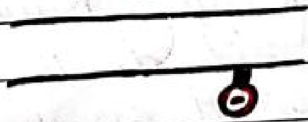
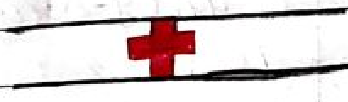
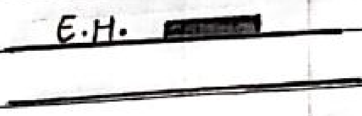
(a). The month of which the plan relates.
(b). A single line sketch of the main roadways, in different colour when more than one seam.
(c). The name of districts with letter reference.
(d). The no. of persons employed in each district category wise, and
(e). The summary of the total no. of persons employed underground.

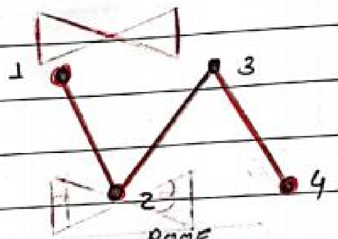
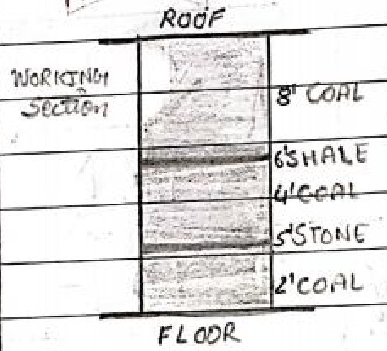
- **Preparation of plans & Sections, Symbols used in mine plans :-**

S. No.	Name	Symbol	Remarks
1).	Fault		In red, showing the amount & direction of the
2).	Dyke or other Intrusion		In green.
3).	Goaf		

S.No.	Name	Symbol	Remarks
4).	Subsidence	SUBSIDENCE	In Red
5).	Bench mark		
6).	Surface Contour		In burnt Sienna
7).	Underground Spot level	+104.94	In blue
8).	Water Dam		In blue
9).	Direction of air current		Intake in blue Return in Red
10).	Brattice		In red
11).	Doors		In red
12).	Brick/stone or Concrete Ventilation Stopping		In red

S.No.	Name	Symbol	Remarks
13).	Boundary of Lease hold		In Red
14).	Underground coal barrier		In green
15).	Shaft		
16).	Abandoned Shaft		
17).	Incline		
18).	Abandoned Incline		
19).	Pillars and galleries		
20).	Drift		In burnt sienna showing gradient in black
21).	Quarterly survey line		
22).	Staple Shaft		In red should state distance up & down to all insets.

S.No.	Name	Symbol	Remarks
23).	Abandoned Staple Shaft		In red
24).	Fire dam, seal or stopping		In red
25).	Explosion proof stopping		In red
26).	Air Crossing		
27).	Explosion proof air crossing		
28).	Regulator		In Red
29).	Auxcilliary fan		In Red
30).	Telephone		In Red
31).	Underground forst-Aid station		Thick cross in Red
32).	Engine house or Room		

S.No.	Name	Symbol	Remark
33).	Bore hole	15cm ● B.H. NO. 57	Should show serial number & diameter.
34).	Survey lines & Stations		In red
35).	Section of Seam		

- **Plotting of traverse :-**

The method is generally used for plotting precise work, mainly a theodolite traverse, both closed and open. in this method, the position of different points are plotted on a plan with reference to two lines yy, (y-axis) and xx, (x-axis) which are respectively parallel and perpendicular to the meridian.

The following are the five main methods of plotting a traverse survey:-

1). By parallel meridians through each station.

2). By Included angles.

3). By central meridian or paper protractor.

4). By Rectangular co-ordinates.

5). By chords.

• Checking accuracy of old mine plans:-

- All possible steps shall be taken to ensure that the outline of all old workings, in the same seam or in any other seam within 60 metres (being the shortest distance measured on any direction whether horizontal, vertical or inclined) thereof are shown correctly on the underground plan, manager's plan. Overman's plan & water Danger plan. Such outline shall be endorsed with the name of seam.

- All old plans shall be regarded with suspicion until their accuracy has been verified, and every effort shall be made to obtain all existing information about old workings, if there is doubt about the position of old workings, this fact shall be mentioned on the plans.

• Planimeter and its uses :-

Planimeter is an instrument used in Surveying to compute the area of any given plan. planimeter only needs plan drawn on the sheet to calculate area.

generally, it is very difficult to determine the area of irregular plot. So, by using planimeter we can easily calculate the area of any shape. the essential parts of planimeter and its working is explained below.

use planimeter in Surveying :-

Planimeter is used to compute the area of given plan of any shape.

in the first step anchor point is to be fixed at one point, if the given plan area is small, then anchor point is placed outside the plan. Similarly, if the given plan area is large then it is placed inside the plan.

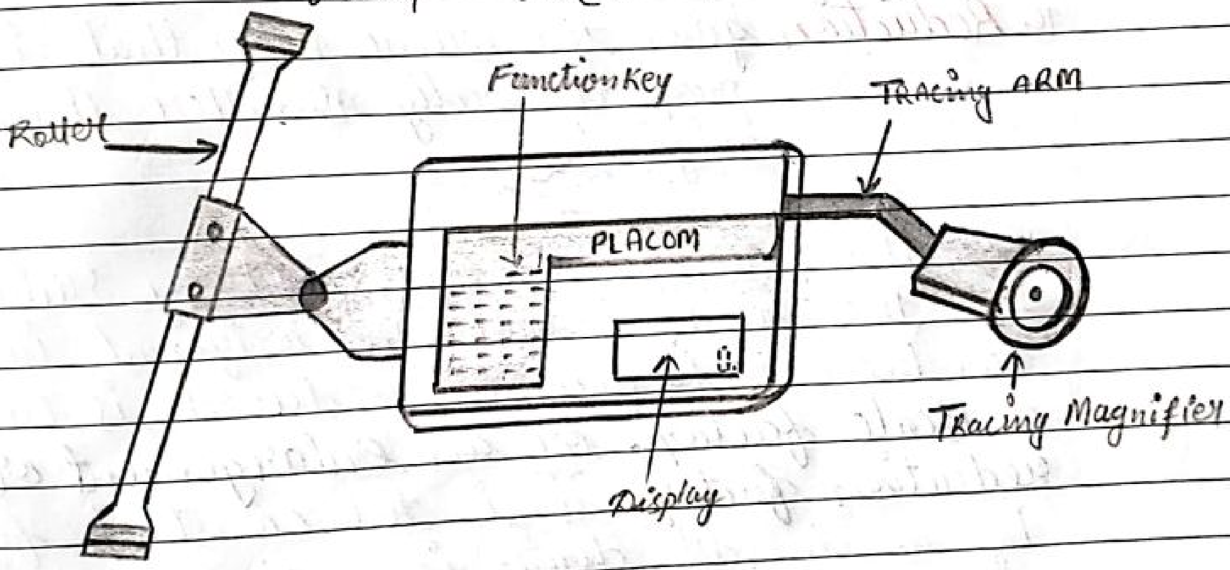
after placing the anchor point, place the tracing point on the anchor point, place the tracing point on the outline of the given plan using tracing arm. mark the tracing point & note down the reading on Vernier as initial reading A.

now move to

The tracing needle carefully over the outline of the given plan till the first point is reached. the movement of tracing needle should be in clockwise direction. note down the reading on vernier after reading the first point and it is the final reading **B.**

Now the area of the plan which boundary is traced by the planimeter is determined from the below formula.

$$Area = M(B - A \pm 10N + C).$$



*** Planimeter ***

• Enlargement and Reduction of plans:-

In the process of compiling maps cartographers are often required to either reduce or enlarge maps. Reduction or enlargement involves change in the size.

An **Enlargement** provides the same map but proportionally larger than the original.

A **Reduction** gives the same map that is proportionally smaller than the original.

The above image or map has been reduced by 1/2 the amount that an original image has been enlarged or reduced is called a **Scale factor**, or an **enlargement or reduction factor**. it is the constant factor by which all dimensions of an object are enlarged or reduced in a map. if shapes have been reduced by half, the scale factor is 1/2.

The ratio between the area of a map on one scale & its area to another scale is equal to the square of the ratios between the scales of the original & enlarged or reduced maps.