BYJU'S EXAM PREP

GATE/ESE

Civil Engineering

Surveying

Important Formula Notes

IMPORTANT FORMULAS ON SURVEYING

CHAPTER 1: FUNDAMENTALS OF SURVEYING

1. INTRODUCTION

- **Surveying:** Surveying is the art of determining the relative positions of points on above or beneath the surface of the earth by means of direct or indirect measurements of distance, direction and elevation.
- All measurements of lengths in surveying are either horizontal or are reduced to horizontal distances, i.e., the plotted measurements are projections on horizontal plane.
- The primary objective of a survey is creating a map or a plan to represent an area on the horizontal plane, to layout or mark out the proposed structure.

2. CLASSIFICATIONS OF SURVEYS

Primarily, Surveying can be divided into two classes:

- **Plane Surveying:** It is that type of surveying where the surface of the earth is considered plane and spheroidal shape is neglected.
- **Geodetic Surveying:** It is that type of survey where the shape of the earth (oblate spheroid) is considered. When, for a triangle having an area of 195.5 sq. km., the spherical excess become greater than one second.

2.1. Classification based on the object of survey

- **Topographical surveying**: Details on man-made and natural features on earth surface including their elevation details, used to obtain map of the area.
- **Engineering survey**: Done for engineering works to obtain data for design of projects such as building, roads, railways, reservoirs etc.
- **Cadastral survey**: Used to establish property boundaries.
- **Military survey**: Used for determining points of strategic importance.
- **Mine survey**: Used for exploring areas containing mineral wealth.
- **Geological survey**: Used for determining different strata in the earth’s crust.
- **Marine or Hydrographic survey:** It deals with bodies of water for the purpose of the navigation, harbour works or for the determination of the mean sea level.
- **Astronomical survey:** These surveys are done in order to determine position of celestial bodies like stars and planets.

2.2. Classification based on instruments used

(i) Chain survey, (ii) Theodolite survey, (iii) Traverse survey, (iv) Triangulation survey, (v) Tacheometric survey, (vi) Plane table survey, (vii) Photogrammetric survey, (viii) Aerial survey

3. PRINCIPLES OF SURVEYING

- **Working from Whole to Part:** main objective of working from whole to part is to localise the error and prevent error accumulation. If we work from part to whole, errors will get accumulated, and it get maximised to greater extent.
- **Location of a point with reference to two reference points:** At least two points of reference are used to locate the relative positions of the points to be surveyed.

4. SCALE: Scale can be represented by (i) Numerical scale (ii) Graphical scale.

- Numerical scale is of two type (a) Engineering scale: 1cm=10km (b) Representative scale (R.F): 1:100000
- Graphical scale is a line drawn on map and marking ground distance directly on it. Graphical scale has advantage over numerical scale because distance on the map can be calculated even though map has shrunk because scale also shrunk in the same ratio with the shrinkage of the map.
- Larger is the denominator smaller is the scale. Normally map has smaller scale and plan has larger scale. In simple words zoomed out picture is of larger scale.

5. VERNIER: Vernier is a device used for measuring the reading which are fractional part of smallest division on main scale.

- Exact measurement = reading before index mark on main scale reading + (N × least count)

  Here, 'N' numbering of division which is matching with main scale division at the time of measurement.
- In direct vernier n division of vernier equal to (n-1) division of main scale and least count for direct vernier is S-V, where S is size of one division on main scale and V is size of one division on vernier scale. It comes out to be L.C.=S/n.
- In retrograde vernier n division on vernier scale are equal to (n+1) division on main scale. Here least count will be V-S, which also comes out to be S/n.
- **Least Count:** It is the smallest measurement that can be made using any measuring device.

6. SHRUNK SCALE: original scale is always larger than shrunk scale, S.F. is always less than 1.

$$\text{Shrinkage factor or shrinkage ratio} = SF = \frac{\text{Shrunk Length}}{\text{Original Length}} = \frac{\text{Shrunk Scale}}{\text{Original Scale}} = \frac{\text{Shurnk R.F.}}{\text{Original R.F.}}$$

7. ERRORS DUE TO USE OF WRONG SCALES

$$\text{Correct length} = \frac{\text{R.F of wrong scale}}{\text{R.F of correct scale}} \times \text{measured length}$$

$$\text{Correct area} = \left(\frac{\text{R.F of wrong scale}}{\text{R.F of correct scale}}\right)^2 \times \text{calculated area.}$$

CHAPTER-2-LINEAR MEASUREMENT

1. **METHOD OF LINEAR MEASURMENT:**
   - **Direct Measurement:** Chain or tape.
   - **Measurements by Optical Means:** Tacheometry.
   - **Electronic distance measuring instrument (EDMI**): Total station.
2. **INSTRUMENTS FOR CHAINING**

2.1. Chain: There are following types of chains.

- **Metric chain:** 20 m [100 links]/30m [150 links].
- **Gunter's chain:** 66 ft [100 links].
- **Engineers chain:** 100 ft [100 links].
- **Revenue chain:** 33 ft [16 links].

2.2. Tape: Tapes are classified depending on material of the tape.

- **Cloth Tape:** It is rarely used for accurate measurements because it is affected by moisture, likely to twist and has the problem of stretching.
- **Metallic Tape:** It is made of brass and copper. It is superior to cloth tape.
- **Steel Tape:** It is made of steel and superior to metallic tape.
- **Invar Tape:** It is made from an alloy of nickel (36%) and steel (64%). Its coefficient of thermal expansion is very low.

2.3. Location Devices

(i) Arrows: These are used by leader to mark end points of the chain length which is later collected by the follower.

(ii) Pegs: Wooden pegs are used to mark definite points on the ground semi permanently or temporarily.

2.4. Ranging devices

(i) Ranging Rod: Used to locate intermediate points along a straight line. It has a length of either 2m or 3m; the 2m length being more common.

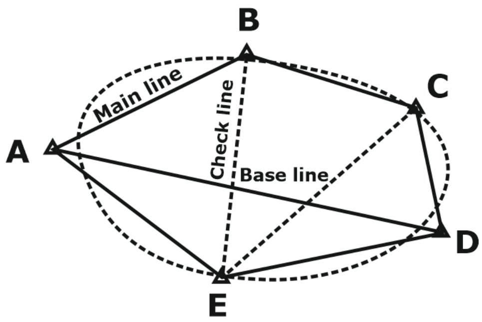
(ii) Offset Rod: It is ranging rod with slot made at right angle, it can be used to establish perpendicular offset with respect to survey line.

2.5 Instrument used for setting perpendicular lines

- cross staff/open cross staff
- French cross staff: can be used to establish angles at 45/135 degree as well.
- Optical square: index mirror->silvered fully, horizon mirror->half silvered.
- prism square: similar arrangement as that of optical square only difference is mirror are replaced with prism.
- **Note: Simple clinometer is used to measure slope of ground or vertical angle.**

3. DIFFERENT STATIONS AND LINES IN CHAIN SURVEYING

- **Main station:** Main station is the point where two sides of a triangle meet these lines decides boundary of survey area, ex: -A, B, C, D.
- **Main Line:** Line joining main stations.
- **Base Line:** Biggest central line which will divide the whole area into two parts.
- **Check Line:** Any line used to check accuracy of survey is known as check line.
- **Tie station/subsidiary station/auxiliary station:** These are stations on main line.
- **Tie Line:** Line joining tie station, used for detailing of features in an area.



4. ERROR AND DIFFERENT CORRECTIONS:

- Error = Measured value – True value
- Correction = True value – measured value
- Correction = -Error

NOTE: Remember SS, if tape is actually SHORT then correction will be SUBTRACTIVE.

4.1. Correction Due to Incorrect Length of Chain/Tape

$$\therefore correct\ length = \left(\frac{actual\ length}{nominal\ length}\right) \times measured\ length$$

4.2. Correction Due to Slope:

θ = Slope of the ground,

L_o = Measured length,

C_{slope} = L_o (1- cosθ),

correction due to slope is always negative.

$C_{slope} = -\frac{h^2}{2L} - \frac{h^4}{8L^3}$, if higher terms are ignored then $C_{slope} = -\frac{h^2}{2L}$

Note: Hypotenuse's allowance = L (secθ-1)

4.3. Correction Due to Temperature

T_m = Temperature at the time of measurement

T_0 = Temperature at the time of standardization

α = Coefficient of Thermal Expansion

C_{Temp} = Lα (T_m – T_o)

4.4. Correction Due to Pull

P_0 = Pull at time of standardization

P_m = pull at time of measurement

A_x = cross section area of tape.

E_x = modulus of elasticity of tape.

L_0 = measured length

$$C_{pull} = \frac{(P_m - P_0)L_0}{A_x E_x}$$

4.5. Correction Due to Sag

W = total weight of tape

w = weight per m length

P_m = pull at time of measurement

n = number of bays.

$$C_{sag} = \frac{(W^2 L_0)}{(24n^2 P_m^2)} = \frac{(w^2 L_0^3)}{(24n^2 P_m^2)}$$

This correction is always negative.

Normal Tension: It is the value of pull such that *Positive Pull Correction= Negative Sag Correction*

$$\frac{(P_m - P_0)L_0}{A_x E_x} = \frac{W^2 L_0}{24 P_m^2}$$

4.6. Correction due to Misalignment

h = perpendicular deviation

$$C_h = (\sqrt{L_1^2 - h^2} + \sqrt{L_2^2 - h^2}) - (L_1 - L_2)$$

This correction is always negative.

4.7. Correction due to Mean Sea Level

D = Equivalent length at MSL

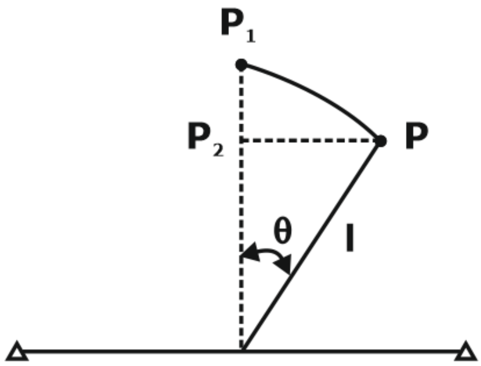
h = Mean equivalent of the base line above MSL

R = Radius of earth

$$C_{msl} = -\frac{Lh}{R}$$

5. **LIMITING LENGTH OF OFFSET:** The maximum length of offset allowed in chain survey due to which no error is reflected on the map. Maximum length of error allowed on the map is 0.025 cm.

5.1. Error in Laying Direction



Here,

P = actual point on ground

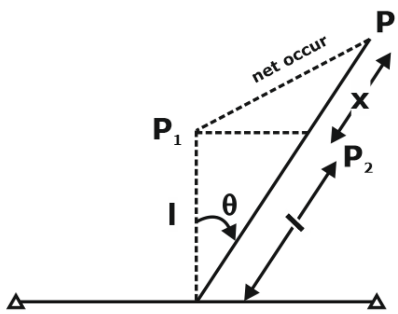
P_1 = Point located on paper

θ = error in laying direction

Scale of map, 1 cm = S m

Limiting length of offset, l = $\frac{0.025S}{sin\theta}$

5.2. Error in Laying Direction as Well as in Linear Measurement



Here,

P = Actual point on ground

P_1 = point located on paper

θ = error in laying direction

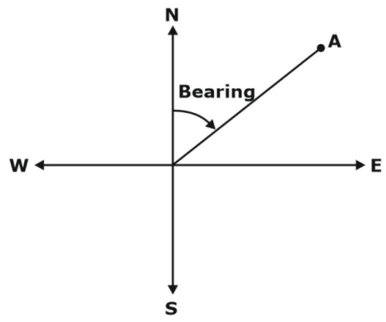
x = error in linear measurement

Scale of map, 1 cm = S m

Limiting length of offset, $l = \frac{\sqrt{(0.025S)^2 - x^2}}{\sin\theta}$

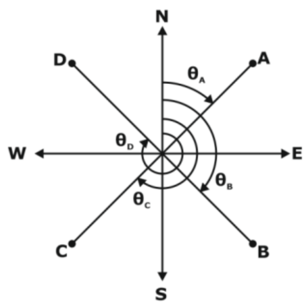
CHAPTER-3-COMPASS SURVEYING

1. **INTRODUCTION:** Objective of the compass survey is to find bearing for any line or to relate different features in terms of angular measurement on horizontal plans.
2. **BEARING AND ANGLES:** The horizontal angle measured for a survey line with respect to fixed direction (meridian) is called bearing.

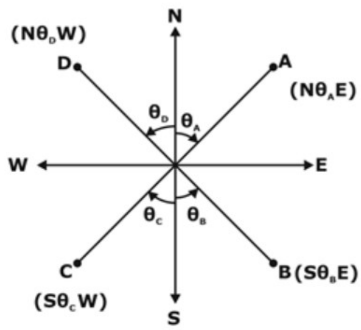


There are two methods for designation of bearing:

2.1. Whole Circle Bearing (WCB): In this system, the bearing of a line is measured with magnetic north in clockwise direction. The value of the bearing thus varies from 0° to 360°. Prismatic compass is graduated on this system.



2.2. Quadrantal Bearing System (QBS) or Reduced Bearing System: In this system, the bearing of a line is measured eastward or westward from north or south, whichever is nearer. The angle varies between 0° to 90°. This system is used in surveyor's compass.



3. MERIDIAN

3.1. True Meridian: Line joining the true north and true south pole of earth along the earth's curvature is known as true meridian. Bearing measured for any line with respect to true meridian is known as true bearing. It is always fixed.

3.2. Magnetic Meridian: Line joining the magnetic north and magnetic south pole of earth along the magnetic flux line is called magnetic meridian. The bearing measured for any line with respect to magnetic meridian is known as magnetic bearing.

3.3. Grid Meridian: For survey of a country the true meridian passing through central area is taken as reference meridian for the whole country and such a reference meridian is called grid meridian. Ex: 82.5-degree East, Allahabad. The bearing measured for any line with respect to Grid meridian is known as grid bearing.

3.4. Arbitrary meridian: it is the meridian taken in arbitrary direction generally it is taken in the direction of a well-defined point at the end of the day. The bearing measured for any line with respect to arbitrary meridian is known as arbitrary bearing.

4. MAGNETIC DECLINATION: Magnetic declination at a place is the horizontal angle between true meridian and magnetic meridian. Its value keeps on changing. Eastward declination is taken as positive, while westward declination is taken as negative.

Note: Declination at a place changes from time to time and declination at same time changes from place to place.

Isogonic Lines: Lines connecting the points having **same** magnetic declination.

Agonic Lines: Lines connecting the points having **zero** magnetic declination.

Variations in magnetic declinations are categorized as following:

(i) Diurnal Variation:

- Daily variation in magnetic declination
- More at magnetic poles and less at equator.
- More in summer, less in winters.
- More in day, less at night.
- It also changes year to year.

(ii) Annual Variation:

- Yearly variation in magnetic declination. It is not same as annular rate of change of secular variation.
- caused due to revolution of earth around sun.

(iii) Secular Variation:

- Magnitude of change is very high and this variation follows sine curve
- Time period is approximately 250-300 Years.

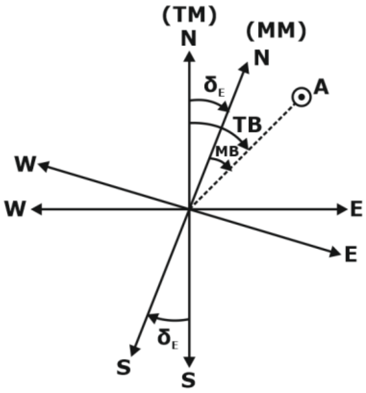
(iv) Irregular Variation:

- Random variation in magnetic declination.
- These occur due to "magnetic storms" like earthquakes and other solar influences.

Conversion of true bearing to magnetic bearing and reverse:

True bearing = Magnetic bearing + δ_E

Note: Care should be taken such that the bearing mentioned are in whole circle system and eastward declination is positive and westward is negative.



5. **ANGLE OF DIP:** Vertical angle of magnetic flux lines measured with respect to earth's surface is known as angle of dip.

Isoclinic Lines: Lines connecting the points having **same** angle of dip. Ex: latitude.

Aclinic Lines: Lines connecting the points having **zero** angle of dip. Ex: equator.

Angle of dips has following value:

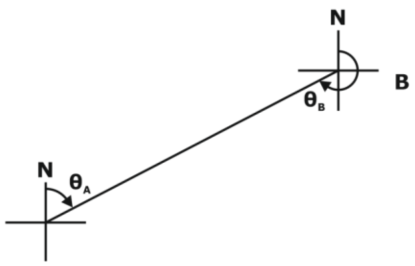
$\theta = 0°$ at equator (as flux lines are parallel to earth's surface at equator)

$\theta = 90°$ at pole (as flux lines are perpendicular to earth's surface at poles)

6. **MEASUREMENTS IN COMPASS SURVEY:**

(i) Fore bearing: measured in the direction of traverse.

(ii) Back bearing: measured from in the direction opposite to traverse.



Line AB → Fore Bearing = θ_A & Back Bearing = θ_B

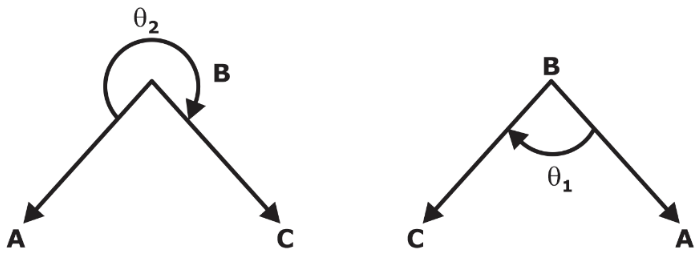
Line BA → Fore Bearing = θ_B & Back Bearing = θ_A

Note: The difference of fore bearing and back bearing for a line is always equal to 180°, provided both the stations are free from local attraction.

7. **INCLUDED ANGLE:** Included angle is the angle measured in clockwise direction from previous line to the next line. Mathematically,

included angle = F.B. of next line -B.B. of previous line {+360}

if a negative value is obtained, simply add 360 to get required value of included angle.



8. CALCULATION OF BEARING FROM INCLUDED ANGLE:

Mathematically, F.B. of next line = B.B. of previous line + included angle {-360}

If value comes out to be more than 360, simply subtract 360 to get WCB of F.B. of next line.

9. LOCAL ATTRACTION: Local attraction is a term used to denote any influence which prevents the needle from pointing to magnetic north in a given locality. Influence on the actual reading can be due to heavy steel, nickel objects, electric poles, transmission lines, steel pens, steel buttons, etc.

- Local attraction affects all bearings taken at a point equally. So, the included angle between two survey lines is unaffected.
- For a particular line, if the difference between fore bearing and back bearing is found to be 180°, the lines/measurement associated with this station are said to be free from the local attraction.
- Correction for local attraction is done using concept of included angle, starting from the station where local attraction is zero. For a closed polygon, firstly we need to calculate and correct the error found while closing the polygon. For interior angles, Theoretical Sum = (2n – 40)90° and for exterior angles, Theoretical Sum = (2n + 40)90°. Error is distributed equally to all the included angles and then correct bearing is found from station where local attraction is zero.

10. ERRORS IN COMPASS SURVEY: The errors in compass survey may be classified as:

A. Instrumental Error: These are those which arise due to faulty adjustments of the instruments. For example:

- The needle not being perfectly straight.
- Pivot being bent.
- Improper balancing weight.
- Plane of sight not being vertical.

B. Personal Error: These may be due to following reasons:

- Inaccurate levelling of the compass.
- Inaccurate centring.
- Inaccurate bisection of the signals.
- Carelessness in readings and recordings.

C. Error due to Natural Causes: These may be due to the following reasons:

- Variations in declinations.
- Local attractions due to proximity of magnetic material.
- Magnetic change in the atmosphere due to clouds and storms.

11. DIFFERENT TYPE OF COMPASS USED:

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

12. THEODOLITE:

A theodolite is a versatile instrument basically designed to measure horizontal and vertical angles. It is also used to give horizontal and vertical distances using stadia hairs. Magnetic bearing of lines can be measured by attaching a trough compass to the theodolite.

12.1. Definitions and Terms

(1) The vertical axis: The vertical axis is the axis about which the instrument can be rotated in a horizontal plane. This is the axis about which the lower and upper plates rotate.

(2) The horizontal axis: The horizontal or trunnion as is the is about which the telescope and the vertical circle rotate in vertical plane.

(3) The line of sight or line of collimation: It is the line passing through the intersection of the horizontal and vertical crosshairs and the optical centre of the object glass its continuation.

(4) The axis of level tube: The axis of the level tube or the bubble line is a straight line tangential to the longitudinal curve of the level tube at its centre. The axis of the level tube is horizontal when the bubble is central.

(5) Centring: The process of setting the theodolite exactly over the station mark is known as centring.

(6) Transiting: It is the process of turning the telescope in vertical plane through 180° about the trunnion axis. Since the line of sight is reversed in this operation, it is also known as plunging or reversing

(7) Swinging the telescope: It is the process of turning the telescope in horizontal plane. If the telescope is rotated in clock-wise direction, is known as right swing. If telescope is rotated in the anti-clockwise direction, it is known as the left swing.

(8) Face left observation: If the face of the vertical circle is to the left of the observer, the observation of the angle (horizontal or vertical) is known as face left observation

(9) Face Right observation: If the face of the vertical circle is to the right of the observer, be observation is known as face right observation.

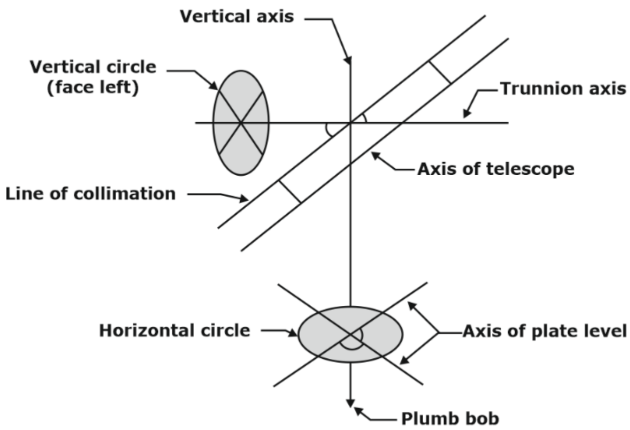
(10) Telescope normal: A telescope is said to be normal or direct when the face of the vertical circle is to the left.

(11) Telescope inverted: A telescope is said to be inverted or reversed if the vertical circle is to the right.

(12) Changing face: It is an operation of bringing the face of the telescope from left to right and vice versa.

12.2. THE DESIRED RELATIONSHIP BETWEEN THE FUNDAMENTAL LINES OF THE THEODOLITE

The line of sight, axis, and circles of the theodolite is as follows:



The desired relationship between the fundamental lines of the theodolite is as follows:

1) The axis of the plate level must lie in a plane perpendicular to the vertical axis. If this condition exists, the vertical axis will be truly vertical when the bubble is in the center of its run.
2) The line of collimation must be perpendicular to the horizontal axis at its intersection with the vertical axis. Also, if the telescope is an external focusing type, the optical axis, the axis of the objective slide, and the line of collimation must coincide. If this condition exists, the line of sight will generate a vertical plane when the telescope is rotated about the horizontal axis.
3) The horizontal axis must be perpendicular to the vertical axis. If this condition exists, the line of sight will generate a vertical plane when the telescope is plunged.
4) The altitude level (or telescope level) axis must be parallel to the line of collimation. If this condition exists, the vertical angles will be free from index error due to a lack of parallelism.
5) The vertical circle vernier must read zero when the line of collimation is horizontal. If this condition exists, the vertical angles will be free from index error due to Displacement of the vernier.
6) The axis of the striding level (if provided) must be parallel to the horizontal axis. If this condition exists, the line of sight (if in adjustment) will generate a vertical plane when the telescope is plunged, the bubble of striding level being in the centre of its run.

12.3 Permanent Adjustment of Theodolite:

The permanent adjustments of a theodolite are done in a prescribed order one adjustment does not affect any other adjustment. The order in which adjustments are to be done is the following.

1. Plate level test to make the plate level at the centre when the vertical axis is truly vertical.

2. Cross hair ring test to make the line of collimation coincide with the optical axis and also to ensure that the line of collimation generates a vertical plane when the telescope is transited.

3. Spire test to make the horizontal axis perpendicular to the vertical axis.

4. Collimation test to make the line of collimation perpendicular to the horizontal axis.

5. Telescope bubble test to centre the telescope bubble when the line of sight is horizontal.

6. Vertical Vernier test to ensure that the vertical circle reads zero when the line of sight is horizontal.

CHAPTER-4-TRAVERSING

1. **TRAVERSING:** Traversing is the type of survey in which several connected survey lines form the framework and the direction and lengths of survey lines are measured with the help of an angle measuring instrument and a tape respectively.

   It can be of two types: open loop or closed loop

   For closed loop starting and end point are of known location, end point can be same as starting point or any other point of known coordinates. For open loop finishing point is of unknown location.

2. **MESURMENT OF TRAVERSING**

   (i) Linear measurements: Linear measurements are taken by chain or tape, tacheometry, EDMI.

   (ii) Angular measurements: The following methods are Generally used for the measurement of angles in a theodolite traverse.

- **Loose needle Method:** In loose needle method, the direction of the magnetic meridian is established at each traverse station and the direction of the line is measured with reference to the magnetic meridian. In other words, the magnetic bearing of each line is measured at each station. The loose needle method is also known as the free needle method.
- **Fast Needle Method:** In fast needle method, the magnetic meridian is established only at the starting station and the magnetic bearing of the first line is measured. The magnetic bearings of all other lines are determined indirectly from the magnetic bearing of the first line and the included angles. However, the magnetic bearing of the first line has the accuracy of the compass, the difference of bearings of the two adjacent lines has the accuracy of the theodolite. The method is more accurate than the loose needle method and is generally preferred in the field.
- **Method of included angle:** Traversing by the method of included angles is the generally used method. In this method, magnetic bearing of any of the one line (generally, the initial line) is measured in the field. All the included angles are also measured. Bearing of all the other lines are determined from the bearing of the initial line and the included angles. This method is more accurate than the fast needle method. An included angle is one of the two angles formed at a station by the two traverse lines meeting there.

  Note: All angles are measured clockwise. This is done because in theodolite the graduations increase in clockwise direction.
- **Method of direct angles**: This method is similar to the method of included angle. In this method, directly angles or the angles to the right are measured. The method is generally used in an open traverse.
- **Method of deflection angles**: The method of deflection angles is mainly used for the open traverse conducted for the survey of roads, railways, canals, pipelines, sewers, etc. where the traverse lines make small deflection angles. Deflection angles are the angles which a line makes with the prolongation of the preceding line.

3. PLOTTING A TRAVERSE SURVEY

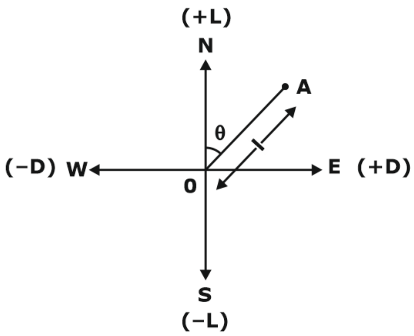
(i) Angle and Distance Method: The distances between the stations are plotted to a scale and the angles between the lines are plotted by some angle plotting or method such as a protractor or the chord or the tangent method. This method is suitable for small surveys and its accuracy for plotting is not as good as the co-ordinate method.

(ii) Co-ordinate Method: This is the most accurate and the most practical method of plotting traverses. The survey stations are plotted by calculating their co-ordinates. Its most important advantage being that that the closing error can be eliminated by balancing before plotting.

4. LATITUDE AND DEPARTURE:

(i) Latitude (L): Projection of a line on North-South (N-S) axis is called latitude. It is considered positive on north axis (northing) and considered negative on south axis (southing).

(ii) Departure (D): Projection of a line on East-West (E-W) axis is called departure. It is considered positive on East axis (easting) and negative on west axis (westing).



Here,

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

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

5. INDEPENDENT COORDINATE:

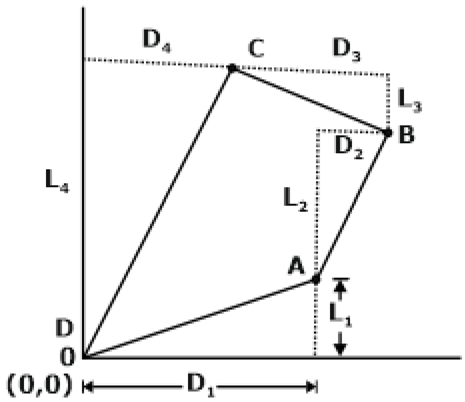
Coordinate of different point with respect to single origin is called independent coordinate.

$$A \equiv (L_1, D_1)$$

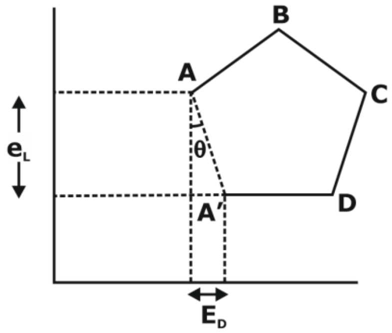
$$B \equiv [(L_1 + L_2), (D_1 + D_2)]$$

$$C \equiv [(L_1 + L_2 + L_3), (D_1 + D_2 - D_3)]$$

$$D \equiv [(L_1 + L_2 + L_3 - L_4), (D_1 + D_2 - D_3 - D_4)] \sim (0, 0).$$



6. **CLOSING ERROR:** After completion of the survey of a closed traverse at time of plotting, if the end point doesn't coincide exactly with the starting point, the closing error is introduced. Hence, $\Sigma L \neq 0$ and $\Sigma D \neq 0$



Here,

error= A'A, correction=AA'

e_L = total error in latitude

e_D = total error in departure

The magnitude of closing error, e = $\sqrt{e_L^2 + e_D^2}$

Direction = θ = $tan^{-1}\left(\frac{e_D}{e_L}\right)$

For a closed Traverse:

$\boxed{\Sigma L = 0}$ and $\boxed{\Sigma\Sigma = 0}$

Where ΣL = Sum of all latitude

ΣD = Sum of all departure

7. **METHODS TO CORRECT CLOSING ERROR**

(i) Bowditch method, (ii) Transit method, (iii) Graphical method

7.1. Bowditch Method

This method is suitable when linear and angular measurement are both taken with an equal degree of precision.

The basis of this method is on the assumptions that

a) the errors in linear measurements are proportional to $\sqrt{l}$ and

b) the errors in angular measurements are inversely proportional to $\sqrt{l}$,

where l is the length of a line.

Correction to lat. (or dep.) of any side = Total error in lat. (or dep.) × $\frac{Length\ of\ that\ side}{Perimeter\ of\ the\ traverse}$

Let,

C_L = correction to latitude or any side

C_D = correction to departure on any side

ΣL = total error in latitude

ΣD = total error in departure

Σl = length of the perimeter, and l = length of any side

We have, $C_L = \sum L \frac{l}{\sum l}$ **and** $C_D = \sum D \frac{l}{\sum l}$

7.2. Transit Method

This method may by employed where angular measurements are more precise than the linear measurements.

According to this rule, the total error in latitude and in departures is distributed in proportion to the latitudes and departures of the sides. It is claimed that the angles are less affected by corrections applied by transit method than by those by Bowditch's method.

Correction to lat.(or dep.)=Total Error in lat.(or dep.) $\times \frac{Latitude\ (or\ departure)\ of\ that\ line}{Arithmetic\ sum\ of\ latitudes\ (or\ departures)}$

Let,

L = latitude of any line

D = departure of any line

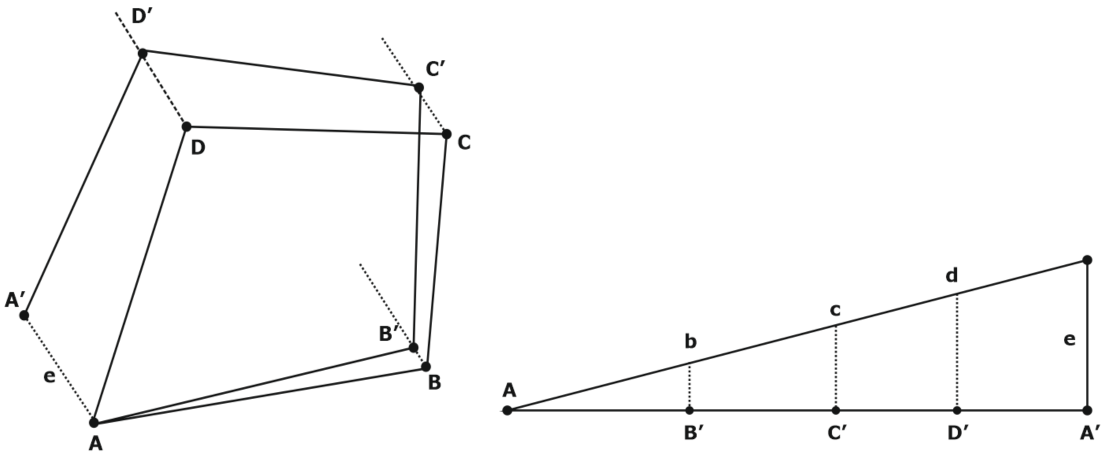
L_T = arithmetic sum of latitudes

D_T = arithmetic sum of departure

We have, $C_L = \Sigma L . \frac{L}{L_T}$ **and** $C_D = \Sigma D \cdot \frac{D}{D_T}$

7.3. Graphical Method

It is a simple method for the application of Bowditch method graphically without calculations. The closing error AA′ is distributed linearly to all the sides in proportion to their length by the graphical construction. The ordinate aA′ is considered equal to the closing error and the corresponding errors bB′, cC′ and dD′ are found by constructing similar triangles. The lines D′D, C′C, B′B are drawn **parallel** to the closing error A′A and are made equal to dD′, cC′ and bB′ respectively. The polygon ABCD thus obtained represents the adjusted traverse.



CHAPTER-5-LEVELLING

1. **INTRODUCTION:** Levelling is that branch of surveying the objective of which is

- to find the elevations of given points with respect to a given or assumed datum.
- to establish points at a given elevation or at different elevations with respect to a given or assumed datum.
- Levelling deals with measurements in a vertical plane.

Level Surface: A curved surface in which each point is perpendicular to the direction of gravity at any point. The surface of still water is a truly level surface.

Datum: A datum is a reference level surface for measuring the elevations of the points. Mean Sea Level is considered a standard datum. It is the mean of 19 years tidal level data considered at Mumbai high.

Horizontal Plane: A plane tangential to the level surface. It is perpendicular to the plumb line.

Elevation: The vertical distance of a point above or below a datum. Vertical distance is always measured along the direction of plumb line. Altitude is vertical distance above the datum, above datum elevation and elevation both are same.

Line of collimation: Line of sight has to be horizontal while taking reading, when LOS become horizontal i.e., perpendicular to plumb line it is called as line of collimation.

2. **TERMS AND ABBREVIATIONS IN LEVELLING WORK**

(i) Reduced level (RL): Reduced level of a point is its height or depth above or below the assumed datum. It is the elevation of the point.

(ii) Benchmark (BM): It is any station or a point which has known reduced level. Reduced levels of other points are found with respect to reduced level of a benchmark.

- GTS Benchmark: Great Triangular Survey benchmark, they are established by survey of India throughout the country with highest precision.
- Permanent Benchmark: These are established at closer intervals between widely spaced GTS BM by SPWD or Survey of India.
- Temporary Benchmark: All the benchmarks which are used for temporary purposes are called temporary benchmarks.

(iii) Station: In levelling, a station is that point where the level rod is held. It is not where the level is set up. It is the point whose elevation is to be determined or the point that is to be established at a given elevation.

(iv) Height of Instrument (HI): The elevation of the plane of sight (Line of Sight) with respect to the assumed datum. It does not mean the height of the telescope above the ground where level stands.

(v) Back Sight (BS): The first reading taken after instrument is set up, with staff held at a point of known elevation. The objective of back sighting is to ascertain the height of the plane of sight.

(vi) Fore Sight (FS): The last reading taken from instrument position. After fore sight, either the instrument is shifted, or the work is closed.

(vii) Intermediate Sight (IS): Every reading except back sight and fore sight is called intermediate sight. Both FS and IS are taken at point of unknown elevation.

(viii) Turning Point (TP): A change point where the instrument is shifted and both FS and BS are taken. The RL will be calculated based on the old HI while the new HI will be calculated from the RL and BS data. This new HI will be used for further stations until another TP is encountered.

(ix) Rocking: to ensure verticality of staff, staff is waved slightly towards instrument and then away from the instrument this process is called rocking of staff, during the process smallest reading should be recorded.

(x) Shimmering: during very intense sunshine, air near the earth surface shimmers hence avoid taking reading for staff height up to 0.5m.

(xi) Parallax: it is apparent movement of image relative to cross hair.

(xii) Use of Inverted Staff: when the point whose elevation is to be determined whose elevation is much above the line of sight, ex:- soffit level of beam or slab. Then the determination of level of that point is done by taking inverted staff reading. Staff is kept inverted with 0m at top and hanging downwards. Readings are recorded with a negative sign in level book field book.

R.L.=H.I.- (-staff reading) =H.I.+ staff reading.

3. OPTICAL DEFECTS IN LENS OF TELESCOPE:

(i) chromatic aberration: It occurs in telescope due to dispersion of white light. White light splits into components of colours, which results in formation of rainbow near the image and focusing become difficult. If chromatic aberration is absent, it is called Achromatic.

(ii) Spherical aberration: This occurs due to the defect in spherical surface of lens. If spherical aberration is absent, it is called Applanation.

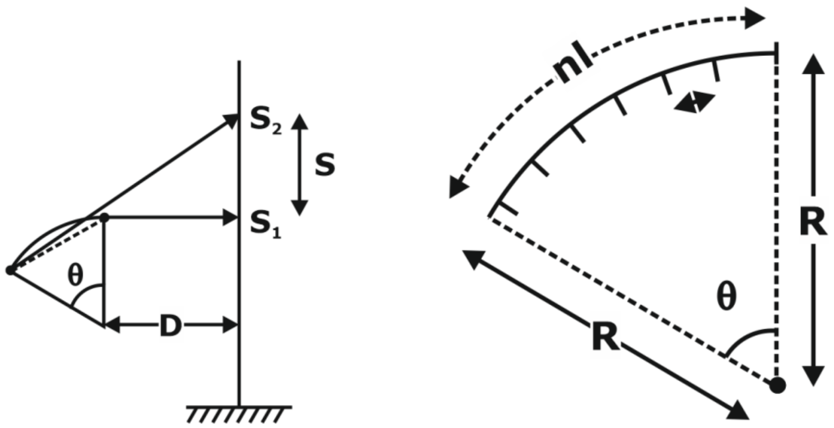
Note: These defects are removed by using combination of (concave lens + convex lens), and liquid used between them is Canada Balsam.

4. THE LEVEL TUBE: The level tube or bubble tube is most important part of the surveying instrument as it is used to make LOS horizontal and plumb line intersect coincide with vertical axis.

Let 'θ' be the rotation given to the level tube, and the staff intercept caused by this movement be 'S', when the staff is at a distance of 'D' from the instrument. So,

$$\tan\theta = \theta = \frac{S}{D},$$

because rotation will be very small.



Within the level tube, the bubble moves by 'n' divisions. If 'l' is the length of one of the divisions of the bubble tube and 'R' is the radius of internal curve of tube,

$$\theta = \frac{nl}{R}$$

Combining the two expressions of θ, we get, $\theta = \frac{nl}{R} = \frac{S}{D}$

Sensitiveness: The angular value of one division of the bubble tube.

$$\text{Sensitiveness } (\alpha) = \frac{\theta}{n}$$

Substituting the expression of θ, we get, $\alpha = \frac{l}{R} = \frac{S}{nD}$, lesser is value of alpha better is the sensitiveness of the instrument.

Note: Sensitivity is expressed as seconds/division, if length of one division is not given then it is not a definite quantity. If not specified, then length of one division is taken as 2mm.

Note: Length of air bubble changes with temperature and also under action of gravity.

Note: Liquid used in tube should be stable and non-freezing at room temperature, its viscosity should be low. Generally, used liquids are Chloroform, Spirit and Synthetic Alcohol.

The Sensitiveness of a Bubble Tube Can Be Increased By

(i) Increasing the radius of curvature of the tube.

(ii) Increasing the diameter of the tube.

(iii) Increasing the length of the air bubble.

(iv) Decreasing the roughness of the walls.

(v) Decreasing the viscosity of the liquid.

(vi) by decreasing the temperature.

5. METHODS OF RECORDING READING AND REDUCED LEVELS CALCULATION:

5.1. Height of Instrument Method: In this method, the height of the instrument (HI) is calculated for each setting of the instrument by adding back sight to the elevation of the benchmark.

The elevation of reduced level of the turning point is then calculated by subtracting the FS from HI. For the next setting of the instrument the HI is obtained by adding the back sight taken on TP1 to its RL. The process continues till the R.L of the last point is obtained by subtracting the staff reading from height of the last setting of the instrument.

If there are some intermediate points, the R.L of these points is calculated by subtracting the intermediate sight from the height of the instrument for that setting.

Arithmetic Check: The difference between the sum of back sights and the sum of fore sights should be equal to the difference between the last and the first RL thus

$$\Sigma BS - \Sigma FS = \text{Last RL} - \text{First RL}$$

Note: If both BS and FS exist at a station, it is a TP and the height of the instrument will change. The RL will be calculated based on the old HI while the new HI will be calculated from the RL and BS data. This new HI will be used for further stations until another TP is encountered.

5.2. Rise and Fall Method: In this method, the height of instrument is not calculated. The difference between the levels of two consecutive stations is found by comparing the staff readings on the two points for the same setting of the instrument. The difference between their staff reading indicates a rise or fall as the staff reading at the point is smaller or greater than that at the preceding point. The figures for 'rise' and 'fall' worked out thus for all the points given the vertical distance of each point above or below the preceding one and the level of the next will be obtained by adding its rise or subtracting its fall.

Arithmetic Check: The difference between the sum of back sights and sum of fore sights should be equal to the difference between the sum of rise and the sum of fall and should also be equal to the difference between the R.L of last and first point.

$$\Sigma BS - \Sigma FS = \Sigma \text{ Rise} - \Sigma \text{ Fall} = \text{Last RL} - \text{First RL}$$

Rise and fall method is better than HI method because,

- It gives better visualisation of terrain.
- R.L. of intermediate sight are also checked.
- Note: staff reading in the methods cannot be checked.

7. CORRECTIONS

7.1. Correction Due to Earth's Curvature:

Radius of earth, R = OA

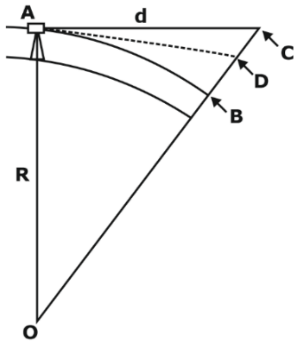
Distance, d = AC

Curvature correction, C_C = BC

∴ C_C = curvature correction = $0.07849\ d^2$

This correction is always negative.

∴ $C_C = -0.0785\ d^2$



Where, C_C is in 'm' and d is in 'km'

7.2. Correction Due to Refraction:

Correction due to refraction = $C_R = \frac{1}{7} C_C$

$\Rightarrow\ C_R = \frac{1}{7} \times 0.0785\ d^2$

$\Rightarrow C_R = 0.0112\ d^2$

This correction is always positive.

Here, C_R is in 'm' and d is in 'km'

7.3. Combined Correction (C):

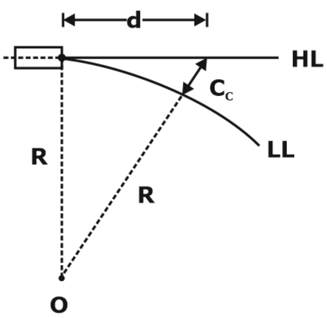
$C = C_C + C_R$

$C = -0.0785d^2 + 0.0112\ d^2 \Rightarrow C = -0.0673d^2$

Here, C is in 'm' and d is in 'km'

8. DISTANCE OF VISIBLE HORIZON

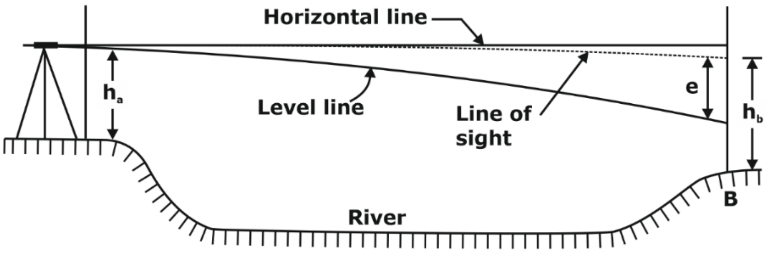
$$d = \sqrt{\frac{C_C}{0.06728}}\,km,\ d = 3.8553\sqrt{C_C}\ km$$



Here, C_C= dip of horizon

9. RECIPROCAL LEVELLING: It eliminates the errors due to the curvature of the earth, atmospheric refraction and collimation.

Case 1: When instrument is near A,



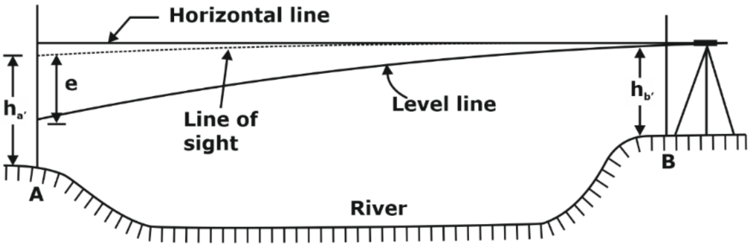
Staff reading at A = h_a

Staff reading at B = h_b

Corrected staff reading at B = $h_b - e$

Exact height difference = H = $(h_b - e) - h_a$

Case 2: When instrument is near station B,



Staff reading at A = h_a'

Staff reading at B = h_b'

Corrected staff reading at A = $h_a' - e$

Exact height difference = H = $h_b' - (h_b' - e)$

From equation 1 and 2, we get

Exact height difference (H), $H = \frac{(h_b - h_a) + (h_b' - h_a')}{2}$

Here e is total error due to collimation, refraction and curvature.

$e = e_L + e_c + e_r$

e_L= collimation error (assumed upwards positive)

e_c = curvature error (+ve)

e_r = refraction error (-ve)

Firstly, calculate correct height difference and then put in any equation to find e and the put values of curvature error and refraction error to calculate error due to collimation.

Collimation Error: This is a type of instrumental error due to which line of collimation (line of sight of the equipment) may not be horizontal even if the levelling bubble is at centre.

11. Contour: Contour is the line joining points of equal or same elevation (RL).

11.1.USES OF CONTOURS:

- Proper and precise location of engineering works such as roads, canals. etc.
- In location of water supply, water distribution and to solve the problems of steam pollution.
- In planning and designing of dams, reservoirs, aqueducts, transmission lines, etc.
- In selection of sites for new industrial plants.
- Determining the intervisibility of stations.
- Determining the profile of the country along any direction.
- To estimate the quantity of cutting filling, and the capacity of reservoirs.

11.2.CONTOUR INTERVAL: Elevation difference between two consecutive contours known as contour interval. It is always kept same for a map, so that difference features of area can be easily identified.

11.3.HORIZONTAL EQUIVALENT: Horizontal distance between two consecutive contours at any point called horizontal equivalent. Generally, for natural feature horizontal equivalent are irregular.

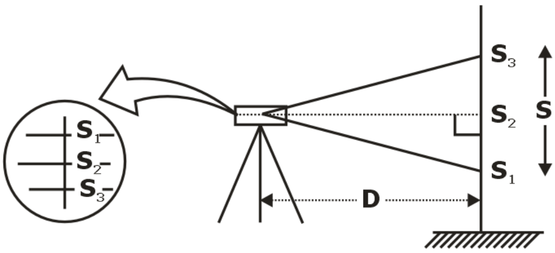
11.4.SOME IMPORTANT POINTS:

- The horizontal distance between any two contour lines indicates the amount of slope and varies inversely on the amount of slope. Thus, contours are spaced equally for uniform slope, closely for steep slope contours, and widely for moderate slope.
- The variation of the vertical distance between any two contour lines is assumed to be uniform.
- Terrain's steepest slope on a contour is represented along the normal of the contour at that point. Thus, they are perpendicular to ridge and valley lines where they cross such lines.
- Contours do not passthrough permanent structures such as buildings.
- Contours of different elevations cannot cross each other (caves and overhanging cliffs are the exceptions).
- Contours of different elevations cannot unite to form one contour (vertical cliff is an exception).
- The contour line must close itself but need not be necessarily within the limits of the map.
- A closed contour lines on a map represent either depression or hill. For example, a set of ring contours with higher values inside depicts a hill, whereas the lower value inside depicts a depression (without an outlet).
- Contours deflect uphill at valley lines and downhill at ridgelines. Contour lines in the U-shape cross a ridge, and in V-shape cross a valley at right angles. The concavity in contour lines is towards the higher ground in the case of the ridge and towards the lower ground in the case of the valley

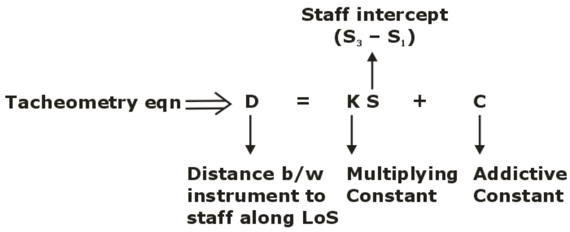
CHAPTER-6-TACHEOMETRY

1. **INTRODUCTION:** Both horizontal and vertical distances are measured without the use of a chain or tape. It is mostly used for contouring. It is extremely useful for rough terrain that is when chaining is difficult. Its accuracy is less than chaining for flat terrain and more than chaining for rough terrain.

2. **BASIC PRINCIPLE OF TACHEOMETRY:** The reading against the middle hair is used for finding differences in elevation, the reading against the top and bottom hairs are used to find horizontal distances.

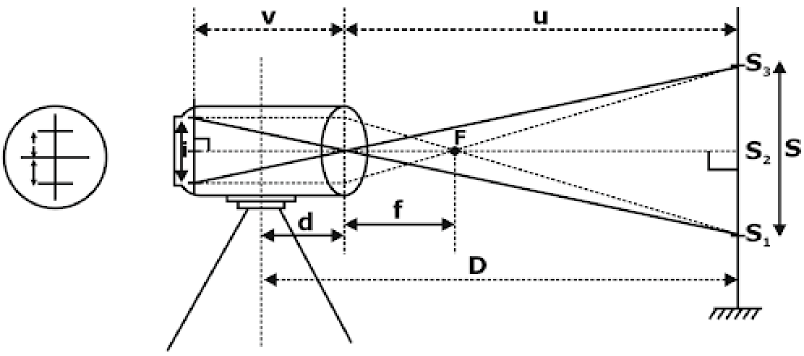


Mathematical equation of tacheometry is as follows.



Note: Telescope for which multiplying constant, k = 100 and additive constant, c = 0, if the telescope is fixed with Analytic lens.

3. **DISTANCE AND ELEVATION FORMULA FOR HORIZONTAL LINE OF SIGHT**



Here,

i = stadia internal (size of image)

s = staff intercept (size of object)

f = focal length

d = distance of vertical axis of instrument from optical centre of objective lens.

u = distance of object from objective lens

v = distance of image from objective lens

D = distance between instrument to staff along line of sight.

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

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

$$\Rightarrow D = Ks + C$$

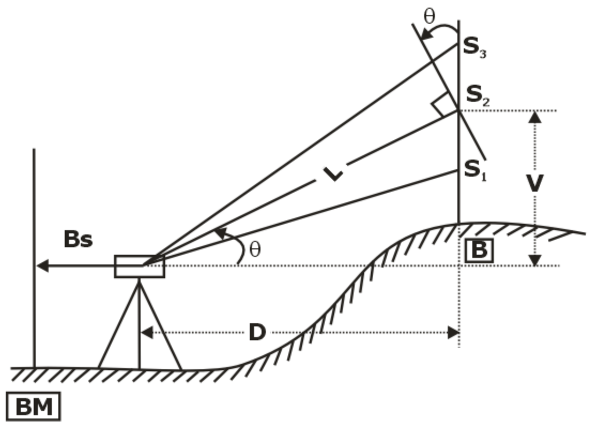
Here, K = multiplying constant = $\left(\frac{f}{i}\right)$ and C = additive constant = (f + d)

4. DISTANCE & ELEVATION FORMULA FOR INCLINED LINE OF SIGHT

There can be two cases for inclined line of sight

Case 1: When staff kept vertical (along gravity)

(a) Angle of elevation:



Staff intercept S = (S_3 – S_1)

Staff intercept perpendicular to Line of Sight = Scosθ

Tacheometry equation

$$L = KS\cos\theta + C$$

Horizontal distance (D)

$$D = L\cos\theta$$

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

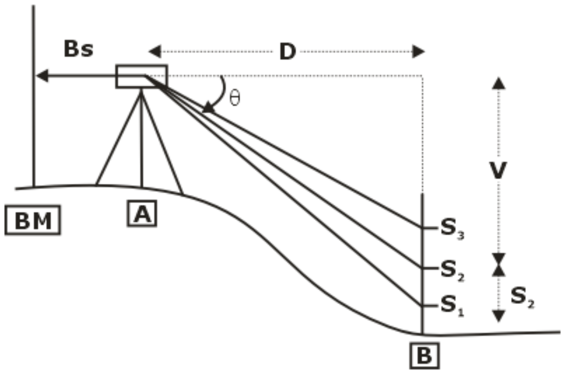
Elevation (V)

$$V = L\sin\theta \quad \longrightarrow \quad V = \frac{1}{2}KS\sin 2\theta + C\sin\theta$$

And,

$$\text{RL of B} = \text{RL of BM} + BS + V - S_2$$

(b) Angle of Depression:



Staff intercept S = (S_3 – S_1)

Staff intercept perpendicular to Line of Sight = S cosθ

Tacheometry equation

$$L = kS\cos\theta + C$$

Horizontal distance (D)

$$D = L\cos\theta$$

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

Depression (V)

$$V = L\sin\theta$$

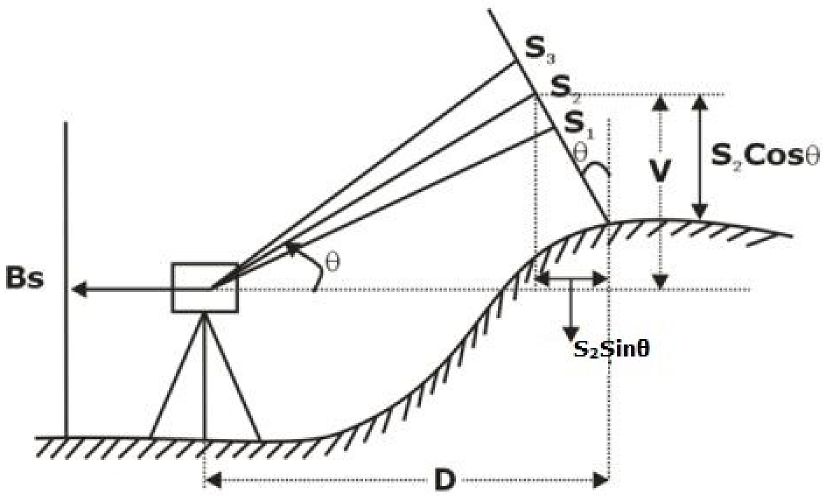
$$V = \frac{1}{2}KS\sin 2\theta + C\sin\theta$$

And,

$$\text{RL of B} = \text{RL of BM} + BS - V - S_2$$

Case 2: When staff kept normal to Line of Sight

(a) Angle of elevation:



Staff intercept perpendicular to Line of Sight (S) = (S_3 –S_1)

Tacheometry equation

$$L = KS + C$$

Horizontal distance (H)

$$D = L \cos\theta + S_2 \sin\theta$$

$$D = (KS + C) \cos\theta + S_2 \sin\theta$$

Elevation (V)

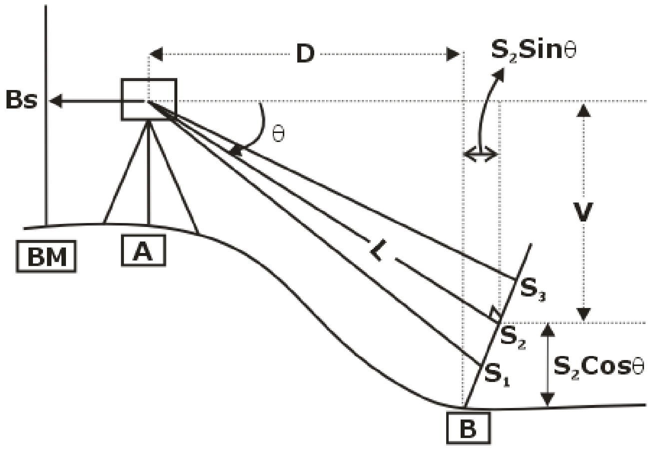
$$V = L \sin\theta$$

$$V = (KS + C)\sin\theta$$

And,

$$\text{RL of B} = \text{RL of BM} + BS + V - S_2 \cos\theta$$

(b) Angle of Depression:



Staff intercept perpendicular to Line of Sight (S) = ($S_3 - S_1$)

Tacheometry equation

$$L = KS + C$$

Horizontal distance (D)

$$D = L \cos\theta + S_2 \sin\theta$$

$$D = (KS + C) \cos\theta + S_2 \sin\theta$$

Depression (V)

$$V = L \sin\theta$$

$$V = (KS + C) \sin\theta$$

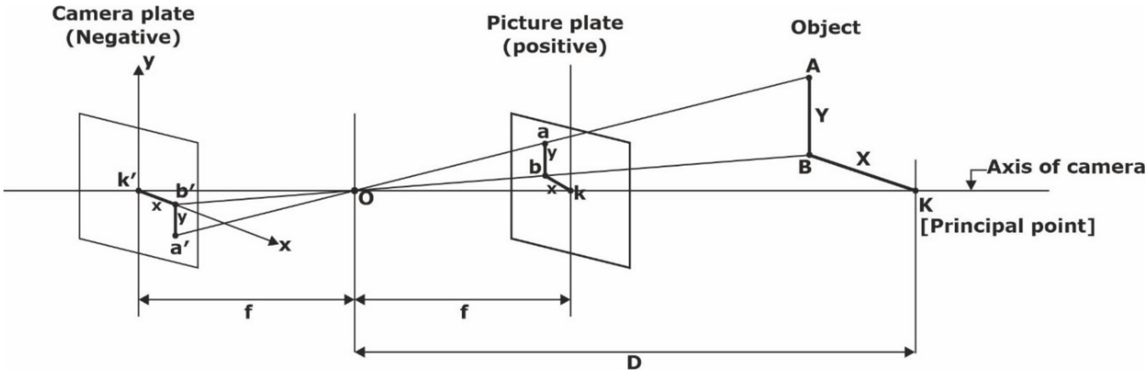
And,

$$\text{RL of B} = \text{RL of BM} + BS - V - S_2 \cos\theta$$

CHAPTER-7-PHOTOGRAMMETRY

1. **INTRODUCTION:** Photogrammetry is the practice of determining the geometric properties of objects from photographic images. Photogrammetry is called horizontal when camera axis is horizontal and if the camera axis is vertical then it is called vertical photogrammetry.

2. **HORIZONTAL PHOTOGRAMMETRY**



Let an object AB be photographed by a camera of focal length *f* at a distance of *D* from the camera.

from Δ Obk and Δ OBK

$$\frac{kb}{KB} = \frac{Ok}{OK} = \frac{Ob}{OB}$$

$$\frac{x}{X} = \frac{f}{D} = \frac{ob}{OB} \quad \text{... (1)}$$

from Δ Oab and Δ OAB

$$\frac{ab}{AB} = \frac{ob}{OB}$$

$$\frac{y}{Y} = \frac{ob}{OB} \quad \text{... (2)}$$

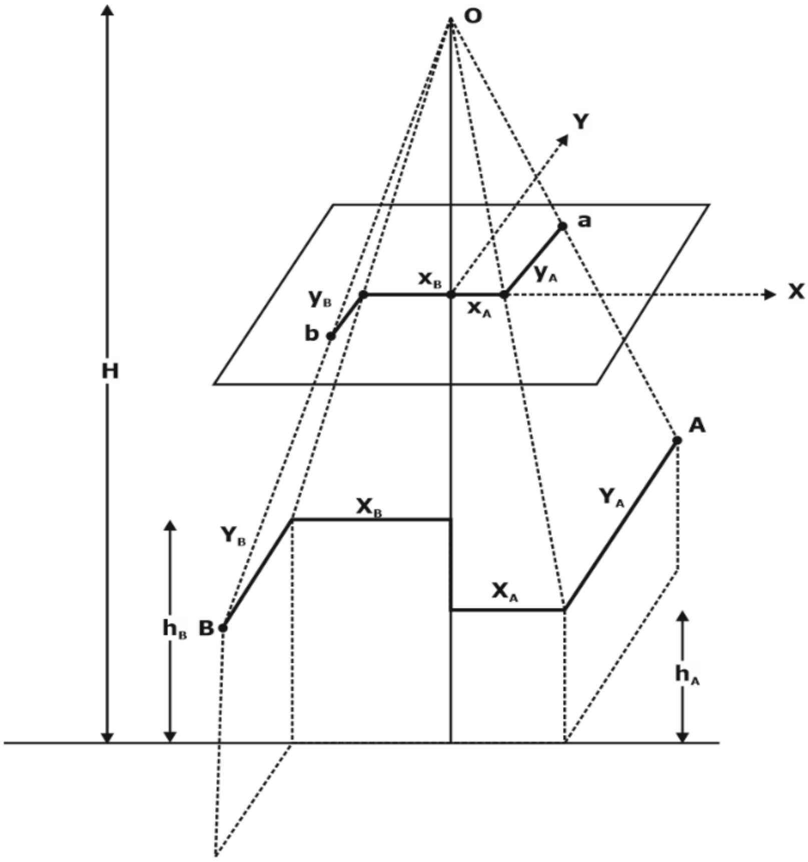
From equation (1) and (2), we get

$$\frac{x}{X} = \frac{y}{Y} = \frac{f}{D}$$

As we know, $Scale\ of\ photograph = \frac{Photo\ distane}{Ground\ distance}$

⇒ Scale of horizontal photograph, S = $\frac{x}{X} = \frac{y}{Y} = \frac{f}{D}$

3. HORIZONTAL DISTANCE BETWEEN TWO POINTS



(i) For point A

$$Scale = \frac{x_A}{X_A} = \frac{y_A}{Y_A} = \frac{f}{(H - h_A)}$$

$$\Rightarrow X_A = \left[\frac{(H-h_A)}{f} \times x_A\right] \text{ and } Y_A = \left[\frac{(H-h_A)}{f} \times y_A\right]$$

Here,

f is the focal length, distance between O and picture plate.

X_A and Y_A are the horizontal distance at ground in a and y direction for point A.

x_A and y_A are the horizontal distance at photo in x and y direction for point A.

(ii) Similarly, for point B

$$Scale = \frac{x_B}{X_B} = \frac{y_B}{Y_B} = \frac{f}{H - h_B}$$

$$\Rightarrow X_B = \left[\left(\frac{H-h_B}{F}\right) \times x_B\right] \text{ and } Y_B = \left[\left(\frac{H-h_B}{F}\right) \times y_B\right]$$

∴ Horizontal distance between A and B = $\sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2}$

4. TYPES OF SCALE

(i) Average Scale: All the points of photograph are assumed to be having average elevation above mean sea level.

$$S_{avg} = \frac{x}{X} = \frac{y}{Y} = \frac{f}{H - h_{avg}}$$

(ii) Datum Scale: All the points of photograph are assumed to be projected on MSL (RL=0)

$$S_D = \frac{x}{X} = \frac{y}{Y} = \frac{f}{H}$$

5. IMPORTANT DEFINITIONS

(i) Exposure Station: Point in the atmosphere occupied by centre of camera lenses at the instant of photography.

(ii) Flying Height: Vertical distance between exposure station and mean sea level.

(iii) Flight Line: Line traced by exposure station in atmosphere (track of aircraft).

(iv) Photo Principal Plane: Point on photograph obtained by projecting camera axis to intersect at a point on photograph.

(v) Photo Nadir Point: Point on photograph obtained by dropping vertical line from camera centre.

(vi) Horizontal Point: Point of intersection of horizontal line through centre of lenses and principal line on photograph.

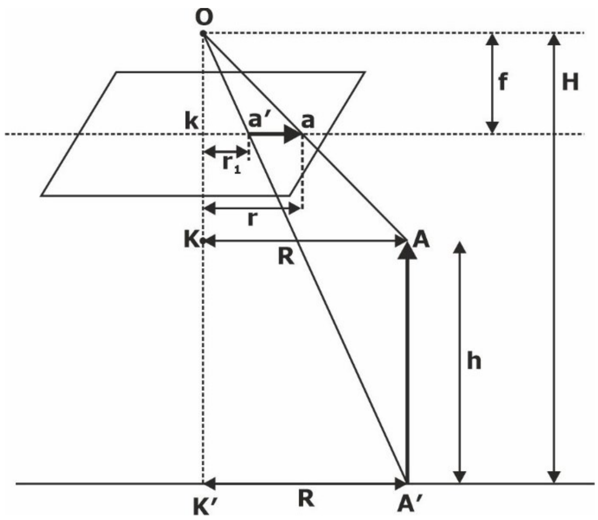
(viii) Azimuth: Clockwise horizontal angle measured about ground nadir point from true north to the principal plane of photograph.

(viii) Swing: Angle measured in plane of photograph from +Y axis clockwise to photo nadir point.

(ix) Iso Centre: Point on photo where bisection of tilt falls on photo.

6. RELIEF DISPLACEMENT:

Any displacement on photo plate which represents height of object on ground is known as relief displacement. It exists because photos are a perspective projection.



Relief displacement, $d = \frac{hr}{H}$

Here,

h = height of object

d = radial distance to top of object – radial distance to bottom of object

r = radial distance to top of object

H = height of flight as measured from the bottom of the object

If the average elevation of ground level is h_{avg} then relief displacement would be,

$$d = \frac{hr}{H - h_{avg}}$$

Here,

h = height of object

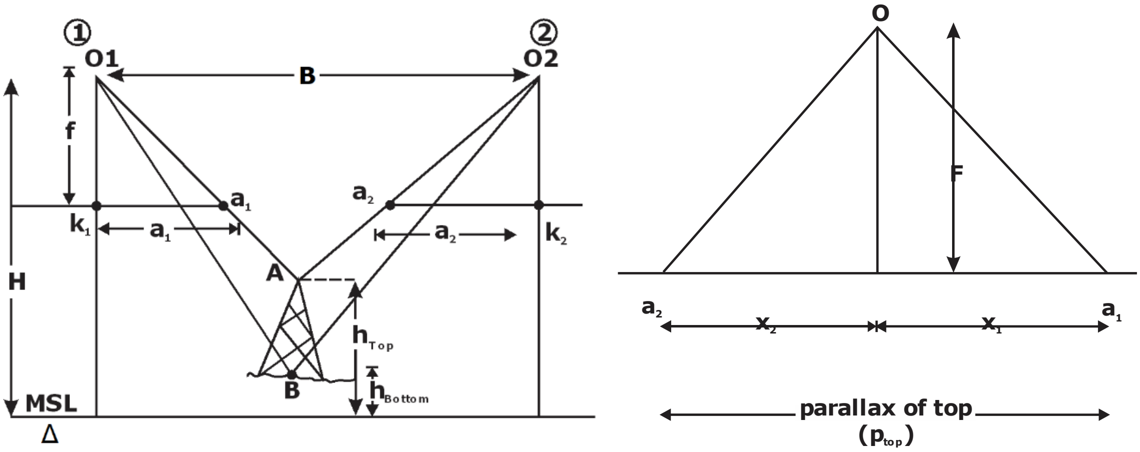
H = flying height

h_{avg} = elevation of ground level

r = distance of image of top from principle point of positive plate.

7. PARALLAX: Parallax is the displacement of two images in successive photographs.

The same tower AB is photographed from two positions, O_1 and O_2. The camera positions are at a distance B apart from each other.



From Δoa_1a_2 and ΔAO_1O_2,

$$\frac{p_{top}}{F} = \frac{B}{H - h_{top}}$$

Or parallax for top, $p_{top} = \frac{BF}{H - h_{top}}$

Similarly, parallax for bottom, $p_{Bottom} = \frac{BF}{H - h_{Bottom}}$

Here, B = length of air base, F = focal length of camera

h_{top} = elevation of tower top, h_{Bottom} = elevation of tower bottom

H = flying height

8. OVERLAP IN THE PHOTOGRAPHS

Longitudinal overlap = 55 to 65%

Lateral Overlap = 15 to 35%

for maximum rectangular area, to be covered by one photograph, the rectangle should have the dimension in the flight to be one-half the dimension normal to the direction of flight. W = 2B

9. INTERVAL BETWEEN EXPOSURES

T = (3.6L)/V

T= time interval between exposures in sec.

V= ground speed of airplane KMPH.

L= ground distance covered by each photograph in the direction of flight in meters.

10. NUMBER OF PHOTOGRAPH TO COVER A GIVEN AREA

$$N = \frac{A}{a}$$

A = Total area to be photographed

a = net ground area covered by each photography

N = number of photographs required.

a = L × W

L = (1 – P_L).S.l

W = (1 – P_W).s.w

a = l.w.S^2 (1 – P_L)*(1 – Pw)

Where, l = length of photograph in direction of flight

w = width of photograph

P_L = % overlap in longitudinal direction

P_W = % overlap in transverse direction

S = Scale of Photograph = $\frac{H}{f}$

- If instead of total area A, the rectangular dimensions L1 × L2 (Parallel and Transverse to flight) are given then, the number of photographs required are given as follows.

  N = N1 × N2

  $$N_1 = \frac{L_1}{(1-P_l)s \times l} + 1 \text{ , } N_2 = \frac{L_2}{(1-P_w)s.w} + 1$$

Let L1 = Dimension of area parallel to the direction flight

L2 = Dimension of area Transverse the direction of flight

N1 = Number of Photographs in each strip

N2 = Number of strips required.

N = Total number of photographs to cover the whole area.

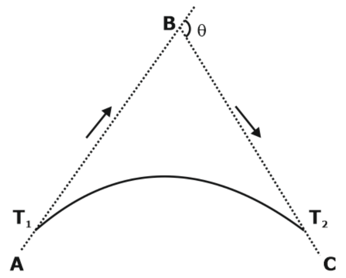
11. CRAB AND DRIFT

Crab: If the line of photographs is not parallel to fight line, the phenomenon is known as crab. At the instant of exposure, the focal plane of the camera is not square with the line of flight. Crabbing should be eliminated by rotating the camera axis since it reduces the effective coverage of photographs.

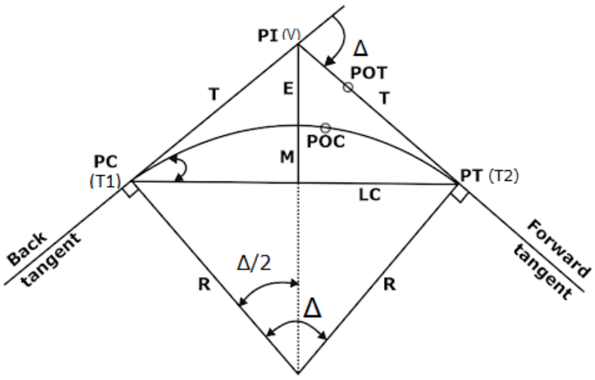
Drift: When aircraft is swayed away from its pre-planned flight line then it is known as drift. In case of excessive drifting, refights may need to be made due to gaps in camera coverage.

CHAPTER-8-CURVES

1. INTRODUCTION: The purpose of the curve is to gradually negotiate the change in direction of the two intersecting straight lines.



2. TERMINOLOGY USED IN SIMPLE CIRCULAR CURVES



Point of curve (PC): It is the beginning point where alignment changes from straight line to a curve.

Back tangent: It is the straight line at the beginning of curve tangent to the point of curve.

Point of Tangency (PT): It is the end point where alignment changes from a curve to tangent.

Forward Tangent: It is the straight line at the end of curve tangent to the point of tangency.

Point of Intersection (PI): The point where back and forward tangent intersects when produced is called Point of intersection.

Tangent Length (T): It is the distance from PC to PI or PI to PT.

Deflection Angle (Δ): It is the angle between the back tangent when produced and forward tangent.

Radius of Curvature (R): It is the radius of curve.

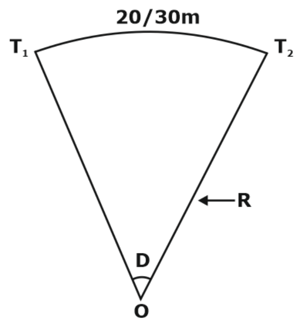
Long Chord (LC): It is the straight-line joining point of curve to point of tangency.

Length of curve (L): It is the total length of curve from PC to PT.

Mid Ordinate (M): It is the ordinate from mid-point of long chord to mid-point of curve.

Apex/ External Distance (E): The distance between POI and apex of curve is known as external distance.

3. DESIGNATION OF A CURVE: A curve is designated by either radius of curve or degree of curve. The degree of a curve is the angle subtended at the centre by a chord or arc of specified length.



For 20m arc length

$$R = 20 \times \frac{360}{2\pi D} = \frac{1146}{D}$$

For 30 m arc length

$$R = 30 \times \frac{360}{2\pi D} = \frac{1719}{D}$$

4. ELEMENTS OF SIMPLE CIRCULAR CURVE

Formulas to calculate various elements of circular curve are as under:

(i) Tangent Length: $T = R\tan\left(\frac{\Delta}{2}\right)$

(ii) Length of curve: $L = R \times \Delta \times \frac{\pi}{180}$

(iii) Length of Long Chord: $LC = 2R\sin\left(\frac{\Delta}{2}\right)$

(iv) Mid ordinate: $M = R\left(1 - \cos\frac{\Delta}{2}\right)$

(v) Apex/External distance: $E = R\left(\sec\frac{\Delta}{2} - 1\right)$

(vi) Chainage:

(a) Chainage at PC = Chainage at PI – length of tangent

(b) Chainage at PT = Chainage at PC + length of curve

(c) Chainage at apex point = Chainage of PC + Half the curve length

(vii) Intermediate chord length: All intermediate chords are normal chord except the first and last chord. The tangent points (point of curve and point of tangency) will not be full station i.e. the chainage will not be multiple of full chains. The distance between PC and first peg will be less than normal chord known as sub chord. Same case will be for the distance between last peg and PT.

(a) Length of First chord:

$$C_1 = \left[\begin{pmatrix}\text{Multiple of chain length}\\ \text{just greater then}\\ \text{chainge at } T_1\end{pmatrix} - \text{Chainage at } T_1\right]$$

(b) Length of Last chord:

$$C_n = \left[\text{Chainage at } T_2 - \begin{pmatrix}\text{Multiple of chain length}\\ \text{just less then}\\ \text{chainge at } T_2\end{pmatrix}\right]$$

(c) Number of intermediate (normal) chord:

$$n = \left[\left(\frac{L - C_1 - C_n}{Chain\ length}\right)\right]$$

(d) All other chords:

$$C_2 = C_3 = ------- = C_{n-1} = 1 \text{ chain length.}$$

5. SETTING OUT OF SIMPLE CIRCULAR CURVE

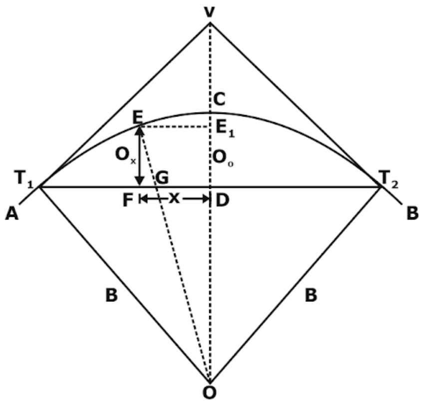
6.1 Linear Method

Linear method makes use of chain or tape only for setting of curves. Following are the methods available:

(i) Offset from the long chord

$$O_o = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

$$O_x = \sqrt{(R^2 - x^2)} - (R - O_0)$$

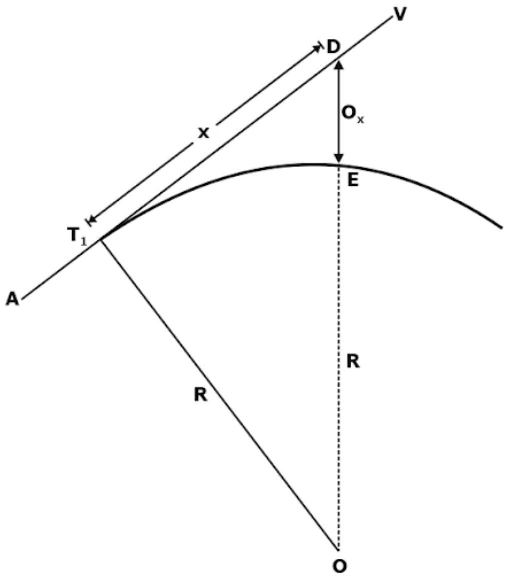


(ii) Radial offset method

$$\Rightarrow O_x = \sqrt{(R^2 + x^2)} - R \ldots\ldots\text{(exact)}$$

Approximately,

$$O_x = \frac{x^2}{2R}$$

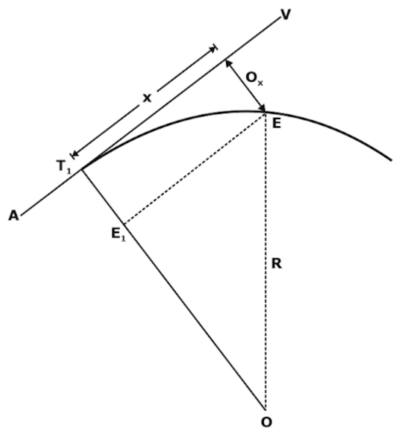


(iii) Perpendicular offsets method

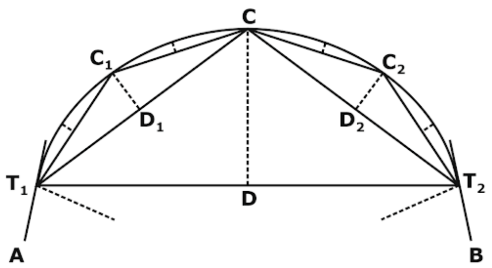
$$\Rightarrow O_x = R - \sqrt{(R^2 - x^2)} \text{ ….. (exact)}$$

Approximately,

$$O_x = \frac{x^2}{2R}$$

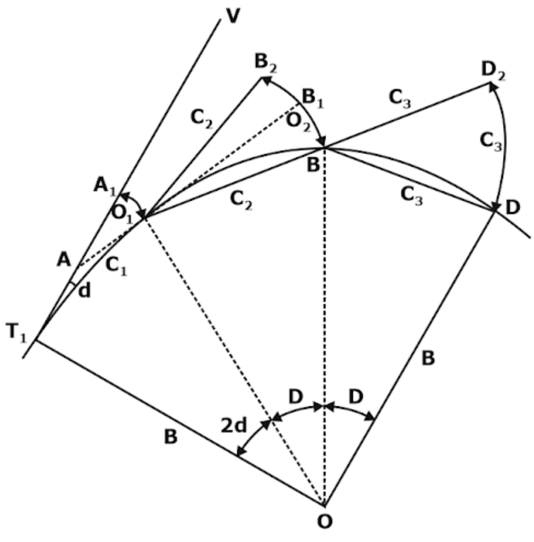


(iv) Successive Bisection of Arcs: Join the tangent point T_1 and T_2 and bisect the long chord at D. Erect the perpendicular DC. Join T_1C and T_2C and bisect them at D_1 and D_2 respectively. At D_1 and D_2, set out perpendicular offsets C_1D_1 $=C_2D_2= R\left(1 - cos\ \frac{\emptyset}{4}\right)$ to get points C_1 and C_2 on the curve. More points can be obtained by successful bisection of chords.



(v) Offsets from the chord produced

This method is very useful for long curves generally used on highway curves when theodolite is not available.



Since T_1V is the tangent to the circle at T_1

$$\angle T_1OA = 2\angle A_1T_1A = 2\delta$$

$$T_1A = R \times 2\delta$$

$$\Rightarrow \delta = \frac{T_1A}{2R}$$

Now,

$$arc\ A_1A = O_1 = T_1A \times \delta$$

Substituting the value of δ, we get

$$A_1A = \frac{T_1A^2}{2R}$$

Taking Arc T_1A = chord T_1A, we get

$$O_1 = \frac{C_1^2}{2R}$$

In the similar manner, all other offsets can be obtained. They will be given as

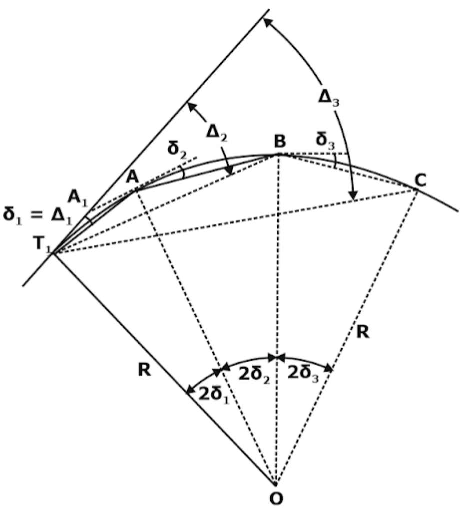
$$O_2 = \frac{C_2}{2R}(C_1 + C_2)$$

$$O_n = \frac{C_n}{2R}(C_{n-1} + C_n)$$

6.2 Angular Methods

These methods make use of angle measuring instruments such as theodolite with or without use of distance measuring instruments. Following are the angular methods.

(i) Rankine Method of deflection Angles



A deflection angle at any point is the angle at P.C. between the back tangent and the chord from P.C. to that point. Rankine method is based on the principle that the deflection angle to any point on a circular curve is equal to one half the angle subtended by the arc from P.C. to that point.

From the property of circle,

$$\angle VT_1A = \frac{1}{2}\angle T_1OA$$

$$\Rightarrow \angle T_1OA = 2\angle VT_1A = 2\delta_1$$

Now,

$$\frac{\angle T_1OA}{C_1} = \frac{180°}{\pi R}$$

$$\angle T_1OA = 2\delta_1 = \frac{180°C_1}{\pi R}$$

$$\Rightarrow \delta_1 = \frac{90°C_1}{\pi R}$$

For the first chord T_1A, the deflection angle = its tangential angle

$$\Delta_1 = \delta_1$$

For the second point B,

$$\Delta_2 = \angle VT_1B = \angle A_1T_1A + \angle AT_1B$$

$$\Rightarrow \Delta_2 = \delta_1 + \delta_2 = \Delta_1 + \delta_2$$

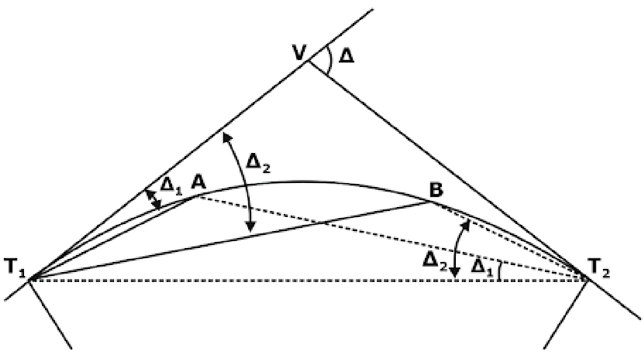
Similarly,

$$\Delta_3 = \Delta_2 + \delta_3$$

$$\Delta_n = \Delta_{n-1} + \delta_n$$

(ii) Two Theodolite Method

In this method two theodolite are used one at P.C. and other at P.T. This method is based on the principle that the angle between the tangent and the chord is equal to the angle which the chord subtends in the opposite segment.



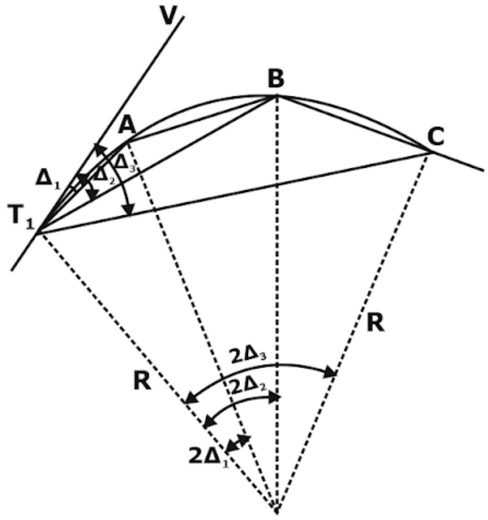
$\angle VT_1A = \Delta_1$ = Deflection angle for A

But $\angle AT_2T_1$ is the angle subtended by the chord T_1A in the opposite segment.

$$\angle AT_2T_1 = \angle VT_1A = \Delta_1$$

Similarly, $\angle VT_1B = \angle T_1T_2B = \Delta_2$

(iii) Tacheometric Method



In this method, a point on the curve is fixed by the deflection angle from the rear tangent and measuring tacheometrically, the distance of that point from T_1.

$$T_1A = L_1 = 2R\, sin\, sin\, \Delta_1$$

$$T_1B = L_2 = 2R\, sin\, sin\, \Delta_2$$

$$T_1T_2 = L_n = 2R\, sin\, sin\, \Delta_n = \ 2R\, sin\, sin\, \frac{\Delta}{2} = L$$

Knowing the lengths, staff intercepts can be calculated.

5. TRANSITION CURVE:

- When a vehicle moves on a curve, a centrifugal force acts on it. Thus, sudden transition from a straight path to a circular curve of radius R will introduce the centrifugal force suddenly. Hence a sudden lateral shock will be felt by the passengers. To avoid this, we introduce a curve of varying radius between straight path circular curve such that the radius changes from infinity (i.e. straight line) to a radius R of circular curve. Thus, curve of varying radius is called transitions curve.
- For a transition curve L.R=constant, ideal transition curve are clothoid, the glover spiral or Euler spiral. For ease of setting out we use cubic spiral, however nowadays with electronic instruments even cubic spiral or clothoid can also be set up easily.

Insertion of Transition Curve

- When transition curves are introduced between the tangents and a circular curve of radius R, the circular curve is 'shifted' inwards from its original position by an amount AB = S (the shift) as shown in the above figure such that the curve can meet tangentially.
- This is equivalent to have a circular curve of radius (R+S) connecting the tangents replaced by two transition curves and a circular curve of radius R, although the tangent points are not the same, being A and B.

The amount of shift S = $\frac{L^2}{24R}$ and TC = CD $= \frac{L}{2}$

Setting out transition Curve

To locate the tangent point T:

1. Calculate the shift S from the expression below

$$S = \frac{L^2}{24R}$$

2. Calculate VA = (R + S) $\tan\frac{\Delta}{2}$

3. Since TA = $\frac{L}{2}$

$$\text{Then VT} = (R+S)\tan\frac{\Delta}{2} + \frac{L}{2}$$

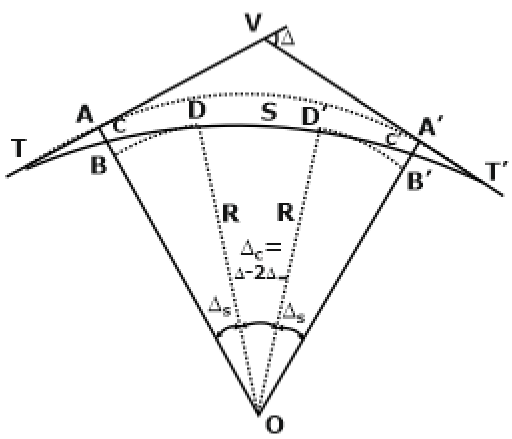
Measure this length back from V and mark/set the point T.

The next step depends on whether it is intended to set out the transition with tapes using the cubic spiral or cubic parabola, or by the theodolite using the cubic spiral.

4. Either calculate offsets from

$$x = \frac{l^3}{6LR} \quad \text{or} \quad x = \frac{y^3}{6LR}$$

Each peg is located by swinging a chord length from the preceding peg.



CHAPTER-9-THEORY OF ERRORS

1. INTRODUCTION

Errors in the surveying may be of three types:

(i) Gross Error/ Mistakes

(ii) Systematic Error/ Cumulative Error

(iii) Random Error/ Compensating Error

Gross errors are not the errors but results of mistakes that are due to the carelessness of observer.

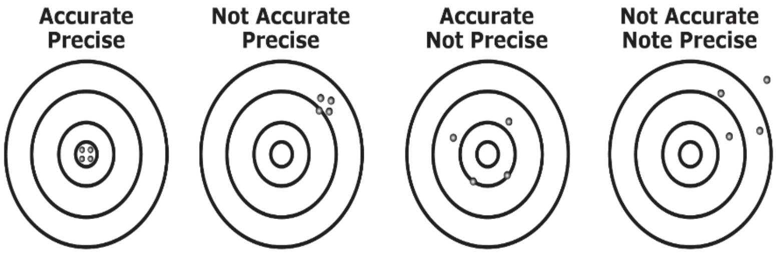
Systematic errors follow some pattern and can be expressed by functional relationship based on some deterministic system. Like the gross errors, the systematic errors must also be removed from the measurement by applying necessary corrections.

After all mistake and systematic errors have been detected and removed from the measurements, there will still be some errors in the measurements called the random errors or accidental errors. The random errors are treated using probability models.

2. PRECISION AND ACCURACY:

Precision: degree of fineness of care with which any physical measurement is done. Précised value represents set of observation that are closely grouped and have small deviation from the true value.

Accuracy: degree of perfection. A value is said to be accurate if it is close to the true value.



3. BASIC DEFINITIONS

(i) Observed Value: Observed value is the value derived from an observation after correcting from all the errors.

(ii) True Value: The true value of a quantity is the value of quantity which is free from all errors.

(iii) Most probable value: The most probable value of a quantity is the value which has maximum chances of being true value.

(iv) Standard Deviation: Standard deviation also called the root-means square (R.M.S) error, is a measure of spread of a distribution and for the population, assuming the observations are of equal reliability it is expressed as

$$\sigma_{n-1} = \sqrt{\left[\frac{\sum(\bar{x}-x)^2}{(n-1)}\right]}$$

(v) Variance: It is used as a measure of dispersion or spread of a distribution. It is equal to square of standard deviation. Mathematically,

$$V = \left[\frac{\sum(\bar{x} - x)^2}{(n-1)}\right] = \sigma^2$$

(vi) True Error: It is the difference between true value and observed value of a quantity.

(vii) Residual Error: It is the difference between the most probable value and observed value of a quantity.

v = Most Probable Value – Observed Value

(viii) Standard Error of mean: The standard error of mean σ_m is given by

$$\sigma_m = \pm\sqrt{\left[\frac{\Sigma v^2}{n(n-1)}\right]}$$

$$= \pm\frac{\sigma}{\sqrt{n}}$$

(ix) Most Probable Error: The most probable error is defined as the error for which there are 50% chances of the true error will be less than the probable error and 50% chances that true error will be more than the probable error. The most probable error is given by

$$e = \pm 0.6745\sqrt{\frac{\Sigma v^2}{(n-1)}} \qquad \Rightarrow e = \pm 0.6745\sigma$$

(x) Most Probable Error of Mean: It is given by, $e_m = \pm\frac{e}{\sqrt{n}}$

(xi) Confidence Limits: The range of values within which true value should lie is called confidence interval and its bounds are called the confidence limits.

(xii) Maximum error: it is not possible to exactly estimate the maximum error, as the probability distribution extends to infinity. But the value corresponding to 99.9% error is assumed to be maximum error in surveying. It corresponds to $\pm 3.29\sigma$.

(xiii) Different percentage error:

- 90% error (E_{90}) corresponds to $\pm 1.645\sigma$
- 95% error (E_{95}) corresponds to $\pm 1.96\sigma$
- 68.3% error ($E_{68.3}$) corresponds to $\pm 1.0\sigma$
- 95.5% error ($E_{95.5}$) corresponds to $\pm 2.0\sigma$
- 99.7% error ($E_{99.7}$) corresponds to $\pm 3.0\sigma$

(xiv) Weights: The weight of a quantity is measure of its relative trust worthiness of the set of observations. In other words, weight indicates the relative precision of a quantity within a set of observations. The greater the precision of an observation, the greater will be its weight. The weights are always expressed in numbers. The greater number indicates higher precision and trust in comparison to the lower number.

Allocation of weights:

- The weights are assigned depending upon the degree of precision. The weights are takes inversely proportional to the variance or square of standard errors (or probable errors). In other words, "For an observation repeated a great number of times, the weight is inversely proportional to the square of the probable error".

- The weights of the quantities measured in similar conditions are assigned in direct proportion to the number of times (n) the quantity measured. For example, if an angle A is measured four times, it will have a weight of 4 in comparison to another angle B which is measured only once.
- The weights are sometimes allocated by personal judgment depending on the field prevailing and environmental conditions. The lower weight is allocated to the observations made in difficult terrain under varying environmental conditions of temperature, winds, humidity, etc. Whereas the observation made on a level terrain under stable conditions is given greater weight.
- The weight of a level line is taken as inversely proportional to the length (L) of the route.

For observations having unequal weight:

- Standard deviation of weighted observation $\sigma_{n-1} = \pm\sqrt{\frac{\sum w_i v_i^2}{(n-1)}}$
- Most Probable error of single observation of weight w_i = $\pm 0.6745\sqrt{\frac{\sum wv^2}{w_i(n-1)}}$
- Most Probable error of weighted arithmetic mean = $\pm 0.6745\sqrt{\frac{\sum wv^2}{\sum w \times (n-1)}}$

3. LAWS OF WEIGHTS

(i) The weight of arithmetic mean of a number of observations of equal weight is equal to the number of observations.

(ii) The weight of weighted arithmetic mean of observation is equal to sum of weight of the observations.

(iii) The weight of algebraic sum of two or more quantities is equal to the reciprocal of the sum of the reciprocal of individual weights.

If measurement 'x_1' taken with weight 'w_1' and 'x_2' taken with 'w_2' are added or subtracted then

Function	**Result [s]**	**Weight of Result [w]**
Addition	$[x_1 + x_2]$	$\frac{1}{\frac{1}{w_1} + \frac{1}{w_2}}$
Subtraction	$[x_1 - x_2]$ Or $[x_2 - x_1]$	$\frac{1}{\frac{1}{w_1} + \frac{1}{w_2}}$

(iv) If measurement 'x_1' taken with weight 'w_1' is multiplied /divided by a constant 'k', then

Function	**Result [s]**	**Weight of Result [w]**
Multiplication	$k.x_1$	$\frac{w_1}{k^2}$
Division	$\frac{x_1}{k}$	$w_1.k^2$

(v) If an equation is multiplied by its own weight, the weight of the resulting quantity is the reciprocal of the weight of the equation.

(vi) The weight of an equation remains the same if the signs of all the terms of the equation are changed or the equation is added to or subtracted from a constant.

4. PROBABLE ERROR IN COMPUTED QUANTITY

The probable error in computed quantities follows the following laws depending upon the relation between the computed quantity and observed quantity.

(i) If the computed quantity is equal to sum or difference of the observed quantity plus/minus a constant, the probable error of the computed quantity is the same as of the observed quantity.

Let, x = observed quantity, y = computed quantity, c = constant

such that $y = \pm x \pm c$

Then, $e_y = e_x$

(ii) If a computed quantity is equal to an observed quantity multiplied by a constant, then the probable error of computed quantity is equal to the probable error of observed quantity multiplied by the constant.

x = observed quantity, y = computed quantity, k = constant

such that, $y = kx$

Then, $e_y = ke_x$

(iii) If the computed quantity is equal to algebraic sum of two or more quantities, then the probable error of computed quantity is equal to the square root of sum of square of the probable error of observed quantities.

Let, x_1, x_2, x_3.... are observed quantities and $y = x_1 \pm x_2 \pm x_3$....

Then, $e_y = \sqrt{e_{x1}^2 + e_{x2}^2 + e_{x3}^2 + \cdots}$

(iv) If the computed quantity is a function of observed quantity, its probable error is obtained by multiplying the probable error of the observed quantity with its differentiation with respect to that quantity.

Let, x = observed quantity, y = computed quantity

Such that $y = f(x)$

Then, $e_y = \frac{dy}{dx} e_x$

(v) If the computed quantity is a function of two or more observed quantities, its probable error is equal to the square root of summation of the squares of the probable error of the observed quantities multiplied by its differentiation with respect to that quantity.

Let, x_1, x_2, x_3…. are observed quantities and $y = f(x_1, x_2, x_3…)$

Then, $$e_y = \sqrt{\left(e_{x1}\frac{dy}{dx_1}\right)^2 + \left(e_{x2}\frac{dy}{dx_2}\right)^2 + \left(e_{x3}\frac{dy}{dx_3}\right)^2}$$

5. DISTRIBUTION OF ERROR OF THE FIELD MEASUREMENTS

Whenever observations are made in field, a check for closing error is necessary. The closing error is distributed to the observed angles as per following rules:

(i) The correction to be applied is inversely proportional to the weight of the observation.

(ii) The correction to be applied to an observation is directly proportional to the square of probable error.

(iii) The correction to be applied is proportional to length of line.

6. PRINCIPLE OF LEAST SQUARES

This principle states that the most probable value of a quantity evaluated from a number of observations of equal weight is the one for which the sum of square of residual error (Σv^2) is minimum. And if the observations are of unequal weight, then most probable value is the one for which the sum of product of weight and square of residual error i.e., $\Sigma(wv^2)$ is a minimum value.

Normal Equation Method: This method is used to find out most probable value of an indirectly observed quantity. A normal equation is a conditional equation from which MPV of any one quantity can be determined by assigning a particular set of values to the remaining quantities. The rules for formation of normal equation are as follows:

Rule 1: If observations are of equal weight, then to form a normal equation for each of the unknown quantities, multiply each observation equation by the algebraic coefficient of that unknown quantity in that equation, and add the results.

Rule 2: If observations are of unequal weight, then to form a normal equation for each of the unknown quantities, multiply each observation equation by the product of the algebraic coefficient of that unknown quantity in that equation and the weight of that observation and add the result.

CHAPTER-10-PLANE TABLE

1. **PLANE TABLE SURVEYING:** Plane table surveying is a graphical method of surveying in which the field observations and plotting are done simultaneously. It is simpler and cheaper than theodolite survey. It is suitable for small scale maps.

2. **Advantages**
   - There is no possibility of omitting the necessary measurements.
   - Surveyor can compare the plotted work with actual features of the area.
   - Simpler and cheaper than theodolite survey.
   - It is most suitable for large scale maps.
   - No great skill is required.
   - It is useful in magnetic areas where compass may not be used.

3 **Disadvantages**
   - It is not very accurate.
   - It is not suitable in monsoon.
   - Equipment is inconvenient to transport.

4. **Instruments Required**
   - **Alidade:** Alidade is useful for establishing a line of sight, nowadays telescopic alidade is also used, when points too high or low are to be sighted, the range and accuracy are considerably increased by providing a telescope.
   - **Drawing board:** It is made from well-seasoned wood. Normally, rectangular in shape with size 75 cm × 60 cm
   - **Plumbing fork:** It is used for centring.
   - **Spirit level:** It is used for ascertaining if the table is properly level.
   - **Trough compass:** it is required for drawing line showing magnetic meridian on the paper.

5. **Principle of Plane Table Surveying**

   All the rays drawn through various details should pass through the survey station.

   The direction of the plane table at each station must be identical i.e., at each survey station the table must be oriented in the direction of magnetic north.

6. **Temporary Adjustment of Plane Table**

   Following three distinct operations at each survey station are carried out for the temporary adjustments of a plane table.
   - **Centring:** This process ascertains the fact that the point on paper represents the station point on ground. Exact centring is required for large scale map only.
   - **Levelling:** For levelling the table, ordinary spirit level may be used.
   - **Orientation:** The process by which the position occupied by the board at various survey stations are kept parallel is known as the orientation.

7. Methods of Plane Tabling

There are four distinct method of plane tabling.

- Method of Radiation
- Method of Intersection
- Method of traversing
- Method of resection

8. Method of plane table orientation

- By trough compass: It cannot be used when local attraction is suspected.
- By back sighting: Most accurate method of orientation.
- Resection.

9. Resection: This method of orientation is employed when the plane table occupies a position not yet plotted on the drawing sheet.

Resection can be defined as the process of locating the instrument station occupied by the plane table by drawing rays from the stations whose positions are already plotted on the drawing sheet. The point representing the resection of two rays will be the station to be located, provided the orientation at the station to be plotted is correct, which is seldom achieved. This problem can be solved by any of the methods such as resection after orientation by back ray, by two points, or by three points. This method is employed when surveyor feels that some important details can be plotted easily by choosing any station other than the triangulation stations. The position of such a station is fixed on the drawing sheet by resection.

10. Errors in Plane Tabling

The various sources of error may be classified as:

- Instrumental errors
- Errors in manipulation and sighting
- Errors in plotting

CHAPTER-11- GPS, GIS & REMOTE SENSING

1. GLOBAL POSITIONING SYSTEM (GPS):

- GPS is a worldwide radio navigation system consisting of satellite, computers and receivers, operated by the US department of defence. A radio navigation system allows a user to determine her position in three dimensions as well as time. Such a system is run with the help of satellites launched for this purpose.
- The GPS is formed from 24 satellites, the satellites are positioned in six earth centred orbital plane with 4 satellite in each plane. Each satellite takes 12hr to complete one full orbit. GPS uses these satellites as a reference point to calculate positions accurately.
- The distance between a user and the satellites can be computed using the satellite signals. As there are four unknowns i.e., three unknowns of position in three-dimensional space and one unknown of time, for the accurate position of a point, we need a minimum of four satellites. The satellites have atomic clocks onboard to provide accurate times.
- GPS can be used for determining position, navigation, tracking, mapping and precise time determination.
- With handheld instruments and precise positioning available with the technology, GPS can be used to undertake survey work accurately for many purposes like establishing control points for geodetic work.

2. GEOGRAPHIC INFORMATION SYSTEM (GIS):

- GIS is a computer-based information system that enables, captures, manipulates, analyses and presents the geographical reference data.
- GIS is used for analysing and manipulating spatial data which can be used to help produce maps and other products in standardized formats. Such data can also be used for research activities.

3. REMOTE SENSING:

It is broadly defined as the science and art of collecting information about objects, area without being in physical contact with them. There are two types of remote sensing.

i) Passive Remote Sensing: In this type of remote sensing, the instrument, such as a camera, doesn’t generate or emit radiation. The source of the radiation is generally the sun and the reflected radiation from the object is used to determine its properties. A photographic camera, or a remote sensing satellite are examples of such systems.

ii) Active Remote Sensing: The sensing equipment emits radiation and the reflection coming back from the object is used to determine the properties of the object. Radar and sonar are types of active remote sensing systems.

3.1. Interaction of EM Radiation with Earth’s Surface

Electromagnetic energy that strikes or encounters matter is called as incident radiation. The Electromagnetic radiation striking may get :

(a) Reflected (scattered): The unpredictable diffusion of radiation by atmospheric particles.

(b) Absorbed: Atmospheric gases absorb incident radiation as per their characteristic absorption spectra. For example, oxygen absorbs in the ultraviolet spectrum.

(c) Transmitted: The electromagnetic waves that pass through the atmosphere undisturbed, without being affected.

It depends on various factors such as:

(a) Wavelength of radiation, (b) Angle of incidence, (c) Surface roughness, (d) Condition and composition of surface material

Incident energy = Transmitted + Absorbed + Reflected energy

$E_{I\lambda} = E_{T\lambda} + E_{A\lambda} + E_{R\lambda}$

$E_{R\lambda} = E_{I\lambda} - (E_{A\lambda} + E_{T\lambda})$

$$\frac{E_{R\lambda}}{E_{I\lambda}} = 1 - \left(\frac{E_{A\lambda}}{E_{I\lambda}} + \frac{E_{I\lambda}}{E_{I\lambda}}\right)$$

Reflectance = 1 – (transmittance + absorbance)

$\zeta = 1 - (\alpha - r)$

3.2. Remote Sensing Platforms

Two types of platforms have been in use in remote sensing.

(i) Air Borne Platforms: Aircrafts have been used as a remote sensing platform for obtaining photographic images. Multi spectral scanners, ocean colour radiometer, photography in various spectra can all be done with aircraft mounted sensors. While expensive, these systems provide flexibility in deployment and higher fidelity as compared to space-based platforms.

(ii) Space Based Platforms: Satellites offer a larger field of view, a systematic and repetitive coverage of an area. These attributes make space-based platforms immensely useful for monitoring natural resources.

4. ADVANTAGES OF REMOTE SENSING:

- Provides data of large areas
- Provides data of very remote and inaccessible regions
- Able to obtain imagery of any area over a continuous period of time through which the any anthropogenic or natural changes in the landscape can be analysed
- Relatively inexpensive when compared to employing a team of surveyors
- Easy and rapid collection of data
- Rapid production of maps for interpretation

5. DISADVANTAGES OF REMOTE SENSING:

- The interpretation of imagery requires a certain skill level.
- Needs cross verification with ground (field) survey data.
- Data from multiple sources may create confusion.
- Objects can be misclassified or confused.
- Distortions may occur in an image due to the relative motion of sensor and source.

6. APPLICATIONS OF REMOTES SENSING:

- Land use and land cover mapping
- Crop identification
- Flood plain mapping
- District level mapping
- Urban growth studies
- Ground water mapping
- Waste land mapping
- Disaster management: effect of earthquake, Tsunami etc.

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