# 1 Fundamentals of Surveying

Surveying is the method of making measurement of the relative positions of natural and man-made features on earth surface and the presentation of this information either graphically or numerically.

Both Plan and Map are the graphical representations of the features on horizontal plane but plan is a large scale representation while map is a small scale representation.

Basic classification of surveying

- Geodetic surveying
  Large area's of earth's surface involved and the curvature are of earth is taken into account.
- Plane surveying
  Relatively small area's are taken into consideration, and earth surface is assumed to be flat.

> **Note:** Geodetic surveying is done by Department of National Survey of India. It is done for fixing widely spaced control point, which may afterwards be used as necessary control points.

**Classification of Surveying Based on Purpose**

(*i*) **Topographical Survey:** Conducted to obtain data and to make a map indicating inequalities of land surface.

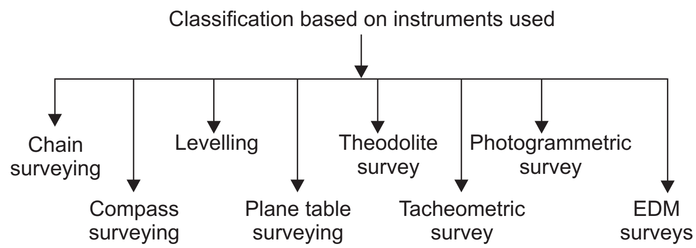
(*ii*) **Engineering Survey:** Used for design and construction of new routes e.g. roads and railways. Also used to calculate the area and volumes of land and data for setting out curves for route alignment.

(*iii*) **Cadastral Survey:** Done to produce plans of property boundries for legal purpose.

(*iv*) **Hydrographic Survey:** Conducted on or near water bodies. Marine survey is also one of it's type.

(*v*) **Astronomic Survey:** Conducted for determination of latitudes, longitudes, azimuths, local time etc. at various places on the earth by observing heavenly bodies.

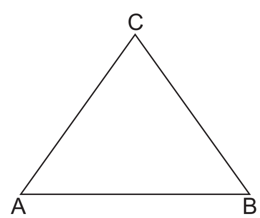
(*vi*) **Geological Surey:** Conducted to obtain data of different strata of earth's surface for the purpose of geological studies.



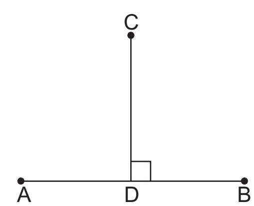

**Principles of Surveying**

(*i*) **Work from Whole to Part:** So as to localise the error and prevent their accumulation.

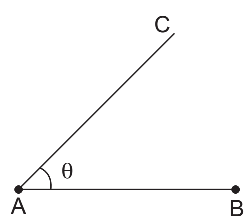
(*ii*) **Locate a Point by Atleast two Measurements:** Locating at point C.



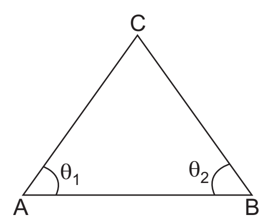

(*a*) By measuring *AC* and *BC*




(*b*) By measuring *CD* at right angle to *AB* while *AD* and *BD* is known.



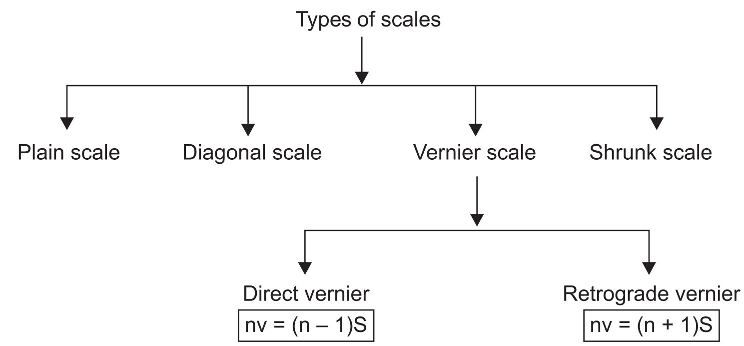

(*c*) By measuring AC and angle $\theta$




(*d*) By measuring $\theta_1$ and $\theta_2$

**Scale of a map:** It is the fixed ratio that every distance on the plan bears with corresponding distance on the ground.

$$\text{Representive fraction (RF)} = \frac{\text{Map distance}}{\text{Ground distance}}$$




(*i*) **Plain Scale:** Used to measure two dimensions only, like units and length.

(*ii*) **Diagonal Scale:** It is possible to measure in three dimensions such as meters, decimeter and centimeters; unit, tenth, hundreds.

(*iii*) (*a*) **Direct Vernier:** $(n - 1)$ divisions of main scale is equal to $n$ divisions of vernier scale. In this Vernier Scale moves in same direction as main scale.

(*b*) **Retrograde Vernier:** $(n + 1)$ divisions of main scale is equal to $n$ divisions of vernier scale. In this vernier scale moves in opposite direction to that of main scale

$$\boxed{\text{Least count of Vernier Scale} = \frac{s}{n}}$$

$S$ = Value of one smallest division of main scale

$n$ = no. of division on the vernier

$V$ = Value of one smallest division of Vernier Scale

(*iv*) **Shrunk Scale**

$$\boxed{\text{Shrunk scale} = \text{Original scale} \times \text{Shrinkage factor (SF)}}$$

$$\text{Shrinkage Ratio (SR) or (SF)} = \frac{\text{Shrunk length}}{\text{Original length}} = \frac{\text{Shrunk scale}}{\text{Original scale}} = \frac{\text{Shrunk RF}}{\text{Original RF}}$$

$$\text{Correct distance on map in case of original scale} = \frac{\text{Measured distance on Map}}{\text{Shrinkage Ratio}}$$

$$\text{Correct area on map in case of original scale} = \frac{\text{Measured distance on map using planimeter}}{(\text{Shrinkage Ratio})^2}$$

### Error due to use of Wrong Scale

(*i*) Correct length $= \dfrac{\text{RF of wrong scale}}{\text{RF of correct scale}} \times \text{Measured length}$

(*ii*) Correct area $= \left(\dfrac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right)^2 \times \text{Measured area}$

### Precision and Accuracy

Precision is the degree of fineness and care with which any physical measurement is made. It represents the set of observations that are closely grouped together and have small deviations from true value.

Accuracy is the degree of perfection obtained. For a set of measurements to be accurate, its value should be close to true value.

> **Note:** A good draughts man can plot a length to with in 0.25 mm.

### Mistakes and Error

Mistakes are caused by misunderstanding of the problem, carelessness or poor judgement and these can be corrected only if discovered.

Error's arise due to physical conditions of the instrument like temperature at the time of measurement and human eye's limitations.

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

Hence Correction = – Error

Error's

- **Systematic error**
  - ⇒ Arises from the source that act in a similar manner on observations.
  - ⇒ Cumulative in nature
  - ⇒ Also known as cumulative error and proportional to the length of line
- **Random error**
  - ⇒ Discrepancies remaining after the mistakes and systematic errors are removed.
  - ⇒ Positive and negative errors are equally likely
  - ⇒ Also known as compensating error and proportional to square root of the length.

# 2 Linear Measurement

Also known as chain surveying or tape or offset surveying. Chain surveying is suitable only for areas of small extent on open ground.

**Terms Used in Large Survey Area**

(*i*) Main station: It is a point in chain survey where two triangle sides meet.

(*ii*) Main survey line: Chain line joining two main survey stations.

(*iii*) Tie station or subsidiary station: Station on survey line joining main stations.

(*iv*) Base line: Longest survey line from which direction of all other survey lines are fixed.

(*v*) Proof line or check line: Provided to check the accuracy of the field work.

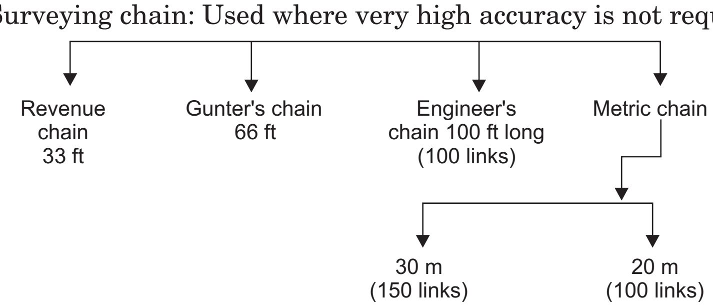
(*vi*) Offset: Distance of object from the survey line.

(*vii*) Chainage: Distance measured along the main survey line in direction of progress of work.

**Well Conditioned Triangle:** Triangle in which all intersections of lines are clear. Angle's between the lines for clear intersections should be 30˚ to 120˚. An **equilateral triangle** is the most appropriate well conditioned triangle.

**Equipments Used for Measuring Lines**

(*i*) Surveying chain: Used where very high accuracy is not required.




> **Note:** As per IS specifications, every metre length of the chain should individually be accurate to within ± 2mm when measured under a tension of 80 Newton.

(*ii*) Tapes:

- Cloth or Linen tape
- Metallic tape: Linen tape with brass or copper wires
- Steel tape
- Invar tape: Alloy of nickle (36%) and steel (64%)

(*iii*) Pegs: To mark definite points on ground temporarily.

(*iv*) Arrows: It provides a check over the length of line as entered in the field notes.

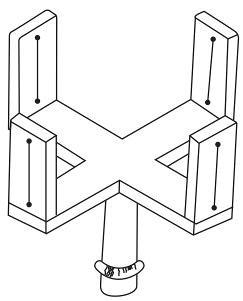
(*v*) Ranging rods: To locate intermediate points such that these points lie on straight lines joining the end stations.

(*vi*) Offset rod: Similar to ranging rod with a sout open hook at the top.

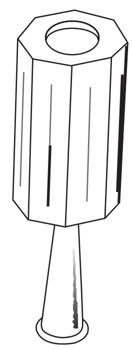
**Equipments for Measurement Right angles**

(*i*) Cross staff

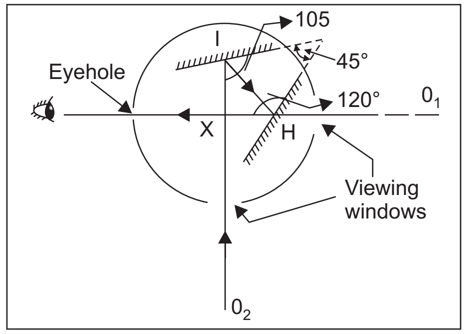
- Open cross staff
- French cross staff



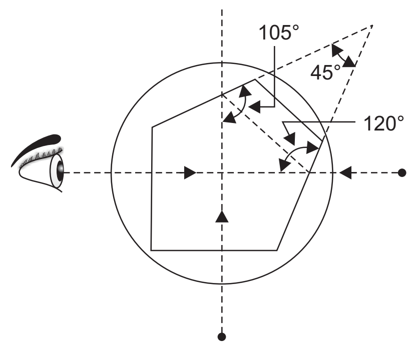
Open cross staff



(*ii*) Optical Square: Pocket instrument, more convenient and accurate than a cross staff.

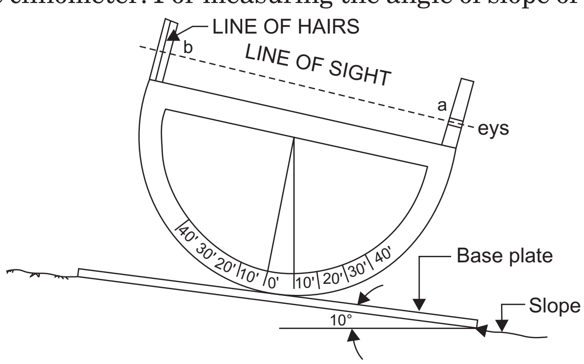



(*iii*) Prism Square: It has two reflecting surfaces fixed at 45°. No adjustment is required in it.



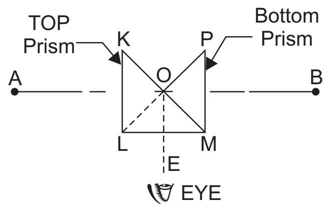

## Equipment for Measuring Ground Slope

(*i*) Simple clinometer: For measuring the angle of slope of the ground.



### Equipments for Establishing Intermediate points

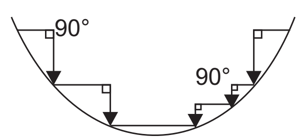
- Direct ranging with line ranger
  Two right angled isosceles triangles placed one above other
- Ranging or ranging out
  - Direct ranging
  - Indirect ranging
  - Random line method

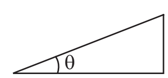



Plan of line ranger

### Linear Measurement with Chain

- **On smooth level ground** with chain, pegs and arrows after establishing intermediate points
- **On sloping ground**
  - Stepping
  - Along slope by Abney level




### Correction in Chain Measurement

(*i*) **Standardisation Correction**

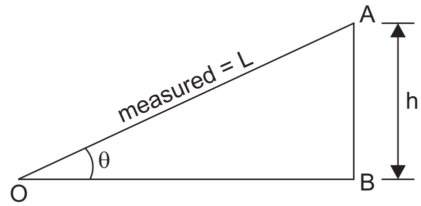
$$\text{Correct length} = \text{Actual length of chain} \times \frac{\text{Length reported to be measured}}{\text{Nominal length of chain}}$$

Correction = True length – measured length

(*ii*) **Slope Correction**

(*a*) when slope θ is measured

Correction $= L \cos\theta - L \Rightarrow -L\,(1 - \cos\theta)$




To be calculated = L cos θ

(*b*) When *AB* is measured

$$\text{Correction} = \frac{-h^2}{2L}$$

**Note:** Slope correction is always negative.

**Corrections in Tape Correction**

(*i*) Standardisation correction: Same as above

(*ii*) Slope correction: Same as above.

(*iii*) Pull correction is ($C_p$):

$$C_p = \left(\frac{P - P_s}{AE}\right)L$$

$P_s$ = Applied pull

$P_s$ = Standard pull

$L$ = Length of tape

$A$ = Area of cross section

$E$ = Modulus of elasticity

= $2.1 \times 10^5$ N/mm² for steel tape

= $1.54 \times 10^5$ N/mm² for Invar tape

**Note:** It pull is more than standard pull correction will be positive.

(*iv*) Temperature Correction ($C_t$):

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

$T_m$ = Mean temperature

$T_o$ = Standardisation temperature

$\propto$ = Thermal coefficient

(*v*) Sag Correction (Cs)

$$C_s = \frac{-w^2 l^3}{24\, p^2}$$

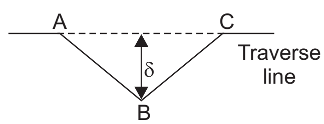
$w$ = weight of tape per unit length in N/m

$l$ = length of tape suspended between supports

$p$ = applied pull

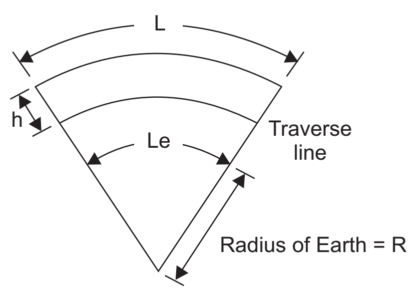
(*vi*) Misalignment correction ($C_m$)

$$C_m = -\left[\frac{\delta^2}{2AB} + \frac{\delta^2}{2BC}\right]$$




(*vii*) Mean sea level correction

$$C_n = \frac{-Lh}{R}$$




**Order of field work in chain surveying**

(*i*) Reconnaissance

(*ii*) Marking of stations

(*iii*) Running survey lines

(*iv*) Taking offsets

# 3 Compass-Surveying

The method of establishing control points by taking linear and angular measurements is called traversing.

Closed traverse        Open Traverse

**Closed Traverse:** It starts from a station and closes either on the same station or another station whose location is already known.

**Open Traverse:** An open trasverse starts from a station and closes on another station whose location is neither known or established. Generally used in areas for road, railway line etc.

**Note:** Error's in closed traverse can easily be detected, adjusted and balanced while in open traverse it is not possible hence it should be avoided.

**Difference Between Traverse Surveying & Chain Surveying**

| Chain Surveying | Traverse Surveying |
|---|---|
| 1. Requires only linear measurements hence relatively easier | Requires both linear and angular measurements. Hence requires trained personnel. |
| 2. The framework consists of triangles. | Frame work consists of a series of connected lines froming an open or closed polygon. As the directions of lines are measured, the polygon can be plotted without construction triangles. |
| 3. Check lines are required in chain Surveying | Check lines are not required because accuracy of the frmework can be checked by the methods of adjustments |
| 4. Used when area to be surveyed is small, ground is flat and accuracy required is low | Used when area involved is large, and better accuracy is required. |

**Meridian:** The direction of line is defined by the horizontal angle which the line makes with the reference angle line. That referance line is called meridian.

- True meridian
- magnetic meridian
- Grid meridian
- Arbitrary meridian

(*i*) **True Meridian:** It represents the true north-south direction at the place. It is determined by astronomical observations of the Sun or Stars. It is fixed at a point.

(*ii*) **Magnetic Meridian:** It is the direction indicated by a freely suspended, balanced magnetic needle at that point.

(*iii*) **Grid Meridian:** For survey of a country, the true Meridian passing through the central place is sometimes taken as a reference meridian for the whole country. Such reference meridian is grid meridian.

(*iv*) **Arbitrary Meridian:** It is the meridian which is taken in any convenient, arbitrary direction.

**Bearing:** It is the horizontal angle which the line makes with the meridian.

- True Bearing
- Magnetic Bearing
- Grid Bearing
- Arbitrary Bearing

> **Note:** True bearing of a line (also called Azimuth) does not change with time and can be re-established even after hundreds of years.

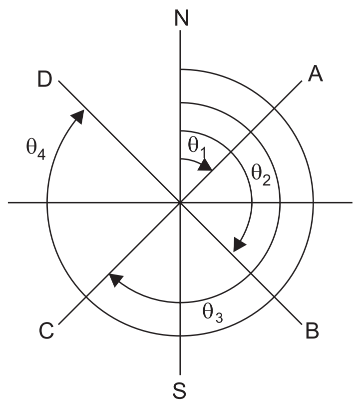
Magnetic bearings are used for small, less important surveys.

Designation of Bearing

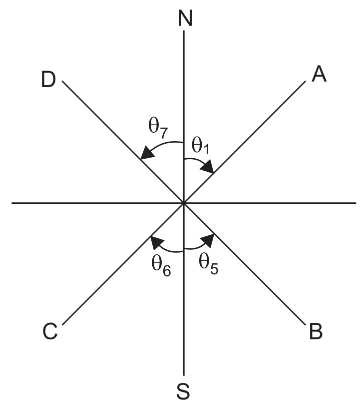
- Whole circle bearing system (WCB)
- Quadrantal bearing system (QB)

**Whole Circle Bearing System:** It is the horizontal angle between the line and the north end of the reference meridian in a clockwise direction. If varies between 0° to 360°.

**Quadrantal Bearing System:** It is the acute angle which the line makes with the meridian. It is measured from North point or South point whichever is closer. It is always less than 90°.




Whole circle Bearing (WCB)



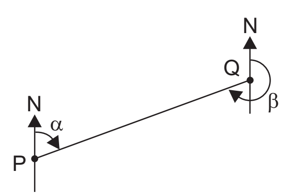

Quadrantal Bearing (OB)

**Reduced Bearing:** When *WCB* exceeds 90° it is reduced to the corresponding angle less than 90°.

| WCB | RB | Quadrant |
|---|---|---|
| 0° – 90° | WCB | NE |
| 90° – 180° | 180–WCB | SE |
| 180° – 270° | WCB–180 | SW |
| 270° – 360° | 360–WCB | NW |

**Fore Bearing (FB):** The bearing of line in the direction of the progress of survey.

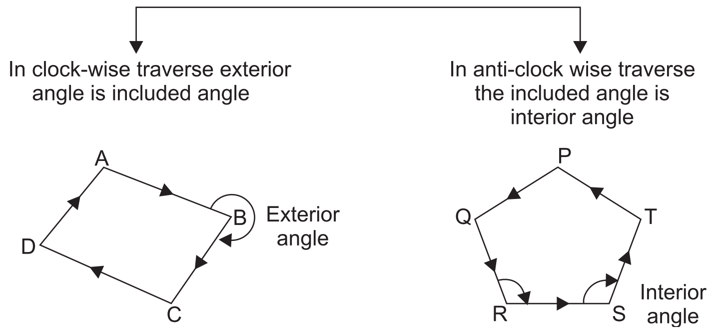
**Back Bearing (BB):** The bearing of line in the opposite direction of the progress of survey



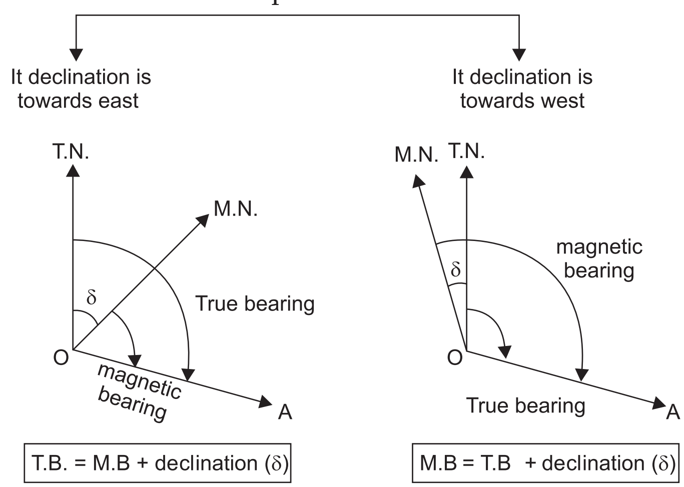

| Line | *FB* | *BB* |
|---|---|---|
| *PQ* | $\alpha$ | $\beta$ |
| *QP* | $\beta$ | $\alpha$ |

$$\boxed{F \cdot B = B \cdot B \pm 180}$$

**Included Angle:** When two line meet at a point, the angle between them is included angle. Angle measured in the clockwise direction from the preceding line of a traverse to the forward line.




**Magnetic Declination:** The horizontal angle which the magnetic meridian makes with the true meridian is known as declination or magnetic declination at that point.




(*i*) **Isogonic Line:** Lines passing through the points on earth surface at which the declination is the same at a given time. They radiate from North and South pole and follow irregular paths.

(*ii*) **Agonic Lines:** Lines passing through points of zero declination. True meridian and magnetic meridian coincides with each other.

Variation of magnetic declination

- **Secular variation**: Occurs over a long period of time due to gradual shift in earth's magnetic field.
- **Annual variation**: Due to rotation of earth about the sun.
- **Secular variation**: Due to rotation of earth about its own aris. It's more near equator and in day time.
- **Irregular variation**: Due to magnetic storms or disturbances in earth's magnetic field.

**Local Attraction:** It is the attraction of the magnetic needle to a local magnetic field other than earth's magnetic field.

$$\boxed{\text{Sum of external included angles} = (2N + 4) \times 90^\circ}$$

where $N$ = No. of sides of the closed traverse.

**Dip:** The angle made by the lines of magnetic force with the earth's surface is called dip. Magnetic needle becomes horizontal at equator but becomes vertical at magnetic poles.

> **Note:** In Southern hemisphere, the South end of the needle dips down.
>
> = Lines joining points of some dip are called Isoclinic while of zero declination are called Aclinic.

# Theodolite

4

It's an instrument used for measuring horizontal and vertical angles in surveying. It is also used in prolonging a line, measuring distances indirectly and levelling.

- Transit theodolite
  Rotated through 180° in vertical plane about its horizontal axis. Process is known as transiting, plunging or reversing
- Non-Transit theodolite
  It cannot be rotated through 180° in vertical plane

**Note:** Size of theodolite is defined by lower graduated circle.

**Basic Definitions**

(*i*) Centering: Process of setting up the instrument exactly over the station mark.

(*ii*) Horizontal axis: Axis about which telecope is rotated in vertical plane.

(*iii*) Vertical axis: Axis about which telescope can be rotated in horizontal plane.

(*iv*) Line of sight: Imaginary line passing through the intersection of the cross-hair of the diaphragm and the optical centre of the objective.

(*v*) Line of collimation: When line of sight comes in horizontal plane.

(*vi*) Axis of level tube: Line tangensial to the longitudinal curve of the level tube at its centre.

(*vii*) Face right: When vertical circle is on the right hand side of observer.

(*viii*) Face left: When vertical circle is on the left hand side of observer.

(*ix*) Telescope Normal: When vertical circle on left side and bubble is up.

(*x*) Telescope Inverted: When vertical circle on right side and bubble is down.

(*xi*) Swinging: Revolving the telescope in the horizontal plane about its vertical axis.

(*xii*) Changing face: Operation of bringing the telescope from face left to face right condition and vice-versa.

Errors eliminated by changing face are:

(*a*) Line of collimation not perpendicular to the horizontal axis.

(*b*) Horizontal axis not perpendicular to the vertical axis.

(*c*) Line of collimation not being parallel to the axis of the altitude level.

(*xii*) Double Sighting: In this process horizontal or vertical angle is measured twice, once in telescope normal condition and other in the inverted condition.

(*xiv*) Lining in: It is the process of establishing intermediate points with the help of theodolite on a given straight line whose ends are intervisible.

(*xv*) Balancing in: It is the process of establishing intermediate points with the help of theodolite on a given straight line whose ends are not intervisible.

**Temporary Adjustments of a Theodolite (in Order)**

(*i*) Setting, (*ii*) Centering, (*iii*) Levelling, (*iv*) Focussing the eye piece, (*v*) Focussing the objective.

**Permanent Adjustment of a Theodolite (in order)**

(*i*) Plate level test

(*ii*) Cross-hair ring test

(*iii*) Collimation in Azimuth test

(*iv*) Spire test

(*v*) Bubble tube adjustment

(*vi*) Verticle arc test

**Comparision Between Method of Repetition and Reiteration**

(*i*) Repetition method is preferred for single angle measurement

(*ii*) Reiteration method is preferred in triangulation, where number of angles are taken at one station only.

(*iii*) Following error's are eliminated in repetition method:

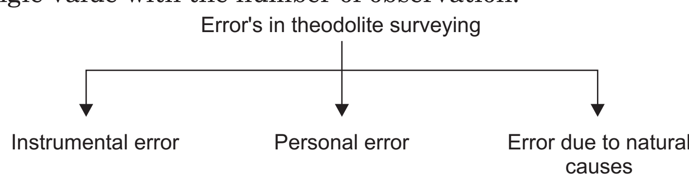
(*a*) Error due to eccentricity of Verniers and centres is eliminated by reading both the Verniers.

(*b*) Error due to line of sight and horizontal axis being out of adjustment is eliminated by taking both face reading.

(*c*) Error due to inaccurate graduations on the main scale is eliminated by taking the reading on the different parts of the circle.

(*d*) Error due to inacurate bisection of signal is eliminated by taking more number of observations.

(*e*) Other errors are also minimised by dividing the cumulative angle value with the number of observation.




(*i*) Line of sight not being perpendicular to horizontal axis.

(*ii*) Horizontal axis not being perpendicular axis.

(*iii*) Spire test is done to check if horizontal and vertical axis are being perpendicular or not.

(*iv*) Vertical index error is the error when there is imperfect adjustment of the vertical vernier circle and the verniers do not read zero.

(*v*) Error due to imperfect graduations on circle.

# Traversing

## 5

A traverse is a series of connected lines whose length and direction are measured in field. In traversing two types of measurements are needed:

**Linear measurement**

(i) Loose needle method
(ii) Fast needle method
(iii) Method of included angle
(iv) Method of direct angle
(v) Method of deflection angle

**Angular measurement**

(i) Taping or chaining
(ii) Tacheometric method
(iii) Electronic distance measuring instrument (EDMI)

**Angle Misclosure:** It is equal to the difference between actual sum of measured angles and the theoretical sum of included angles:

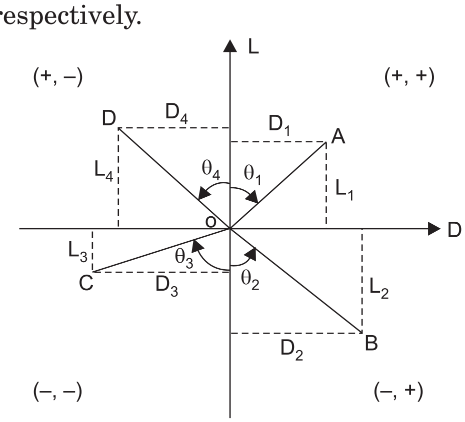
Sum of internal angles of a traverse = $(2N - 4) \times 90°$

Permissible angle misclosure = $K\sqrt{N}$

where N = Number of sides of traverse

K = Depends on theodolite least count, accuracy desired and no. of repetitions. Generally taken as 20″.

**Latitude and Departures:** The orthographic projection of a line on meridian and on the axis perpendicular to the meridian is called latitude and departure respectively.



| Line | Latitude | Departure |
|---|---|---|
| OA | $+L_1 \cos\theta_1$ | $+L_1 \sin\theta_1$ |
| OB | $-L_2 \cos\theta_2$ | $+L_2 \sin\theta_2$ |
| OC | $-L_3 \cos\theta_3$ | $-L_3 \sin\theta_3$ |
| OD | $+L_4 \cos\theta_4$ | $-L_4 \sin\theta_4$ |

**Checks in Traverse**

Closed Traverse

(*i*) Algebric sum of latitude = 0
$\Sigma L = 0$

(*ii*) Algebric sum of Departure=0
$\Sigma D = 0$

Open Traverse

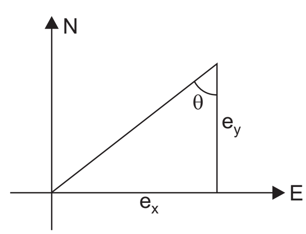
(*i*) Algebric sum of latitude = Difference in the latitude of final and initial control points.

(*ii*) Algebric sum of Departure= Difference in the departures of final and initial control points.

If in closed traverse $\Sigma L \neq 0$ so $\Sigma L = e_y$ and $\Sigma D \neq 0$ so $\Sigma D = e_x$

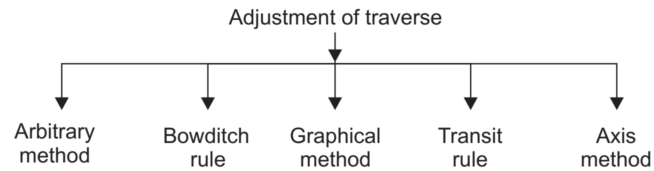
then Error of closure $e = \sqrt{e_x^2 + e_y^2}$

Direction of closing error $\tan\theta = \dfrac{e_x}{e_y}$




$$\text{Relative error of closure} = \frac{\text{Error of closure}}{\text{Perimeter of traverse}} = \frac{e}{p}$$

**Note:** Relative error of closure is also known as relative accuracy or degree of accuracy.




(*i*) Arbitrary method: It is based on the discretion of the surveyor. Based on field conditions.

(*ii*) Bowditch rule: Used where lengths are changed less and angles are changed more.

Error in latitude of any line

$$= \text{Total error in latitude } (e_y) \times \left(\frac{\text{Length of that line}}{\text{Traverse perimeter}}\right)$$

Similarly for departure of that line

(*iii*) Graphical method: It's based on Bowditch rule used for theodolite traverse with low accuracy.

(*iv*) Transit rule: Used where Angular measurements are more precise than the linear measurement.

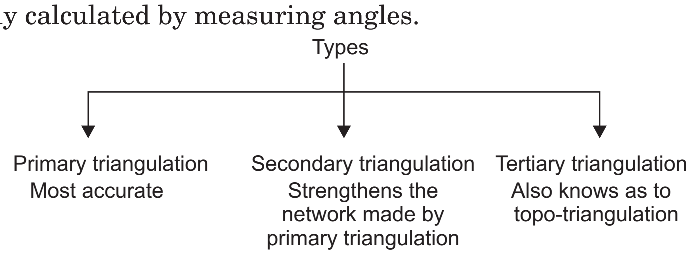
Error in latitude of any line

$$= \frac{\text{Total error in latitude } (e_y) \times \text{Numerical value of the latitude of that line}}{\text{Arithmetic sum of all latitudes}}$$

Similarly for departure of that line.

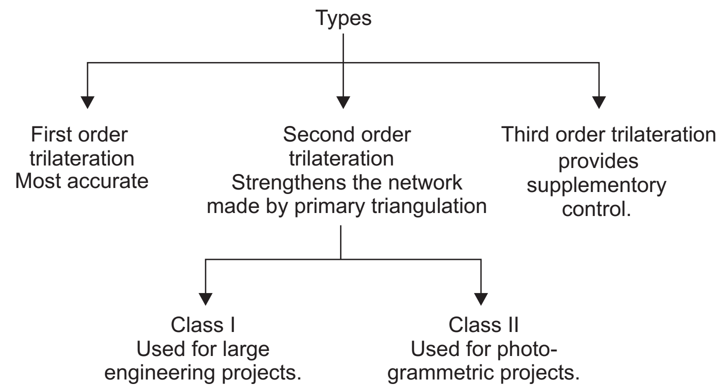
(*v*) Axis method: Corrections are applied only to length and angles are measured very precisely.

**Triangulation:** It is a network of triangles which are used for control network in which only one base line is measured and remaining sides are only calculated by measuring angles.



**Note:** Accuracy of shape is measured in terms of strength of figures and its value depends upon No. of observed directions. No. of geometric conditions and magnitude of distance angles A and B.

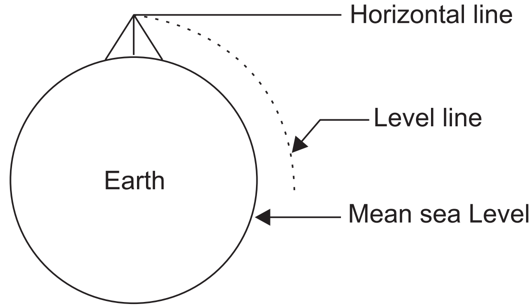
**Trilateration:** All sides of each triangles are measured in the field itself. Angles are indirectly computed from the lengths of the sides of triangle.



# 6 Levelling

A level line is the one that is at a constant height relative to mean sea level. It is a curved line.

The value of mean sea level at datum is obtained by averaging the elevations of high and low tides (for a period of nearly 19 years).

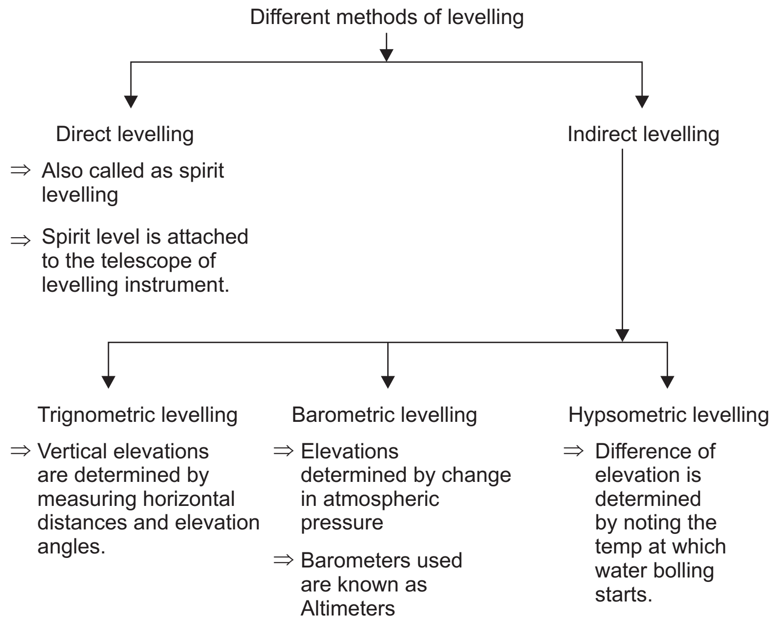


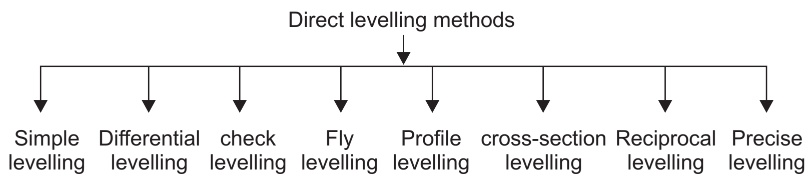

Elevations are measured along the gravity and it is the vertical distance above or below the datum surface.

Altitude is the vertical distance of the point above mean sea level.

**Bench Marks (B.M.):** It is a fixed point of known elevation above the datum. Any point whose elevation is definitely known can be used as bench mark.

- Great trignometrical survey (G.T.S) B.M.
  - ⇒ Established by S.O.I with respect to mean sea level at Mumbai port
- Permanent B.M.
  - ⇒ Established by P.W.D. or S.O.I
- Temporary B.M.
  - ⇒ Established temporarily for a day's work
- Arbitrary B.M.
  - ⇒ Arbitrarly assumed for levelling small area




(*i*) **Simple Levelling** is used for determining the difference of elevations of two points which are visible from a single position of the instrument.

(*ii*) **Differential Levelling** is used when points are situated quite apart. Also called as compound levelling.

(*iii*) **Check Levelling** is done for checking the already obtained elevations.

(*iv*) **Fly Levelling** is done where rapidly but low precision is required. Generally used in reconnaissance.

(*v*) **Profile Levelling** is done for the purpose of determining the elevations of the ground surface along a fixed line. Also called as longitudinal levelling.

(*vi*) **Cross-section Levelling** is done to determine the difference of ground surface along the lines perpendicular to the centre line.

(*vii*) **Reciprocal Levelling** is done where points are situated quite apart and its not possible to set up the instrument mid way between the points.

(*viii*) **Precise Levelling** is done where high accuracy is desired.

Major components of level

- Telescope
- Bubble tube

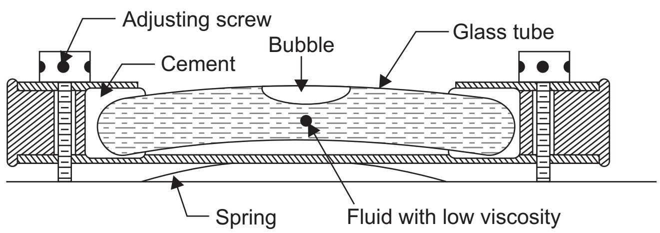
## Optical Defects of Lens

(*i*) Chromatic Aberration: Occurs due to dispersion of light. White light is split it into different colour components.

(*ii*) Spherical Aberration: Occurs as the rays incident on the edge of the lens are refracted more than rays incident on the centre of the lens.

> **Note:** An achromatic combination (convex lens of crown glass and concave lens flint glass) is free from chromatic aberration while an aplantic combination of lens (two identical plano convex lenses) is free from spherical aberration.

**Level Tube:** Sensitivity of level tube is expressed in terms of the angle in seconds substended at the centre by an arc of the level tube equal to one division of the tube.




$$\text{Sensitivity} = \frac{412.53}{R}$$

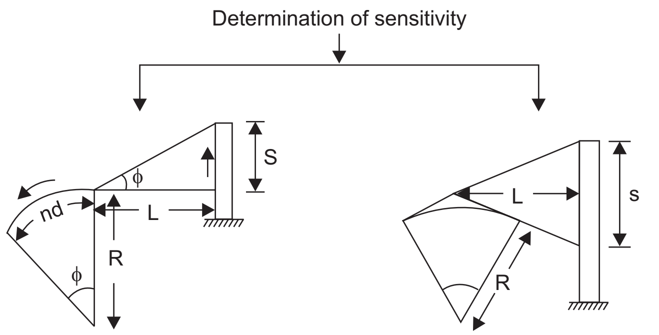
where, $R$ = Radius of upper surface of tube in meters

Graduations are assumed as 2 mm.

Sensitivity of level tube can be **increased** by

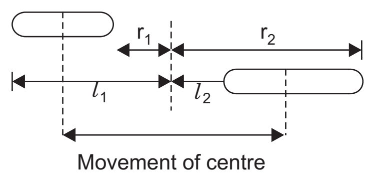
Increasing
(i) Radius R
(ii) Length of the tube
(iii) Diameter of the tube

Decreasing
(i) Viscosity of the liquid
(ii) Roughness of the inner wall of the tube.



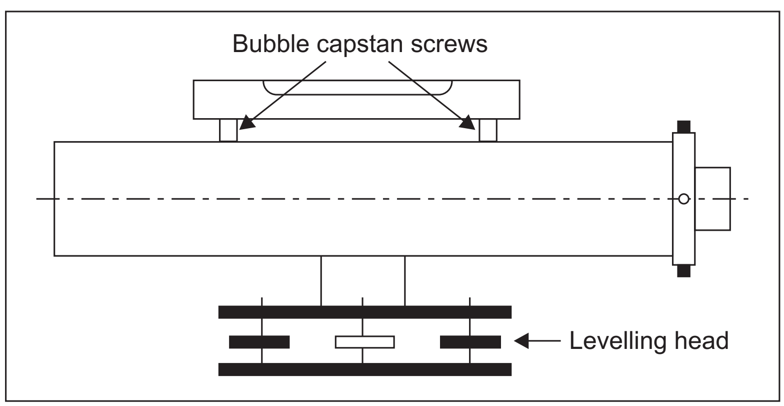

$$\phi = \frac{nd}{R} = \frac{S}{L}$$

$$\boxed{\phi = \frac{d}{R} = \frac{s}{nL}\ \text{Radian}}$$

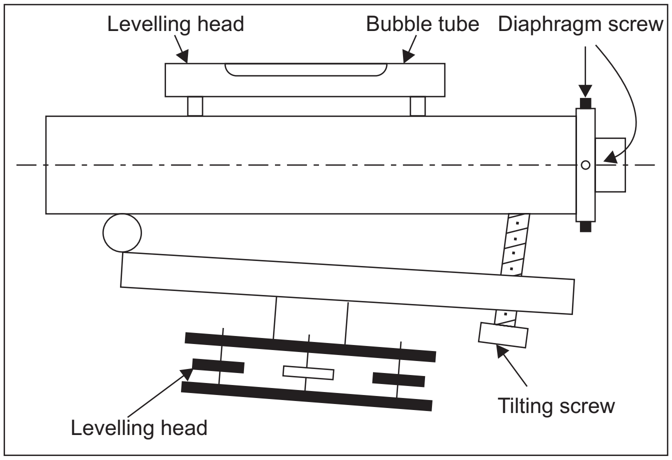



$n$ = No. of division in movement of centre, then apply same formula

**Dumpy level**



**Tilting Level**

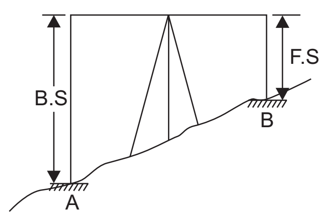



(*i*) Dumpy level is less accurate and consumes large time in levelling hence generally not preferred nowadays.

(*ii*) In tilting level, the telescope is not rigidly fixed to the vertical spindle but is capable of a slight tilt in the vertical plane about an axis placed just below the telescope. Hence, line of collimation need not to be perpendicular to the vertical axis.

**Procedure of Levelling**

R.L. of A = may be B.M. or 100 (assumed)




Height of instrument = RL of A + Back sight (BS)

RL of B = Height of instrument – Fore sight (FS)

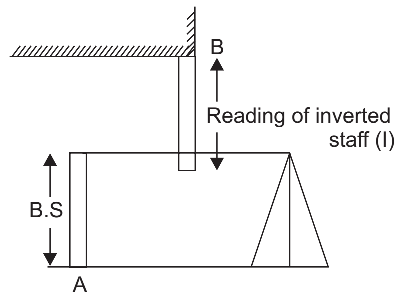
$$\boxed{RL \text{ of } B = RL \text{ of } A + BS - FS}$$

**Note:** First reading made on a point of known reduced level is always a Back sight reading.

Readings are booked in the level book by two methods—Rise and fall method, Height of instrument method.

**Inverted Staff:** When the point whose elevation is to be found is much above the line of collimation, the staff is placed inverted with its zero end touching the point.

$$\boxed{RL \text{ of soffit } (B) = RL \text{ of } A + BS \text{ at } A + I}$$

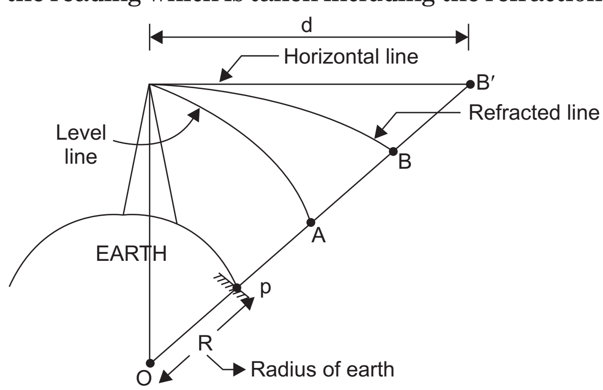



**Effect of Curvature of Earth and Retraction**

Actual readings needed = $PA$

Theoretical reading observed = $PB'$

Practically the reading which is taken including the refraction effect = $PB$




Curvature correction = $AB' = 0.0785\, d^2$

Refraction correction = $BB' = \frac{1}{7} AB' = 0.0112 d^2$

$\boxed{PA = PB + BB' - AB'}$ where $d$ = Is in kilometers

**Note:** Curvature correction ($AB'$) is negative while retraction correction ($BB'$) is positive. So total correction needed is $-0.0673d^2$

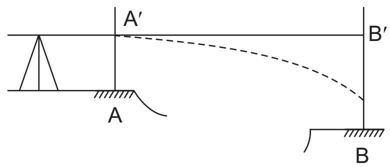
$$\boxed{PA = PB - 0.8673\,d^2}$$

**Distance of Visible Horizon:** $\boxed{d = 3.85\sqrt{h}}$ $h$ is in meter and $d$ in km.

**Reciprocal Levelling:** It eliminates the error's due to curvature of earth, refraction and collimation.

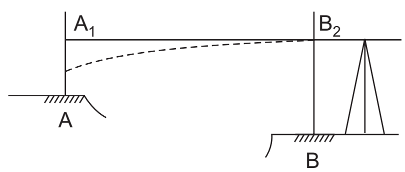
Apparent difference when instrument near $A = AA_1 - BB_1 = X$

Apparent difference when instrument near $B = AA_2 - BB_2 = Y$




$$\text{True difference in level} = \frac{1}{2}(x + y)$$

$$\text{Error in level} = \frac{1}{2}(x - y)$$




If this error in level is total error '$e$' then

$$\boxed{\text{Collimation error} = e - 0.0673\,d^2}$$

# 7 Tacheometry

It is an optical distance measurement method. Generally used for rough or steep grounds where accuracy is less while chaining (or tapeing).

**Tacheometer:** Transit theodolite fitted with Stadia diaphragm.

(*i*) Telescope is fitted with an anallactic lens.

(*ii*) Multiplying constant (K) should be 100.

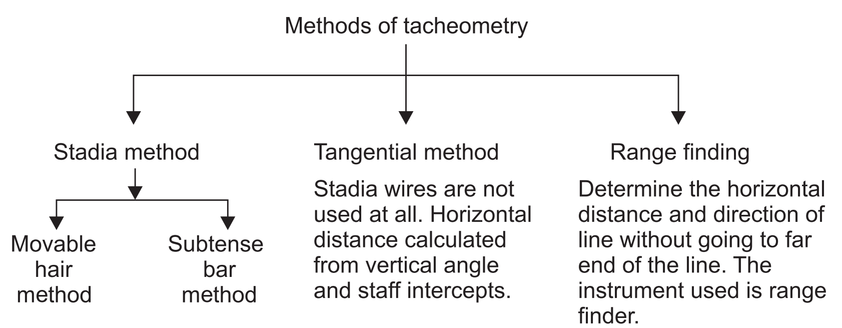
(*iii*) Additive constant (*c*) should be zero.

(*iv*) Eyepiece has high magnification power.

**Substense Theodolite:** Special diaphragm is used in tacheometer, whose stadia hairs can be raised or lowered by a micrometer screw.

**Stadia Rod:** It is a 5-15 m long graduated rod in decimals of metre. Also known as **vertical stave**.

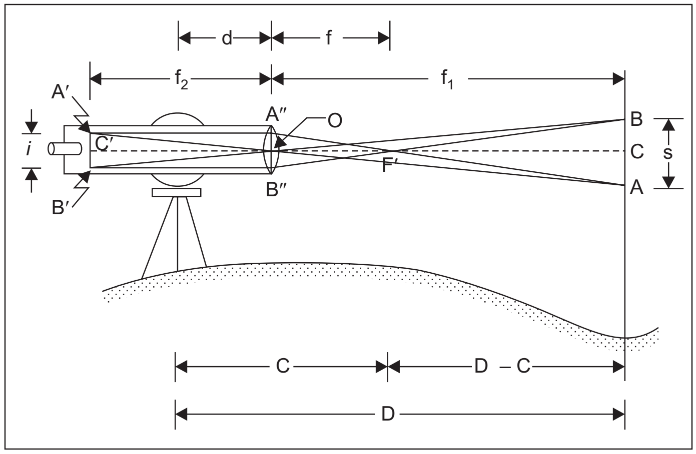
**Subtense Bar:** Used in measuring both horizontal and vertical distances in places where chaining is impossible. It is also known as **horizontal stave**.




**Principal of Stadia Method**

$$D = KS + C$$

$D$ = Horizontal distance between staff and vertical axis of tacheometer




$S$ = Staff intercept

$$\boxed{K = \frac{f}{i}} \quad \boxed{C = f + d} \text{ where } \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

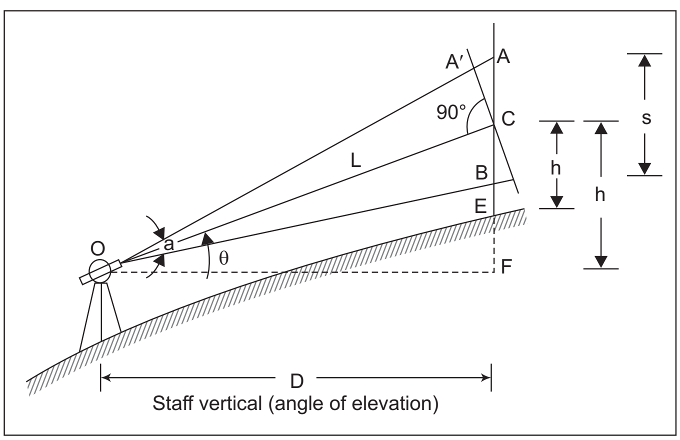
Multiplying constant $K$, generally taken as 100

Additive constnat $C$, ranges from 0.25 to 0.35 and taken as 0.

$d$ = horizontal distance between optical center $O$ and vertical axis of tacheometer.

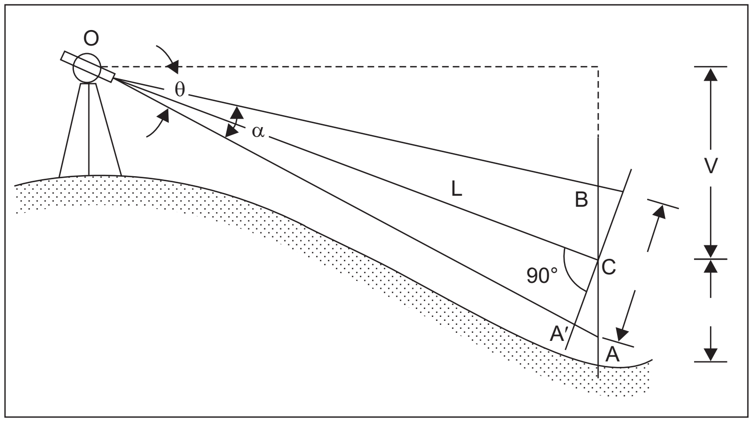
**Distance and Elevation Formula for Inclined Sights**

(*i*) When staff is vertical




Angle of elevation

Elevation of staff staton when elevation angle is $\theta = HI + V - h$



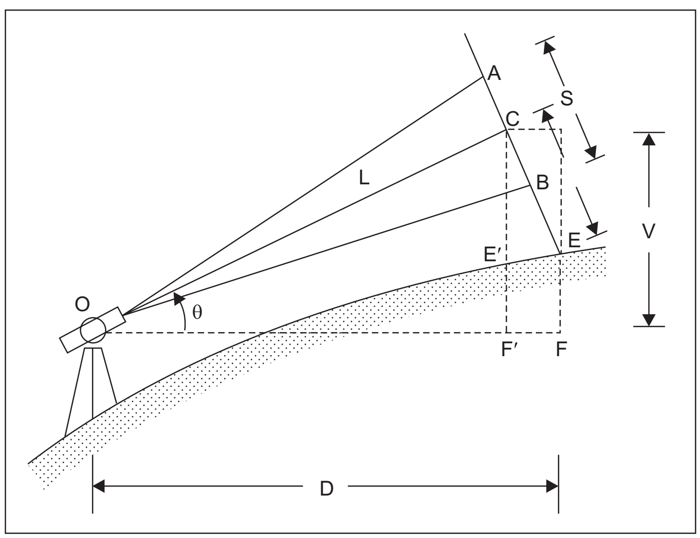

Angle of depression

Elevation of Staff Station when depression angle is $\theta = HI - V - h$

where, $V = L \sin\theta = (KS \cos\theta + C) \sin\theta$

$D = L \cos\theta = (KS \cos\theta + C) \cos\theta$

(*ii*) When staff is normal

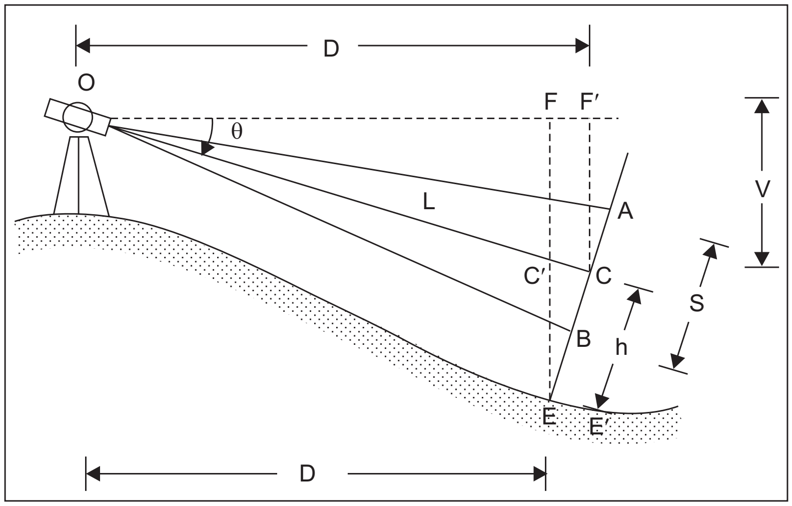



Angle of elevation

Elevation of staff station = $HI + V - h \cos \theta$

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

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




Angle of depression

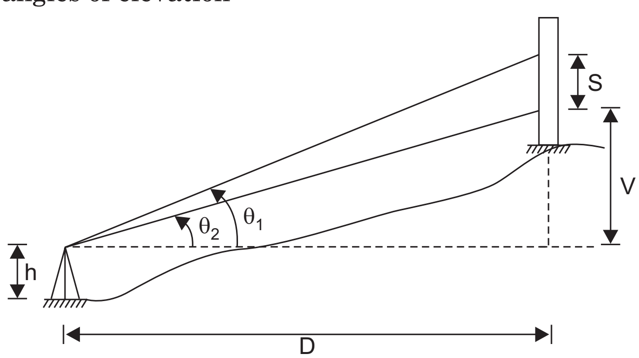
Elevation of staff station = $HI - V - h \cos\theta$

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

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

**Tangential Method of Tacheometry**

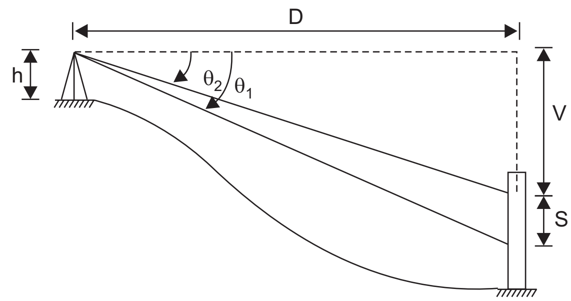
(*i*) Two angles of elevation




$$D = \frac{S}{\tan\theta_1 - \tan\theta_2}$$

$$V = D \tan\theta_2$$

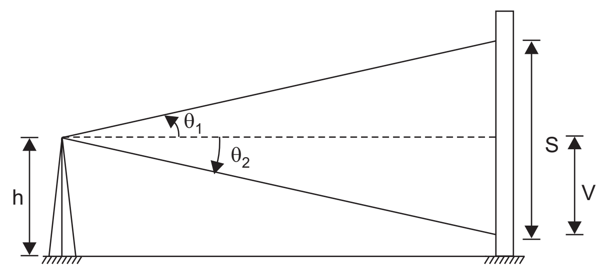
(*ii*) Two angles of depression




$$D = \frac{S}{\tan\theta_1 - \tan\theta_2}$$

$$V = D\tan\theta_2$$

(*iii*) One angle of elevation and one angle of depression




$$D = \frac{S}{\tan\theta_1 + \tan\theta_2}$$

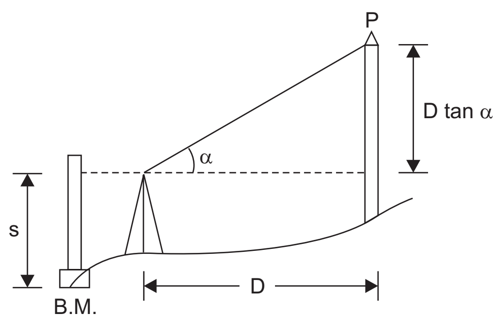
$$V = D\tan\theta_2$$

**Note:** Subtense bar is an instrument used for measuring horizontal distances.

# 8 Trigonometric Levelling

It's an indirect levelling method in which relative elevation of various points are determined from the vertical angle and horizontal distances.

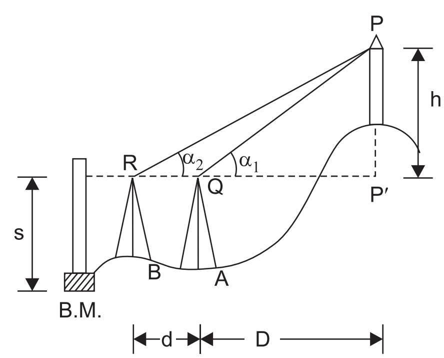
(*i*) Determination of top level of a high object when base is accessible




$RL$ of Point $P$ = $RL$ of B.M. + Staff reading ($S$) + $D \tan \alpha$

(*ii*) Determination of top level of a high object when base is not accessible

(*a*) Line of collimation of station $A$ and station $B$ are at same level

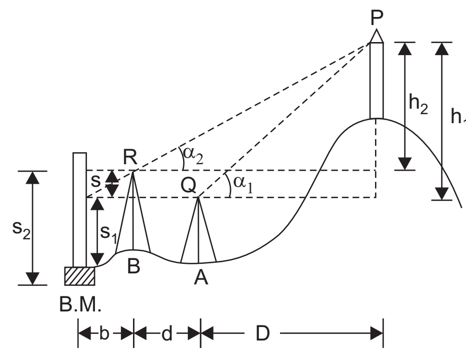



$$h = \frac{d \sin \alpha_1 \sin \alpha_2}{\sin (\alpha_1 - \alpha_2)} = \frac{d \tan \alpha_1 \tan \alpha_2}{\tan \alpha_1 - \tan \alpha_2}$$

$RL$ of point $P$ = $RL$ of $BM$ + Staff reading ($S$) + $h$

**Note:** It is very difficult to set up the line of colimation at *B* exactly at the same level at *A*.

(*b*) Instrument axis at *B* higher than that of *A*

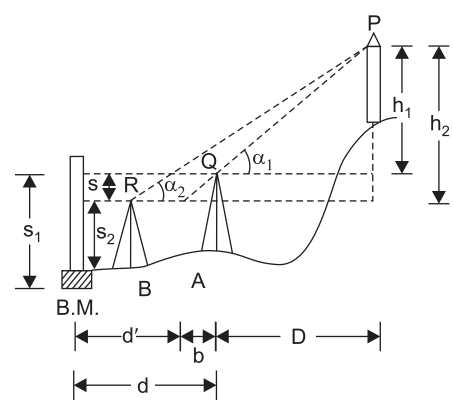



$$RL \text{ of point } P = RL \text{ of } BM + \text{Staff reading } (s_1) + h_1$$

$$h_1 = \frac{(d + s\cot\alpha_2)\sin\alpha_1 \sin\alpha_2}{\sin(\alpha_1 - \alpha_2)}$$

$$s = s_2 - s_1$$

(*c*) Iinstrument axis at *B* lower than that of *A*

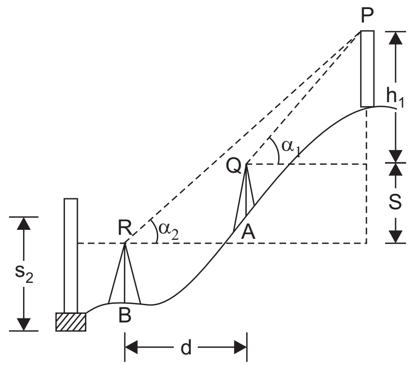



$$RL \text{ of point } P = RL \text{ of } BM + \text{Staff reading } (s_1) + h_1$$

$$h_1 = \frac{(d - s\cot\alpha_2)\sin\alpha_1 \sin\alpha_2}{\sin(\alpha_1 - \alpha_2)}$$

$$s = s_1 - s_2$$

(*d*) Instrument axis have large difference of level




$RL$ of point $P = RL$ of $BM + s_2 + s + h_1$

$$h_1 = \frac{(d - s \cot \alpha_2) \sin \alpha_1 \sin \alpha_2}{\sin(\alpha_1 - \alpha_2)}$$

# Photogrammetry

**9**

It is the science of obtaining information about physical objects through process of recording, measuring and interpreting of photographs of the area.

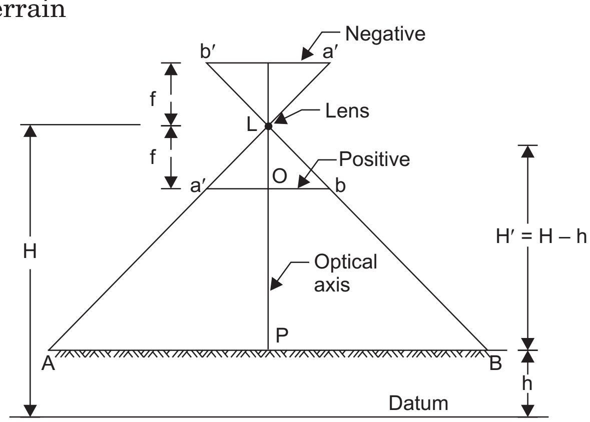
Types of photographs
- Vertical photographs
- Oblique photographs
  - Low oblique photrographs (Does not include horizon)
  - High oblique photographs (Includes the horizon)

Comparators are used for accurate measurement of distance on photograph Mono-comparator is used for measurement on one photograph at a time while stereo comparators are used for measurement on an overlapping stereo pair of photographs.

> **Note:** Map is an orthographic projection while an aerial photograph is a central projection.

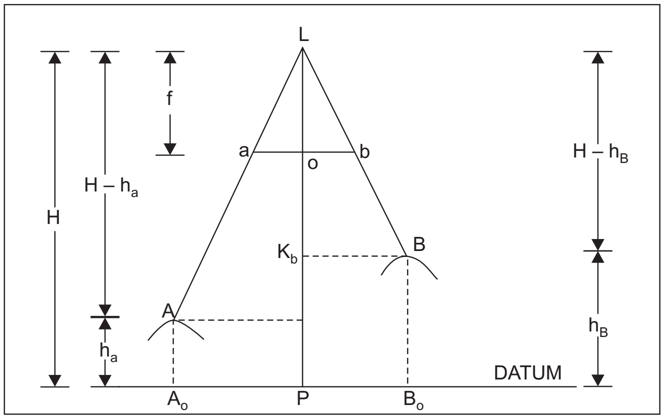
**Scale of a Vertical Photograph**

(*a*) Flat terrain



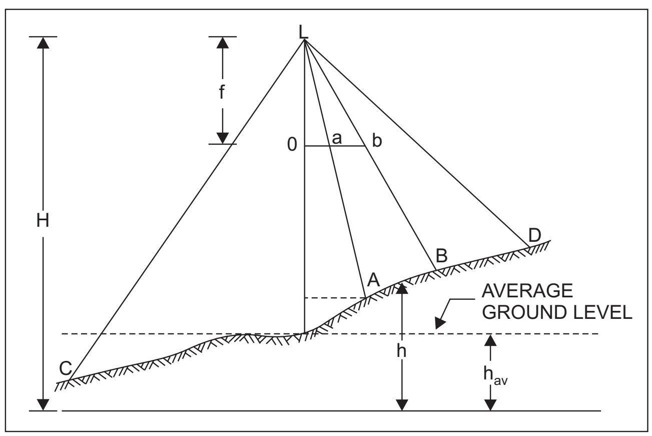

$$S = \frac{f}{H - h}$$

(*b*) Datum scale




$$S = \frac{f}{H}$$

(*c*) Average scale




$$S_{av} = \frac{f}{H - h_{avg}}$$

Ground coordinates

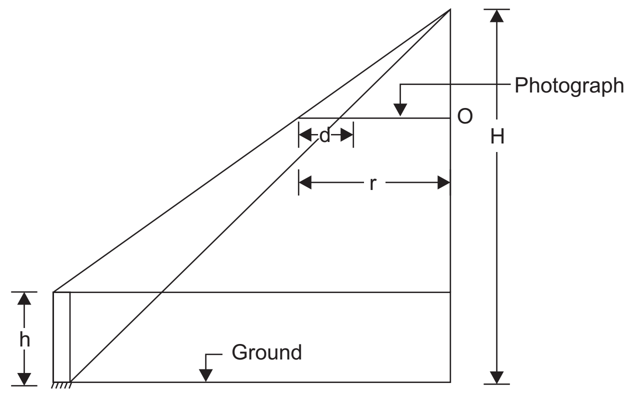
$(X_A, Y_A)$: Ground co-ordinates $H$ = flying height

$(x_a, y_a)$: Photo co-ordinates $h_A$ = elevation of point A above datun

$f$ = focal length of lens

$$\boxed{X_A = x_a \left(\frac{H - ha}{f}\right)} \quad \boxed{Y_A = y_a \left(\frac{H - ha}{f}\right)}$$

### Reliet Displacements in a Vertical Photograph




$d$ = relief displacement

$h$ = height of the object above datum

$H$ = flying height above the datum

$r$ = radial distance of the image of the top of object

$$d = \frac{rh}{H}$$

### Calculation of Flying Height of a Vertical Photograph

(*i*) When focal length is '$f$' and scale of photograph is '$s$' then

$H' = \frac{f}{s}$ $H'$ = flying height above ground

(*ii*) When photo coordinates are $(x_a, y_a)$, and $(x_b, y_b)$, focal length is $f$, elevation of points above ground is $h_a$ & $h_b$ respectively then distance between points on the photograph will be

$$AB = \sqrt{\left[\frac{x_b}{f}(H - h_b) - \frac{x_a}{f}(H - h_a)\right]^2 + \left[\frac{y_b}{f}(H - h_b) - \frac{y_a}{f}(H - h_a)\right]^2}$$

### Required Number of Photographs

Ground Area: $A$ Area covered by one photograph: a

longitudinal overlap/end lap = $p_l$

side lap = $p_s$

Length of photograph in direction of flight = $l$

Width of photograph normal to the direction of flight = $w$

Scale of photograph = $s$

(*i*) $N = \dfrac{AS^2}{(1-p_l)(1-p_s)\,wl}$

(*ii*) $N = \left[\dfrac{L_1}{(1-p_l)\dfrac{l}{s}} + 1\right]\left[\dfrac{W_1}{(1-p_w)\dfrac{w}{s}} + 1\right]$

$L_1$ = Length of ground to be covered

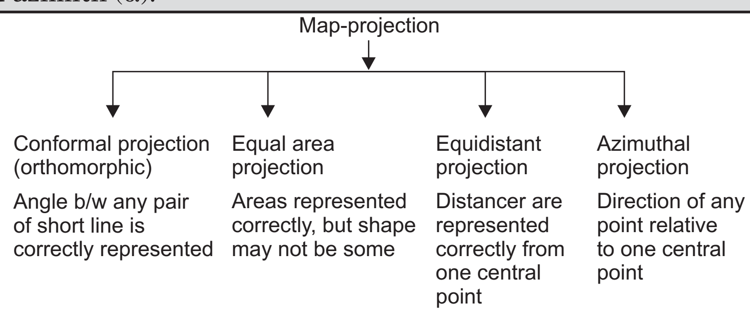
$W_1$ = Width of ground to be covered.

**Crab and Drift**

Crab of a photograph is the **angle** formed between the flight line and edges of the photograph in the direction of flight.

Drift is the **lateral shifting** of the photograph. It is generally due to wind. The crab is generally introduced to avoid draft.

> **Note:** In tilted photographs, three angles completely define the angular orientation of that photograph. These are tilt ($t$), swing ($s$) and azimith ($\alpha$).



# 10 Theory of Errors

True value of the quantities (angles and distances) is impossible to determine as some type of errors always creep in every measurement.

Type of errors

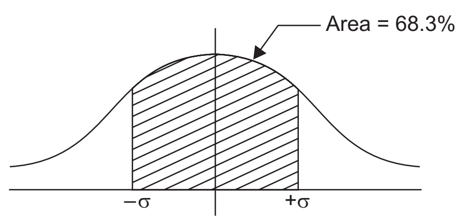
- **Gross errors/mistakes** — Due to inexperience or carelessness of the surveyor.
- **Systematic errors** — Same magnitude and nature in the identical conditions
- **Accidental/Random error** — It is beyond the control of the surveyor. It obey's Law of chance.

> **Note:** In this chapter it is preassumed that mistakes and systematic errors have been eliminated and only accidental errors are left to be eliminated.

### Laws of Accidental Error

It follows normal probability distribution curve also known as Gaussian distribution

| Error = Measured value − True value |
|---|
| Residual = Measured value − Most probable value |




Most probable value is the value which is close to true value than any other value.

$y$ = frequency of occurance of the residual or variation

$$y = \frac{1}{\sqrt{2\pi\sigma}} e^{-0.5(v/\sigma)^2}$$

$v$ = residual

$\sigma =$ standard deviation

$$\sigma = \sqrt{\frac{\Sigma v^2}{n-1}}$$

**Note:** Standard deviation is also known as root mean square error of a measurement.

Smaller the value of standard deviation, the greater is the precision.

**Indices of Precision for Observations of Qqual Weight**

(*i*) Standard deviation ($\sigma$)

$$\sigma = \sqrt{\frac{\Sigma v^2}{n-1}}$$

For accessing the precision of a set of observations.

(*ii*) Variance ($v$)

$$V = \frac{\Sigma v^2}{n-1} = \sigma^2$$

Used as a measure of dispersion or spread.

(*iii*) Standard error of the mean ($\sigma_m$)

$$\sigma_m = \pm\sqrt{\frac{\Sigma v^2}{n(n-1)}} = \pm\frac{\sigma}{\sqrt{n}}$$

(*iv*) Standard error of single observation ($\sigma_1$)

$$\sigma_1 = \sqrt{\frac{\Sigma v^2}{n-1}}$$

(*v*) Most probable error in single observation ($e$)

$$e = \pm 0.6745\sigma$$

(*vi*) Most probable error of the mean ($e_m$)

$$e_m = \pm 0.6745\,\sigma_m$$

(*vii*) Maximum error: If any measurement deviates from mean by more than $\pm 3.29\sigma$ then that measurement is considered as mistake and it can be rejected.

(*viii*) Different percentage error:

(*a*) 90% error ($E_{90}$) = ± 1.645 σ

(*b*) 95% error ($E_{95}$) = ± 1.96 σ

(*c*) 95.5% error ($E_{95.5}$) = ± 2.0 σ

(*d*) 97.7% error ($E_{97.7}$) = ± 3.0 σ

**Definition of Weight:** It is a measure of relative trust worthiness of the set of observations. The greater the precision of an observation, the greater will be its weight.

**Rules of Weight Allocation**

(*i*) The weights are taken inversely proportional to the variance or square of standard errors (or probable errors).

$$\frac{w_1}{w_2} = \frac{v_2}{v_1}$$

(*ii*) The weights of the quantities measured in similar conditions are assigned in direct proportion to the number of times ($n$) the quantity is measured.

$$\frac{w_1}{w_2} = \frac{n_1}{n_2}$$

(*iii*) Weights are sometimes allocated by personal judgement depending on field prevailing and environmental conditions i.e. lower weights allocated to observations in difficult terrain.

(*iv*) Weight of level line is taken as inversely proportional to the length (L) of the route. Thus,

$$\frac{w_1}{w_2} = \frac{L_2}{L_1}$$

**Laws of Weight**

(*i*) If the no. of observations ($a$, $b$, $c$ ...) of a particular quantity have unit weight (i.e. 1) then the value of quantity will be the arithmetic mean of observation.

| Observation | Weight |
|---|---|
| $a$ | 1 |
| $b$ | 1 |
| $c$ | 1 |

$$\text{Value} = \frac{a + b + c}{3}$$

(*ii*) The weight of the weighted arithmetic mean is equal to the sum of individual weights. (i.e. $w_1 + w_2 + w_b$)

| Observation | Weight |
|---|---|
| $a$ | $w_1$ |
| $b$ | $w_2$ |
| $c$ | $w_3$ |

$$\text{Value} = \frac{aw_1 + bw_2 + cw_3}{w_1 + w_2 + w_3}$$

(*iii*) Weight of observation $a$ is $w_1$ and weight of observation $b$ is $w_2$.

$$\text{Weight of } a \pm b = \frac{1}{\frac{1}{w_1} + \frac{1}{w_2}} = \frac{w_1 w_2}{w_1 + w_2}$$

(*iv*) Weight of observation $a$ is $w_1$. If the observation is multiplied by factor $K$ then

$$\text{Weight of } Ka = \frac{w_1}{k^2}$$

(*v*) If the equation is multiplied by its own weight, then the weight of resulting equation is equal to the reciprocal of the weight of that equation.

Weight of $a + b =$ is $w_1$

Weight of $w_1 (a + b)$ will be $\frac{1}{w_1}$.

(*vi*) Weight of an equation remains unchanged if all signs of equations are changed

Weight of $a + b$ is $w_1$

Weight of $-(a + b)$ will be $w_1$ only.

(*vi*) Weight of an equation remain unchanged if the equation is added or subtrated from a constant.

Weight of $a + b$ is $w_1$

Weight of $180 - (a + b)$ or constant $\pm (a + b)$ will be $w_1$

**Indices of Precision for Observations of Different Weights**

(*i*) Standard deviation of weighted observations ($\sigma_w$)

$$\sigma_w = \pm\sqrt{\frac{\Sigma(wv^2)}{n-1}}$$

(*ii*) Standard error of the mean of the weighted observations $(\sigma_m)_w$ is

$$(\sigma_m)_w = \pm \frac{\sigma_w}{\sqrt{\Sigma w}}$$

(*iii*) Standard error of the single observations of weight $w_1$

$$(\sigma_1)_w = \pm \frac{\sigma_w}{\sqrt{w_i}}$$

(*iv*) Most probable error of the single observations of weight $w_1$

$$E_w = \pm 0.6745\,(\sigma_1)_w$$

(*v*) Most probable error of the mean $(E_m)_w$

$$(E_m)_w = \pm 0.6745\,(\sigma_m)_w$$

**Propagation of Standard Errors**

If $A = f(x, y, z)$ then total error in $A$, $\delta_A = \frac{\partial f}{\partial x}\delta x + \frac{\partial f}{\partial y}\delta y + \frac{\partial f}{\partial z}\delta z + \ldots$

The standard error in $A$ due to standard errors $e_x$, $e_y$, $e_z$ in $x, y, z$ etc. is obtained from the following reaction:

$$\boxed{e_A^2 = \left(\frac{\partial f}{\partial x}e_x\right)^2 + \left(\frac{\partial f}{\partial y}e_y\right)^2 + \left(\frac{\partial f}{\partial z}e_z\right)^2 + \ldots}$$

(*i*) Addition or subtraction of Quantities

A$(f) = a + b$ where $e_a$ and $e_b$ are Std. errors in $a$ and $b$ respectively

$\boxed{e_A = \pm\sqrt{e_a^2 + e_b^2}}$ $e_A$ = error in observation $A$

(*ii*) Product of Quantities

$A\,(f) = a \times b \times c$

$$\boxed{e_A = \pm abc\left[\left(\frac{e_a}{a}\right)^2 + \left(\frac{e_b}{b}\right)^2 + \left(\frac{e_c}{c}\right)^2\right]^{1/2}}$$

(*iii*) Quotient of Quantities

$A\,(f) = \frac{a}{b}$ $\boxed{e_A = \pm\frac{a}{b}\left[\left(\frac{e_a}{a}\right)^2 + \left(\frac{e_b}{b}\right)^2\right]^{1/2}}$

(*iv*) Power of a quantity

$A(f) = a^n$ $\quad \boxed{e_A = \pm n a^{n-1} e_a}$

(*v*) Root of a quantity

$A(f) = a^{1/n}$ $\quad \boxed{e_A = \pm\left(\frac{a^{1/n}}{n}\frac{e_a}{a}\right)}$

(*vi*) Addition of a constant to a quantity

$A(f) = a \pm k$ $\quad \boxed{e_A = e_a}$

(*vii*) Product of a constant

$A(f) = Ka$ $\quad \boxed{e_A = \pm k e_a}$

**Theory of Least Square:** The most probable value is that value which makes the sum of squares of the residual to a **minimum** value.

(*i*) If the observations have equal weight, then $\Sigma v^2$ = minimum

(*ii*) If the measurements are of unequal weights, then $\Sigma w(v^2)$ = minimum

Methods of least square adjustments are

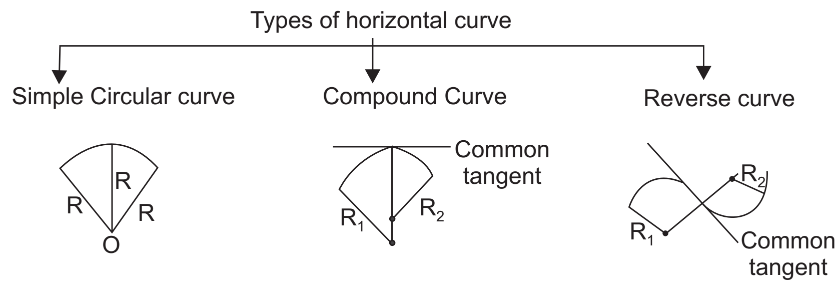
(*i*) Normal equation method

(*ii*) Method of correlates or condition equations method

# 11 Curves

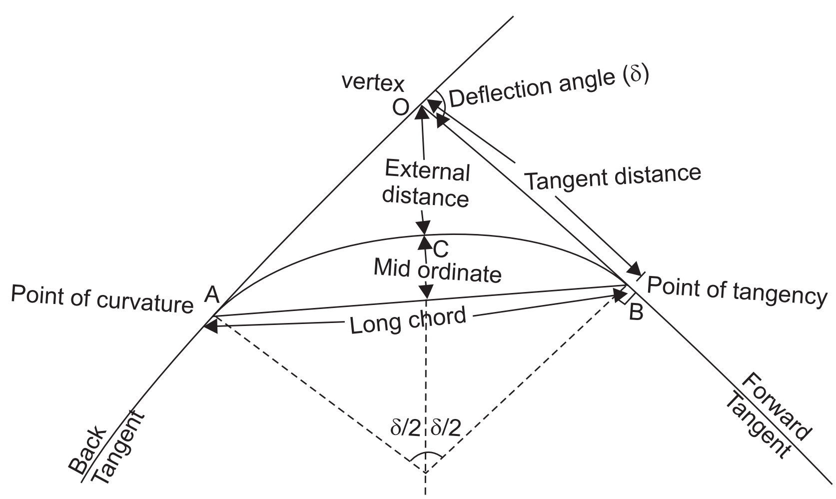
A horizontal curve is provided at the point where two straight lines intersect in the horizontal plane.

A vertical curve is provided at the point where two straight lines at different gradient intersect in the vertical plane.




> **Note:** Reverse curves are provided on the routes when two straight lines are parallel or when angle between them is very small. These are very frequently used in hilly roads.

### Horizontal Circular Curve



**Degree of a Curve:** It is the angle substended at the centre by **an arc or chord** of a specified length. Arc definition is used in case of highways while chord definition is used in case of railways.

- Arc definition
  - 30 m arc: $R = \frac{1719}{D}$
  - 20 m arc: $R = \frac{1146}{D}$
- Chord definition
  - 30 m arc: $R = \frac{15}{\sin D/2}$
  - 20 m arc: $R = \frac{10}{\sin D/2}$

**Elements of a Simple Circular Curve**

(*i*) Length of curve ($l$): Length of $ACB$

$$l = \left(\frac{2\pi R}{360}\right)\delta$$

(*ii*) Tangent length Tangent distance:

$$T = R\tan\left(\frac{\delta}{2}\right)$$

(*iii*) Change of tangent points:

(*a*) Chainage of $A$ = Chainage of Vertex – Tangent distance

(*b*) Chainage of $B$ = Chainage of $A$ + length of curve

Note: Chainage of $B \neq$ Chainage of Vertex + Tangent distance

(*iv*) Length of long chord ($L$)

$$L = 2R\sin\left(\frac{\delta}{2}\right)$$

(*v*) External distance or Apex distance ($E$):

$$E = R\left(\sec\frac{\delta}{2} - 1\right)$$

(*vi*) Mid-ordinate ($m$)

$$M = R\left(1 - \cos\frac{\delta}{2}\right)$$

Methods of setting out of curves

- Tape method
  - off set from long chord (for curves of small radius)
  - offset from the tangent (suitable for short curves)
  - offset from chord produced (for longer curves of larger radius)
- Tape & Theodolite method
- Two theodolite method
- Tacheometric method
- Total-station Instrument

(*i*) Tape method: Only chain or tape is used and no angular measurements are made.

(*ii*) Tape and theodlite method: Linear and angular measurements are made.

(*iii*) Two theodolite method: No linear measurements are made, curve is plotted by angular measurements only. It is very accurate.

(*iv*) Tacheometric method: Angular and linear measurements are done with the help of tacheometer.

(*v*) Total station method: Curve is set out by the co-ordinates at various points.

**Note:** In horizontal curves to avoid inconvenience to slow moving vehicles, the maximum value of the centrifugal ratio for roads is specified as 1/4 and for railway tracks its 1/8.

**Bernoulli's Lemniscate:** It is special type of transition curve which is generally used when angle of deflection is very large. As it is symmetrical, so it can even be used when curve is transitional throughout without a circular curve between the two transition curves. It is objectionable in Railways but allowed on highways.

# Field Astronomy

12

- On 21st March, sun crosses the equator from South to North and it is called first point of Aries. On this day, day and night are equal. Also called as vernal equinox.

  On 21st/22nd September, sun crosses the equator from South to North and it is called first point of Libra. Also called as Autumnal equinox.
- Angular distance of any plane North or South of equator is called Latitude ($\theta$).
- Measured angle between pole to zenith point for any place is called Colatitude (c).

$$\boxed{c + \theta = 90°}$$

- Angle between meridian of a place from a fixed meridian is called longitude.
- Angular distance from horizon, measured on a vertical circle passing through the body is called Altitude ($\alpha$).
- Angular distance of body from Zenith is called Co-Altitude ($z$) or Zenith distance.

$$\boxed{\alpha + z = 90°}$$

- Angle between vertical circle passing through the body from observer's meridian is called Azimuth ($A$).
- Angular distance of a body from the plane of celestial equator, measured along declination circle is called Declination ($\delta$).
- Angular distance of heavenly body from pole is called co-declination ($\delta$)

$$\boxed{\delta + \delta = 90°}$$

- Angle between observer's meridian and declination circle passing through the body is called Hour Angle (H). It is measured from South in Wistward direction.
- Angular distance measured Eastward from first point of Aries is called right ascension (R.A.). It is angle between hour circle passing from body to hour circle passing from first point of Aries, measured in East direction.

**Terrestrial Latitude and Longitude**

(*i*) Axis of the earth: Axis joining the North and South pole of the earth.

(*ii*) Meridian: Any great circle whose plane passes through the axis of earth.

(*iii*) Equator: Great circle perpendicular to axis of the earth.

(*iv*) Latitude : Vertical angle above or below equator.

(*v*) Longitude: Horizontal angle between great circle passing through place and standard meridian.

Note: Prime meridian or standard meridian is a meridian passing through Greenwich.

(*vi*) Parallel of latitude: Parallel of latitude through a point is a small circle passing through that point and parallel to equator.

1 Nautical mile = 1.852 km

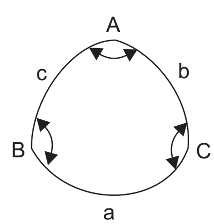
1 Nautical mile is the distance on arc of great circle by 1 minute angle at the centre of earth.

**Celestial Latitude and Longitude System**

Celestial latitude is the vertical angle measured above or below arc of ecliptic while celestial longitude is the horizontal angle measured from first point of Aries to the east.

**Spherical triangle:** If $a$, $b$, $c$ are sides of spherical triangle then A is the angle fromed at centre of sphere by arc $BC$ or $A$ is the angle between two great circle passing from $AB$ and $AC$.

**Properties of Spherical Triangle**




(*i*) Any angle is less than $\pi$.

(*ii*) $\pi < (A + B + C) \leq 3\pi$

(*iii*) Sum of any two sides > third side.

(*iv*) If sum of any two sides is equal to two right angle ($\pi$) then the sum of angles opposite them is also equal to $\pi$.

(*v*) The smaller angle is always opposite the smaller side.

(*vi*) Area of spherical triangle = $\frac{\pi R^2}{180} \times E$ where $E = (A + B + C) - 180$.

**Time:** Interval lapsed between any two instants. Several time measurements used by astronomers are:

(*i*) **Sidereal Time:** Hour angle of first point of Aries (*r*) measured westward at any instant is called sidereal time of that instant.

The interval of time which elapses since the upper transit of first point of Aries over observer's meridian is known as local side real time of the place i.e. L.S.T.

| |
|---|
| LST = Right Ascension (RA) of the observer's meridian<br>= RA of a star + HA of star |

(*ii*) **Apparent Solar Time:** Measurement of time based on daily apparent motion of the sun round the earth.

The interval of time which lapses between two successive lower transit of centre of sun over meridian of the place is called apparent Solar day.

(*iii*) **Mean Solar Day:** Interval of time between two successive lower transit of mean sun.

The instant when the mean sun crosses the local meridian at its upper transit is known as local mean noon. While the hour angle of the mean sun recorded westward from 0 to 24 hours is known as local mean time.

(*iv*) **Standard Time:** It's the time of the watch. Standard meridian of a country is generally selected such that it lies at an exact number of hours from Greenwich but Indian standard meridian which passes from Allahabad is at 6 hours 30 minutes East of Greenwhich.

Standards, time (ST) = LMT + Difference of longitude converted to time

| |
|---|
| Equation of time = Apparent solar time<br>– Mean solar time |

**Conversion of Time:** 1° = 4 minutes, as 360° = 24 hrs.

(*i*) Local time to Std. time.

LMT = MT + Difference in longitude.

(*ii*) Local time to Greenwhich time

LMT = GMT ± Longitude of place

(*iii*) Local apparent time = local mean time + equation of time

(*iv*) Mean solar time = Sidereal time – retardation

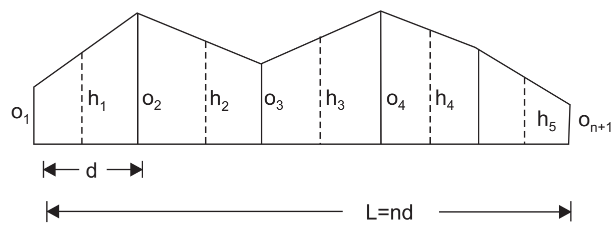
(*v*) Sidereal time = Mean solar time + Acceleration

| |
|---|
| 1 Tropical year = 365.24422 mean solar days |
| 1 side real year = 366.2422 sidereal days |

# Measurement of Area and Volume

13

**Measurement of Area**




$h_1, h_2 \ldots h_n$ are offsets at mid point of each division.

(*i*) Mid-ordinate rule

Area = $(h_1 + h_2 + \ldots + h_n)\, d$

(*ii*) Average ordinate rule

Area = $\dfrac{o_1 + o_2 + \ldots + o_{n+1}}{n+1} \times nd$ ; Area = $\dfrac{nd\,\Sigma o}{n+1}$

(*iii*) Trapezoidal rule: $A = d\left(\dfrac{o_1 + o_n}{2} + o_2 + o_3 + \ldots + o_{n-1}\right)$

where $o_1$ & $o_n$ are end ordinates.

Trapezoidal rule is more accurate than the above two.

(*iv*) Simpson's one-third rule

$$A = \frac{d}{3}[(o_1 + o_n) + 4(o_2 + o_4 + \ldots + o_{n-1}) + 2(o_3 + o_5 + \ldots + o_{n-2})]$$

(*a*) Short length of boundries between two adjacent ordinates is a **parabolic arch**.

(*b*) It is applicable only when there are odd number of offsets.

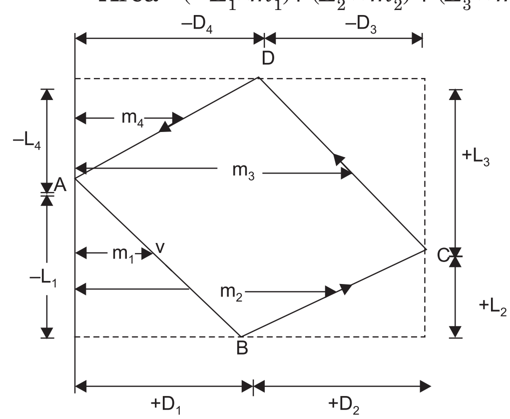
(*c*) If there are even no.of offset's then area upto the second last segment is calculated by Simpson's rule and for the last segment trapezoidal rule is used.

(*v*) Area of meridian distance method

$$\text{Area} = \Sigma \Delta L.m$$

Or

$$\text{Area} = (-L_1 \times m_1) + (L_2 \times m_2) + (L_3 \times m_3) + L - L_4 \times m_4)$$




Here, '*m*' is a meridian distance

$$m_1 = \frac{D_1}{2} \qquad m_2 = m_1 + \frac{D_1}{2} + \frac{D_2}{2}$$

$$m_3 = m_2 + \frac{D_2}{2} - \frac{D_3}{2} \qquad m_4 = \frac{D_4}{2}$$

Meridian distance: Distance of mid-point of a line w.r.t. fixed meridian.

(*vi*) Area by double meridian distance method (D.M.D.)

$$\text{Area} = \frac{1}{2}\Sigma ML$$

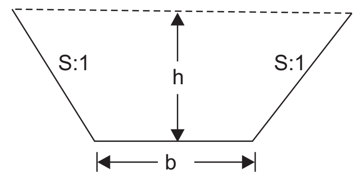
$$\text{Area} = \frac{1}{2}(-L_1m_1 + L_2m_2 + L_3m_3 - L_4m_4)$$

Here '*m*' is double meridian distance

$$m_1 = D_1 \qquad m_2 = m_1 + (D_1 + D_2) \qquad m_3 = m_2 + D_2 - D_3 \qquad m_4 = D_4$$

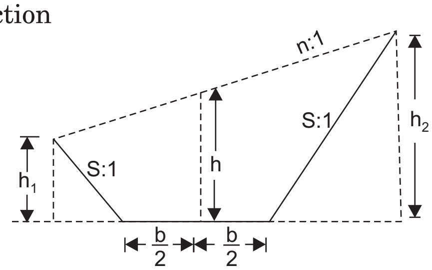
**Measurement of Area of Cross-section**

(*i*) Level Section



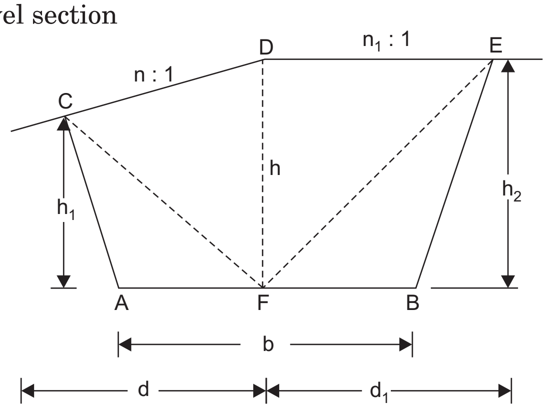

$$\text{Area} = (b + Sh)\,h$$

(*ii*) Two-level section



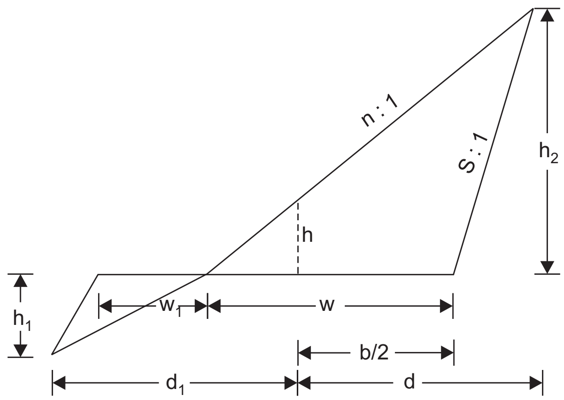

$$\text{Area} = \frac{s\left(\frac{b}{2}\right)^2 + n^2\left(bh + sh^2\right)}{n^2 - s^2}$$

(*iii*) Thee level section




$$\text{Area} = \frac{b}{4}(h_1 + h_2) + \frac{h}{2}(d + d_1)$$

(*iv*) Side hill two level section




$$\text{Excavation Area} = \frac{\left(\frac{b}{2} + nh\right)^2}{2(n-s)}$$

$$\text{Enbankment Area} = \frac{\left(\frac{b}{2} - nh\right)^2}{2(n-s)}$$

**Volume Measurement**

(*i*) Trapezoidal formula

$$V = \left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \dots + A_{n-1}\right]L$$

$A_1, A_2, A_3 \dots A_n$ are the end consecutive areas and $L$ is the **distance between them**.

(*ii*) Prismoidal formula (Simpson's rule is used)

$$V = \frac{L}{3}\left((A_1 + A_n) + 4(A_2 + A_4 + \dots + A_{n-1}) + 2(A_3 + A_5 + \dots + A_{n-2})\right)$$

**Note:** In case if only prismoidal rule is to be applied, then the area halfway between the sections is interpolated by averaging the dimensions of the end sections and not by averaging the end areas.

**Planimeter** is used to find the areas of irregular shapes which are plotted to scale. Types of planimeter are Amisler polar planimeter (commonly used) and the rolling planimeter.

# Plane-Table Surveying 14

It is an instrument used for surveying by a graphical method in which the field work and plotting are done simultaneously. This graphical method of producing topographic maps is known as cartographic surveying.

**Principle Used:** Unknown point of interest can be established by measuring its directions from known points.

**Accessories Used:**

(*i*) Plane Table Board

(*ii*) Tripod: To support the plane table board

(*iii*) Alidade: To set direction

(*iv*) Trough compass: To locate North-South direction

(*v*) Spirit level/level tube: To make plane table board horizontal.

(*vi*) Plumbing fork: For centering of plane table.

(*vii*) Indian clinometer: To determine the difference of elevations of two points by measuring the inclination of line of sight.

(*viii*) Drawing sheet.

**Temporary Adjustments in Plane Table**

(*i*) Surface of board should be perpendicular to the vertical axis of the instrument.

(*ii*) The fudicial edge of the alidade should be a straight line.

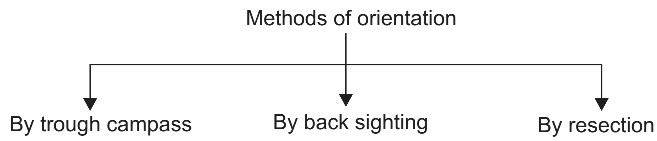
(*iii*) The two vanes (object vane & eye vane) should be perpendicular to the base of the alidade.

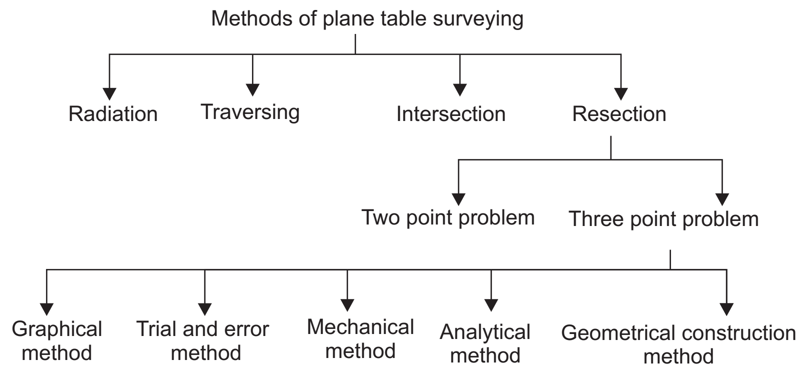
**Setting up the Plane Table**

(*i*) Centering: Process of bringing the plotted station point exactly over the ground station.

(*ii*) Levelling: Operation of bringing the plane table in a horizontal plane.

(*iii*) Orientation: Process of keeping the plane table parallel to the position it occupied at the first station.




(*i*) Radiation: Suitable when area to be surveyed is small and all the required stations to be plotted are clearly visible and accessible from the instrument station.

(*ii*) Traversing: Generally used when a narrow strip of terrain is to be surveyed. It is used for both open and close traverses.

(*iii*) Intersection: It is used when the base stations are visible as well as accessible while the other stations are only visible but not accessible.

(*iv*) It is employed when the plane table occupies a position not yet plotted on the drawing sheet.

**Two Point/Three Point Problem:** It consist of locating the position of plane table station on the drawing sheet by observation of two/three well defined points which are visible as well as already plotted on the plane table.

**Note:** Three point problem is better than two point problem because its simple and accurate.

# 15 Contouring

**Contour:** Its an imaginary line passing through the points of equal elevation on the earth surface.

When contours are drawn under water, they are termed as **Submarine contours, fathoms or bathymetric curves**.

**Contour Interval:** Vertical distance between consecutive contour. It is desirable to have constant contour interval through the map. It depends on following factors:

(*i*) Scale of map

(*ii*) Purpose of map

(*iii*) Nature of the country

(*iv*) Time

(*v*) Funds

**Characteristics of Contour**

(*i*) A zero meter contour line represents the coastline. When no vlaue is represented, it indicates a flat terrain.

(*ii*) Two contours intersect eachother only in case of overhanging cliff or a cave penetrating a hill side.

(*iii*) Equally spaced contours represent uniform slope.

(*iv*) A watershed or edge line contour crosses the valley contour at right angle.

(*v*) Direction of steepest slope is along the shortest distance between the contours.

(*vi*) Two contour lines having same elevations cannot unite and continue as one line.

(*vii*) A set of close contour with higher figures inside and lower figure outside represent a hill while with those having lower figures inside and higher figures outside represent lakes or depressions.

**Application:** Determination of intervisibility, Route location, Drainage area, Site of structures, Capacity of reservoir, earthwork estimates.

**Note:** A very steep slope is scrap and a high scrap is known as crag.