Surveying

SURVEYING

Surveying is the art of determining the relative positions of distinctive features on the surface of the earth or beneath the surface of the earth by means of measurements of distances, directions and elevations.

The surveying may primarily be divided into two divisions :

1. Plane surveying
2. Geodetic surveying

1. **Plane surveying :** The surveys in which earth surface is assumed as a plane and the curvature of the earth is ignored, are known as plane surveys.
2. **Geodetic surveying :** The surveys in which curvature of the earth is taken into account and higher degree of accuracy in linear as well as angular observations is achieved, are known as Geodetic surveying.

Classification based on Instrument used :

(1) Chain surveying
(2) Compass surveying
(3) Plane table surveying
(4) Theodolite surveying
(5) Tacheometric surveying
(6) Triangulation surveying
(7) Aerial surveying
(8) Photogrammetric surveying

MAP : The representation of the earth surface on a small scale, is called a map.

Units of Measurement : There are two kinds of measurements used in plane surveying :

1. **Linear measurement** i.e. horizontal or vertical distances.
2. **Angular measure** i.e. horizontal or vertical angles.

⇒ 1.852 kilometres = 1 nautrical mile

100 sq. metres = 1 are

Basic unit of length in F.P.S. System

12 inches	=	1 foot
3 feet	=	1 yard
5.5 yeards	=	1 rod, pole
4 poles	–	1 chain (66 feet)
10 chain	=	1 furlong
8 furlong	=	1 mile
6 feet	=	1 fathom.
120 fathoms	=	1 cubic length
6080 feet	=	1 nautical mile

- Scales of the maps are represented by the following two methods :

(*i*) Numerical scales

(*ii*) Graphical scales

(*a*) Engineer's scale

(*b*) Fractional scale

(*a*) Engineer's scale : The scale on which one cm on the plan represents some whole number of metres in the ground, is known as Engineer's scale, e.g., 1 cm = 5 m, 1 cm = 1.0 m etc.

(*b*) Fractional scale : The scale on which an unit of length on the plan represents some number of the same unit of length on the ground is known as frictional scale, c.g , 1 : 500, 1 : 3000, 1 : 5000 etc.

Classification of Scales :

The scales drawn on the maps or plans, may be classified as :

(*i*) Plain scale

(*ii*) Diagonal scale

(*iii*) Scale of chords

(*iv*) Varnier scale

- **Plane Scale :** A plane scale is one on which it is possible to measure only two dimensions, i.e. metres and decimetre, kilometres and hectametrcs, miles and furlongs etc.

Plane scales as Recommended by IS 1481–1959

Full size	—	1 : 1
50 cm to a metre	—	1 : 2
40 cm to a metre	—	1 : 2.5
20 cm to a metre	—	1 : 5
10 cm to a metre	—	1 : 10

- A useful map scale should be sufficiently long and should not be less than 18 cm and more than 32 cm.

(*i*) **Diagonal scales :** On a diagonal scale, it is possible to measure three dimensions such as kilometres, hectametres and decametres; or yards, feet and inches etc.

(*ii*) **Vernier scales :** It consists of two approximating scales, one of them is fixed and is called the primary scale, the other is movable and is called the *vernier*.

Least count of a vernier is equal to the difference between the smallest division on the main scale and the smallest division on the vernier scale.

Value of one division of primary scale

- Least count (L — C)

$$= \frac{\text{Value of one division of primary scale}}{\text{Number of divisions of vernier scale}}$$

- 1 hectares = 10,000 m^2
- . If 1 cm = 50m, then R.F. = $\frac{1\text{ cm}}{50{,}000\text{ cm}} = \frac{1}{5000}$

Measuring a correct length with a wrong scale

1. Correct length

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

2. Correct area

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

LEVELLING

The art of determining relative altitudes of points on the surface of the earth of beneath the surface of the earth is called **levelling**. This branch of surveying deals with measurement in vertical planes.

LEVEL : The instrument which is used for levelling is known as a level :

It consists essentially of the following parts:

(*i*) A telescope to provide a line of sight

(*ii*) A level tube to make the line of sight horizontal

(*iii*) A levelling head to bring the bubble of the tube level at the centre of its run.

(*iv*) A tripod to support the instrument

DUMPY LEVEL : It is a simple, compact and stable instrument. The telescope is rigidly fixed to its support and it can neither be rotated about its longitudinal axis and nor it can be removed from its support.Thus it has

(*i*) Levelling head

(*ii*) Telescope

(*iii*) Eye piece

(*iv*) Diaphragm screws

(*v*) Focussing–screws

(*vi*) Ray–shade

(*vii*) Longitudinal/Altitude bubble tube

(*viii*) Babble tube adjusting screws

(*ix*) Cross bubble tube

Advantage and disadvantage of Dumpy Level :

(*i*) It is simple in construction with a few movable parts.

(*ii*) It requires fewer permanent adjustments.

(*iii*) Adjustment once carried out remains for a longer period.

Levelling Staff : A straight, rectangular wooden rod grduated into meters/feet and further smaller divisions, called a *levelling staff*. The bottom of the levelling staff represents the zero–reading. In the most common forms the smallest division is of 5 mm and graduations arc in the form of alternate black and white strips.

The purpose of a level (instrument) is to establish a horizontal line of sight. The purpose of the levelling staff is to determine the amount by the which station (i.e. foot of the staff) is above or below the line of sight.

TECHNICAL TERMS USED IN LEVELLING

Level surface : Level surface is a curved surface which is parallel to the mean spheroidal surface of the earth, such that every point on this level surface is equidistant from the centre of the earth. The surface of still water in a lake represents a level surface.

Any line lying on the level surface is known as *level line.*

Horizontal surface : A surface tangential to the level surface at any point is known as a *horizontal surface*. It is perpendicular to the plumb line at the tangent point.

Horizontal line : A line lying on he horizontal surface, is known as *horizontal line*. It is a

straight line tangential to the level line.

Vertical line : A line perpendicular to the level line is called a vertical line. The plumb line at any place, is called the vertical line.

Vertical plane : The plane which contains the vertical line at a place is, called a vertical plane.

Vertical angle : The angle between an inclined line and a horizontal line at a place in **vertical plane**, is called vertical angle.

DATUM SURFACE : The imaginary level surface with reference to which vertical distance of the points (above or below) are measured, is called **Datum Surface**. In India the datum adopted for G.T.S. Bench marks is the mean sea level at Karanchi.

Mean Sea Level datum : The M.S.L. datum adopted by the survey of India for determining the elevation of different points in India is that of Bombay.

Reduced Level (R.L.) : The height or depth of a point above or below the assumed datum, is called reduced level (R.L.). It is also known as elevation of the point. Elevations of the points below the datum surface, arc known as negative elevation.

Line of sight : The line passing through the optical centre of the objective, and intersection of cross hairs is known as line of sight.

Bench mark (B.M.) : A relatively permanent and fixed reference point of known elevation above the assumed datum, is called a bench mark.

Levelling instrument : Mainly there are two instruments which are commonly used in direct levelling

(*i*) A level (Telescope)

(*ii*) A levelling staff

Special Term and their Abbreviation Used in Levelling

1. **Instrument station :** The point where instrument is set up for observation, is called **instrument station**.
2. **Station :** The point where levelling staff is held, is called station. It is the point whose elevation is to be determined.

Height of the instrument (H.I.) : The elevation of the line of sight with respect to assumed datum, is known as height of instrument.

Back Sight (B. S.) : The first sight taken on a levelling staff held at point of known elevation, is called back sight. It is also known as + ve sight.

Back sight enables the surveyor to obtain the height of the instrument.

Fore sight (F.S.) : The sight taken on a levelling staff held at a point of unknown elevation to ascertain the amount by which the point is above or below the line of sight, is called a *foresight*.

Fore sight enables the surveyor to obtain he elevation of the point. It is also generally known as *minus sight*.

Change point : The point on which both the fore sight and back sight, are taken during the operation of levelling, is called a change point.
It is also called a turning point (T.P.)

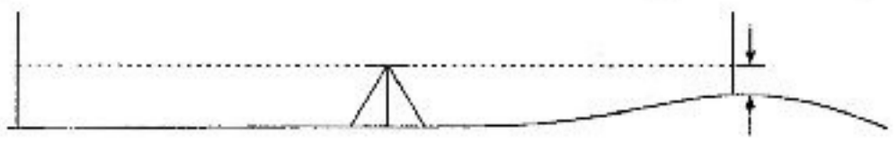
Intermediate sight : The fore sight taken on a levelling staff held at a point between two turning points, to determine the elevation of that point, is known as intermediate sight.

It may be noted that for one setting of a level there will be only a back sight and a fore sight but there can be a number of *intermediate sights*.

Levelling may be classified as :

1. Simple levelling,
2. Differential levelling.

1. **Simple levelling :** The operation of levelling for determining the difference in elevation, if not too great between two points visible from a single position of the level, is known as *simple levelling*.

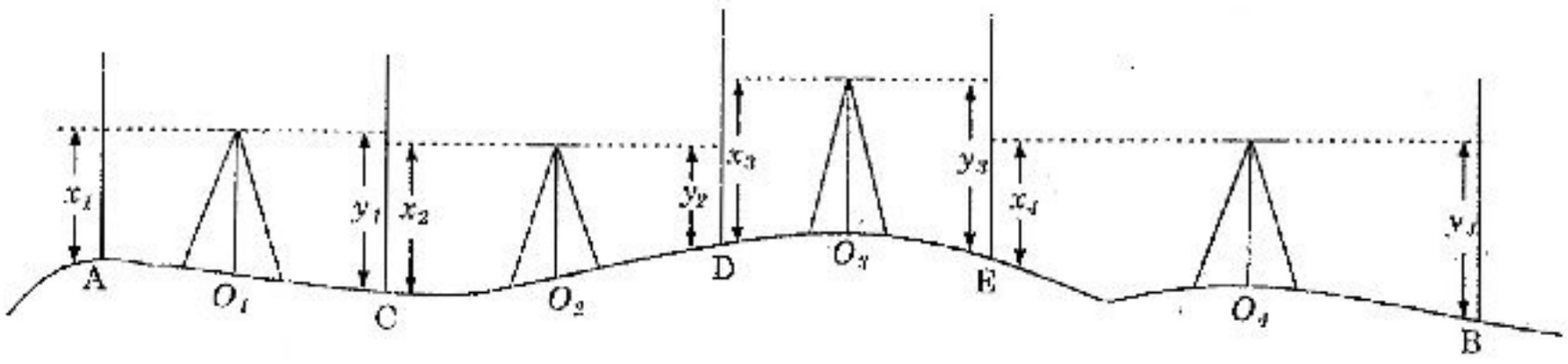


2. **Differential levelling** (fly levelling or continuous levelling)

   The method of levelling for determining the difference in elevation of two points either too far apart or obstructed by an intervening ground, is known as *Differential levelling*.

   In this method, the level is set up at a number of points and the difference in elevation of successive points is determined as in the case of levelling. This levelling process is also known as *Fly compound or continuous levelling*.

Suppose that A and B are two points which are far apart and the difference in their elevation, is to be determined by differential levelling.



Procedure : Following steps are involved :

1. Set up the level at O_1 ensuring that the line of sight intersects the staff held at A. Level it correctly.
2. With the bubble central, take the back staff reading on the staff held vertically at A.
3. Select a point C equidistant from the instrument position Q_1 and take the fore sight reading on the staff held vertically at C.
4. Shift the instrument to Q_2, set up and level it correctly.

5. With the bubble central, take the back staff reading on the staff held vertically at C again.
6. Select a point D equidistant from the instrument position Q_2 and take the fore staff reading on the staff held vertically at D.
7. Repeat the process until the fore staff reading is taken on the staff held on the point B.

Notes : The following points may be noted :

(*i*) The points where two readings are taken at the successive points C, D, E, etc. are called *change points*.

(*ii*) The level must be set up on firm ground otherwise it may sink during the interval of reading the back and foresight.

(*iii*) The bubble must always be brought to the centre of its run before staff reading is taken.

(*iv*) The staff from the change point must not be removed till a back sight is taken

Let $x_1, x_2, x_3 \ldots\ldots x_n$ be the back sights and $y_1, y_2, y_3 \ldots\ldots y_n$ be the fore sights on the staff held vertically at A, C, D, ... etc. Here,

Difference of level between A and C = $x_1 - y_1$

Difference of level between C and D = $x_2 - y_2$

Difference of level between D and E = $x_3 - y_3$ and so on.

Difference of level of points A and B = Σ B.S. — Σ F.S.

If the difference in level is +vc, the closing point B is higher than starting point A. Wheras if negative, the point B is lower than the point A.

R.L. of the point B = R.L. of point A $\pm$ (Σ B.S. — Σ F.S.)

Booking and Reduction of the Level :

Booking and reduction of the level may be done by following two methods :

1. Rise and fall method.
2. Height of collimation method

Arithmetic check of Rise and fall method :

$$\Sigma B.S. - \Sigma F.S. = \Sigma Rise - \Sigma Fall$$
$$= Last\ R.L. - First\ R.L.$$

In the rise and fall method of reduction, a complete check on intermediate sights also is provided because these are included for calculating the rises and falls.

Arithmetic Check of Height of Collimation method :

$$\Sigma B.S. - \Sigma F.S. = Last\ R.L. - First\ R.\ L.$$

In this method there is no check on intermediate sights.

Comparison of line of Collimation Method with Rise and Fall method :

Height of Collimation method		Rise and Fall method	
1.	It is more rapid and saves a considerable time and labour	1.	It is laborious as the staff reading of each station is compared to get a rise or fall
2.	It is well adopted for reduction of levels for construction work such as longitudinal or cross–section levelling operation.	2.	It is well adopted for determining the difference in levels of two points where precision is required
3.	There is no check on reduction of R.Ls of intermediate stations.	3.	There is complete check on the reduction of R.Ls of intermediate stations.
4.	There are only two arithmetic checks i.e. the difference between the sum of back sight and the sum of fore sight must be equal to be the difference in R.L. of last station and first station.	4.	There are three arithmetical checks is the difference between the sum of the back sights and the sum of fore sights must be equal to the difference between the sum of the rises and the sum of falls as well as it must be equal to the difference in R.L.s of the last station and first station.
5.	Errors if any in intermediate sights are not detected	5.	Errors in intermediate sight are noticed as these are used for finding out rises and fall

Gradient of a line :

The gradient of a line joining two points, is calculated as given below,

Procedure : Following steps are followed :

1. Calculate the R.L. of each station.
2. Apply usual arithmetic checks to the calculations.
3. Calculate the difference in level of the given two points
   i.e., R.L. of the last point — R. L. of the first point.
4. If RL of the last point is more as compared to that of the first point the gradient is positive i.e., rising gradient. On the other hand, if R.L. of the last point is less than R.L. of the first point, it is a negative gradient i.e., down gradient.
5. Calculate the distance between the end points. It is equal to nd where, n is total number of fore sights and intermediate sight readings on the straight line joining the end points and d is the constant distance between consecutive stations.
6. Divide the distance obtained is step (5) by the difference in level obtained in step (3), to obtain the desired gradient.

Readings recorded in a level book may be classified into two categories :

(1) **Basic readings :** The reading which arc observed by a level on a levelling staff held vertically at the starting B.M. and other intermediate stations, are known as basic readings, such as back sight, intermediate sights, fore sights and the R. L. of the get bench marks.

(2) **Derived readings :** The reading which are derived with the help of the basic readings, are known as the derived readings such as rises, falls, the height of collimation and R.L.s of unknown points.

Spirit Levelling classification of :

(1) Differential levelling
(2) Check levelling
(3) Reciprocal levelling
(4) Profile levelling
(5) Cross–sectional levelling
(6) Precision levelling

Differential levelling : The operation of levelling to determine the elevation, reduced – level of points at some distance apart to establish Bench Marks in the area, is called *differential levelling* or *fly levelling* or *simple fly levelling*.

Profile levelling : The operation of levelling carried out to determine the elevations of the points at known distances apart, and also other salient features, along a given straight line is called *profile levellindinal* or *longitude levelling*.

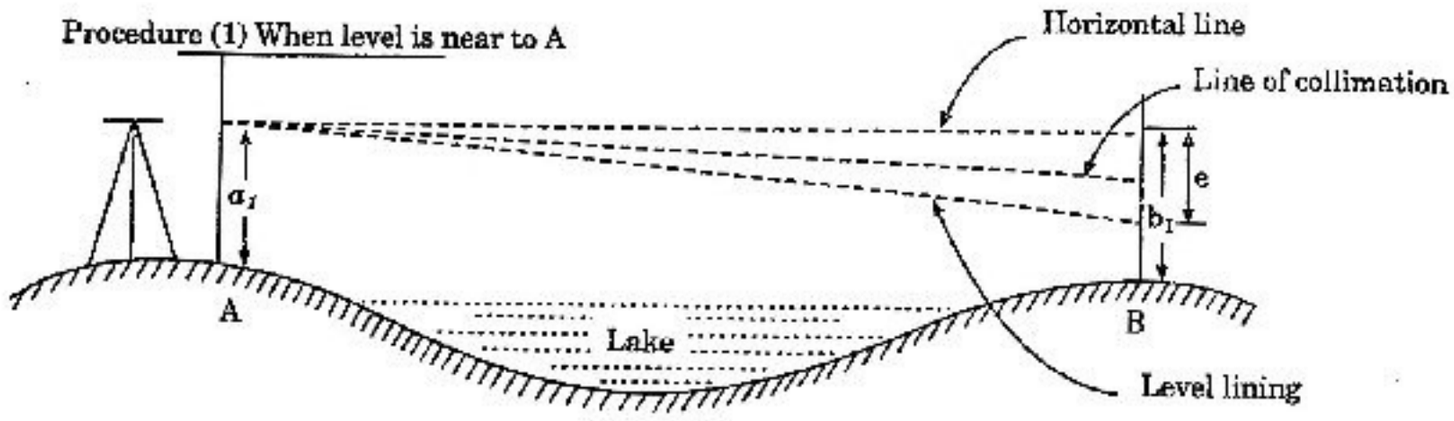
Reciprocal levelling : The operation of levelling in which difference in elevations between the points is according determined by two sets of reciprocal observations, is called *reciprocal levelling*.

- Reciprocal levelling is employed when it is not possible to set up the level between two points due to an intervening obstruction such as large water bodies.
- It is used to obtain accuracy and a eliminate the following :

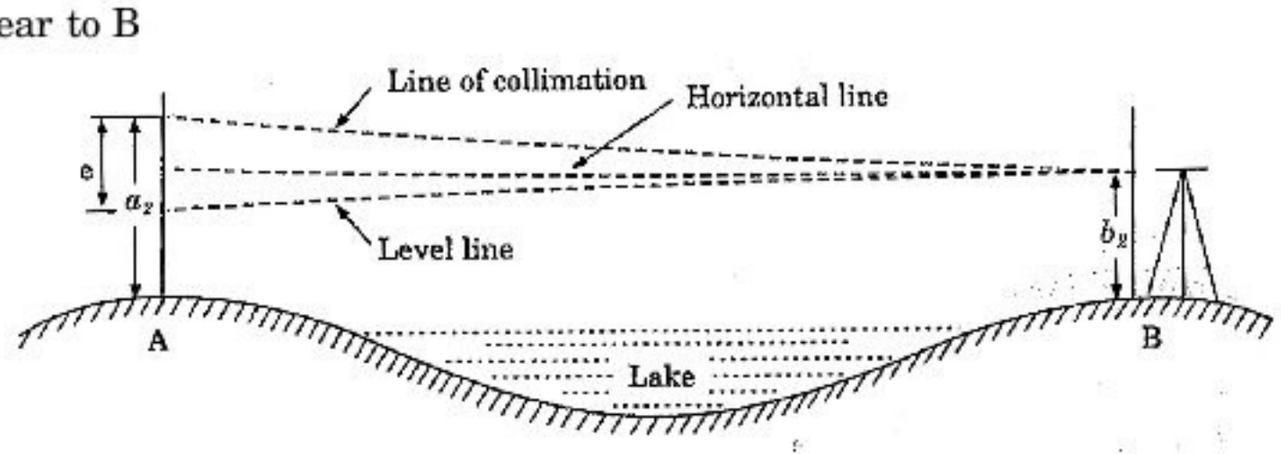
(*i*) error in instrument adjustment.
(*ii*) combined effect of earth's curvature and the refraction the atmosphere, and
(*iii*) variations in the average rejection.

Procedure

(I) When level is near to A



(II) When level is near to B



Let h = true difference of levels between A and B

e = combined error due to refraction, curvature and imperfect adjustment of the line of collimation.

First Position of the Level :

The correct reading on staff B = $b_1 - e$

The correct reading on staff A = a_1

Assuming A to be higher than B, the true difference of level

$$h = b_1 - e - a_1$$

or $$h = (b_1 - a_1) - e \quad \ldots\ldots\ldots (i)$$

Second Position of the Level :

The correct reading on staff B = b_2

The correct reading on staff A = $(a_2 - e)$

The true difference in level

$$h = b_2 - (a_1 - e)$$

or $$h = (b_2 - a_2) + e \quad \ldots\ldots\ldots (ii)$$

Adding equations (i) and (ii), we have

$$2h = (b_1 - a_1) + (b_2 - a_2)$$

$\therefore$ True difference of level between A and B

$$h = \frac{(b_1 - a_1) + (b_2 - a_2)}{2}$$

The true difference of level between A and B is equal to the mean of the two apparent difference of level.

The combined error can be obtained by equating the equations (i) and (ii),

$$(b_1 - a_1) - e = (b_2 - a_2) + e$$

$$\therefore \quad 2e = (b_1 - a_1) - (b_2 - a_2)$$

$\therefore$ Combined error, $e = \dfrac{(b_1 - a_1) + (b_2 - a_2)}{2}$

i.e. , combined error is equal to the half of the difference of the apparent differences of levels.

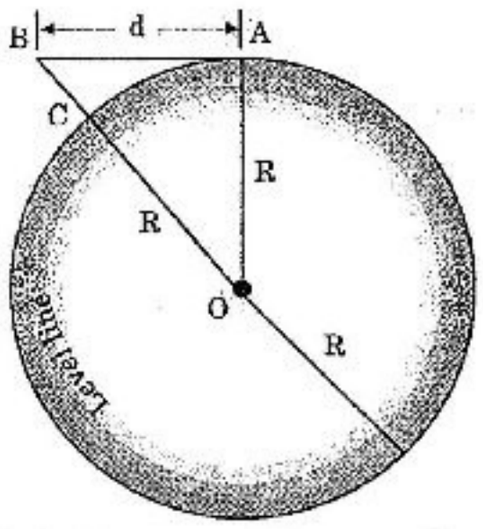
Note :

(i) In reciprocal levelling, the collimation error and the error due to curvature are completely eliminated.

(ii) The elimination of the error due to refraction depends upon the change in the climatic conditions during the transfer of the instrument.

(iii) A set of observations at different times of the day, may be made to obtain the accurate difference of levels by taking the mean of all the differences.

Curvature correction :



Let AB = d, the horizontal distance between A and B

OC = OA = R, the radius of earth

BC = C_C, the correction for the curvature

From the right angled ΔBAO, we get

$$BO^2 = OA^2 + AB^2$$

or $$(OC + BC)^2 = OA^2 + AB^2$$

or $$(R + C_C)^2 = R^2 + d^2$$

or $$R^2 + 2RC_C + C^c_2 = R^2 + d^2$$

or $$C_C (2R + C_C) = d^2$$

or $$C_C = \frac{d^2}{2R + C_C} \text{(Exact)}$$

But C_C is negligible as compared to the diameter of the earth, therefore

$$C_C = \frac{d^2}{2R} \text{(Approximate)}$$

If the distance d is in kms and the radius of earth is taken to be 6370 km, the correction of curvature.

$$C_C = \frac{d^2 km^2}{2 \times 6370\ km}$$

$$= \frac{d^2 km}{12740} = \frac{1000 d^2}{12740} \text{ metre}$$

$$= 0.0785\ d^2 \text{ metre}$$

correction for curvature is, negative and is always substrated from the staff reading.

$\therefore$ Correction for refraction,

$$C_r = \frac{1}{7} \times \frac{d^2}{2R} = 0.112\ d^2$$

Hence correction for curvature is, negative and is always added to the staff reading.

Correction due to curvature and refraction :

Correction due to curvature = $\dfrac{d^2}{2R} = (-\text{ ve})$

Correction due to refraction = $\dfrac{1}{7}\dfrac{d^2}{2R} = (+\text{ ve})$

Hence, combined correction due to curvature and refraction

$$= -\frac{d^2}{2R} + \frac{1}{7}\frac{d^2}{2R}$$

$$= \frac{d^2}{2R}\left(-1 + \frac{1}{7}\right) = \frac{d^2}{2R}\left(\frac{-7+1}{7}\right)$$

$$= \frac{6d^2}{7 \times 2R}(-\text{ ve}) = \frac{6 \times 1000 d^2}{72 \times 6370}$$

$$= 0.0673\ d^2 \text{ metre}$$

Combined correction due to curvature and refraction = 0.0673 d^2 m

where d is in km.

Note :

(*i*) For ordinary lengths of sight, the error due to curvature and refraction is very small and is generally ignored.

(*ii*) The error due to curvature and refraction can be eliminated by equalising back sight and fore sight distance i.e., by balancing the sights.

(*iii*) The error due to curvature and refraction can also be eliminated by the method of reciprocal levelling.

CAMPASS SURVEYING

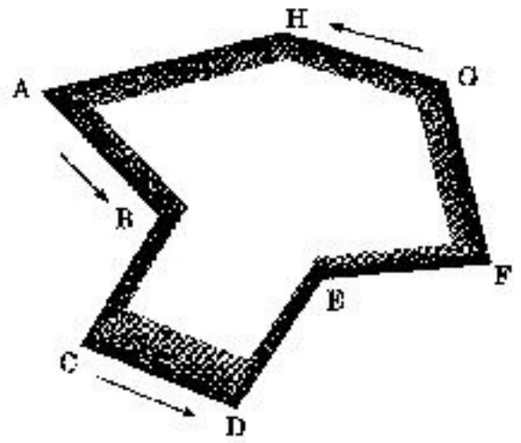
Campus surveying : The branch of surveying in which directions of survey lines are determined by a complex and their lengths by chaining or taping directly on the surface of the earth, is called cojnpass surveying.

Before recommending the compass survey for any area, it must be ascertained that area is not magnetically disturbed.

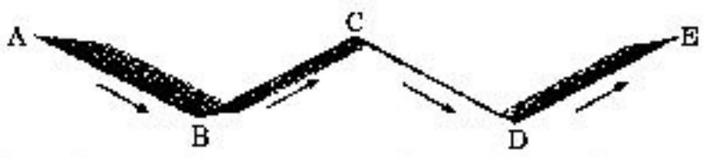
Traverse : A series of connected straight lines each joining two points on the ground, is called a traverse. End points are known as traverse stations and straight lines between two consecutive stations, are called traverse legs.

Traverses may be either a closed traverse or an open traverse.

1. **Closed traverse :** The traverse which either originates from a station and returns to the same station completing a circuit, is known as closed traverse.



Open traverse : The traverse which neither returns to its starting station nor closes on any other known station, is called an open traverse.



Classification of traverses based on instruments used :

(*i*) Chain traversing

(*ii*) Compass traversing

(*iii*) Plane table traveling,

(*iv*) Theodolite traversing

(*v*) Tacheometric traversing.

Surveying compasses :

(1) Prismatic Compass

(2) Surveyor's Compass.

(1) Chain traversing or chain angles method : In chain traversing the entire work is done by a chain or tape and no angle measuring instrument is needed. The angle computed by the measurements, is known as a chain angle.

(2) Compass travering : The traverse in which angular measurements are made with a surveying compass, is know as compass travering. The traverse angle between two consecutive legs is computed by observing the magnetic bearing of the sides.

(3) Plane table traversing : The traverse in which angular measurements between the traverse sides are plotted graphically on a plane table with the help of an alidade, is know as plane table traversing.

(4) Theodolite traversing : The traverse in which angular measurements between traverse sides are made with a theodolite, is known as theodolite traversing.

(5) Tacheometric traversing : The traverse in which direct measurements of traverse sides by chaining is dispensed and these are obtained by making observation with a tacheometer, is known as tacheometric traversing.

Surveying Compass :

The surveying compasses are of two to types:

(1) Prismatic compass

(2) Surveyor's compass

Comparison between a Surveyor's Compass and Prismatic Compass :

1. Magnetic needle
2. Graduated ring
3. Sighting vanes
4. Reading system
5. Tripod

Surveyor's Compass

The needle is of edge bar type and also acts as an index.

(*i*) The graduated ring is attached to the box and not to the needle. This rotate along with the line of sight.

(*ii*) The graduations are in Q.B. system, having 0° at North and South and 90° at East and West. East and West are interchangeable.

(*iii*) The graduations are engraved erect.

The instrument cannot be used without a tripod

Prismatic Compass

(*i*) The needle is broad needle type but does not act as an index.

(*ii*) The graduated ring is attached with the needle. This does not rotate along with the line of sight.

(*iii*) The graduations are in W.C.B. system having 0° at South or North.

Tripod may or may not be provided. The instrument may be used even by holding in hand.

Meridian : The fixed direction on the surface of the earth with reference to which, bearing of survey lines are expressed, called a meridian.

Bearing : The horizontal angle between and the reference meridian the survey line measured in a clockwise direction, is called bearing.

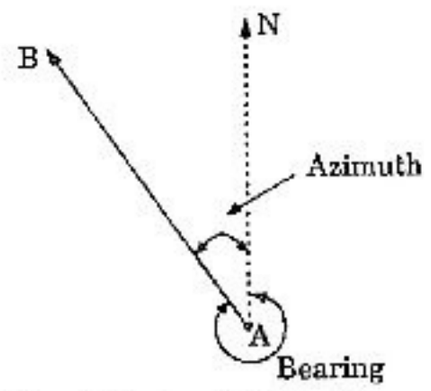
The meridians of reference directions employed in surveying may one of the following.

1. True meridian
2. Magnetic meridian
3. Grid meridian
4. Arbitrary direction

True Meridian : The true or geographical meridian for a point on earth surface is the line in which a plane passing through that point and true north and south pole intersects with the surface of the earth.

Magnetic Meridian : The magnetic meridian for a point on earth surface is the line in which a plane passing through that point and the magnetic north and south intersects with the surface of the earth.

True north : The surface of earth intersected by its axis yield two points namely North Geographical pole and South Geographical pole. This geographical north is called true north.



Magnetic north : Magnetic North and South line is determined as indicated by a freely supported and properly balanced magnetic needle.

The maps prepared by the national survey department of any country, are based on true meridian.

True bearing : The horizontal angle between the true meridian and the survey line measured in a clockwise direction, is called true *bearing of the line*. It is also sometimes called azimuth.

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

If given true bearing of the line is 275°41'then find its azimuth.

Solution. Azimuth of line = 360° — 375° 15^1 = **84° 15**

If given true bearing of the line = 30°45^1 which is less than 180°, then find its azimuth.

Solution. Azimuth of the line = True bearing of the line = **30°45**

Magnetic bearing : The horizontal angle which a line makes with the magnetic meridian, is called magnetic bearing. It is not constant at a point but varies with laps of time.

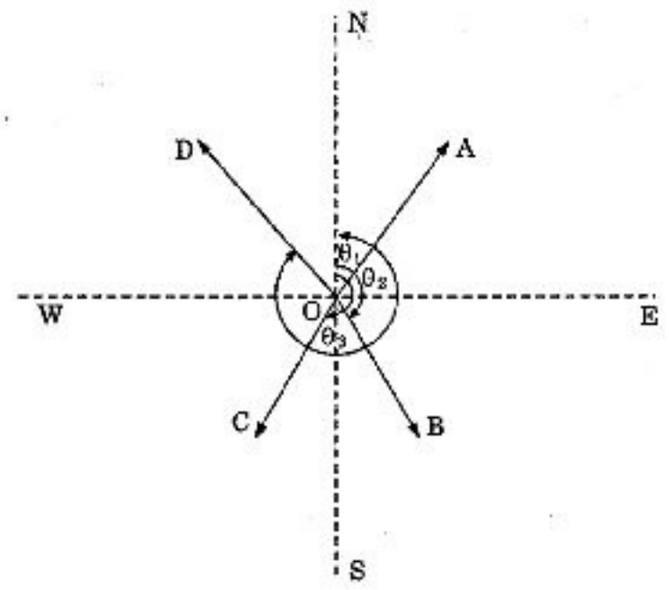
Designation of Bearings :

Bearing of survey lines are designated in the following system :

(*i*) The whole circle bearing system (W.C.B.)

(*ii*) The quadrental bearing system (Q.B.)

(1) The whole circle bearing system (W.C.B.) : The whole circle bearing system is also sometimes known as acimuthal system. In this system bearing of a line is measured from the true north or magnetic north in clockwise direction. The value of bearing may vary from 0° to 360°.



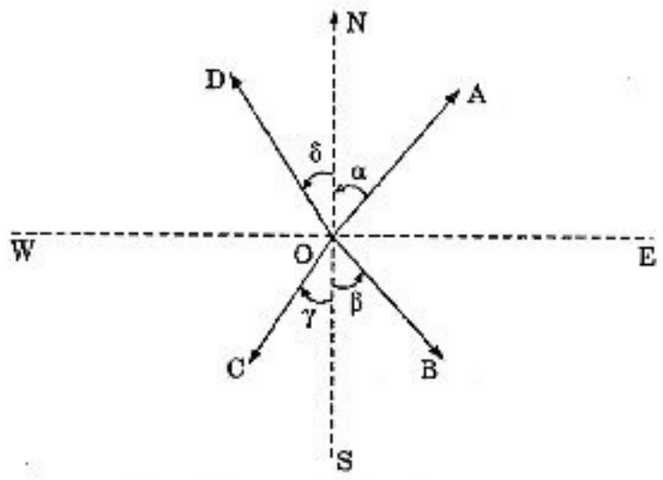
Whole circle bearing of aline

W.C.B. of a line OA, OB, OC and OD are θ_1, θ_2, θ_3 and θ_4 respectively.

(2) The Quadrantal bearing system (Q.B.) : In quadrantal bearing system, bearing of survey lines are measured eastward or westward from North and South whichever is nearest.

Bearing designated by Q.B. system, are sometimes called. Reduced Bearings (R.B.)

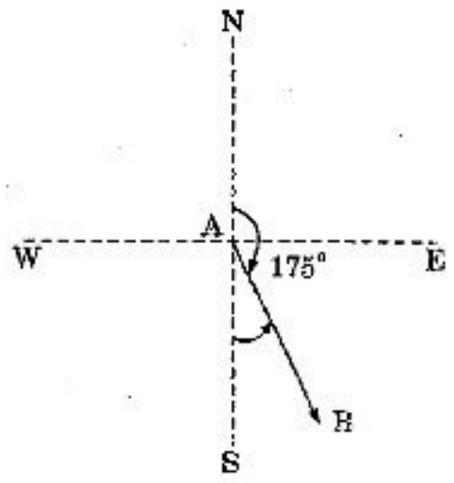
The numerical value of a quadrantal bearing may vary from 0° to 90°



Quadrantal bearing system

Q.B. of a line OA, OB, OC and OD are designated as Nα°E, Sβ°E, Sγ°W and Nδ°S, respectively.

Conversion of bearing from one system to the other :



Suppose W.C.B. of any line is 175°

Q.B. of the line = 180 — 175° = 5°

hence the line is lying in SE Quadrant. It is also nearer to the south direction.

Hence the Q.B. of the line is designated as 55°E

Converting W.C. bearing into Reduced bearing or Q.B.

Case	W.C.B. between	Rule of Q.B. or R.B.	Quadrant
I	0° and 90°	W.C.B.	N.E.
II	90° and 180°	180 — W.C.B.	S.E.
III	180° and 270°	W.C.B. — 180	S. W.
IV	270° and 360°	360° — W.C.B.	N.W.

Note : When a line lies exactly either along North, South, East or West, the W.C.B. of the line is converted in the quadrantal system as follows.

If W.C.B. of a line = 0°, then Q.B. of the line is N

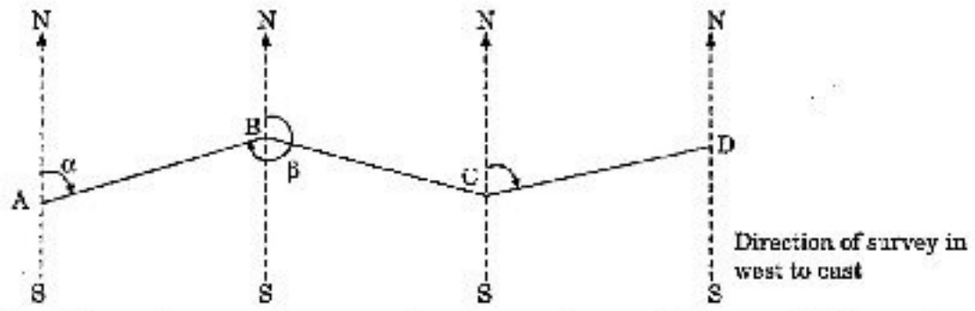
W.C.B. of a line = 90°, then Q.B. of the line is E 90°

W.C.B. of a line = 180°, then Q.B. of the line is S

W.C.B. of a line = 270°, then Q.B. of the line is W 90°

Fore and Back Bearings : Every line may be defined by two bearings. Both the bearing are expressed in W.C.B. system and differ each other by 180°.

The bearing of a line in the direction of the progress of survey is called *Fore* or *Forward Bearing (F.B.)* while the bearing in the opposite direction of the progress of survey, is known as *Reverse or Back Bearing* (B.B.)



In the above figure the bearing of line AB in the direction from A to B is a fore bearing (α) whereas the bearing of the line AB in the direction from B to A is a back bearing (β).

$\Rightarrow$ Back bearing = Fore bearing $\pm$ 180°,

using + ve sign if the fore bearing is less than 180° and —ve sign if it is more than 180° in W.C.B. System.

- To convert the fore bearing of a line into its back bearing in Q.B. system, replace N by S, S by N, E by W and W by E, without changing the numerical value of the bearing

  Let the fore bearing of a line AB = N α° E

  $\therefore$ Back bearing of a line AB = S α° W

Calculation of included angles from bearings :

(I) Given W.C.B. of lines

Included angle BAC = $\angle$NAC — $\angle$NAB

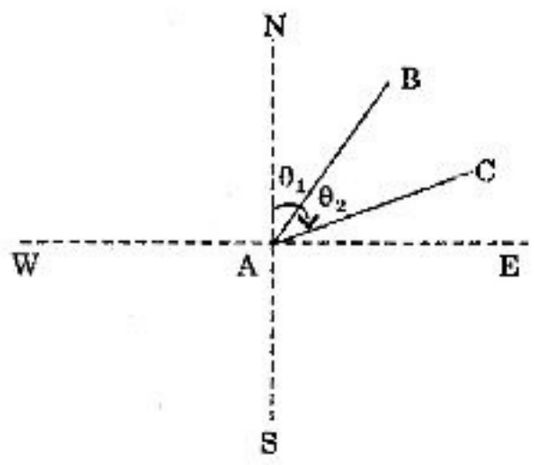
= $\beta - \alpha$

Included angle BAC = Bearing of AC — Bearing of AB

= difference in bearing of AC and AB

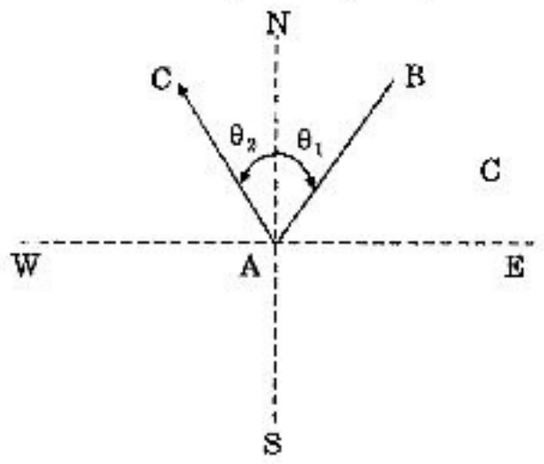
(II) Given Q.B. of lines

(*a*)



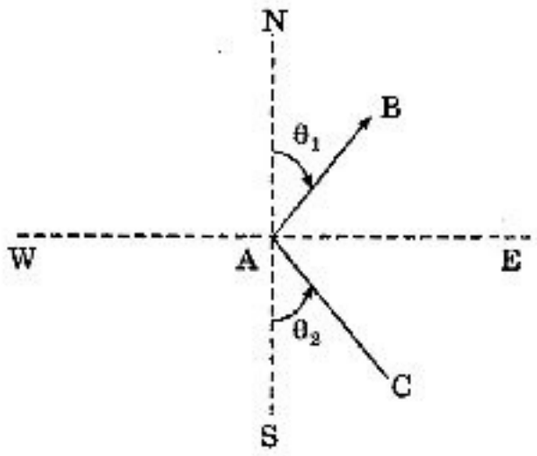
Included angle = $\theta_2 - \theta_1$

(*b*)



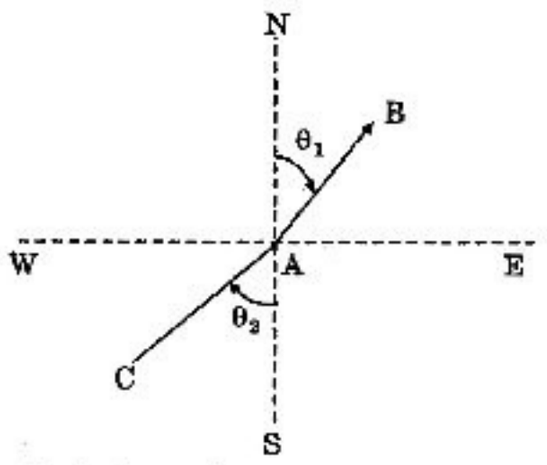
Included angle = $\theta_1 + \theta_2$

(*c*)



Included angle = 180 — ($\theta_1 + \theta_2$)

(*d*)



The included angle

$= 180 + \theta_1 - \theta_2 = 180 - (\theta_2 - \theta_1)$

Note :

(*i*) In a closed traverse run in anticlockwise direction, the observed included angles are interior angles.

(*ii*) In a closed traverse run in clockwise direction, the observing included angles, are exterior

- The included angle of the lines is always less than 180°. If we calculate included angle and it is found greater than 180° than it substract from 360°.

LOCAL ATTRACTION :

North end of a freely suspended magnetic needle always points to the magnetic north, if it is not influenced by any other external forces except the earth magnetic field. It is a common experience that the magnetic needle gets deflected from its normal position, if placed near magnetic rocks, iron ores, cable carrying current or iron electric poles. Such a disturbing force is known as local attraction.

Detection of Local attraction : The presence of local attraction at any station may be detected by observing the fore and back bearing of the line. If the difference between fore and back bearing is 180°, both end stations are free from local attention and if not, the discrepancy may be due to :

(*i*) an error in observation of either fore or back bearing or both.

(*ii*) presence of local attraction at either station.

(*iii*) presence of local attraction at both the stations.

The correction may be made according to the following methods

(*i*) By calculating the included angles at the affected stations.

(*ii*) By calculating the local attraction of each station, and poles, applying the required corrections, starting from the unaffected bearing.

Sum of the exterior angles of the polygon

$$= (2n + 4)\ \frac{\pi}{2}$$

Error = Observed back bearing = Calculated back braring.

Magnetic Declination : The horizontal angle between true north and magnetic north at a place at the time of observed is called *magnetic declination*.

THEODOLITE

Theodolite is a versatile instrument and can be used for the following purposes :

(*i*) To measure horizontal angle

(*ii*) To measure vertical angle

(*iii*) For astronomical observations

(*iv*) For levelling work

(*v*) For foundation layout of buildings, boundaries etc.

(*vi*) To fix alignment of rail, road, electric poles, telephone poles, etc.

CLASSIFICATION OF THEODOLITE :

Theodolite is primarily classified as :

(*i*) Transit Theodolite

(*ii*) Non–transit Theodolite

1. **Transit Theodolite :** A theodolite is called a transit when its telescope can be revolved through a complete revolution about its horizontal axis in a vertical plane. It is mainly used now a days.
2. **Non–transit Theodolite :** A theodolite is called a non–transit when its telescope cannot be revolved through a complete revolution about its horizontal axis in a vertical plane.

Theodolie are also classified as :

(*i*) Vernier theodolites

(*ii*) Glass arc theodolite

(*i*) Vernier Theodolite : In this type of theodolites, vernieres are provided for reading horizontal and vertical graduated circles.

(*ii*) Glass are theodolite : In this type of theodolites, micrometers are provided for reading horizontal and vertical graduated circles.

PARTS OF TRANSIT THEODOLITE :

A transit theodolite consists of following essential parts.

(*i*) Levelling head

(*ii*) Lower plate (or scale plate)

(*iii*) Upper plate (or Vernier plate)

(*iv*) The standards (or A Frame)

(*v*) T–frame or Index–Bar

(*vi*) Plate levels

(*vii*) Telescope

(*viii*) Vertical Circle

(*ix*) Tripod

(*x*) The plumb bob

(*i*) **Levelling head :** It consists of a tribarch on a trivet plate with three arms, each carrying a level screw or foot screw.

The three distinct functions of a levelling head are.

(*a*) To support the main part of the instrument.

(*b*) To attach the theodolite to the tripod.

(c) To provide a means for levelling the theodolite

(*ii*) **Lower Plate :** The lower plate is attached to the outer spindal. It is also called the scale plans, having its levelled. The edge is silvered and graduated from 0° to 360° in a clockwise–direction. This scale is also called horizontal circle. The size of theodolite is determined by the size of the diameter of the lower plate.

(*iii*) **Upper Plate :** It is also called the vernier plate and is attached to the inner axis.

(*iv*) **The Standards :** A frames stand upon the upper plate to support the horizontal axis are called standards.

(*v*) **Telescope :** The telescope is rigidly fixed but the center and at the right angles to the horizontal axis.

(*vi*) **Vertical Circle :** It is rigidly attached to the telescope and moves with it.

(*vii*) **Plumb bob :** A Plumb bob is suspended from the hook fitted to the bottom of the main vertical axis to centre the theodolite exactly over the ground station work.

Definitions and other Technical Terms :

Following terms are used while making observations with a theodolite.

1. **VERTICAL AXIS :** The axis about which the theodolite, may be rotated in a horizontal plane, is called vertical axis. Both upper and lower plates may be rotated about vertical axis.
2. **HORIZONTAL AXIS (or Trunnmior or Transverse axis) :** The axis about which the telescope along with the vertical circle of a theodolite, may be rotated in vertical plane is called horizontal axis.
3. **LINE OF COLLIMATION :** The line which passes through the intersection of the cross hairs of the eye–piece and optical centre of the objective and its continuation, is called line of collimation.
4. **AXIS OF THE TELESCOPE :** The axis about which the telescope may be rotated is called the axis of telescope.
5. **AXIS OF THE LEVEL TUBE :** The axis of the level or bubble tube is the straight line tangential to the longitudinal curve of the level tube at the centre of the tube. It is also called the bubble line
6. **CENTERING :** It means setting up the theodolite exactly over a station mark. It can be done by means of plumb bob.
7. **TRANSITING (Plunging or Reversing) :** The process of turning the telescope in vertical plane through 180° about its horizontal axis, is known as transisting.
8. **SWING :** It means turning the telescope in a horizontal plane. If the telescope is rotated in clockwise direction it is known as right swing and if the telescope is rotated in at the anti–clock wise direction, it is known as the left swing.
9. **FACE LEFT OBSERVATIONS :** When the vertical circle is at the left of the telescope at the time of observations, observations of the angles, are known as face left observation.
10. **FACE RIGHT OBSERVATIONS :** When the vertical circle on the right of the telescope at the time of observation observations of the angles, are known as face right observation.
11. **CHANGING FACE :** It is the operation of changing the face of the telescope from left to right and vice–versa.
12. **A 'MEASURE' :** It is the determination of the number degrees, minutes and seconds, or grades contained in an angle.
13. **A 'SET' :** A 'set' of horizontal observation of any angle consists of two horizontal measures, one on the left to and other on the face right.
14. **TELESCOPE NORMAL :** A telescope is said to be normal when its vertical circle is to its left and the bubble of the telescope is up.
15. **TELESCOPE INVERTED :** A telescope is said to be inverted or reversed when its verticle circle is to its right and the bubble of the telescope is down.

Vertical Curve

Gradient or grade may be defined as a Proportional rise fall between two points along a straight line. It is expressed there as a percentage or as a ratio.

As a percentage : Vertical rise or fall per 100 horizontal e.g. 1%, 2%, 3%. etc.

As a ratio : One vertical rise or fall in n horizontals e.g. 1 in 200. 1 in 500 etc.

Classification of Grades :

The grade are further classified into following two categories

(*i*) Up – grades or positive goodes,

(*ii*) Down grades or negative grades