

**VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELGAUM**



ENGINEERING SURVEY

(Subject Code: BCV302)

LECTURE NOTES

(MODULE-2)

III-SEMESTER

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MODULE -2- PART 1

Vertical Control- Concepts of various types of Datum – Mean Sea level, Bench marks – Temporary and Permanent. Levelling- Terms used in levelling, Setting up of Dumpy level. Differential levelling by plane of collimation method using Dumpy level.

LEVELLING

Levelling may be defined as the art of determining the relative heights or elevation of point's or objects on the earth surface. It deals with measurement in a vertical plane.

The object of Levelling is:

- To find the elevations of given points with respect to a given or assumed datum &
- To establish points at a given elevation or at different elevation with respect to given or assumed datum.

Basic terms and definitions

- **Level surface:** A level surface is any surface parallel to the mean spheroidal surface of the earth. Since the earth is an oblate spheroid, a level surface any be regarded as a curved surface, every point on which is equidistant from the center of the earth. It is normal to the plumb line at all points.
- **Level line:** A level line is a line lying in a level surface. It is, therefore, normal to the plumb line at all points.
- **Horizontal plane:** Horizontal plane through a point is a plane tangential to the level surface at that point. It is also perpendicular to the plumb line.
- **Horizontal line:** Any line lying in the horizontal plane. It is straight line tangential to the level line at a point.
- **Vertical line:** It is a line normal to the level line at a point.
- **Vertical plane:** It is plane containing a vertical line.

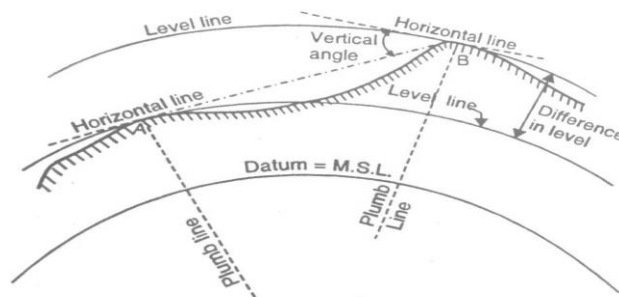
- **Datum:** Datum is any surface to which elevations are referred. The mean sea level refers as convenient datum world over & elevations are commonly given as so much above or below sea level.
- **Elevation:** The elevation of a point on or near the surface of the earth is its vertical distance above or below the datum. It is also known as reduced level (R.L). The elevation of a point is plus or minus according as the point is above or below the datum.

The *difference in elevation* between the (H) between the two point is the vertical distance between the level surface passing through the points.

- **Vertical angle:** It is an angle between two intersecting lines in a vertical plane.
- **Mean sea level:** It is the average height of the sea for all stages of the tides. At any particular place it is derived by averaging the hourly tide heights over a long period of 19 years.
- **Bench Mark:** It is relatively permanent point of reference whose elevation with respect to some assumed datum is known.

Types of Bench Mark:

- (1) **G.T.S Bench Mark:** The Great Trigonometrical Survey [G.T.S] bench marks are established by the Survey of India throughout the country. The elevations of the bench marks are correct to two decimal places of a meter.
- (2) **Permanent Bench Mark:** The permanent bench marks are established at a closer interval between widely spaced G.T.S bench marks.
- (3) **Temporary Bench Marks:** These are the bench marks established temporarily whenever required.
- (4) **Arbitrary Bench Marks:** These are the bench marks whose elevations are arbitrary assumed for leveling of a small area.





Methods of Levelling

Three principal methods are used for determining difference in elevation, namely, barometric levelling, trigonometric levelling and spirit leveling.

- **Barometric levelling:** Barometric levelling makes use of the phenomenon that difference in elevation between two points is proportional to the difference in atmospheric pressures at these points. A barometer, therefore, may be used and the readings observed at different points would yield a measure of the relative elevations of those points. At a given point, the atmospheric pressure does not remain constant in the Course of the day, even in the course of an hour. The method is, therefore, relatively inaccurate and is little used in surveying work except on reconnaissance or exploratory surveys.
- **Trigonometric Levelling (Indirect levelling):** Trigonometric or Indirect levelling is the process of levelling in which the elevations of points are computed from the vertical angles and horizontal distances measured in the field, just as the length of any side in any triangle can be computed from proper trigonometric relations. In a modified form called stadia levelling, commonly used in mapping, both the difference in elevation and the horizontal distance between the points are directly computed from the measured vertical angles and staff readings.
- **Spirit Levelling (Direct Levelling) :** It is that branch of levelling in which the vertical distances with respect to a horizontal line (perpendicular to the direction of gravity) may be used to determine the relative difference in elevation between two adjacent points. A horizontal plane of sight tangent to level surface at any point is readily established by means of a spirit level or a level vial. In spirit levelling, a spirit level and a sighting device (telescope) are combined and vertical distances are measured by observing on graduated rods placed on the points. The method is also known as direct levelling. It is the most precise method of determining elevations and the one most commonly used by engineers. The commonly used type of direct levelling are,
 - **Simple leveling:** One set up of level. To find elevation of points.



- Differential leveling: Numbers of set-ups of level. To find elevation of non-intervisible points.
- Fly leveling: Low precision, to find/check approximate level, generally used during reconnaissance survey.
- Precise leveling: Precise form of differential leveling.
- Profile leveling: finding of elevation along a line and its cross section.
- Reciprocal leveling: Along a river or pond. Two level simultaneously used, one at either end.

Leveling Instrument

The instruments commonly used in direct leveling are:

- (1) A level
- (2) A leveling staff

1. A level

The purpose of level is to provide a horizontal line of sight. A level consists of the following four parts.

- (a) A telescope to provide line of sight.
- (b) A level tube to make the line of sight horizontal.
- (c) A leveling head (tribrach & trivet stage) to bring the bubble in its centre of run.
- (d) A tripod

A schematic diagram of an engineer's level is shown in Figure 4.2. An engineer's level primarily consists of a telescope mounted upon a level bar which is rigidly fastened to the spindle. Inside the tube of the telescope, there are objective and eye piece lens at the either end of the tube. A diaphragm fitted with cross hairs is present near the eye piece end. A focussing screw is attached with the telescope. A level tube housing a sensitive plate bubble is attached to the telescope (or to the level bar) and parallel to it. The spindle fits into a cone-shaped bearing of the leveling head.

The leveling head consists of tribrach and trivet with three foot screws known as leveling screws in between. The trivet is attached to a tripod stand.

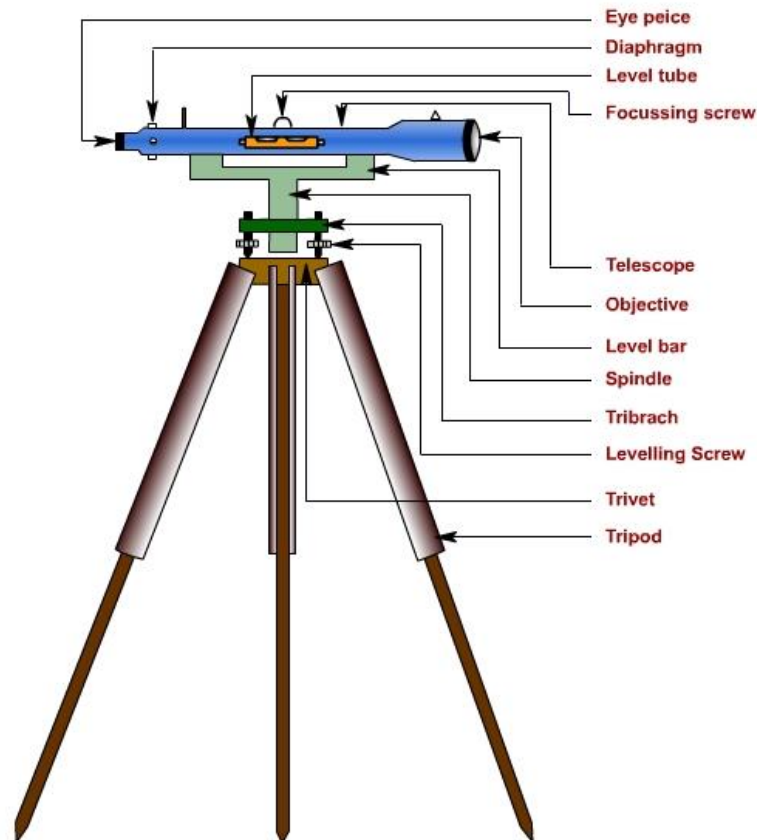


Fig : Schematic diagram of an engineer's level.

Functions of Salient Parts:

- **Telescope** : used to sight a staff placed at desired station and to read staff reading distinctly.
- **Diaphragm** : holds the cross hairs (fitted with it).
- **Eye piece** : magnifies the image formed in the plane of the diaphragm and thus to read staff during leveling.

- **Level Tube** : used to make the axis of the telescope horizontal and thus the line of sight.
- **Leveling screws** : to adjust instrument (level) so that the line of sight is horizontal for any orientation of the telescope.
- **Tripod stand** : to fix the instrument (level) at a convenient height of an observer.

The following are the chief types of levels:

- Dumpy level
- Wye or (Y) level
- Reversible level
- Tilting level
- Auto level
- Digital level
- Laser level.

➤ **Dumpy level**

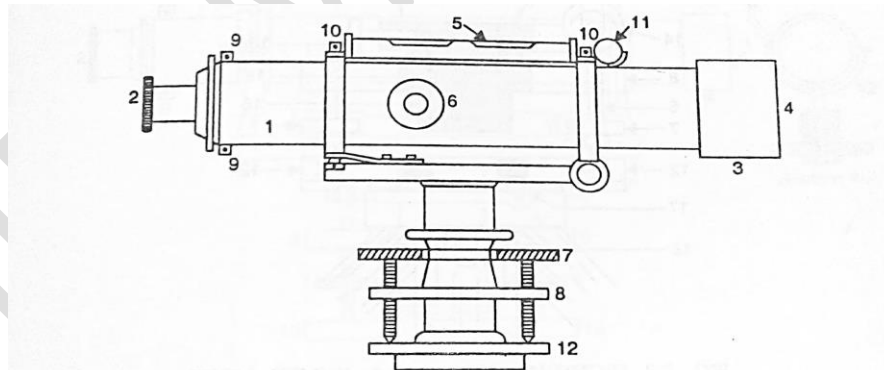


FIG. 9.2. DUMPY LEVEL

- | | |
|------------------------|------------------------------------|
| 1. TELESCOPE | 7. FOOT SCREWS |
| 2. EYE-PIECE | 8. UPPER PARALLEL PLATE (TRIBRACH) |
| 3. RAY SHADE | 9. DIAPHRAGM ADJUSTING SCREWS |
| 4. OBJECTIVE END | 10. BUBBLE TUBE ADJUSTING SCREWS |
| 5. LONGITUDINAL BUBBLE | 11. TRANSVERSE BUBBLE TUBE |
| 6. FOCUSING SCREWS | 12. FOOT PLATE (TRIVET STAGE). |

Fig : Dumpy level



The Dumpy level originally designed by Gravatt, consists of a telescope tube firmly secured in two collars fixed by adjusting screws to the stage carried by the vertical spindle. The Dumpy level is commonly used for leveling. The dumpy level consists of a telescope fixed on vertical spindle. The telescope tube and the vertical spindle are cast as one piece. The spindle revolves in the socket of the leveling head. The leveling head consists of two parallel plates held apart by three leveling screws. The upper parallel plate is called tribatch, the lower plate, known as trivet stage, is screwed on the top of a tripod when the instrument is to be used. The telescope can be rotated in the horizontal plane about its vertical axis.

The telescope of the dumpy level is generally of the internal focusing type. A sensitive level tube is fitted on the top of the telescope or on its one side. The cross hairs of the diaphragm normally have a vertical line and horizontal line (the line joining the point of intersection of the cross hairs and the optical centre of the objective is called the “Line of Sight” or “line of collimation”).

The advantages of the dumpy level over Wye level are:

- (i). Simpler construction with fewer movable parts.
- (ii). Fewer adjustments to be made.
- (iii). Longer life of the adjustments

A leveling staff

A leveling staff is a straight rectangular rod having graduations, the foot of the staff representing zero reading. The purpose of a level is to establish a horizontal line of sight. The purpose of the leveling staff is to determine the amount by which the station is above or below the line of sight.

Leveling staffs may be divided into two classes:

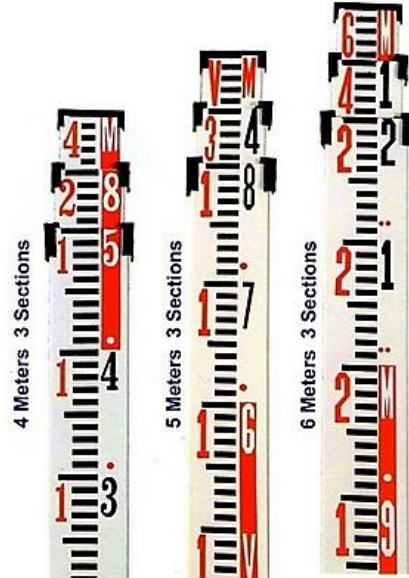
- Self reading staff
- Target staff



Fig a) Solid staff



b) Folding staff



c) Telescopic staff

(ii) Target staff: If the sighting distance is more, instrument man finds it difficult to read self-reading staff. In such case a target staff shown in [Fig.] may be used. Target staff is similar to self-reading staff, but provided with a movable target. Target is a circular or oval shape, painted red and white in alternate quadrant. It is fitted with a vernier at the centre. The instrument man directs the person holding target staff to move the target, till its centre is in the horizontal line of sight. Then target man reads the target and is recorded.

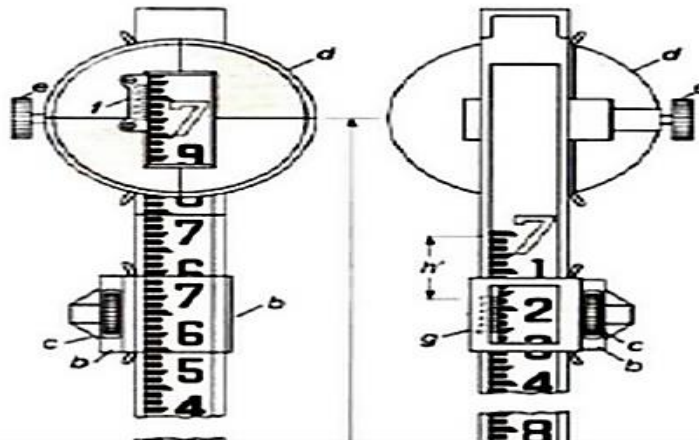


Fig : Target staff



➤ Temporary adjustment of a dumpy Level

Temporary adjustments are the adjustments which are done at every setting of the instruments and preparatory to taking observation with the instrument. When the setup is changed, the temporary adjustments are disturbed. The following adjustments are done in the case of a dumpy level.

1. Setting up

First the tripod is setup so that its top is at a convenient height. For fixing the level on the tripod, hold the level in the right hand and fix it on the tripod by turning the trivet stage with the left hand. The tripod legs are moved radially or circumferentially so that leveling head is approximately horizontal some instruments are also provided with a small circular bubble on the tribrach.

2. Leveling up

After having leveled the instrument approximately, accurate leveling is done with the help of foot screws and with reference to the plate levels. The purpose of leveling is to make the vertical axis truly vertical. The manner of leveling the instrument by the plate levels depends upon whether there are three leveling screws or four leveling screws.

a) Three screw head

- (1) Loose the clamp, turn the instrument until the longitudinal axis of the plate level is roughly parallel to a line joining any two of the leveling screws.
- (2) Hold these two leveling screws between the thumb and first finger of each hand and turn them uniformly so that the thumbs move either towards each other or away from each other until the bubble is central. It should be noted that the bubble will move in the direction of movement of the left thumb.
- (3) Turn the upper plate through 90° i.e until the axis on the level passes over the position of the third leveling screw as shown in fig below.
- (4) Turn this leveling screw until the bubble is central.
- (5) Return the upper part through 90° to its original position and repeated step (2) till bubble is central.

- (6) Turn back again through 90° and repeat step (4).
- (7) Repeat steps (2) & (4) till the bubble is central in both the positions.
- (8) Now rotate the instrument through 180° . The bubble should remain in the centre of its run, provided it is in correct adjustment. The vertical axis will then be truly vertical. If not, it needs permanent adjustment.

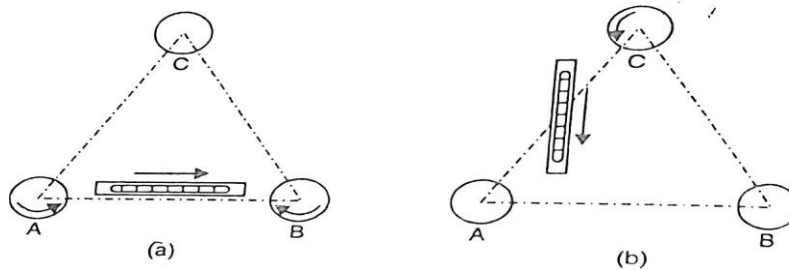


Fig . Levelling up with three foot screw

3. Elimination of Parallax

Parallax is a condition arising when the image formed by the objective is not in the plane of the cross-hairs. Unless parallax is eliminated, accurate sighting is impossible. Parallax can be eliminated in two steps.

- 1) By focusing the eye-piece
- 2) By focusing the objective.

1) **By focusing the eye-piece**

To focus the eye-piece for distinct vision the cross-hairs, point the telescope towards the sky and move eye-piece in or out till the cross hairs are seen sharp and distinct

2) **Focusing the objective**

The telescope is now directed towards the staff and the focusing screw is turned till the image appears clear and sharp. The image so formed is in the plane of cross hairs.



THEORY OF DIRECT LEVELLING (SPIRIT LEVELING)

A level provides horizontal line of sight, i.e., a line tangential to level surface at the point where the instrument stands. The difference in elevation between two points is the vertical distance between two level lines. Strictly speaking, therefore, we must have a level line of sight and not a horizontal line of sight; but the distinction between a level surface and a horizontal plane is not an important one in plane surveying. Neglecting the curvature of earth and refraction, therefore, the theory of direct levelling is very simple. With a level set up at any place, the difference in elevation between any two points within proper lengths of sight is given by the difference between the rod readings taken on these points. By a succession of instrument stations and related readings, the difference in elevation between widely separated points is thus obtained.

SPECIAL METHODS OF SPIRIT LEVELLING

(a) Differential Levelling. It is the method of direct levelling the object of which is solely to determine the difference in elevation of two points regardless of the horizontal positions of the points with respect of each other. When the points are apart, it may be necessary to set up the instruments several times. This type of levelling is also known as fly levelling.

(b) Profile Levelling. It is the method of direct-levelling the object of which is to determine the elevations of points at measured intervals along a given line in order to obtain a profile of the surface along that line.

(c) Cross-Sectioning. Cross-sectioning or cross-levelling is the process of taking levels on each side of a main line at right angles to that line, in order to determine a vertical cross-section of the surface of the ground, or of underlying strata, or of both.

(d) Reciprocal Levelling. It is the method of levelling in which the difference in elevation between two points is accurately determined by two sets of reciprocal observations when it is not possible to set up the level between the two points.



(e) **Precise Levelling.** It is the levelling in which the degree of precision required is too great to be attained by ordinary methods, and in which, therefore, special, equipment or special precautions or both are necessary to eliminate, as far as possible. all sources of error.

Terms & Abbreviations

(i) Station

In levelling, a station is that point where the leveling staff is held and not where the level is set up. It is a point whose elevation is to be established at a given elevation.

(ii) Height of Instrument (H.I)

For any set up of the level, the height of instrument is the elevation of the line of sight with respect to the assumed datum is called height of instrument.

(iii) Back sight (B.S)

It is the reading taken on the staff held at a point of known elevation, to ascertain the amount by which the line of sight is above that point and thus to obtain the height of instrument. It is also known as plus sight as the back sight reading is always added to the level of the datum to get the height of instrument. The object of back sighting is therefore to ascertain the height of the line of sight.

(iv) Fore sight (F.S)

It is the reading taken on the staff held at a point of known elevation, to ascertain the amount by which the point is below the line of sight and thus to obtain the elevation of the station. It is also known as minus sight as fore sight reading is always subtracted from the height of instrument. The object of fore sight is therefore to determine the elevation of the staff station.

(v) Change point (C.P)

A change point or turning (T.P) is the point where staff is held & after taking fore sight to determine the elevation of the point where the staff is held, the instrument is shifted & back sight is taken at

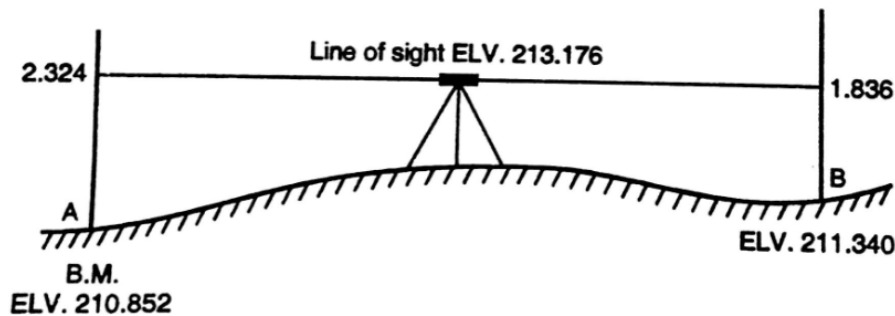
the same point, to determine the new height of instrument. Therefore, at the change point both the back sight and fore sight are taken.

(vi) Intermediate station (I.S)

Intermediate station is a point, intermediate between two turning points, on which only one sight (Minus sight) is taken to determine the elevation of the station.

STEPS IN LEVELLING

There are two steps in levelling: (a) to find by how much amount the line of sight is above the bench mark, and (b) to ascertain by how much amount the next point is below or above the line of sight.



A level is set up approximately midway between the bench mark (or a Point of known elevation) and the point, the elevation of which is to be ascertained by direct levelling. A back sight is taken on the rod held at the bench mark. Then

$$\text{H.I.} = \text{Elv. Of B.M} + \text{B.S}$$

Turning the telescope to bring into view the rod held on point B, a foresight (minus sight) is taken.

Then, $\text{Elv} = \text{H.I} - \text{F.S.}$

For example, if elevation of B.M. = 210.852 m, B.S. = 2.324 m and F.S. = 1.836 m

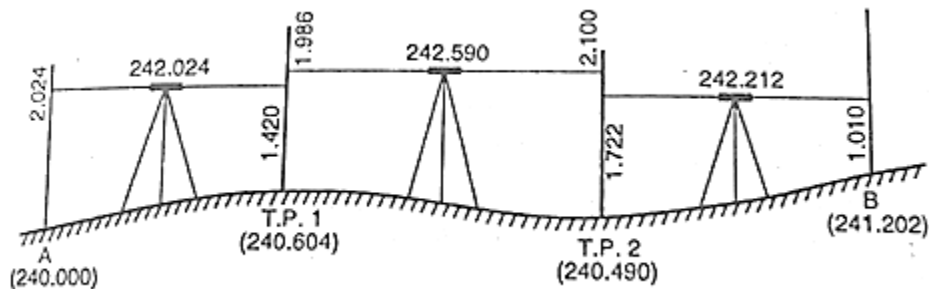
Then $\text{H.I.} = 210.852 + 2.324 = 213.176 \text{ m}$

and $\text{Elv. Of B} = 213.176 - 1.836 = 211.340 \text{ m.}$

It is to be noted that if a back sight is taken on a bench mark located on the roof of a tunnel or on the ceiling of a room with the instrument at a lower elevation, the back sight must be subtracted from the elevation to get the height of the instrument. Similarly, if a foresight is taken on a point higher than the instrument, the foresight must be added to the height of the instrument, to get the elevation of the point.

DIFFERENTIAL LEVELLING

The operation of levelling to determine the elevation of points at some distance apart is called differential levelling and is usually accomplished by direct levelling. When two points are at such a distance from each other that they cannot both be within range of the level at the same time, the difference in elevation is not found by single setting but the distance between the points is divided in two stages by turning points on which the staff is held and the difference of elevation of each of succeeding pair of such turning points is found by separate setting up of the level.



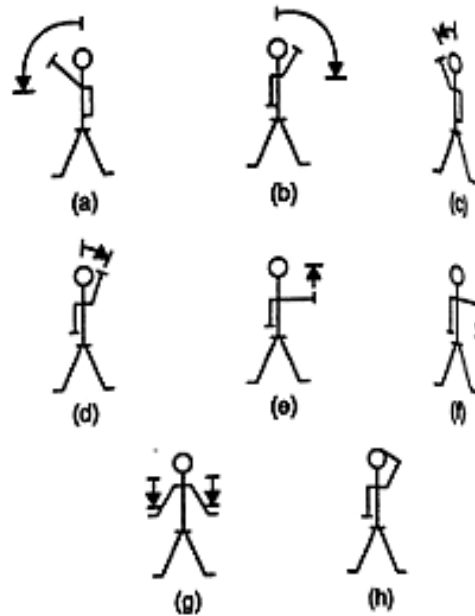
Referring to Fig., A and B are the two points. The distance AB has been divided into three parts by choosing two additional points on which staff readings (both plus sight and minus sight) have been taken. Points 1 and 2 thus serve as turning points.

The R.L. of point A is 240.00 m. The height of the first setting of the instrument is therefore = $240.00 + 2.024 = 242.024$. If the following. F.S. is 1.420, the R.L. of T.P. 1 = $242.024 - 1.420 = 240.604$ m. By a similar process of calculations, R.L. of T.P. 2 = 240.490 m and of B = 241.202 m.

Hand signal during observation

When leveling is done at construction site located in busy areas, it become difficult for the instrument man to give instruction to man holding the staff at the other end, through vocal sound. In that case the following hand signal are found to be useful,

Refer Fig. 9.33	Signal	Message
(a)	Movement of left arm over 90°	Move to my left
(b)	Movement of right arm over 90°	Move to my right
(c)	Movement of left arm over 30°	Move top of staff to my left
(d)	Movement of right arm over 30°	Move top of staff to my right
(e)	Extension of arm horizontally and moving hand upwards	Raise height peg or staff
(f)	Extension of arm horizontally and moving hand downwards	Lower height peg or staff
(g)	Extension of both arms and slightly thrusting downwards	Establish the position
(h)	Extension of arms and placement of hand on top of head.	Return to me



BOOKING AND REDUCING LEVELS

There are two methods of booking and reducing the elevation of points from the observed staff readings: (1) Collimation or Height of Instrument method; (2) Rise and Fall method.

(1) HEIGHT OF INSTRUMENT METHOD

In this method, the height of the instrument (H.I.) is calculated for each setting of the instrument by adding back sight (plus sight) to the elevation of the B.M. (First point). The elevation of reduced level of the turning point is then calculated by subtracting from H.I. the fore sight (minus sight). For the next setting of the instrument, the H.I. is obtained by adding the B.S taken on T.P. 1 to its



R.L. The process continues till the R.L. of the last point (a fore sight) is obtained by subtracting the staff reading from height of the last setting of the instrument. If there are some intermediate points, the R.L. of those points is calculated by subtracting the intermediate sight (minus sight) from the height of the instrument for that setting.

The following is the specimen page of a level field book illustrating the method of booking staff readings and calculating reduced levels by height of instrument method.

Station	B.S	I.S.	F.S.	H.I.	R.L.	Remarks
A	0.865			561.365	560.500	B.M. on Gate
B	1.025		2.105	560.285	559.260	
C		1.580			558.705	Platform
D	2.230		1.865	560.650	558.420	
E	2.355		2.835	560.270	557.815	
F			1.760		558.410	
Check	6.475		8.565 6.475		558.410 560.500	Checked
			2.090	Fall	2.090	

Arithmetic Check: The difference between the sum of back sights and the sum of fore sights should be equal to the difference between the last and the first R.L. Thus,

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

The method affords a check for the H.I. and R.L. of turning points but not for the intermediate points.

3) RISE AND FALL METHOD

In rise and fall method, the height of instrument is not at all calculated but the difference of level between consecutive points is found by comparing the staff readings on the two points for the same setting of the instrument. The difference between their staff readings indicates a rise or fall according as the staff reading at the point is smaller or greater than that at the preceding point. The figures for 'rise' and 'fall' worked out thus for all the points give the vertical distance of each point



above or below the preceding one, and if the level of any one point is known the level of the next will be obtained by adding its rise or subtracting its fall, as the case may be. The following is the specimen page of a level field book illustrating the method of booking staff readings and calculating reduced levels by rise and fall method:

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remarks
A	0.865					560.500	B.M. on Gate
B	1.025		2.105		1.240	559.260	
C		1.580			0.555	558.705	Platform
D	2.230		1.865		0.285	558.420	
E	2.355		2.835		0.605	557.815	
F			1.760	0.595		558.410	
Check	6.475	Fall	8.565	0.595	2.685	558.410	Checked
			6.475				
			2.090				

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

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

This provides a complete check on the intermediate sights also. The arithmetic check would only fail in the unlikely, but possible, case of two more errors occurring in such a manner as to balance each other. It is advisable that on each page the rise and fall calculations shall be completed and checked by comparing with the difference of the back and fore sight column summations, before the reduced level calculations are commenced.

Comparison of the Two Methods.

The height of the instrument (or collimation level) method is more rapid, less tedious and simple. However, since the check on the calculations for intermediate sights is not available, the mistakes in their levels pass unnoticed. The rise and fall method though more tedious, provides a full check



in calculations for all sights. However, the height of instrument method is more suitable in case, where it is required to take a number of readings from the same instrument setting, such as for constructional work, profile levelling etc.

Numerical Problem

- The following staff readings were observed successively with a level, the instrument having been moved after third, sixth and eighth readings: 2.228; 1.606; 0.988; 2.090 ; 2.864 ; 1.262 ; 0.602 ; 1.982 : 1.044 ; 2.684 metres.

Enter the above readings in a page of a level book and calculate the R.L. of points if the first reading was taken with a staff held on a bench mark of 432.384 m.

Solution

Since the instrument was shifted after third, sixth and eighth readings, these readings will be entered in the F.S. column and therefore, the fourth, seventh and ninth reading; will be entered on the B.S. column. Also, the first reading will be entered in the B.S column and the last reading in the F.S. column. All other readings will be entered it the I.S. column. The reduced levels of the points may be calculated by rise and fall method as tabulated below

Station	B.S	I.S	F.S	Rise	Fall	R.L	Remarks
1	2.228					432.384	B.M
2		1.606		0.622		433.006	
3	2.090		0.988	0.618		433.624	T.P1
4		2.864			0.774	432.850	
5	0.602		1.262	1.602		434.452	T.P2
6	1.044		1.982		1.380	433.072	T.P3
7			2.684		1.640	431.432	
Check	5.964		6.916	2.842	3.794	432.384	
			<u>5.964</u>		<u>2.842</u>	<u>431.432</u>	
		Fall	0.952	Fall	0.952	0.952	Checked



2. It was required was required to ascertain the elevation two points P and Q and line of level was rum from P to Q. The levelling was then continued to a bench marks of 83.500, the reading obtained being as shown below. Obtain the R.L. of P and Q.

B.S	I.S	F.S	R.L	Remarks
1.622				P
1.874		0.354		
2.032		1.78		
	2.362			Q
0.984		1.122		
1.906		2.824		
		2.036	83.5	B.M

Solution

To find the R. Ls. of P and Q, we will have to proceed from bottom to the top. To find the H.I., therefore, F.S. readings will have to be added to the R.L. of the known point and to find the R.L. of the previous point, the B.S. will have to be subtracted from the so obtained H.I. as clearly shown in the table below

Station	B.S	I.S	F.S	H.I	R.L	Remarks
P	1.622			84.82	83.198	
	1.874		0.354	86.34	84.466	
	2.032		1.78	86.592	84.560	
Q		2.362			84.230	
	0.984		1.122	86.454	85.470	
	1.906		2.824	85.539	83.630	
			2.036		83.500	B.M



Check	8.418		8.116		83.500	Checked
	<u>8.116</u>				<u>83.198</u>	
	0.302				0.302	

IMPOTANT QUESTIONS:

1. Explain the following: i) Types of adjustments of dumpy level. ii) Differential leveling
2. Define the following terms:
i) Benchmark ii) Back sight iii) Foresight iv) Reduced level
3. What are the temporary adjustment of the Dumpy level explain
4. The following staff readings were observed successively with level, the instrument having been moved forward after the second, fourth and eighth 0.875, 1.235, 2.310, 1.385, 2.930, 3.125, 4.125, 0.120, 1.875, 2.030, 3.765. The first reading was taken on a BM of elevation 132.135 m. Enter the readings in a level book format and reduce the levels. Apply the usual checks
5. List and explain different types of Bench Mark



Module 2- Part-2

SYLLABUS:

Theodolite Surveying – Terms used in Theodolite surveying. Setting up a Theodolite. Measurement of horizontal and vertical angles with Theodolite.

THEODOLITE SURVEY

An instrument used for measuring horizontal and vertical angles accurately is known as a theodolite. It is used for prolongation of survey lines, finding the difference in elevation, and setting out engineering works requiring higher precision, i.e. ranging the highway and railway curves, aligning the tunnels, etc.

Classification of theodolites

- Transit theodolite
- Non-transit theodolite

Transit theodolite

A theodolite is called a transit theodolite if its telescope can be transited, for example, it can revolve through a complete revolution about its horizontal axis in a vertical plane.

Non-transit theodolite

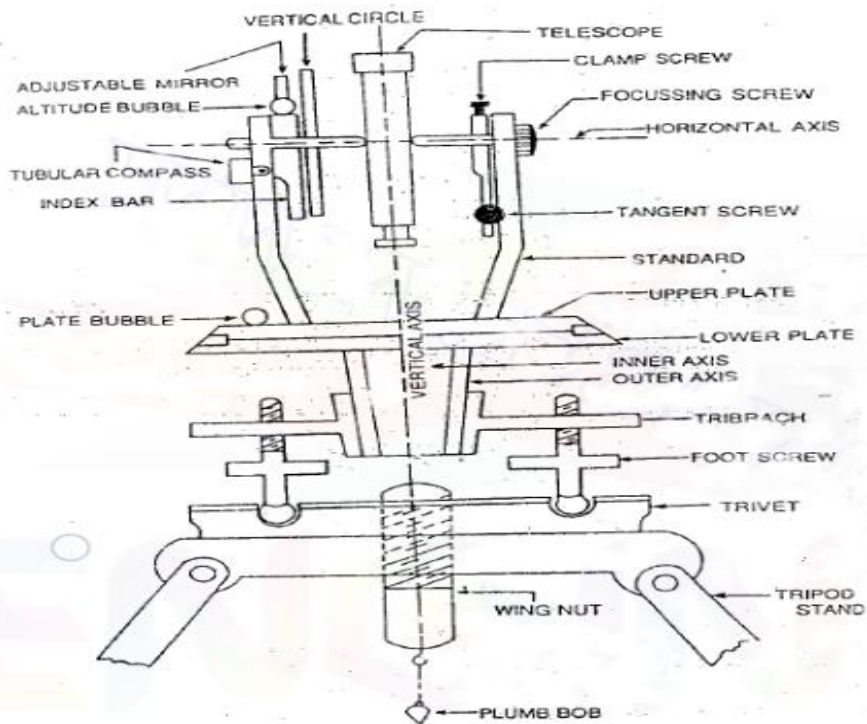
In non-transit theodolite its telescope cannot be transited, i.e, it cannot revolve through a complete revolution about its horizontal axis in a vertical plane.

A theodolite is a precision instrument for measuring angles in the horizontal and vertical planes. Theodolites are used mainly for surveying applications, and have been adapted for specialized purposes in fields like metrology and rocket launch technology. A modern Theodolite consists of a movable telescope mounted within two perpendicular axes the horizontal or trunnion axis, and the

vertical axis. When the telescope is pointed at a target object, the angle of each of these axes can be measured with great precision.

Parts of Theodolite and their Functions

A Theodolite consist of following parts, are as under



Theodolite Parts

Trivet or Base Plate

It is a circular plate and has a central threaded hole to fit it on the tripod. Three foot screws are attached to base plate with ball and socket arrangement.

Foot screws

D.....



They are provided for the levelling of the theodolite. The lower part of the foot screws are attached to the base plate and upper part to the tribranch plate.

Tribranch plate

It is a triangular plate carrying three foot screws at its end.

Levelling head

The assembly of base plate, foot screws and tribranch plate is known as levelling head.

Spindles

Spindles or axes are attached to the tribranch plate. There are two spindles in the theodolite. Inner spindle or axis which is solid and conical. The outer spindle is hollow and co-axial with the inner spindle.

Lower plate

It is attached to the outer axis and contains a horizontal scale graduated from 0 degrees to 360 degrees in a clockwise direction. Each degree is then sub-divided into further divisions. The value of one division maybe 15 or 20 seconds.

It is provided with the clamp screw and tangent screw. When the clamp screw is tightened the plate is fixed with the outer axis. The tangent screw is used for fine-tuning.

Upper plate

It is attached to the inner axes and contains verniers A and B. It is provided with the upper clamp and tangent screw. When tangent screw is tightened it is attached with the inner axis.



Plate bubbles

Two plate bubbles are attached at a right angle to each other on the upper surface of the vernier plate. These bubbles are meant for leveling of the instrument for horizontal angle measurement.

Standard or A frame

Standard or A frame supports the telescope, the vertical circle and the vernier scales.

Telescope

It is pivoted between the standards at a right angle to the horizontal axis. It can be moved in a vertical plane and consists of focusing screws, tangent screw, and clamping screw

Vertical circle

It is fixed with the telescope and moves with it. It is divided into four quadrants, each quadrant is graduated from 0 degrees to 90 degrees in opposite directions.

Altitude bubbles

It is provided for levelling when measuring vertical angles.

Compass

Sometimes compass is provided for measuring the magnetic bearing of a line.

Least count of vernier theodolite

It is the difference between the value of the smallest division on the main scale and that of the smallest division of the vernier scale. It is the smallest value measured by the theodolite.

Let (n-1) small divisions of the main scale is divided into n small divisions in the vernier scale

$$\text{Then } n \times v = (n-1)d$$



$$v = (n-1)d/n$$

v = value of smallest division of Vernier scale.

d = value of smallest division of main scale.

So least count = $d - v = d - (n-1)d/n = d/n$

for example; $d = 20'$ and $n = 60$; least count = $20/60 \times 60 = 20''$

IMPORTANT TERMS:

1. Centering: The setting of theodolite exactly over a station marked by means of plumb bob is known as centering.
2. Transiting: The method of turning the telescope about its horizontal axis in a vertical plane through $180'$ is termed as transiting. In other words, transiting results in a change of face.
3. Face left: It means that the vertical circle of theodolite is on the left of the observer at the time of taking reading.
4. Face right: This refers to the situation when the vertical circle of the instrument is on the right of the observer when the reading is taken.
5. Changing face: The operation of bringing the vertical circle from one side of the observer to the other is known as changing face.
6. Swinging the telescope: This indicates turning the telescope in a horizontal plane. It is called 'right swing' when the telescope is turned clockwise and 'left swing' when the telescope is turned anticlockwise.
7. Line of collimation: It is an imaginary line passing through the optical centre of the objective glass and its continuation.
8. Axis of telescope: The axis is an imaginary line passing through the optical centre of the object glass and optical centre of eyepiece.
9. Axis of the bubble tube: It is an imaginary line tangential to longitudinal curve of bubble tube at its middle point.

Temporary Adjustments of Theodolite



Theodolite has two types of adjustments-temporary and permanent. Temporary adjustments are to be done at every station the instrument is set up. Permanent adjustments deal with the fundamental lines and their relationships and should be done once in a while to ensure that the instrument is properly adjusted. The fundamental lines and their desired relationships are explained later in this chapter and the permanent adjustments are explained in detail in Chapter 4. In this section we will discuss temporary adjustments.

The temporary adjustments are the following:

- (a) setting up and centring,
- (b) levelling,
- (c) focusing the eyepiece, and
- (d) focusing the objective.

Setting Up and Centring

The following procedure is adopted for this operation.

1. Remove the theodolite from its box carefully and fix it onto a tripod kept over the station where the instrument is to be set up. The tripod legs should be well apart and the telescope should be at a convenient height for sighting.
2. Tie a plumb bob onto the hook provided at the base. If there is no shifting head in the instrument, centre it by adjusting the tripod legs and shifting the instrument as a whole to bring the plumb bob over the station mark.
3. To centre the plumb bob, shift the tripod legs radially as well as circumferentially. *Moving any leg radially shifts the plumb bob in the direction of the leg.* This does not affect the level status of the instrument. *Moving any leg circumferentially does not appreciably shift the plumb.* However, this movement tilts the instrument and affects the level of the plate bubbles. By moving the legs the



plumb bob is brought over the station mark at the same time ensuring that the instrument is approximately level. This saves a lot of time for the next operation of levelling.

4. If the instrument has a shifting head with a clamp, first centre the instrument using legs. Make the final adjustment by loosening the clamp and shifting the head (or the instrument as a whole) to bring the plumb bob over the station mark. In all operations, the starting step should be to first bring the plumb bob very close to the mark and then make the final adjustment using the legs or the shifting head.

Levelling

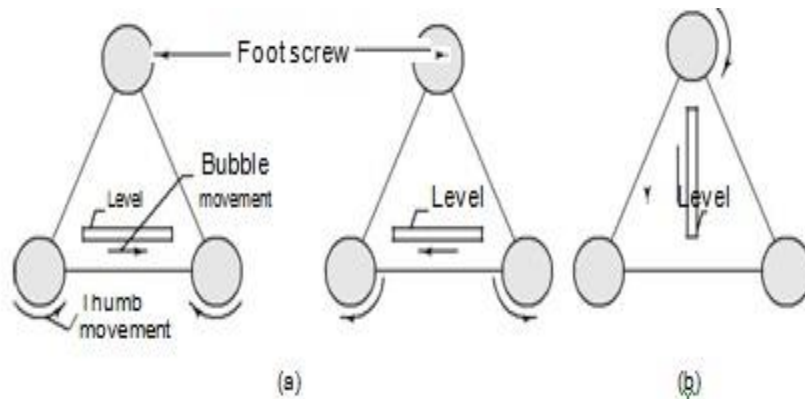
After setting up and centring the instrument, levelling is done. Levelling has to be done at every station the instrument is set up. By levelling the instrument, it is ensured that as the instrument is swung about the vertical axis, the horizontal plate moves in a horizontal plane. The instrument may have a three-screw or a four-screw levelling head. The levelling operations differ slightly in these two cases as detailed in the following sections. Most instruments have only one bubble tube, but some instruments have two bubble tubes set at right angles over the plates.

Three-screw levelling head

When the theodolite has a three-screw levelling head, the following procedure is adopted.

1. Swing the theodolite and bring the plate bubble parallel to any two of the foot screws. Centre the bubble by rotating the foot screws. *Rotate both either inwards or outwards*. Also note that the bubble moves in the direction of movement of the left thumb during this operation.

Once the bubble traverses (or comes to the central position from the graduation of the tube), swing the instrument and bring the bubble over the third foot screw. In this position, the bubble tube is at right angles to the earlier position. Centre the bubble by rotating the third foot screw alone.



Three-foot-screw levelling head

3. Bring the plate bubble to its previous position by swinging the instrument back. Check whether the bubble traverses. If it does not traverse, bring the bubble to the centre using the two foot screws as before.
4. Repeat the procedure till the bubble traverses in both these positions.
5. Swing the instrument through 180° and check whether the bubble traverses. The bubble should traverse in all positions if the instrument has been properly adjusted.

If two plate bubbles are provided [see Fig. 6.3(b)], the procedure is the same except that swinging the instrument through 90° is not required. When one plate level is kept parallel to a pair of foot screws, the other plate level is over the third foot screw (in a perpendicular direction). The third foot screw is adjusted alternately by the same process using the foot screws over which they are parallel.

Focusing the Eyepiece

Focusing the eyepiece is the operation of bringing the cross hairs to focus. The focusing position varies with the eyesight of the observer. If the same observer is taking the readings, this has to be done only once. To focus the eyepiece, use the following procedure.

1. Keep a piece of white paper in front of the telescope or direct the telescope towards a clear portion of the sky.

2. Looking through the telescope, adjust the vision by rotating the eyepiece till the cross hairs come into sharp and clear view.
3. If the eyepiece has graduations, note the graduation at which you get a clear view of the cross hairs. This can help in later adjustment if required.

METHODS OF MEASURING HORIZONTAL AND VERTICAL ANGLES

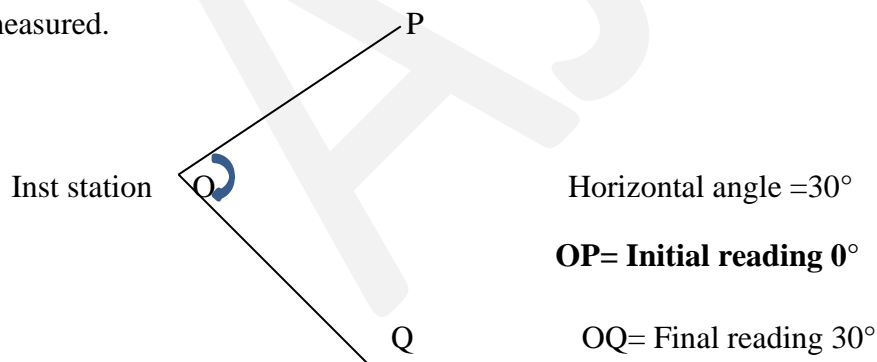
Methods of measuring horizontal angles

- a) Direct Method
- b) Repetition method
- c) Reiteration method

a) Direct method of measuring horizontal angle

A theodolite can be used to measure the horizontal angle subtended at the centre of the instrument by two station signals. Horizontal angles are measured on the horizontal circle of a theodolite by operating the upper clamp, the lower clamp and the upper and the lower tangent screw.

To represent the direction of a line, the horizontal angle of the line from a reference line is to be measured.



The steps required to be adopted are as follows.

1. Two points one on each of the lines say P and Q are to be marked.
2. A transit theodolite is to be set at the point of intersection of the lines, say at O. Initially the



Instrument is in the face left condition and its temporary adjustment is to be done over the point O.

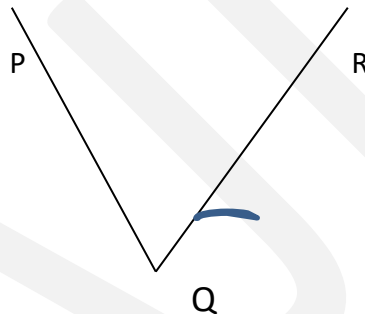
3. Both the lower and upper plate main screws are to be released and get the vernier A set to 0° mark on the main scale. After clamping the upper main screw, index of vernier A is to be brought exactly to the zero of the main scale using the upper tangent screw.
4. At this stage the reading of the vernier B should be 180° .
5. Swing the telescope in the horizontal plane and point it to the left station say P. Tighten the lower plate clamp screw and bisect the signal at P exactly using the lower plate tangent screw.
6. Loosen the upper plate main screw and turn the telescope the signal at Q is sighted. Tighten the upper plate clamp screw and bisect the ranging rod at Q exactly using the upper plate tangent screw.
7. Read both the vernier A and B and record the readings. The reading of the vernier A is the angle POQ. The vernier B gives the value of angle POQ after deducting from it 180° . The mean of two values of the angles obtained from the verniers A and B is required and POQ.
8. Change the face of the instrument to the face right by transiting the telescope and swinging it by 180° .
9. Repeat the steps 3 to 8 and determine another value of the angle POQ.
10. The mean of the face left and right observations is the final required angle POQ.

b) Repetition method

This method is used to measure small horizontal angles accurately. In this method the horizontal angle is measured several times and the value is added mechanically. The horizontal angle is obtained by dividing the accumulated value by the number of repetitions. Usually 3 repetitions with face left and 3 repetitions with face right are adopted. The precision thus attained is to a much finer degree than the least count of vernier.

The steps involved in the measurement of horizontal angle say PQR by method of repetition are as follows.

1. To measure the angle PQR set the Instrument at Q level it with the help of upper clamp and tangent screw.
2. Set Zero reading on vernier A. Note the reading on vernier B. Loose the lower clamp and direct the telescope towards the point P.
3. Clamp the lower clamp and bisect point P accurately by lower tangential screw. Unclamp the upper clamp and turn the instrument clock wise towards R. clamp the upper clamp and bisect R accurately with the upper tangent screw.
4. Note the reading on vernier A and B.
5. Unclamp the lower clamp and turn the telescope clockwise to sight P again. Bisect P accurately by using lower tangential screw unclamp the upper clamp turn the telescope clockwise and sight R. Bisect R accurately by upper tangent screw.
6. Repeat the process until the angle is repeated 3 times.



OBSERVATION AND CALCULATION TABLE

S. No	Instru- ment	sighted to	Face left swing Right												
			A			B			MEAN			No. of	Horizontal		
			°	'	"	°	'	"	°	'	"		°	'	"
1.	Q	P													
2.	Q	R										1			
3.	Q	R										2			
	Q	R										3			
			Face right						swing right						



			A			B			MEAN			No. of	Horizontal		
			o	'	"	o	'	"	o	'	"		o	'	"
1.	Q	P													
2.	Q	R										1			
3.	Q	R										2			
	Q	R										3			
												Average horizontal angle			
												o	'	"	

Advantages of repetition method

The following errors are eliminated by repetition method

1. Taking reading on both the verniers eliminates the errors due to eccentricity of verniers and centers.
2. Errors due to inaccurate bisection of the signal are eliminated as they tend to balance each other.
3. Errors due to imperfect adjustment of instrument are eliminated by taking face left and face right observations.

Reiteration method

This method is suitable when several angles are measured from a single station. Several angles measured successively from the initial station. The angle between last and first station is also measured and thus horizon is closed.

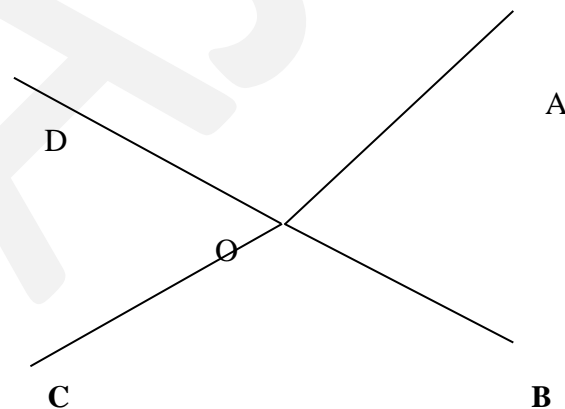
The process of measuring angles at an instrument station around the point to obtain a check on their sum which should be equal to 360° is called closing the horizon. When the horizon is closed, the final



reading should be same as initial reading. If there is any error within permissible limit, it can be distributed equally among all the angles. If the error is large, the whole field work will be repeated.

PROCEDURE:-

1. Set up the instrument at O and level it correctly.
2. Set the vernier A to zero
3. Direct the telescope to some well-defined object P or say the station point A, which is known as the “referring object”, and bisect it accurately by using the lower clamp and lower tangent screw. Note the vernier readings.
4. Loosen the upper plate and turn the telescope clockwise until the point B is exactly bisected by turning the upper tangent screw. Read both vernier. The mean of the two vernier readings will give the value of the angle AOB.
5. Similarly bisect C and D successively, read both vernier at each bisections.
6. Finally close the horizon by sighting the referring object P or station point A.
7. The Vernier A should read 360° . if not note the reading and find the error due to slip etc,.
8. If the error is small it is equally distributed among the several angles. If large, the reading should be discarded and a new set is taken.





OBSERVATION AND CALCULATION TABLE

S. No	Instru ment at	sighted to	Face left				swing Right										
			A			B			MEAN			Horizontal					
			°	'	"	°	'	"	°	'	"	°	'	"			
1.	O	A															
2.	O	B															
3.	O	C															
4.	O	D															
			Face right				swing right				Average						
			A			B			MEAN			Horizontal angle			Horizontal		
			°	'	"	°	'	"	°	'	"	°	'	"	°	'	"
1.	O	A															
2.	O	B															
3.	O	C															
4.	O	D															

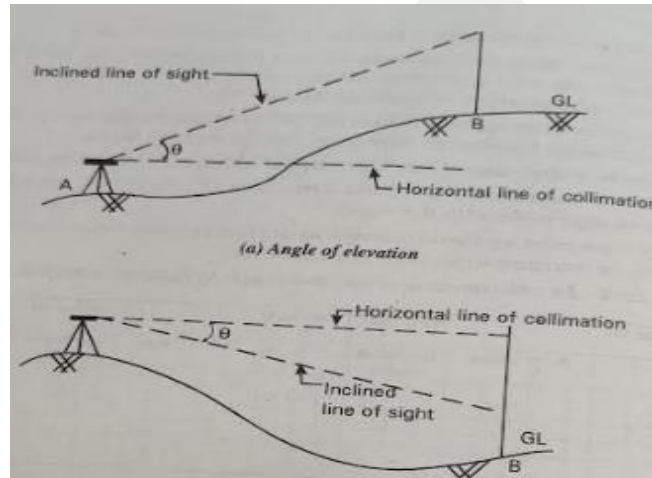
Measurement of vertical angles

A vertical angle is defined as the angle subtended by the inclined line of sight and the horizontal line of sight in the vertical plane. If the point is above the horizontal axis of the theodolite, the vertical angle is known as an angle of elevation, and if it is below it is known as an angle of depression.

To measure a vertical angle subtended by the station B at the instrument station A the following steps are involved.

1. The temporary adjustment of the instrument is to be done on the station A
2. The levelling of theodolite is to be done using altitude level (the operation involved are same as levelling using plate level)

3. Loosen the vertical circle clamp and direct the telescope towards the object whose vertical angle is required to be measured. Clamp the vertical circle and bisect the point by turning the vertical tangent screw.
4. Read and record the scale with vernier C and D in the table.
5. Change the face of the instrument and read the vertical angle again.
6. The required vertical angle is the average of the values in steps 4 and 5



Observation table

Inst at	Sighted to	Face left												Face right												Average vertical angle														
		C			D			Mean			Vertical Angle			C			D			Mean			Vertical Angle																	
		o	'	“	o	'	“	o	'	“	o	'	“	o	'	“	o	'	“	o	'	“	o	'	“	o	'	“	o	'	“									



REVIEW QUESTION:

1. Define the following: i) Face left ii) Face right iii) Swinging iv) Transiting V) Trunnion axis
2. Explain the measurement of horizontal angle by Repetition method. Draw typical tabular column. List the errors eliminated by this method.
3. Explain the temporary adjustment of the theodolite setup.
4. Explain the measurement of horizontal angle by Reiteration method. Draw typical tabular column. List the errors eliminated by this method.
5. Define all the terms used in theodolite surveying.



Module 2- Part-3

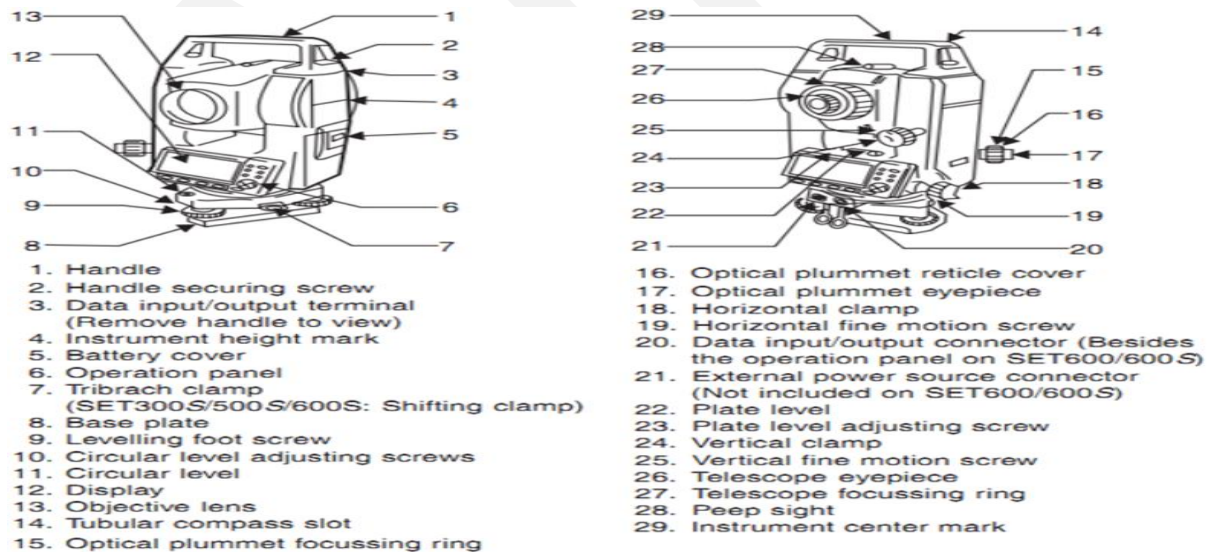
SYLLABUS:

Total Station Surveying – Features, parts, accessories and advantages of Total Station. Surveying with total station – Measurement of Horizontal angle, vertical angle, distance, slope, vertical distance, multiple angles with Total station. Using Total station for Area measurement and Volume calculation.

Total Station Surveying

A total station is an electronic theodolite and an electronic distance meter (EDM). This combination makes it possible to determine the coordinates of a reflector by aligning the instrument's cross hairs on the reflector and simultaneously measuring the vertical and horizontal angles and slope distances.

A microprocessor in the instrument takes care of recording, readings, and the necessary computations. The data is easily transferred to a computer where it can be used to generate a map. Wild, 'Tachymat 'TC 2000, and it is manufactured by M/s Wild Heerbrugg.





As a teaching tool, a total station fulfils several purposes. Learning how to properly use the total station involves the physics of making measurements, the geometry of calculations, and statistics for analysing the results of a traverse. In the field, it requires teamwork, planning, and careful observations.

If the total station is equipped with a data collector it also involves interfacing the data-logger with a computer, transferring the data, and working with the data on a computer. The more the user understands how a total station works, the better they will be able to use it.

Fundamental Measurements

- The rotation of the instrument's optical axis from the instrument north in a horizontal plane :
i.e. **horizontal angle**
- Inclination of the optical axis from the local vertical i.e. **vertical angle**.
- Distance between the instrument and the target i.e. **slope distance**.

Horizontal Angle

The horizontal angle is measure from the zero direction on the horizontal scale. When the user first sets up the instrument the choice of the zero direction is made – this is Instrument North. The user may decide to set zero (North) in the direction of the long axis of the map area, or choose to orient the instrument approximately to True, Magnetic or Grid North.

The zero direction should be set so that it can be recover if the instrument was set up at the same location at some later date. This is usually do by sighting to another benchmark, or to a distance recognizable object. Using a magnetic compass to determine the orientation of the instrument is not recommended and can be very inaccurate.

Most total stations can measure angle to at least 5 seconds, or 0.0013888 degree. The best procedure when using a Total Station is to set a convenient " north " and carry this through the survey by using back sights when the instrument is move.



Vertical Angle

The vertical angle is measure relative to the local vertical (plumb) direction. The vertical angle is usually measure as a zenith angle (0 degree is vertically up, 90 degree is horizontal, and 180 degree is vertically down), although one is also given the option of making 0 degree horizontal. The zenith angle is generally easier to work with. The telescope will be pointing downward for zenith angles greater than 90 degree and upward for angles less than 90 degree.

Measuring vertical angles require that the instrument be exactly vertical. It is very difficult to level an instrument to the degree of accuracy of the instrument. Total stations contain an internal sensor (the vertical compensator) that can detect small deviations of the instrument from vertical.

Electronic in the instrument then adjust the horizontal and vertical angles accordingly. The compensator can only make small adjustments, so the instrument still must be well level. If it is too far out of the level, the instrument will give some kind of " tilt " error message.

Slope Distance

The instrument to reflect distance is measure using an Electronic Distance Meter (EDM). Most EDM's use a Gallium Arsenide Diode to emit an infra light beam. This beam is usually modulated to two or more different frequencies. The infra beam is emitted from the total station, reflect by the reflector, and received and amplify by the total station.

The receive signal is then compare with a reference signal generate by the instrument (the same signal generate that transmits the microwave pulse) and the phase-shift is determine. This phase shift is a measure of the travel time and thus the distance between the total station and the reflector.



Basic Calculations

Total Stations only measure three parameters:

- **Horizontal Angle**
- **Vertical Angle**
- **Slope Distance**

Horizontal Distance

Let us use symbol I for instrument (total station) and symbol R for the reflector. In order to calculate coordinates or elevations it is first necessary to convert the slope distance to a horizontal distance. The horizontal distance is –

$$Hd = Sd \cos (90^* - Za) = Sd \sin Za$$

where Sd is the slope distance and Za is the zenith angle. The horizontal distance will be use in the coordinate calculations.

Vertical Distance

We can consider two vertical distances. One is the Elevation Difference (dZ) between the two points on the ground. The other is the Vertical Difference (Vd) between the tilting axis of the instrument and the tilting axis of the reflector. For elevation difference calculation we need to know the height of the tilting-axis of the instrument, that is the height of the center of the telescope, and the height of the center of the reflector (Rh)

The way to keep the calculation straight is to imagine that you are on the ground under the instrument. If you move up the distance Ih, then travel horizontally to a vertical line passing through the reflector then up (or down) the vertical distance (Vd) to the reflector, and then down to the ground. This can be write as

$$dZ = Vd + (Ih - Rh)$$



The quantities I_h and R_h are measure and recorded in the field. The vertical difference V_d is calculate from the vertical angle and the slope distance

$$V_d = S_d \sin (90^\circ - Z_a) = S_d \cos Z_a$$

where dZ is the change in elevation with respect to the ground under the total station. We have chosen to group the instrument and the reflector heights. Note that if they are the same then this part of the equation drops out. If you have to do calculations by hand it is convenient to set the reflector height the same as the instrument height.

If the instrument is at a know elevation, I_z , then the elevation of the ground beneath the reflector, R_z , is

$$R_z = I_z + S_d \cos Z_a + (I_h - R_h)$$

General setting required for station point or temporary adjustment of total Station:- Temporary Adjustments of a Total Station

A total station is basically a theodolite hence temporary adjustments of the total station are more or same as that of a theodolite. Following are the temporary adjustments of a total station.

1. Setting up of tripod, taking out instrument from box & fixing the instrument on tripod head.
2. Levelling up of the instrument
 - a) Coarse leveling with spirit level by leg adjustment.
 - b) Fine leveling with digital bubble and foot screws.
3. Centering Up of the instrument
 - a) Coarse centering by leg adjustment.
 - b) Fine centering with laser plummet by shifting the instrument bodily on machine finished tripod head.

Levelling & centering shall be done in succession to each other till both of them are satisfactory.



4. Setting up the Station
 - a) By inputting station name, instrument height & coordinates at first station &
 - b) By recalling the station occupied from the memory at next stations.
5. Orienting the instrument
 - a) By setting horizontal angle to 00 when instrument is directed toward the accepted meridian (usually North direction) at first station and
 - b) By taking back sight to previously occupied traverse station (So that same meridian will be referred).

Features of Total Station

(a) Angle Measurement:

An electronic theodolite of a total station is used to measure angles. All the features of electronic theodolites are same as total station.

A total station can record angles with a resolution between 1" and 20". All the instruments incorporate either single-axis or dual-axis compensator, the latter being expensive.

(b) Distance Measurement:

Generally, a total station measures a slope distance and the microprocessor uses the vertical angle recorded by the theodolite along the line of sight to calculate the horizontal distance.

In addition, the height between the trunnion axis and prism center is also calculated and displayed.

All the total stations use co-axial optics in which the EDM transmitter and receiver are combined with the theodolite telescope.

These 3 modes are generally available for distance measurement.

#Standard or Coarse Mode

It has a resolution of 1 mm and measurement time of 1-2 seconds.



#Precise or Fine Mode

It has a resolution of 1" but a measurement time of 8 – 4 seconds. This is more accurate than the standard mode, since the instrument refines the arithmetic mean value by making repeated measurements.

#Tracking or Fast Mode

The distance measurement is repeated automatically at interval of less than 1". Normally this mode has a resolution of 10 mm.

(c) Control Panel:

The total station is activated through its control panel. It consists of keyboard and multiple line liquid crystal display (LCD).

The LCD is moisture-proof, can be illuminated and some LCD's incorporate contrast controls to accommodate different viewing angles.

Some of the total stations have two control panels, one of each face the electronic theodolite to make them easier to use.

The keyboard enables the user to select different measurement and implement modes, enables instrument parameters to be changed and allows special software functions to be used.

Some keyboards incorporate multi-function keys to carry out specific tasks, whereas others use keys to activate and display menu systems.

Angle and distances are usually recorded electronically in a digital form as data. If a code is entered from the keyboard to define the feature being observed the data can be processed much more quickly by downloading it into appropriate software.

On numeric keyboards, codes are represented by numbers, whereas keyboards with feature codes are also available.



(d) Power Supply:

Rechargeable nickel- cadmium batteries are used for power supply. The usage time is 2-10 h.

Some total stations have an auto power save feature which switches the instrument off or into some standby mode after it has not been used for a specified time.

Components of a Total Station

Total Station is a compact instrument that weighs around 50 N to 55 N. It consists of a simple microprocessor, an angle measuring instrument (Theodolite), and a distance measuring instrument (EDM).

Moreover, there are approximately more than 40 different models available globally. Total-station is currently the most used instrument in the surveying field. The cheapest instrument is available in the range of 2000\$ to 2500\$.

The Total Station components used in surveying are the following:

1. Tripod

Uses to hold the total Station.

2. Electronic Notebook

Used to manipulate, calculate and record the field data

3. Prism and its Pole

It can measure lengths with a triple prism to 2 km and up to 6-7 km

4. Battery



Review questions

1. List out the accessories and advantages of Total Station
2. List and explain the components of total station
3. Explain the temporary adjustment of total station