TVET CERTIFICATE III in LAND SURVEYING

Operating Theodolite

LSVOT301

Operate Theodolite

Competence

Credits: 6

Learning hours:60

Sector: Construction

Sub-sector: Land Surveying

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Purpose statement

This is a core module which describes the performance outcomes, skills knowledge and attitude required to collect basic spatial data.

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Total Number of Pages: 47

Learning Unit 1 – Determine Classifications and specifications of theodolite

LO 1.1 – Identify theodolite instrument

- **Topic 1: Introduction to theodolite**

So far, we have been measuring horizontal angles by using a Compass with respect to meridian, which is less accurate and also it is not possible to measure vertical angles with a Compass.

So, when the objects are at a considerable distance or situated at a considerable elevation or depression, it becomes necessary to measure horizontal and vertical angles more precisely. So, these measurements are taken by using an instrument known as a theodolite.

The system of surveying in which the angles are measured with the help of a theodolite, is called "Theodolite surveying".

A theodolite is a versatile instrument basically designed to measure horizontal and vertical angles. It is also used to give horizontal and vertical distances, finding difference of levels, ranging curves using stadia hairs.

Other function

- Determining horizontal and vertical distances by stadia
- Extending straight lines
- Differential levelling

It is used for horizontal and vertical alignments and for many other purposes.

Theodolites are precision instruments and are either electronic (capable of displaying angle readings automatically) or optical, which need to be read manually.

Theodolite is more precise than magnetic compass, where a magnetic compass measures the angle up to as accuracy of 30". However, a vernier theodolite measures the angles up to and accuracy of 10", 20".

- **Topic 2: Description of Classification of theodolite**

To clearly saying, theodolites can be classified into two types

- Primary Theodolite
- Electronic Digital Theodolite

Theodolite is broadly classified into two categories as primary theodolite:

a. Transit theodolite

b. Non-transit theodolite

a) Transit Theodolite: A theodolite is called a transit theodolite when its telescope (line of sight) can be reversed by revolving the telescope 180 degrees along the vertical plane. Rotated through a whole revolution regarding its horizontal axis within the vertical plane.

b) Non-Transit Theodolite in this type of Theodolite, the line of sight cannot be revolved in the vertical plane. They are inferior in utility and have now become obsolete.

- Electronic Digital Theodolite

This type of theodolite provides the worth of observation directly within the viewing panel. The exactitude of this sort of instrument varies within the order of 1" to 10". It has also two types.

a) Vernier Theodolites: For reading the graduated circle, verniers are used to correct reading of measuring points and this theodolite is termed as a Vernier theodolite.
b) Micrometer Theodolites: A micrometer provides to browse the graduated circle identical be termed as a Micrometer theodolite.

This Digital theodolite is also known as Modern Theodolite and can perform the following functions:

- Distance measurement
- Angular measurement
- Data processing
- Digital display of point details
- Storing data is an electronic field book

- **Topic 3. Identification of Types of theodolite**

There are various kinds of theodolites for different purposes of different constructional works. Usually, four types of theodolites are uses in site works for different measuring points.

Such as-

- Repeating Theodolite
- Directional Theodolite
- Electrical Digital Theodolite
- Total Station

a) Repeating Theodolite: This design facilitates horizontal angles to be remade any number of times and added directly on the instrument circles. This type of instruments is restricted for locations where the support is not steady, or area for using other such instruments is limited.

Advantages of this design are:

- Better accuracy obtained through averaging
- Disclosure of errors and mistakes by computing values of the single and multiple readings

Repeating Measurement

- Measure the angle (e.g. 23° 19’)
- Tighten the lower motion clamp
- Re-sight on the initial point
- Sight the second point and re-measure the angle (e.g. 46° 40”)
- Repeat process as many times as desired

Solution equals the average of the measurement, or the final measurement divided by the number of measurements

For example:

1st measurement: 23° 19’

2nd measurement: 46° 40’

3rd measurement: 69° 59’

4th measurement: 93° 23’

5th measurement: 116° 44’

6th measurement: 140° 32’

Average angle measurement: 23° 20’

b) Directional Theodolite: Angles are obtained by deducting the first direction reading from the second direction reading. This reads directions rather than angles. The non-repeating instrument has no minor motion.

Reads “directions” rather than angles

Angles are obtained by subtracting the first direction reading from the second direction reading

Directional Measurement

- Set up the theodolite
- Sight the initial point and read the direction (e.g. 31° 19’ 27”)
- Sight the second point and read the direction (e.g. 85° 24’ 49”)
- The angle is then calculated as the difference between the two directions (e.g. 54° 05’ 22”)

c) Electrical Digital Theodolite: Naturally interprets and records horizontal and vertical angles. Eliminates the standard reading of scales on graduated circles. Automatically reads and records horizontal and vertical angles. Eliminates the manual reading of scales on graduated circles

Advantages of electronic digital theodolite

- Circles can be instantaneously zeroed, or initialized to any value
- Angles can be measured with increasing values either left or right
- Angles measured by repetition can be added to provide a total larger than 360°
- Mistakes in reading angles are greatly reduced
- Speed of operation is increased
- Cost of instrument is lower

d) Total Station: The total Station accommodates the functions of a theodolite for measuring angles, an EDM for measuring gaps, digital data, and information documentation. Examples of Total Stations are the Nikon DTM 801, Topcon, and Geodimeter 400 series.

LO 1.2 – Identify theodolite components

- **Topic 1. Description of Theodolite Parts and their Functions**

Knowing the parts of a theodolite is important. The parts should be accustomed to each other. Without regulate of the parts cannot be worked accurately. Whenever theodolite uses in sites, each part takes seriously. Depends on placing the parts, measuring result could be changed or stabled.

There are many different theodolite parts. But here, you'll understand the common and essential parts of theodolite.

1. Levelling Head: Levelling head is used for three purposes;

   - ✓ It provides a bearing for the outer hollow spindle.
   - ✓ It is the mean of attaching the instrument to its tripod, and
   - ✓ It is the mean of levelling the instrument.

   In the modern instruments, it embodies a shifting stage or shifting head or cantering arrangement with which the suspended plumb-bob may easily and quickly be cantered over a point.

   The levelling head may consist of either two circular plates (called parallel plates kept at a fixed distance apart by a socket-and-ball arrangement with four screws which are called the foot screws or levelling screws) or a tribrach plate (with three arms which carries a levelling screw).

2. Limb or Lower Plate: The outer axis is attached to the lower plate which consists of a horizontal circle, usually whole circle division, i.e., with whole circle graduation: from 0° to 360° in clockwise direction. Perpendicular to the lower plate is the outer hollow spindle which, enclosing the inner Spindle, rotates in the levelling head.

This lower plate is locked to the levelling head and also moves relatively by means of a clamp screw and tangent screw, and such motion is called the lower motion. It is also called as scale plate and has its edge bevelled (chamfered). The nature of graduations depends upon the size of the instrument; It may be graduated to degrees and half degrees and one-third of a degree or degrees and one-sixth of a degree.

3. Spindles: There are two spindles or axes or centers one inside the other. The two axes are such that they are co-axial which form the vertical axis of the instrument. The outer spindle is hollow whose interior is formed conical to accommodate the central vertical axis or inner axis which is solid and conical.

4. Upper plate: This part of the theodolite is also known as the vernier plate and is attached to the inner axis. The clamp and tangent screws are provided to clamp the upper plate with lower plate.

The upper plate with standards (A-frames) is sometimes called the alidade of the theodolite.

5. Standards or A-frames: These two theodolite parts or standards, which resemble the letter A in shape, stand on the upper plates for supporting the horizontal axis.

6. Level Tube: Two spirit levels which are called the plate levels are fixed on the upper surface of the vernier plate. These are at right angles to each other, and one of them is parallel to the horizontal axis.

7. Compass: The circular or trough type compass box is attached to the instrument. The circular type is mounted on the upper plate between the A-frame. In modern Theodolites, the tubular type compass is screwed to one of the standards.

8. Telescope: This Theodolite Part is used to sight distant objects. It is rigidly fixed at the centre of a horizontal axis and is perpendicular to it. It can be either rotated in a horizontal plane or in a vertical plane.

The horizontal motion may be measured on a horizontal graduated circle by means of two Vernier's, and the vertical motion may be measured on the vertical graduated circle by two more Vernier's.

9. Vertical circle: These theodolite parts are rigidly attached to the telescope and moves with the movement or rotation of the telescope.

10. T-frame or index bar: It is T-shaped and is centered on the horizontal axis of a telescope in front of the vertical circle. Two verniers C and D are provided at the ends of the horizontal arms or limbs called the index arm.

11. Plumb bob: A plumb bob is suspended from the hook fitted to the bottom of the vertical axis. It is used to center the instrument exactly over a station point. The cord is provided with a slip knot to allow the plummet to be adjusted at the desired level.

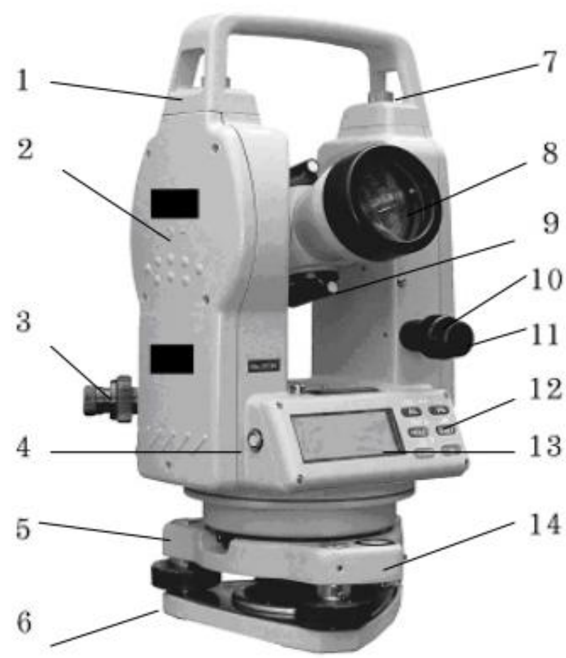
12. Tripod: It is numbered in the most important theodolite parts. It is a stand with three legs on which the theodolite is supported while taking the angular measurement during a survey. The cap is screwed to protect the external screw when a tripod is not in use.

13. Plumb-Bob: A plumb-bob is suspended from the hook fitted to the bottom of the vertical axis for centering the instrument exactly over a station point.

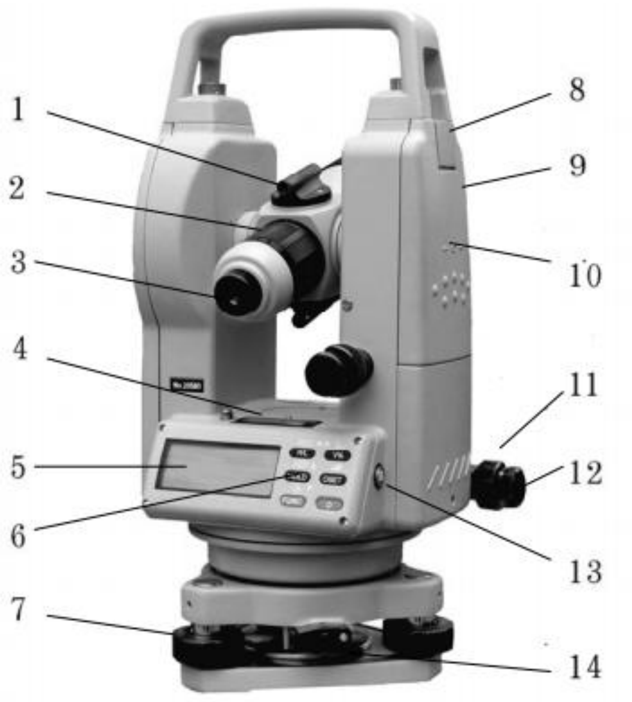
14. The shifting head-Shifting head conjointly consists of two parallel plates that are modified one over the opposite among a limited range. Shifting head lies below the lower plate. It is helpful to centralize the complete instrument over the positioning

15. Magnetic compass- A circular box compass or magnetic compass is mounted on the vernier scale between the standards. It is provided for taking the magnetic bearing points.

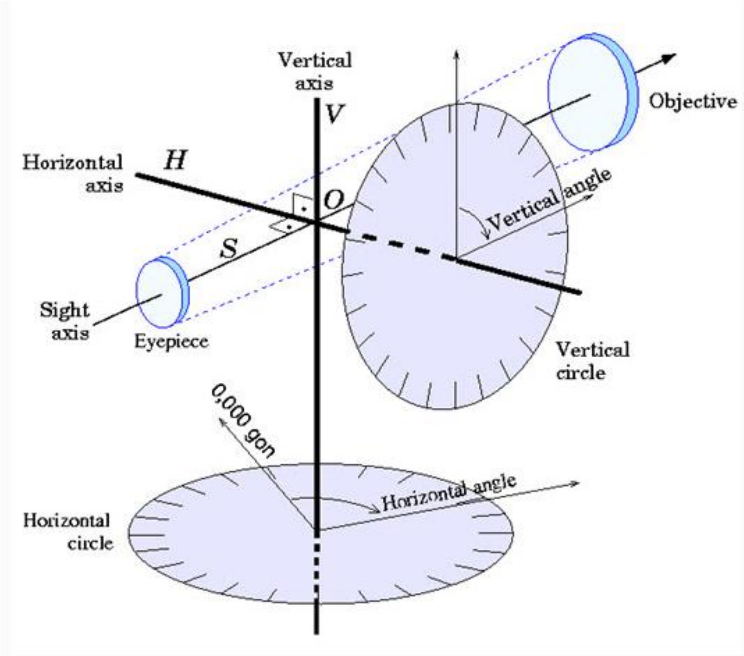
16. Tripod- The theodolite is mounted on a powerful tripod once getting used within the field. The tripod's legs are sturdy or framed. At the lower ends of the legs, pointed steel shoes are provided to urge them pushed into the bottom. The tripod head has male screws on that the trivet of the levelling head is screwed.



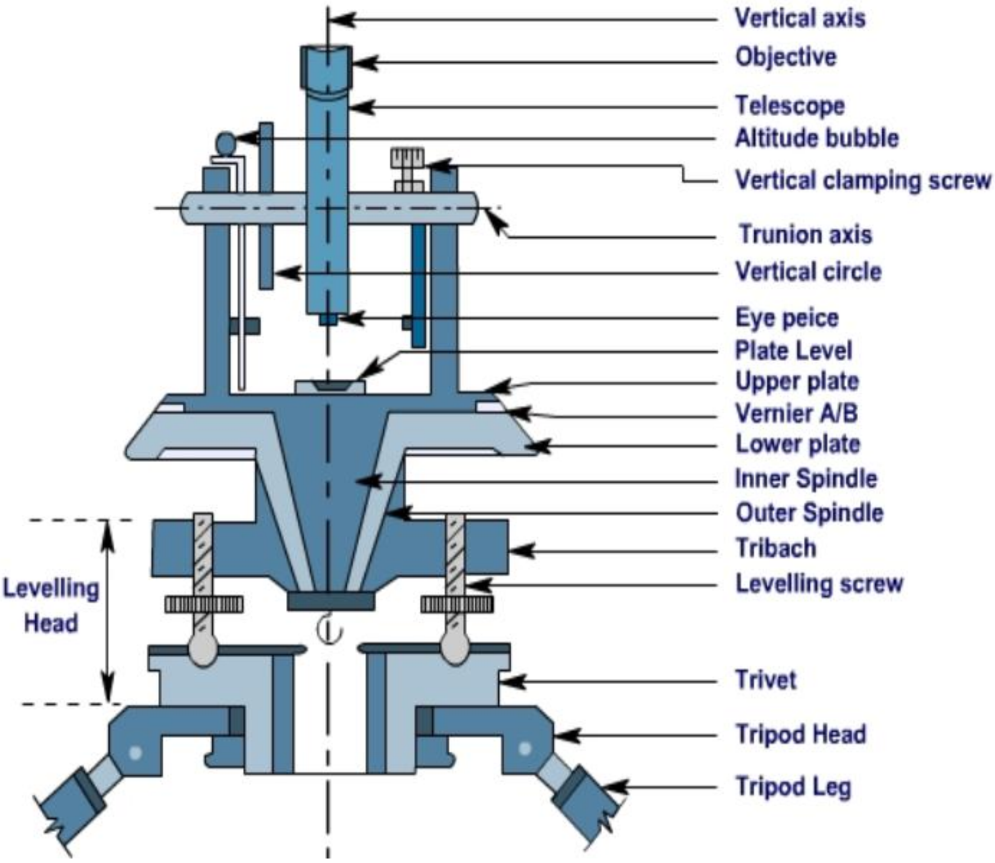
1. Carrying handle
2. Instrument height mark
3. Optical plummet
4. EDM input port
5. Tribrach
6. foot screw
7. Handle screw
8. Objective lens
9. Sighting collimator
10. Vertical clamp
11. Vertical tangent screw
12. Operating key
13. LCD
14. Circular level



1. Sighting collimator
2. Focusing knob
3. Eyepiece
4. Plate level
5. LCD
6. Operating key
7. foot screw
8. Locking lever
9. Battery case
10. Instrument height mark
11. Horizontal clamp
12. Horizontal tangent screw
13. Data output port
14. Base locking lever

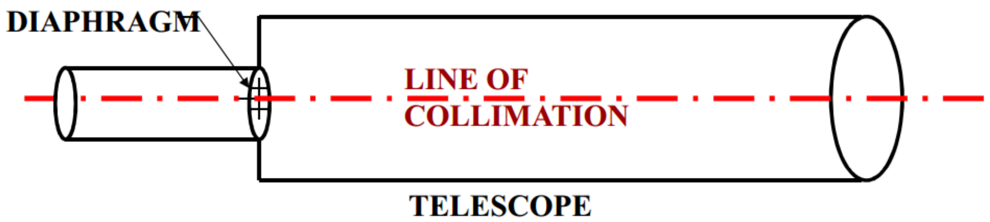


SECTION PARTS OF THEODOLITE



- **Topic 2. Description of Terms used in manipulating a transit vernier theodolite**

1. Centering: Centering means setting the theodolite exactly over an instrument- station so that its vertical axis lies immediately above the station- mark. It can be done by means of plumb bob suspended from a small hook attached to the vertical axis of the theodolite. The centre shifting arrangement if provided with the instrument helps in easy and rapid performance of the centring.
2. Transiting: Transiting is also known as plunging or reversing. It is the process of turning the telescope about its horizontal axis through 1800 in the vertical plane thus bringing it upside down and making it point, exactly in opposite direction.
3. Swinging the telescope: It means turning the telescope about its vertical axis in the horizontal plane. A swing is called right or left according as the telescope is rotated clockwise or counter clockwise.
4. Face Left: If the vertical circle of the instrument is on the left side of the observer while taking a reading, the position is called the face left and the observation taken on the horizontal or vertical circle in this position, is known as the face left observation
5. Face Right: If the vertical circle of the instrument is on the right side of the observer while taking a reading, the position is called the face right and the observation taken on the horizontal or vertical circle in this position, is known as the face right observation.
6. Changing Face: It is the operation of bringing the vertical circle to the right of the observer, if originally it is to the left, and vice – versa. It is done in two steps; Firstly, revolve the telescope through 1800 in a vertical plane and then rotate it through 1800 in the horizontal plane i.e first transit the telescope and then swing it through 1800.
7. Line of Collimation: It is also known as the line of sight. It is an imaginary line joining the intersection of the cross- hairs of the diaphragm to the optical centre of the object- glass and its continuation.



8. Axis of the Level Tube: It is also called the bubble line. It is a straight line tangential to the longitudinal curve of the level tube at the centre of the tube. It is horizontal when the bubble is in the centre.

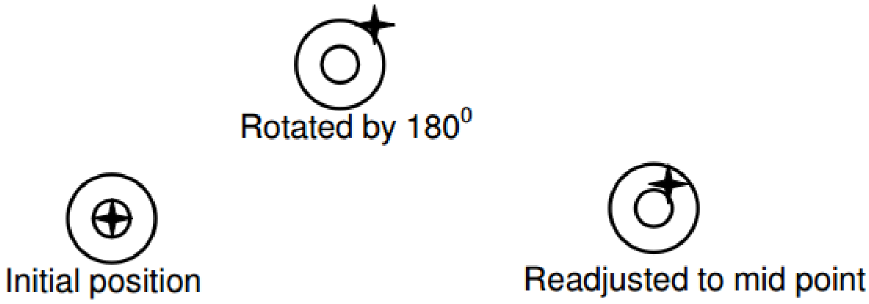
- **Topic 3. Identification of six standard checks on a conventional theodolite**

A theodolite should be checked at least once a month or before any precise work is to be carried out.

There are 6 possible instrument errors to check:

1) Plate Bubble Error. This is checked every time the theodolite is set up. i.e. check the bubble drift in positions c) and d) and then eliminate the error by “Freezing the Bubble”
2) Non - Vertical Cross Hairs. Move the telescope up and down while sighting a well-defined distant point. Any error will be very obvious
3) Horizontal Collimation Error. Sight a well-defined point and read the horizontal circle on F/L and F/R. The difference in the minutes and seconds should be <40”

4) Trunnion Axis Dislevelment. Spire Test. Sight a well-defined elevated point (church spire) then lowers the telescope onto a tape or staff about 40m away. The difference between F/L and F/R should be < 5mm for most engineering applications
5) Vertical Collimation Error. Sight a well-defined point and read the vertical circle on F/L and F/R. The difference in the minutes and seconds should be <40"
6) Laser Plumb Error. Check the laser plumb alignment in two positions 180° different



The checks on a theodolite should comprise of an eight-point check carried out in the following order.

a. Plate bubble
- Set up the instrument on a sturdy tripod.
- Turn theodolite until the bubble tube is parallel with 2 of the foots crews, and level the bubble carefully.
- Turn the theodolite through 90 degrees, and level the bubble using third foots crew carefully.
- Turn the theodolite back through 90 degrees, and re-level bubble if necessary. Keep repeating this process until you are confident the bubble rests in the centre.
- Then turn the theodolite through 180 degrees. The bubble should be central if correctly adjusted.
- If the bubble does not stay central, then you are best advised to have it adjusted, or repaired, and calibrated by your specialist survey equipment supplier.

b. Verticality of crosshairs

In a perfectly adjusted transit, the vertical cross hair should lie in a plane that is perpendicular to the horizontal axis. In this way, any point on the hair may be used when measuring horizontal angles or running lines. To make the vertical cross hair lie in a plane perpendicular to the horizontal axis, you should follow the procedure below:

i. See that parallax is eliminated. Sight the vertical cross hair on a well-defined point; and with all motions clamped, move the telescope slightly up and down omits horizontal axis, using the vertical slow-motion tangent screw. If the instrument is in adjustment, the vertical hair will appear to stay on the point through its entire length.
ii. If it does not stay on the point, loosen the two capstan screws holding the cross hairs and slightly rotate the ring by tapping the screws lightly.
iii. Sight again on the point. If the vertical cross hair does not stay on the point through its entire length as the telescope is moved up and down, rotate the ring again.

c. Horizontal collimation

Horizontal axis error - The horizontal and vertical axes of a theodolite must be perpendicular; if not then a "horizontal axis error" exists. This can be tested by aligning the tubular spirit bubble parallel to a line between two-foot screws and setting the bubble central. A horizontal axis error is present if the bubble runs off central when the tubular spirit bubble is reversed (turned through 180°). To adjust, the operator removes 1/2 the amount the bubble has run off using the adjusting screw, then re-level, test and refine the adjustment.

d. Horizontal Circle.

i. Set up and level the instrument.

ii. Select and sight a well-defined distant point, this should be at least 100m away and you should also be careful to ensure a clear line of sight (A cool overcast day would be ideal). Read the Horizontal angle scale (H1) and note down your reading.

iii. Transit the telescope and re-sight the same point on the opposite face. Read the Horizontal angle scale (H2) and note down your reading.

iv. Work out the difference between H1 and H2. The difference between H1 and H2 should be 180 degrees. However, your angular error should be less than the stated accuracy of the theodolite.

- For example, H1 = 180 degrees 0 minutes 0 seconds. H2 = 0 degrees 0 minutes 3 seconds. Then (H1) -(H2) =179 degrees 59 minutes 57 seconds. This is a 3 second inaccuracy. If the theodolite is classed at 5 second accuracy, then the result would be acceptable.
- If the result is greater than the accuracy stated on the theodolite then you are best advised to have it adjusted, or repaired, and calibrated by your specialist survey equipment supplier.

e. Vertical Circle.

i. Set up and level the theodolite as before.

ii. Select and sight a well-defined elevated point. Again, this is best done on a cool and overcast day.

iii. Read the vertical angle scale (V1) and note down the reading.

iv. Transit the telescope and re-sight the same point on the opposite face.

v. Read the vertical scale (V2) and note down your reading.

vi. V1 and V2 the abstract angles of elevation or depression should total 360 degrees.

- For example, V1 = 100 degrees 0 minutes 0 seconds. V2 = 260 degrees 59 minutes 57 seconds. Then (V1) +(V2) =359 degrees 59 minutes 57 seconds. This is a 3 second inaccuracy. If the theodolite is classed at 5 second accuracy, then the result would be acceptable.
- If the result is greater than the accuracy stated on the theodolite then you are best advised to have it adjusted, or repaired, and calibrated by your specialist survey equipment supplier.

f. Trunnion (or horizontal) axis error

i. Set up and level the instrument as before.

ii. Sight a well-defined high-level point with the centre of the cross hairs (like a steeple or a fixed radio mast.

iii. Depress the telescope and read a tape set (perpendicular on the floor) close to the instrument (T1) and record your reading.

iv. Repeat on the opposite face and read the tape again (T2).

v. The readings T1 and T2 should be equal.

vi. If the result is greater than the accuracy stated on the theodolite then you are best advised to have it adjusted, or repaired, and calibrated by your specialist survey equipment supplier

g. Optical plummet

g.1. Fixed in Tribrach.

i. Having set up the theodolite and checked the Plate Bubble as described above, level the tribrach with theodolite or plate level over a point defined by a cross (the finer the cross the better).
ii. With a sharp pencil trace the outline of the tribrach base plate on the tripod head.
iii. Release the retaining screw slightly and carefully turn the tribrach through 120 degrees keeping within the marks on the tripod. Re-level and sight the cross and note if the cross is not in the centre.
iv. Repeat, turning through a further 120 degrees. The cross should be central each time.
v. If the cross is not in the centre each time then you are best advised to have it adjusted, or repaired, and calibrated by your specialist survey equipment supplier.

g.2. Revolving Plummet. (Fixed in the theodolite or plate level.)

i. Having set up the theodolite and checked the Plate Bubble as described previously, level the tribrach with theodolite or plate level over a point defined by a cross (the finer the cross the better).
ii. Level and centre over a point defined by a cross.
iii. Rotate the theodolite through 120 degrees and observe the cross. The cross should remain central.
iv. Rotate the theodolite through a further 120 degrees and observe the cross. The cross should remain central once more.

- **Topic 4. Discussion on types of Adjustment of a theodolite**

The adjustments of a theodolite are of two kinds:

a) Permanent Adjustments
b) Temporary Adjustments.

- **Permanent adjustments:** The permanent adjustments are made to establish the relationship between the fundamental lines of the theodolite and, once made, they last for a long time. They are essential for the accuracy of observations.

Permanent adjustments: The permanent adjustments in case of a transit theodolites are:

i. Adjustment of Horizontal Plate Levels. The axis of the plate levels must be perpendicular to the vertical axis.
ii. Collimation Adjustment. The line of collimation should coincide with the axis of the telescope and the axis of the objective slide and should be at right angles to the horizontal axis.
iii. Horizontal axis adjustment. The horizontal axis must be perpendicular to the vertical axis.
iv. Adjustment of Telescope Level or the Altitude Level Plate Levels. The axis of the telescope levels or the altitude level must be parallel to the line of collimation.
v. Vertical Circle Index Adjustment. The vertical circle Vernier must read zero when the line of collimation is horizontal.

- **Temporary Adjustment:**

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

The temporary adjustments are made at each set up of the instrument before we start taking observations with the instrument. There are three temporary adjustments of a theodolite: -

i. Centering.
ii. Setting up.
iii. Levelling.
iv. Focussing.

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

ii. Setting up/fixing firmly instrument on tripod head. fixing the theodolite onto a tripod along with approximate levelling and centering over the station mark.

Operation of setting up a theodolite includes:

a) centering the theodolite over the ground mark
b) approximate levelling with the help of tripod legs.

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

The operation of making the vertical axis and horizontal axes truly vertical/ horizontal is known as levelling of Theodolite.

a) Turn the horizontal plate until the longitudinal axis of the plate level is approximately parallel to a line joining any two levelling screws.
b) Bring the bubble to the centre of its run by turning both foot screws simultaneously in opposite directions either inwards or outwards. The movement of the left thumb indicates the direction of movement of bubble.
c) Turn the instrument through 180^0 in azimuth.
d) Note the position of the bubble. If it occupies a different position, move it by means of the same two-foot screws to the approx. mean of the two positions.
e) Turn the theodolite through 90 in azimuth so that the plate level becomes perpendicular to the previous position.
f) With the help of third floor screw, move the bubble to the approx. mean position already indicated.
g) Repeat the process until the bubble, retains the same position for every setting of the instrument.

iii. Focussing/Elimination of Parallax: removing parallax error by proper focusing of objective and eye-piece. The eye-piece only requires adjustment once at a station. The objective will be re-focused for each subsequent sighting from this station because of the different distances to the target.

Elimination of parallax may be done by focusing the eye piece for distinct vision of cross hairs and focusing the objective to bring the image of the object in the plane of cross hairs.

If the cross is not in the centre each time then you are best advised to have it adjusted, or repaired, and calibrated by your specialist survey equipment supplier.

- ***<u>Errors in measurement</u>***

1. Index error

The angles in the vertical axis should read 90° (100 grad) when the sight axis is horizontal, or 270° (300 grad) when the instrument is transited. Half of the difference between the two positions is called the index error. This can only be checked on transit instruments.

2. Horizontal axis error

The horizontal and vertical axes of a theodolite must be perpendicular; if not then a horizontal axis error exists.

This can be tested by aligning the tubular spirit bubble parallel to a line between two foots crews and setting the bubble central.

A horizontal axis error is present if the bubble runs off central when the tubular spirit bubble is reversed (turned through 180°).

To adjust, the operator removes half the amount the bubble has run off using the adjusting screw, then re-level, test and refine the adjustment.

3. Collimation error

The optical axis of the telescope, must also be perpendicular to the horizontal axis. If not, then a collimation error exists.

Index error, horizontal-axis error (trunnion-axis error) and collimation error are regularly determined by calibration and are removed by mechanical adjustment. Their existence is taken into account in the choice of measurement procedure in order to eliminate their effect on the measurement results of the theodolite.

Calibration is the comparison of measurement values delivered by a device under test with those of a calibration standard of known accuracy. Such a standard could be another measurement device of known accuracy, a device generating the quantity to be measured

- ***<u>Precaution in use of theodolite</u>***

The following precautions must be taken while using a theodolite:

- **i.** After centering a theodolite, do not fix the locking nut of the head too tightly while using the shifting head.
- **ii.** Place the telescope vertical with the clamp slack and release the lower clamp while carrying a theodolite.
- **iii.** The vertical arc should never be touched with the fingers as it will tarnish.
- **iv.** The telescope of the theodolite should be set vertically with the eye-piece down. In wet climate a waterproof hood should be used.
- **v.** When placing the transit in the box, special care should be taken so that the telescope does not touch the side of the box, and that all clamps are tightened so that the telescope cannot suing against the sides of the box during transport.

vi. Special care should be taken to avoid any situation that might result in the theodolite being dropped or otherwise subjected to a severe shock.

vii. Inspect the theodolite for loose parts and screws. Remove dust from the objective lens and eyepiece with a lens brush and lens tissue using procedures consistent with delicate optics. Keep the lens covered with the theodolite when it is not in use. Use a sun shade to protect the lens from the direct rays of the sun.

viii. The graduated circles and venires are coated with a lacquer to retard oxidation. Avoid touching these parts. A thin film of oil applied with a lint less cloth will aid in keeping the surfaces clean.

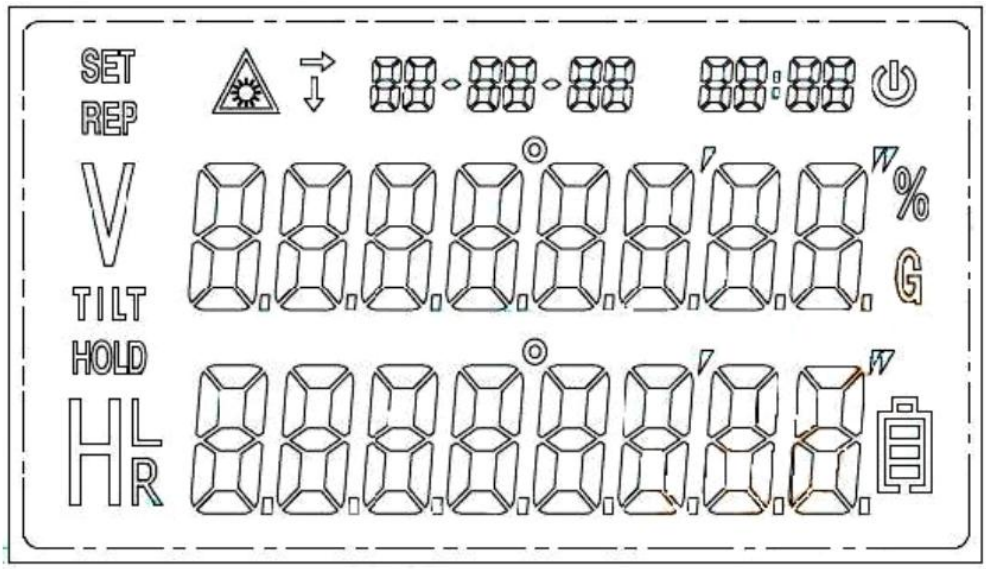
ix. Store the theodolite in its case or another dry dust free location when it is not in use.

x. If the theodolite is to be taken from a cool environment to a warm one (especially in humid conditions) allow the theodolite to warm up inside its case where it will not be subject to condensation.

- **<u>Topic 5. Identification of manufacturing of theodolite</u>**

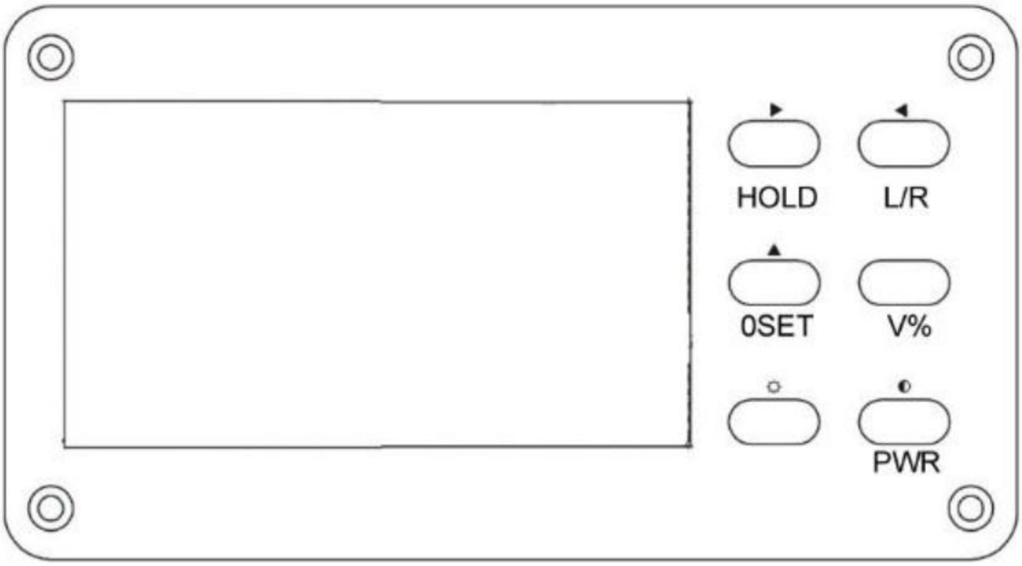
➢ **Display Marks and Keyboard**

- <u>Display marks</u>



Marks	Meanings	Marks	Meanings
V	Vertical Angle	REP	Repeat horizontal angel
TILT	Tilt Compensation		Laser
HOLD	Hold Horizontal Angle	%	Angle Percent
HL	Horizontal Angle Left	G	Gon
HR	Horizontal Angle Right		Battery

Keyboards



Keys	Surveying Function	Setting Function
V%	Percent grade of vertical angel	Press 2 sec turn on laser plummet
L/R	Switch horizontal angle right or left	Left move the cursor
HOLD	Hold horizontal angle	Right move the cursor
0SET	Set horizontal angle to 0°	Up move the cursor
☼	Display back light	Press 2 sec turn on laser pointer
⏻	Power switch	

➢ **<u>Instrument Settings</u>**

User setting

Press [HOLD] + [0SET] power on. Press [HOLD] or [L/R] shift items, press [0SET] shift options. Press [V%] save and quit.

Options followed by:

1. Angle value: *360º/ 400gon/ 6400mil
2. Horizontal angle 90º beep ON / *OFF
3. Vertical angle tilt compensation *TILT OFF, TILT ON
4. Minimum angle *DSP 1 / DSP 5
5. 30min Auto off NO OFF, *30OFF
6. Vertical angle 0° position * ZENITH: 0, ZENITH: 90

Time and Date Settings

Press [0SET] + [☼] then [POWER]. ADJ2 displayed. Press

[HOLD] to shift date/time, Press [L/R] and [V%] as [+] and [-].

Press [☼] save and quit.

LO 1.3 – Clarify theodolite advantages

- **Topic 1. Clarification of theodolite advantages**

➢ **USES of Theodolites**

- Laying of horizontal angles
- Locating points on line
- Prolonging surveying lines
- Establishing grades
- Determining differences in elevation
- Setting out curves
- Navigating
- Meteorology
- Laying out building corners and lines
- Measuring and laying out angles and straight lines
- Aligning wood frame walls
- Forming panels
- Plumbing a column or building corner

- **Advantages of Theodolites**

Theodolites have many advantages when compared to other levelling instruments:

- Greater accuracy
- Internal magnification optical system
- Electronic readings
- Horizontal circles can be instantly zeroed or set to any other value
- Horizontal circle readings can be taken either to the left or to the right or zero
- Repeat readings are unnecessary.
- Angles measured by repetition can be added to provide a total larger than 360°
- Mistakes in reading angles are greatly reduced
- Speed of operation is increased
- Cost of instrument is lower

Theodolites have an internal optical device that makes reading circles much more accurate than other instruments. Also, because the theodolite allows you to take fewer repeat readings, these measurements can be made much more quickly. Theodolites with optical instruments have advantages over other layout tools. They have more precise measurements, they are unaffected by wind or other weather factors, and they can be used on both flat ground and sloped ground.

- **Disadvantages of Theodolites**

- It is limited in functions
- It cannot measure distance and cannot take points
- Most will also not interface with a data collector
- You need to manually write every measurement down

Learning Unit 2 – Apply Measuring Principles

LO 2.1 – Identify measurement principles

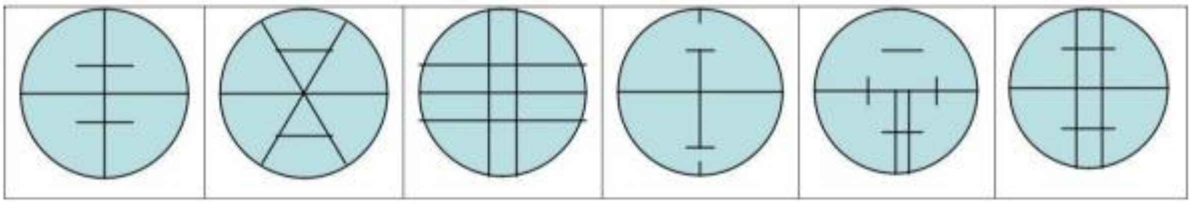
- **Topic 1. Interpretation of Stadia Principles**

A. Stadia hairs.

A rapid and efficient method of measuring distances. Not accurate for high order surveys, but is accurate enough for trigonometric levelling, locating topographic details, and some traverses. Stadia readings can be taken with theodolites, transits, and levels.

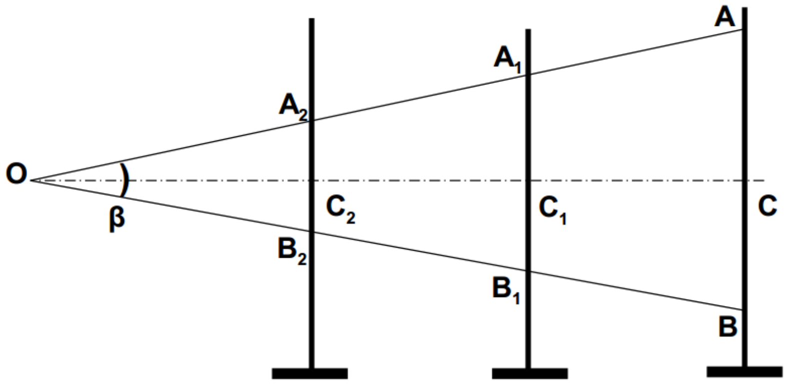
The stadia lines on the telescope reticule correspond to the focal distance. This ratio will always be supplied by the manufacturer of the equipment. For most levels, transits, and theodolites the stadia lines correspond to one hundredth (1/100) of the focal distance.

Different shape/Forms of cross hairs



Principle of Stadia

The stadia method is based on the principle that the ratio of the perpendicular to the base is constant in similar isosceles triangles.



In figure, let two rays OA and OB be equally inclined to central ray OC.

Let A2B2, A1B1 and AB be the staff intercepts. Evidently,

$$\frac{OC_2}{A_2B_2} = \frac{OC_1}{A_1B_1} = \frac{OC}{AB} = \text{constant } k = \tfrac{1}{2}\cot \beta/2$$

This constant k entirely depends upon the magnitude of the angle β.

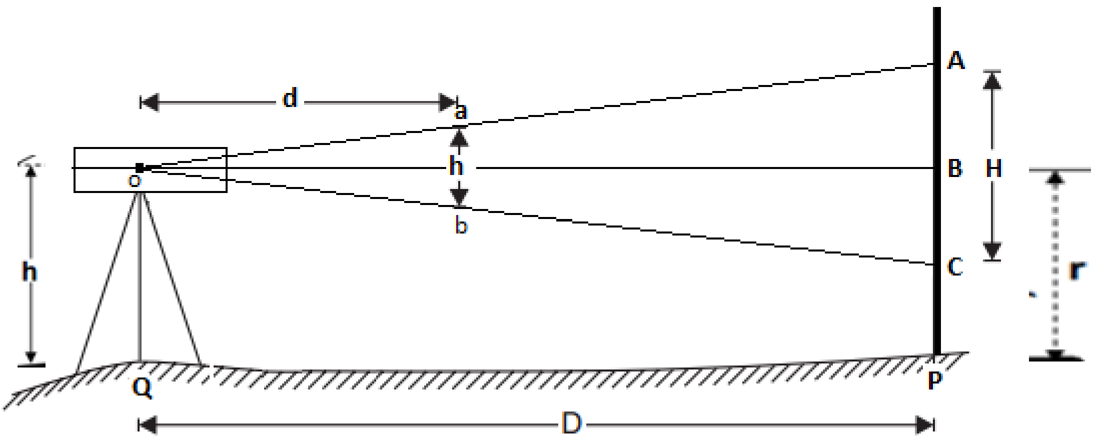
<u>Distance and Elevation determination</u>

The principle common to all the systems is to calculate the horizontal distance between two points A and B and their distances in elevation, by observing

i. The angle at the instrument at A subtended by a known short distance along a staff kept at B, and
ii. The vertical angle to B from A.

The distance can be found either by horizontal sight when there is plane surface or by inclined sight when there is inclined surface

a. For horizontal sight



Let: A, B and C = the points cut by the three horizontal hairs

AC = H = Staff intercept

D = Reduced horizontal distance between staff station and the vertical axis of the instrument

a and b = Stadia hairs on the reticule (inside the telescope)

ab = h = Stadia interval

d = Distance between reticule and the vertical axis of the instrument

Distance equation: As the triangle "aOb" and "AOC" are similar; D/H= d/h=K=100

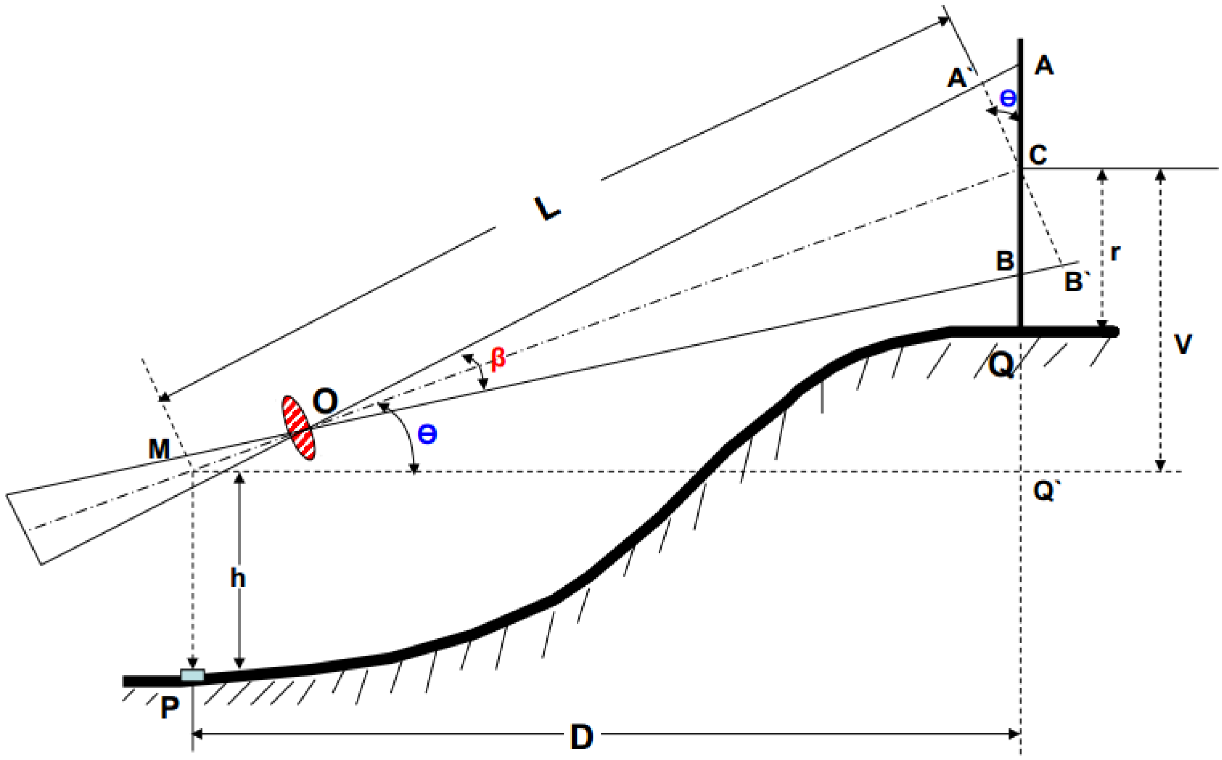
Where: "K" is "the multiplying constant" or "Stadia interval factor".

Thus, to calculate the reduced horizontal distance the following equation is to be applied:

D=K*H ≫≫≫ D=100*H

Therefore, elevation at P= ELEVATION AT Q+h-r

b. For inclined sight



Let P = Instrument station;
Q = Staff station
M = position of instruments axis;
O = Optical centre of the objective
A, C, B = Points corresponding to the readings of the three hairs
s = AB = Staff intercept;
i = Stadia interval
Ө = Inclination of the line of sight from the horizontal
L = Length MC measured along the line of sight
D = MQ' = Horizontal distance between the instrument and the staff
V = Vertical intercept at Q, between the line of sight and the horizontal line
h = height of the instrument;
r = central hair reading
β = angle between the two extreme rays corresponding to stadia hairs.

Since β/2 is very small (its value being equal to 17' 11" for k = 100), angle AA'C and angle BB'C may be approximately taken equal to 90^0. ∟AA'C = ∟BB'C = 90^0
From Δ ACA', A'C = AC cos Ө or A'B' = AB cos Ө = s cos Ө

Since the line A'B' is perpendicular to the line of sight OC, equation D = k s + C is directly applicable. Hence, we have

MC = L = k. A'B' + C = k s cosӨ + C

The horizontal distance

D = L cosӨ = (k s cosӨ + C) cosӨ

$D = k\,s\cos^2\Theta + C\cos\Theta$

Similarly, V = L sin Ө = (k s cosӨ + C) sinӨ = k s cosӨ. sinӨ + C sinӨ

$V = k\,s\,\frac{\sin 2\theta}{2} + C\sin\Theta$

- Elevation at Point Q

(a) Elevation of the staff station for angle of elevation

If the line of sight has an angle of elevation ϴ, as shown in the figure, we have Elevation of staff station = Elevation of instrument station + h + V – r.

(b) Elevation of the staff station for the angle of depression:

Elevation of Q = Elevation of P + h – V - r

- **Angle determination**

Terminology:

a) An angle is the difference in directions of two intersecting lines. Angle is the direction of a survey line established with relation to each other.

b) Bearing is the direction of a survey line established with relation to any meridian. It can be named as True, Magnetic or Arbitrary according to referred meridian.

c) Meridian is the vertical circle passing through a place and the north and south poles. It is a north-south reference line. It is said: True, Magnetic or Arbitrary according to referred celestial poles.

d) Azimuth of a point (place) is the bearing between the observer's meridian and the vertical circle passing through that place. Thus, it is the bearing to a line of sight, measured clockwise (usually) from a north direction.

e) Vertical plane: At a point is any plane that contains the vertical line at the point. There are unlimited number of vertical planes at a given points.

f) Traverse: a continuous series of measured (angle and distance) lines.

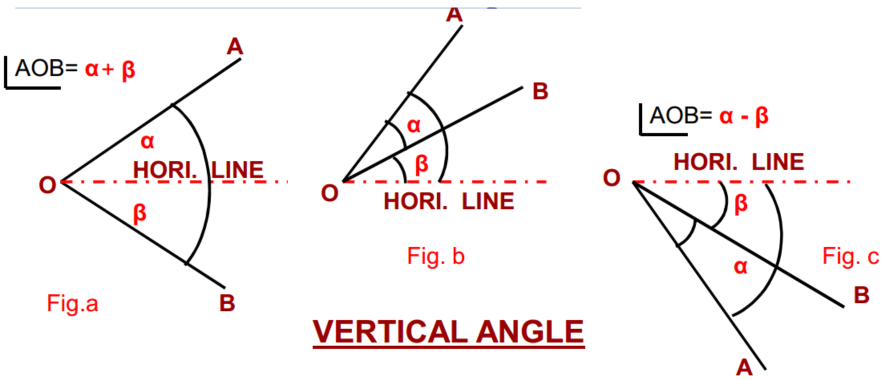
Types of Angles

Angles are mainly grouped into two types: Vertical and Horizontal

a) Horizontal angles are used to determine bearings and directions in control surveys, for locating detail when mapping and for setting out all types of structures.

b) Vertical angles are used when determining the heights of points and to calculate slope corrections.

Vertical Angle: A vertical angle is an angle between the inclined line of sight and the horizontal. It may be an angle of elevation or depression according as the object is above or below the horizontal plane (above or below the trunnion axis of the instrument). They also be named as Zenithal, Nadiral or Perpendicular (inclination) depending upon whether the vertical angle is measured respectively from Zenith, Nadir or Horizontal direction.



VERTICAL ANGLE

To Measure the Vertical Angle of an object A at a station O:

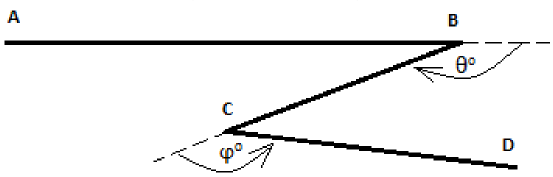
i. Set up the theodolite at station point O and level it accurately with reference to the altitude bubble.
ii. Set the zero of vertical vernier exactly to the zero of the vertical circle clamp and tangent screw.
iii. Bring the bubble of the altitude level in the central position by using clip screw. The line of sight is thus made horizontal and vernier still reads zero.
iv. Loosen the vertical circle clamp screw and direct the telescope towards the object A and sight it exactly by using the vertical circle tangent screw.
v. Read both verniers on the vertical circle, the mean of the two vernier readings gives the value of the required angle.
vi. Change the face of the instrument and repeat the process. The mean of the two vernier readings gives the second value of the required angle.
vii. The average of the two values of the angles thus obtained, is the required value of the angle free from instrumental errors.

For measuring Vertical Angle between two points A &B

i. Sight A as before, and take the mean of the two Vernier readings at the vertical circle. Let it be α
ii. Similarly, sight B and take the mean of the two Vernier readings at the vertical circle. Let it be
iii. The sum or difference of these dings will give the value of the vertical angle between A and B according as one of the points is above and the other below the horizontal plane. or both points are on the same side of the horizontal plane Fig b & c

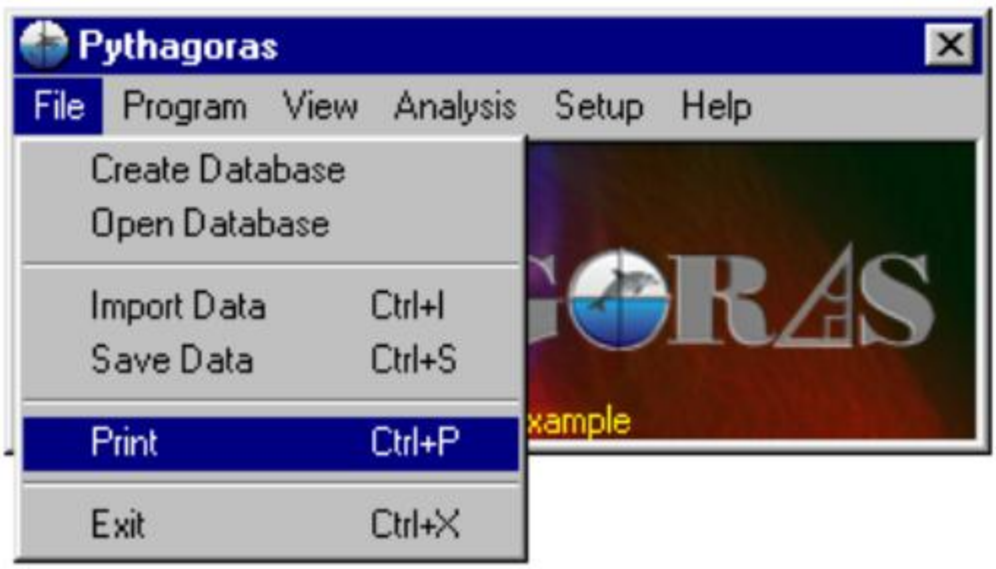
Horizontal angle: is the angular distance between two intersecting lines measured in horizontal direction. It can be named as deflection angle or direct angle.

a) Direct angle: Is an angle measured clockwise from the previous line to the following line. It is also known as “angle to the right” or “Azimuth from the back line” and may vary from 0o to 360o
b) Deflection angle: Is the angle which a survey line makes with the prolongation of the previous line.



It is designed as right (θ^o) or left (φ^o) depending whether it is measured to the clockwise or anticlockwise from the prolongation of the previous line.

- **Printing Data**



You may printout your data for the currently selected station. The data are formatted as an Excel spreadsheet and printed to the computer system's default printer.

- Importing Data
- Pythagoras' MetaFile

Data can be imported into an existing Pythagoras database by means of a comma-delimited metafile. The file contains a command (telling Pythagoras what to add), the station name, relevant variables and an End command. Below is a list of commands to add data to Pythagoras. All Commands are case sensitive.

Add Station Command (Command = AddStation)

(AddStation, Name of Station, Eye Height, Reference Name, Reference Azimuth, Station Height, Environmental Check interval (as Integer), Station Latitude Hemisphere, Latitude Degrees, Latitude Minutes, Latitude Seconds, Longitude Hemisphere, Longitude Degrees, Longitude Minutes, Longitude Seconds, Tide Height, END)

Data can also be edited as a process from the beginning to end of file.

Editing Data commands are:

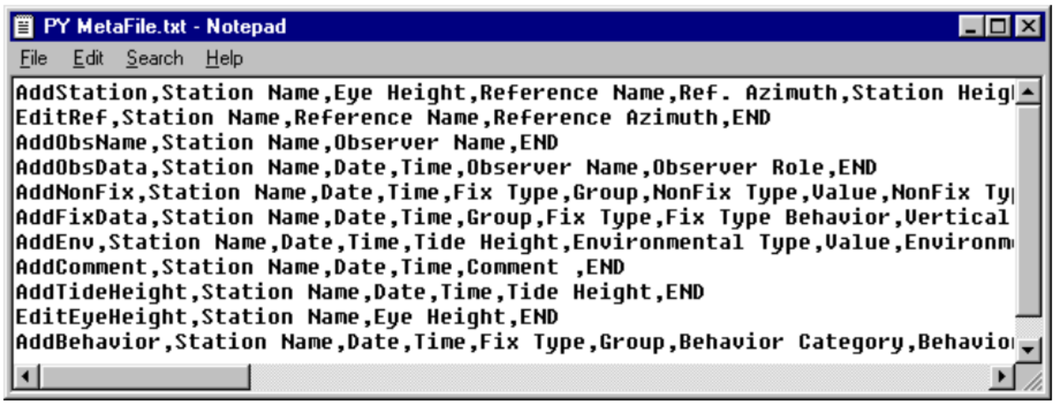
Edit Reference Azimuth (Command = "EditRef")

(EditRef, Name of Station, Reference Name, Reference Azimuth, END)

Edit Station Eye Height Value (Command = "EditEyeHeight")

(EditEyeHeight, Name of Station, Eye Height value, END)

Below is an example of a Pythagoras' Metafile:


PY MetaFile.txt - Notepad

File Edit Search Help

```
AddStation,Station Name,Eye Height,Reference Name,Ref. Azimuth,Station Heig
EditRef,Station Name,Reference Name,Reference Azimuth,END
AddObsName,Station Name,Observer Name,END
AddObsData,Station Name,Date,Time,Observer Name,Observer Role,END
AddNonFix,Station Name,Date,Time,Fix Type,Group,NonFix Type,Value,NonFix Ty
AddFixData,Station Name,Date,Time,Group,Fix Type,Fix Type Behavior,Vertical
AddEnv,Station Name,Date,Time,Tide Height,Environmental Type,Value,Environm
AddComment,Station Name,Date,Time,Comment ,END
AddTideHeight,Station Name,Date,Time,Tide Height,END
EditEyeHeight,Station Name,Eye Height,END
AddBehavior,Station Name,Date,Time,Fix Type,Group,Behavior Category,Behavio
```

Importing Excel Data Files

Excel files can be used to import comment, fix data, and focal behavior data into Pythagoras' database. Each Excel worksheet must have Excel's default worksheet title "Sheet1". Header information in the first row is optional and Pythagoras will prompt the user if the file they are importing contains such information. Each column within the Excel worksheet must be in the same order to properly import your data.

Excel Comment Data File

The comment Excel file contains four columns: A) Station Name,

B) Date, C) Time, and D) Comment line.

LO 2.2 – Identify measuring methods

- **Topic 1. Identification of measuring methods**

The various measuring methods of the tacheometric survey may be classified as follows:

1. The Stadia System
   i. Fixed Hair Method
   ii. Movable Hair Method, or Subtense Method
2. The Tangential System
3. Measurements by means of Special Instruments

- Stadia system

i. Fixed Hair Method (Stadia method)

In this method, stadia hairs are kept at fixed interval and the staff interval or intercept (corresponding to the stadia hairs) on the levelling staff varies. Staff intercept depends upon the distance between the instrument station and the staff.

ii. Movable Hair Method (Subtense method)

This method is similar to the fixed hair method except that the stadia interval is variable. Suitable arrangement is made to the distance between the stadia hairs so as to set them against the two targets on the staff kept at the point under observation. Thus, in the case the staff intercept i.e., the distance between the two targets is kept fixed while the stadia interval, i.e., the distance between the stadia hairs is varied. As in the case of fixed hair method inclined sights may also be taken.

COMPARISON BETWEEN FIXED HAIR AND MOVABLE HAIR

Sr.no	Fixed hair	Movable hair
1	In this method interval between two stadia hair is fixed.	In this method interval between two stadia hair is variable. Stadia line are not fixed and moved by micrometer screw.
2	In this method horizontal distance from the instrument to the staff can be determine from the value of staff intercept intercepted by the stadia line.	In this method horizontal distance from the instrument to the staff can be determine from the value of stadia variable interval.
3	Staff intercept varies with the distance at which the staff is held.	The staff is provided with two vanes or target fixed at a known distance apart normally 3m to staff.
4	This method is commonly used	This method is not commonly used but now rarely used.

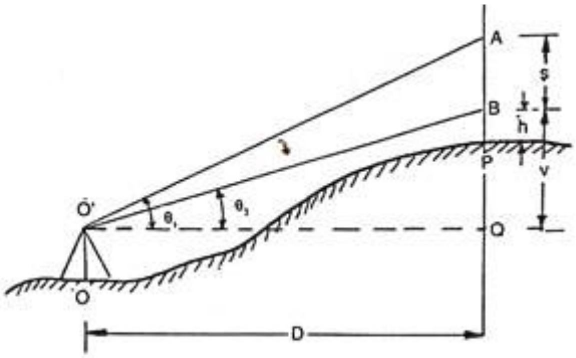
➢ Tangential Method

In this method the stadia hair is not used, the readings are taken against the horizontal cross hair. To measure the staff intercept, two points are noted on the staff along with in their corresponding vertical angles. This necessitates the measurement of vertical angles twice for one observation.

The horizontal and vertical distances are then calculated as follows:

Case 1:

When both the observed angles are angles of elevation:



O=The instruments station.

O'=The position of the instruments axis

P= The staff station.

∠AO'Q= θ1= vertical angle to the upper vane.

∠BO'Q= θ2 =" " " lower

AB=S=the staff intercept.

BQ=V= the horizontal distance from the inst, axis to the lower vane.

O'Q=D= the horizontal distance from the inst. station O to the staff station P

PB= h= the height of the lower vane above the foot of the staff.

$$BQ = V = D \tan \theta_2$$

$$S = D (\tan \theta_1 - \tan \theta_2)$$

$$D = \frac{S}{(\tan\theta_1 - \tan\theta_2)} \quad \dots \quad \dots \quad \text{Eqn. } 10.13$$

$$\text{and} \quad V = D \tan \theta_2 = \frac{S \tan\theta_2}{(\tan\theta_1 - \tan\theta_2)} \quad \dots \quad \dots \quad \text{Eqn. } 10.14$$

R.L. of staff station P = R.L. of the line of sight + V - *h*.

Case II:

When both the observed angles are angles of depression:

$$S = QB - QA = D(\tan\theta_2 - \tan\theta_1)$$

$$\therefore \quad D = \frac{S}{(\tan\theta_2 - \tan\theta_1)} \quad \ldots \quad \ldots \quad \text{Eqn. 10.15}$$

$$\text{and} \quad V = D\tan\theta_2 = \frac{S.\tan\theta_2}{(\tan\theta_2 - \tan\theta_1)} \quad \ldots \quad \ldots \quad \text{Eqn. 10.16}$$

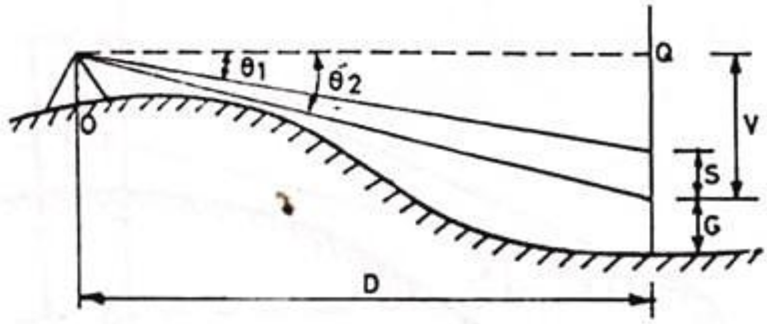


Fig. 10.11

R.L. of staff stn. P = R.L. of the line of sight - V - h.

Case III.

When one of the observed angle is the angle of elevation and the other an angle of depression:

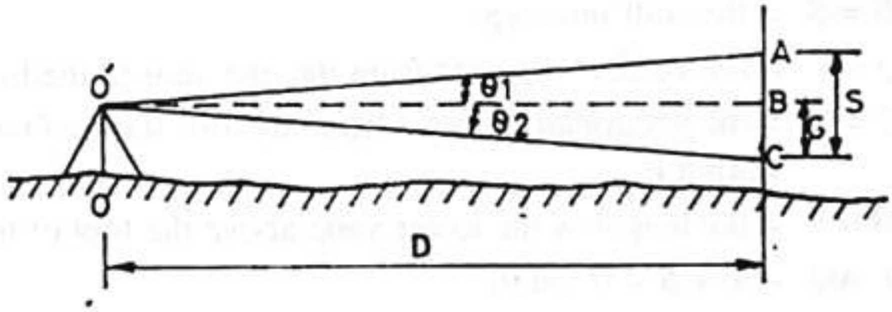


Fig. 10.12

$$S = AC = AB + BC = D(\tan\theta_1 + \tan\theta_2)$$

$$\therefore \quad D = \frac{S}{(\tan\theta_1 + \tan\theta_2)} \quad \ldots \quad \ldots \quad \ldots\text{Eqn. 10.17}$$

$$\text{and } V = D\tan\theta_2 = \frac{S\tan\theta_2}{(\tan\theta_1 + \tan\theta_2)} \quad \ldots \quad \ldots \quad \ldots\text{Eqn. 10.18}$$

R.L. of staff station = R.L. of line of sight - V - h

- Measurements by means of Special Instruments
- Carrying out a level traverse (Booking levels)

To determine the difference in level between points on the surface of the ground a 'series' of levels will need to be carried out; this is called a level traverse or level run.

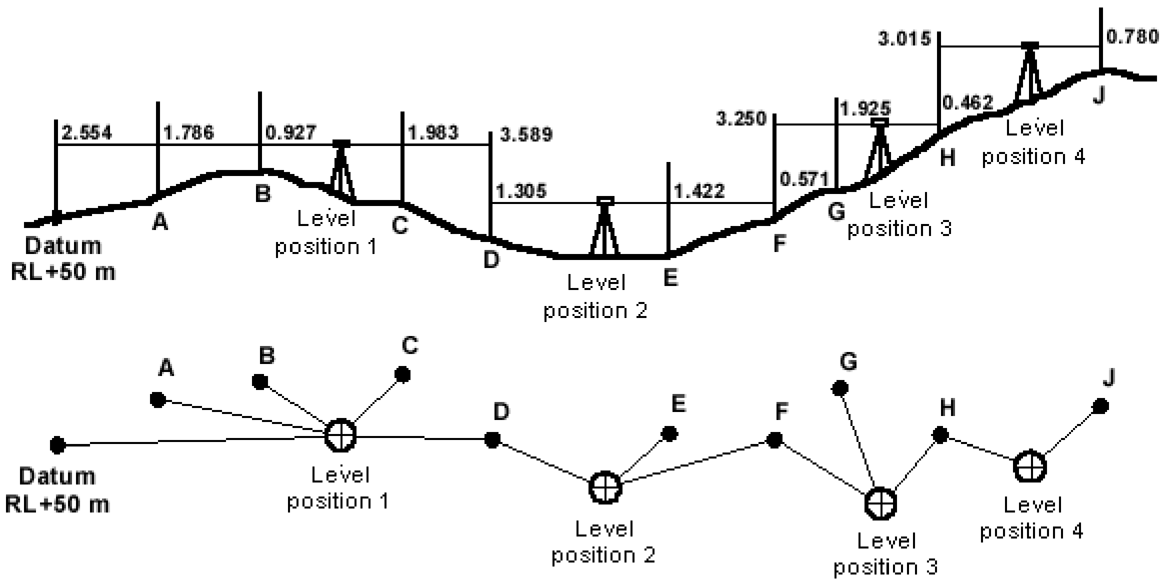
❖ Booking terminology:

Before discussing the booking and methods of reducing levels, the following terms associated with differential levelling must be understood.

a) Station: A station is the point where the levelling staff is held.
b) Height of instrument (H.I.) or height of collimation: For any set up of the level, the elevation of the line of sight is the height of instrument.
c) Back sight (B.S.): It is the first reading taken on the staff after setting up the level usually to determine the height of instrument. It is usually made to some form of a bench mark (B.M.) or to the points whose elevations have already been determined.
d) Fore sight (F.S.): It is the last reading from an instrument position on to a staff held at a point. It is thus the last reading taken within a section of levels before shifting the instrument to the next section, and also the last reading taken over the whole series of levels.
e) Change point (C.P.) or turning point: A change point or turning point is the point where both the fore sight and back sight are made on a staff held at that point. A change point is required before moving the level from one section to another section. By taking the fore sight the elevation of the change point is determined and by taking the back sight the height of instrument is determined. The change points relate the various sections by making fore sight and back sight at the same point.
f) Intermediate sight (I.S.): The term 'intermediate sight' covers all sightings and consequent staff readings made between back sight and fore sight within each section. Thus, intermediate sight station is neither the change point nor the last point.
g) Balancing of sights: When the distances of the stations where back sight and fore sight are taken from the instrument station, are kept approximately equal, it is known as balancing of sights. Balancing of sights minimizes the effect of instrumental and other errors.
h) Reduced level (R.L.): Reduced level of a point is its height or depth above or below the assumed datum. It is the elevation of the point.
i) Rise and fall: The difference of level between two consecutive points indicates a rise or a fall between the two points. Is positive, it is a rise and if negative, it is a fall. Rise and fall are determined for the points lying within a section.
j) Section: A section comprises of one back sight, one fore sight and all the intermediate sights taken from one instrument set up within that section. Thus, the number of sections is equal to the number of set ups of the instrument.

❖ Levelling or Field Procedures

The leveling or field procedure that should be followed is shown in Figure below.



Procedure:

1. Set up the leveling instrument at Level position 1.
2. Hold the staff on the Datum (RL+50 m) and take a reading. This will be a backsight, because it is the first staff reading after the leveling instrument has been set up.
3. Move the staff to A and take a reading. This will be an intermediate sight.
4. Move the staff to B and take a reading. This also will be an intermediate sight.
5. Move the staff to C and take a reading. This will be another intermediate sight.
6. Move the staff to D and take a reading. This will be a foresight; because after this reading the level will be moved. (A change plate should be placed on the ground to maintain the same level.)
7. The distance between the stations should be measured and recorded in the field book
8. Set up the level at Level position 2 and leave the staff at D on the change plate. Turn the staff so that it faces the level and take a reading. This will be a backsight.
9. Move the staff to E and take a reading. This will be an intermediate sight.
10. Move the staff to F and take a reading. This will be a foresight; because after taking this reading the level will be moved.
11. Now move the level to Leveling position 3 and leave the staff at F on the change plate.

Now repeat the steps describe 8 to 10 until you finished at point J.

❖ Methods/system of booking

For booking and reducing the levels of points, there are two systems, namely the height of instrument or height of collimation method and rise and fall method

There are two main methods of booking levels:

a) Height of instrument or height of collimation method of booking/ Horizontal Plane of Collimation
b) Rise and fall method of booking

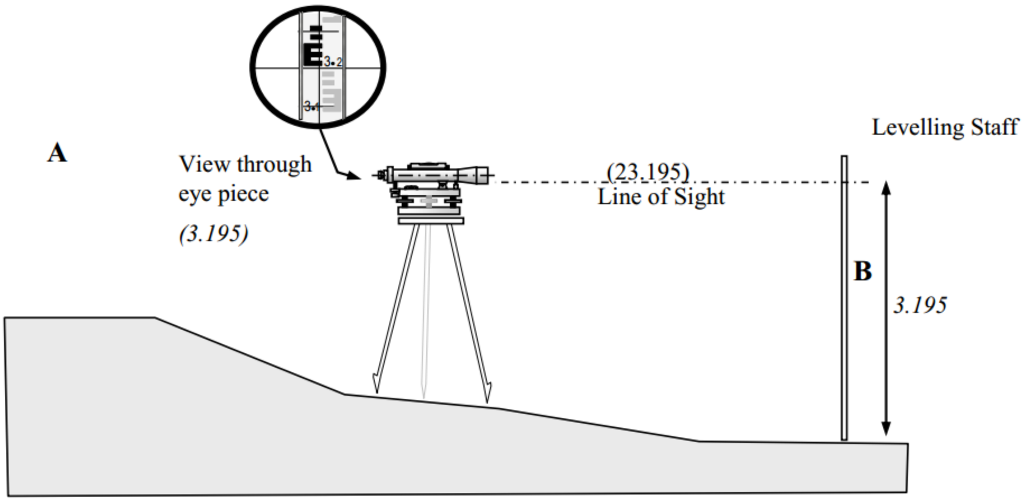
c) HEIGHT OF INSTRUMENT/ HORIZONTAL PLANE OF COLLIMATION (HPC)

The line of sight is termed the HORIZONTAL PLANE OF COLLIMATION (HPC).

Hence HPC = Known reduced level + BS

The plane of reference has now been established (HPC) and the next reading of the staff can be referred to this.

The staff is next placed at the point whose reduced level is desired (B) and the telescope of the level is rotated to target the new staff position, care being taken not to alter the adjustment of the instrument (i.e. don't knock it).



The new staff reading is taken, 3.195m (say). This indicates that point B is 3.195m below the level of the line of sight or HPC, which was calculated to be 23.195m. The reduced level of point B is therefore: -

23.195m – 3.195m = 20.000

This staff reading onto the point whose desired level is required is termed the FORESIGHT reading (FS).

Hence Reduced Level = HPC – FS

The staff readings and calculations are booked in a standard field book as follows: -

BACK SIGHT	INTER MEDIATE	FORE SIGHT	H.P.C.	REDUCED LEVEL	DISTANCE	COMMENTS
2.195	23.195	21.000	known reduced level at A			
3.195	20.000	calculated reduced level at B				

If is required to the reduced level of a point a considerable distance from a known point, or where obstructions occur, then it is necessary to use CHANGE POINTS.

A number of observations can be made.

1. All levelling operations start with a backsight and end with a foresight.

2. There are the same numbers of backsights as foresights.

3. The arithmetic involved can be written as two simple formulae: -

a) HPC = RL + BS

b) RL = HPC - FS

Where

HPC = Horizontal Plane of Collimation (sometimes referred to as height of collimation

or height of instrument.)

RL = Reduced Level

BS = Backsight staff reading

FS = Foresight staff reading

- RISE AND FALL METHOD

It has been seen that in the HPC method the intermediate sightings cannot be checked. The rise and fall method will check all the arithmetic because each staff reading is used to determine the reduced levels. Consider the previous example, the determination of reduced levels for points B to E are independent calculations and do not come within the arithmetic check.

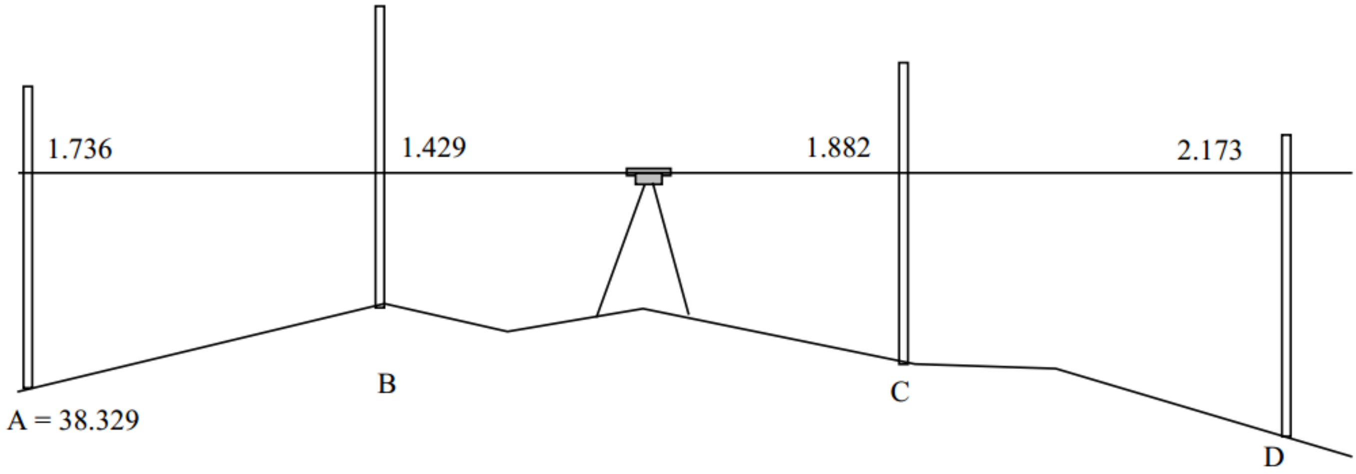
With the rise and fall system each consecutive pair of staff readings are compared in turn to find their difference in height and whether the second of the two readings is higher or lower than the first.

Referring to the diagram below, comparing the first two readings A and B it can be seen that B is higher than A indicating a RISE of 0.307m, the difference between the staff readings. Between the next two readings, B and C, C is lower than B by 0.453m (the difference between staff readings). This is therefore a FALL. Finally, there is a FALL from C to D of 0.291m. The rises and falls can be checked arithmetically as shown later, and it is easier to check for arithmetic error at this stage than to leave it until the reduced levels are calculated.

The reduced level of A is known, 38.329m and so is the Rise to B of 0.307m. The reduced level of B must therefore be 38.329 + 0.307m i.e. 38.636m. Similarly knowing the reduced level of B and that there is a fall to C of 0.453m, the reduced level of c must be 38.636-0.453 i.e. 38.183m.

Finally, the reduced level of D is found by subtracting the Fall of 0.291 from the reduced level of C i.e. 37.892m.

The arithmetic check can now be completed, which is given by:
ΣBacksights - ΣForesights
= ΣRises - ΣFalls
= Last reduced level – First reduced level



Booking:

BACK SIGHT	INTER-MEDIATE	FORE SIGHT	RISE	FALL	REDUCED LEVEL	COMMENTS
1.736					*38.329*	A
	1.429		*0.307*		*38.636*	*B*
	1.882			*0.453*	*38.183*	*C*
		2.173		*0.291*	*37.892*	*D*
1.736		2.173	0.307	0.744	37.892	Arithmetic check OK
2.173			0.744		38.329	
-0.437			-0.437		-0.437	

The main advantage of the Rise and Fall system over the HPC method for reducing levels is the ability to check the arithmetic of intermediate sights. Where you are faced with large quantities of intermediate sights this is the preferred method.

- **Topic 2. Identification of Methods of measuring horizontal angles**

➢ Methods of measuring horizontal angles

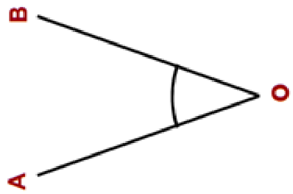
There are three methods of measuring horizontal angles:

a. Ordinary Method.
b. Repetition Method.
c. Reiteration Method.

a. Ordinary Method. To measure horizontal angle AOB:

i. Set up the theodolite at station point O and level it accurately.
ii. Set the Vernier A to the zero or 360^0 of the horizontal circles. Tighten the upper clamp.

iii. Loosen the lower clamp. Turn the instrument and direct the telescope towards A to bisect it accurately with the use of tangent screw. After bisecting accurately check the reading which must still read zero. Read the Vernier B and record both the readings.
iv. Loosen the upper clamp and turn the telescope clockwise until line of sight bisects point B on the right-hand side. Then tighten the upper clamp and bisect it accurately by turning its tangent screw.
v. Read both Vernier's. The reading of the Vernier a which was initially set at zero gives the value of the angle AOB directly and that of the other Vernier B by deducting 180^0. The mean of the two Vernier readings gives the value of the required angle AOB.
vi. Change the face of the instrument and repeat the whole process. The mean of the two Vernier readings gives the second value of the angle AOB which should be approximately or exactly equal to the previous value.
vii. The mean of the two values of the angle AOB, one with face left and the other with face right, gives the required angle free from all instrumental errors.



HORIZONTAL ANGLE AOB

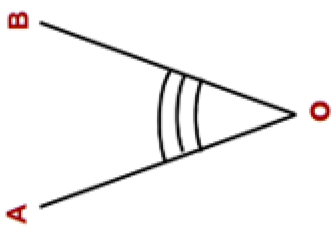
b. Repetition Method.

This method is used for very accurate work. In this method, the same angle is added several times mechanically and the correct value of the angle is obtained by dividing the accumulated reading by the no. of repetitions.

The No. of repetitions made usually in this method is six, three with the face left and three with the face right. In this way, angles can be measured to a finer degree of accuracy than that obtainable with the least count of the Vernier.

To measure horizontal angle by repetitions:

i. Set up the theodolite at starting point O and level it accurately.
ii. Measure The horizontal angle AOB.
iii. Loosen the lower clamp and turn the telescope clock – wise until the object (A) is sighted again. Bisect B accurately by using the upper tangent screw. The Vernier will now read the twice the value of the angle now.
iv. Repeat the process until the angle is repeated the required number of times (usually 3). Read again both Vernier. The final reading after n repetitions should be approximately n X (angle). Divide the sum by the number of repetitions and the result thus obtained gives the correct value of the angle AOB.
v. Change the face of the instrument. Repeat exactly in the same manner and find another value of the angle AOB. The average of two readings gives the required precise value of the angle AOB.



HORIZONTAL ANGLE AOB

c. Reiteration Method

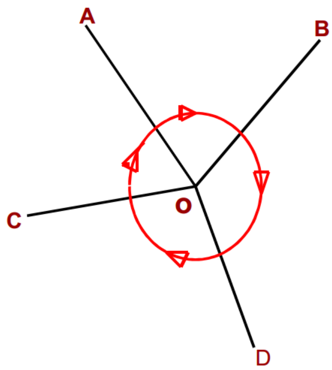
This method is another precise and comparatively less tedious method of measuring the horizontal angles.

It is generally preferred when several angles are to be measured at a particular station.

This method consists in measuring several angles successively and finally closing the horizon at the starting point. The final reading of the Vernier A should be same as its initial reading. If not, the discrepancy is equally distributed among all the measured angles.

Procedures

i. Suppose it is required to measure the angles AOB, BOC and COD. Then to measure these angles by repetition method:
ii. Set up the instrument over station point O and level it accurately.
iii. Direct the telescope towards point A which is known as referring object. Bisect it accurately and check the reading of Vernier as 0 or 360^0. Loosen the lower clamp and turn the telescope clockwise to sight point B exactly. Read the verniers again and the mean reading will give the value of angle AOB.
iv. Similarly bisect C & D successively, read both verniers at each bisection, find the value of the angle BOC and COD.
v. Finally close the horizon by sighting towards the referring object (point A).
vi. The Vernier A should now read 3600. If not note down the error. This error occurs due to slip etc.
vii. If the error is small, it is equally distributed among the several angles. If large the readings should be discarded and a new set of readings be taken.



Reiteration Method

- Mistakes in angle measurement

Some common mistakes in angle measurement work are:

- Sighting on, or setting up over the wrong point
- Calling out or recording an incorrect value
- Improper focusing of the eyepiece and objective lenses of the instrument
- Partiality on the tripod, or placing a hand on the instrument when pointing or taking readings

LO 2.3 –Compare measuring methods

- **Topic 1: Comparison between measuring methods**

– Demonstration of Tangential method is less accurate than the stadia hair method.
– Repetition Method improves precision and accuracy of measurements of horizontal angles (for single angle).
– Reiteration Method for more than one angle.
– Ordinary method of measuring horizontal angles is used as it is less time consuming.

Learning Unit 3 – Perform basic applications theodolite

LO 3.1 – Select Theodolite

- **Topic 1: Differentiate Classes (Categories) and Types of Theodolite**

➢ Classification of Theodolite

Theodolite is broadly classified into two categories as:

a. Transit theodolite

b. Non-transit theodolite

a) Transit Theodolite: A theodolite is called a transit theodolite when its telescope (line of sight) can be reversed by revolving the telescope 180 degrees along the vertical plane. Rotated through a whole revolution regarding its horizontal axis within the vertical plane.

b) Non-Transit Theodolite in this type of Theodolite, the line of sight cannot be revolved in the vertical plane. They are inferior in utility and have now become obsolete.

Comparison between classes of theodolite

A transit is a surveying instrument that also takes accurate angular measurements. A theodolite may be either transit or non-transit. Some types of transit theodolites do not allow the measurement of vertical angles. The rotation in the vertical plane is restricted to a semi-circle in a non-transit theodolite.

A theodolite is a precision instrument that is used for measuring horizontal and vertical angles. Theodolites can rotate along their horizontal axis as well as their vertical axis. A transit is a surveying instrument that also takes accurate angular measurements. A theodolite may be either transit or non-transit.

A theodolite may be either transit or non-transit. In a transit theodolite, the telescope can be inverted in the vertical plane. Some types of transit theodolites do not allow the measurement of vertical angles.The rotation in the vertical plane is restricted to a semi-circle in a non-transit theodolite.

➢ Types of Theodolite

Modern theodolites involve a movable telescope which is mounted within two perpendicular axes. Moreover, these two axes are the horizontal axis and the vertical axis.

When the telescope focuses on a target object, the measurement of the angle of these axes takes place with high precision. Theodolites generally include three types.

a. Repeating theodolites

b. Directional theodolites

c. Electrical digital theodolites

i. **Repeating Theodolite:**

Repeating theodolites refer to those theodolites which measure angles on a graduated scale. The average of the angle measure is then derived. This takes place by dividing the total of these readings by the number of readings which were taken.

The use of repeating theodolites takes place in locations where the base is not steady. Furthermore, their use also occurs in places where space is too limited. This limited space makes the use of other instruments futile.

Repeating theodolites are certainly more accurate than other types of theodolites. This is because a reduction of errors takes place here. This is possible due to comparing the values of multiple readings rather than a single reading.

This design facilitates horizontal angles to be remade any number of times and added directly on the instrument circles. This type of instruments is restricted for locations where the support is not steady, or area for using other such instruments is limited.

Advantages of this design are:

- Better accuracy obtained through averaging
- Disclosure of errors and mistakes by computing values of the single and multiple readings

ii. Directional Theodolite:

Direction theodolites refer to those theodolites which determine angles through a circle. Here, a circle is set and the direction of the telescope is at several signals.

An individual can acquire readings from every direction. The determination of the angle measurements is by subtracting the first reading from the second reading.

The common usage of direction theodolites is by surveyors in triangulation. Moreover, triangulation is the process of determining a point by measuring the angles from certain known points on a baseline. Angles are obtained by deducting the first direction reading from the second direction reading. This reads directions rather than angles. The non-repeating instrument has no minor motion.

Reads “directions” rather than angles

Angles are obtained by subtracting the first direction reading from the second direction reading

iii. Electrical Digital Theodolite: Naturally interprets and records horizontal and vertical angles. Eliminates the standard reading of scales on graduated circles. Automatically reads and records horizontal and vertical angles. Eliminates the manual reading of scales on graduated circles

Advantages of electronic digital theodolite

- Circles can be instantaneously zeroed, or initialized to any value
- Angles can be measured with increasing values either left or right
- Angles measured by repetition can be added to provide a total larger than 360°
- Mistakes in reading angles are greatly reduced
- Speed of operation is increased
- Cost of instrument is lower

LO 3.2 – Use Theodolite in measurements

- **Topic 1: Discussion on the use or manipulation of theodolite**

➢ **Casing and uncasing**

Before removing an instrument, study the way it is placed and secured in the case. Place it in the same position when you return it to the case. In removing the instrument from the case, carefully grip it with both hands, but do not grip the vertical circle standard or where pressure will be exerted or tubular or circular level vials

➢ **Tripod setup**

The tripod consists of three legs and a head where the level instrument is mounted. The tripod could be of aluminium or wood material. When leveling the level instrument, the tripod head must be set approximately leve beforehand by adjusting the tripod legs.

Care of Tripods

A stable tripod is required for precision in measuring angles. A tripod should not have any loose joints or parts which might cause instability. Some suggestions for proper tripod care are:

- Maintain firm snugness in all metal fittings, but never tighten them to the point where they will unduly compress or injure the wood, strip threads or twist off bolts or screws.
- Tighten leg hinges only enough for each leg to just sustain its own weight when legs are spread out in their normal working position.
- Keep metal tripod shoes tight and free of dirt.
- Keep wooden parts of tripods well painted or varnished to reduce moisture absorption and swelling or drying out and shrinking.
- Replace top caps on tripods when not in use.
- The most damage occurs to tripods when being placed in or taken out of survey vehicles. The life and usefulness of tripods can be significantly extended if compartments are constructed so that the tripods are not riding on or against other equipment.

➢ **Theodolite setup**

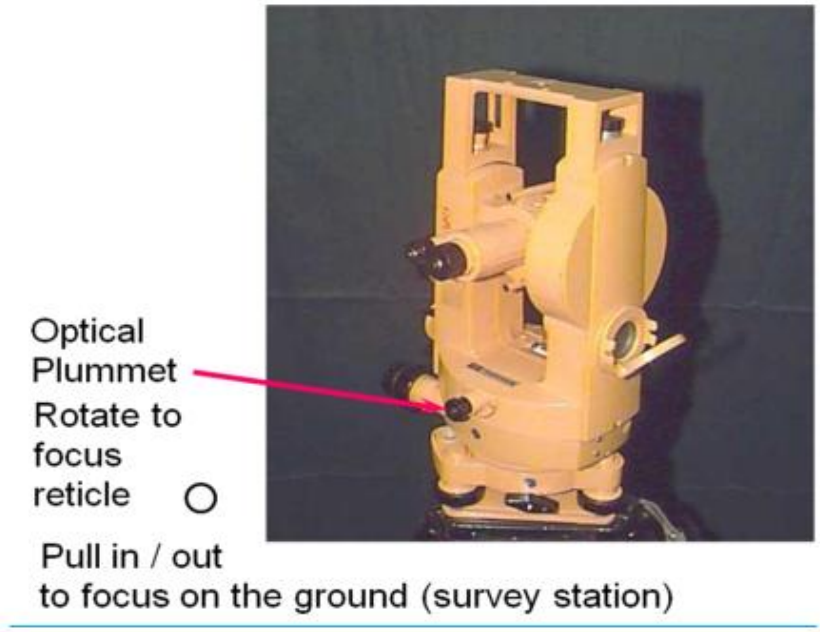
Ensure that

- the tripod head is approximately level
- the tripod feet are firmly fixed in the ground

This should be done BEFORE removing the theodolite from its box, Place the theodolite on top of the tripod, and tighten the centering screw to Clamp the theodolite centrally on the tripod head.

Use the optical plummet to focus onto the survey station (e.g. nail in top of peg)

- Turn the optical plummet eyepiece to focus the reticule (i.e. the black Circular mark)
- push (or pull) the optical plummet focussing ring to focus on the Survey station



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- Turn the optical plummet eyepiece to focus the reticule (i.e. the black Circular mark)
- push (or pull) the optical plummet focussing ring to focus on the survey station

By rotating the levelling foot SCREWS, using all three in a random manner if necessary, centre the reticule (black circle) in the optical plummet onto the survey station.

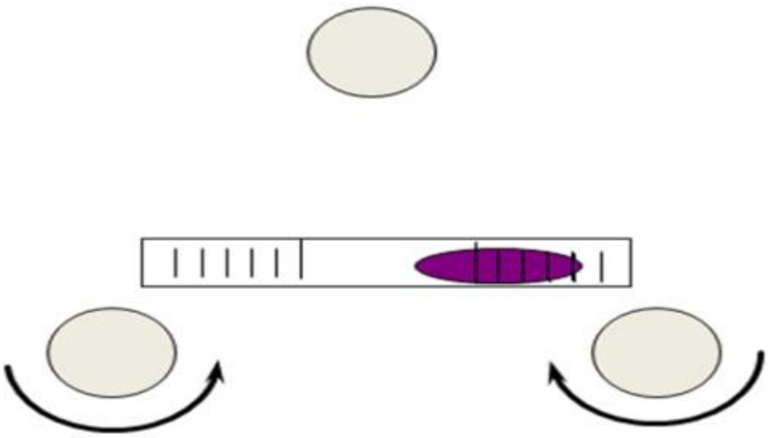
Carry out an approximate levelling. Using the pond bubble and by adjusting the length of TWO tripod LEGS, bring the pond bubble into the centre of the pond bubble tube.

Fine level the theodolite using the PLATE level bubble tube and foot SCREWS

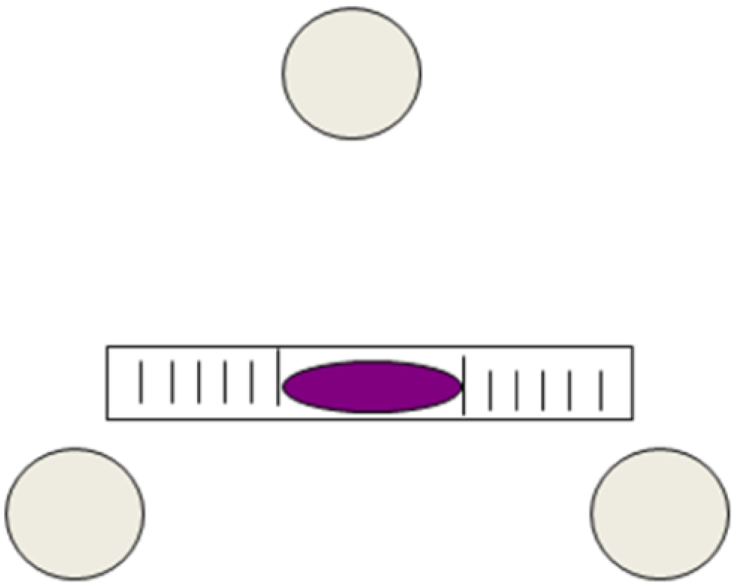
• Position align the plate level bubble tube with two-foot screws.

Centre the bubble by rotating the two-foot screws in opposite Directions. The bubble

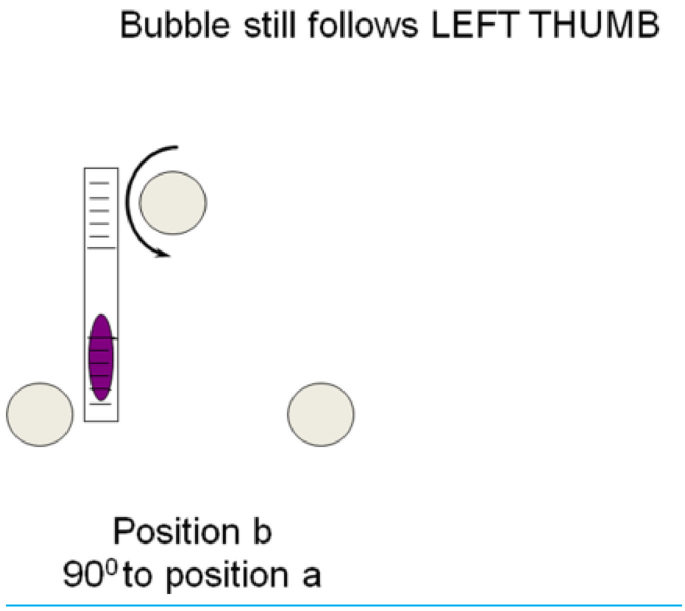
follows the LEFT thumb.



Position a



Position a



- **Ranging and chaining.**

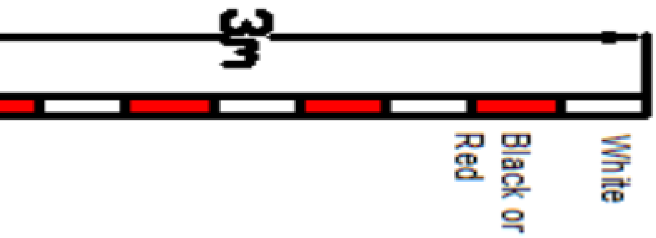
By the various methods of determining distance the most accurate and common method is the method of measuring distance with a chain or tape is called Chaining. For work of ordinary precision, a chain is used. But where great accuracy is Required a steel tape is invariably used.

The term chaining was originally applied to measure Distance with a chain. The term chaining is used to denote measuring distance with either chain or tape, In the process of chaining, the survey party consists of a leader (the surveyor at the forward end of the chain) a follower (the surveyor at the rare end of the chain and an assistant to establish intermediate points).

The accuracy to which measurement can be made with chain and tape varies with the methods used and precautions exercised. The precision of chaining. For ordinary work, ranges from 1/1000 to 1/30,000 and precise measurement such as Baseline may be of the order of 1000000 in diameter called links. The end of each link is bent into a loop and connected together by means of three oval rings which afford flexibility to the chain and make it less liable to become kinked. The ends of chain are provided with brass handles for dragging the chain on the ground, each with a swivel Joints so that the chain can be turned round without twisting. The length of the A link is the distance between the centres of the two consecutive middle rings. The end links include the handles metallic rings indicators of distinctive points of the Chain to facilitate quick reading of fractions of chain in surveying measurements.

Ranging Rod: The ranging rods are used for marking the positions of Stations conspicuously and for ranging the lines. Io order to make these visible at a distance, they are painted alternately black and white, or red and white or red White and black successively. The adjustment of the chain should as far as possible be affected symmetrically on either side of the middle so as that the position of central tag remains unaltered. In measuring the length of survey line also called as chain line. It is necessary that the chain should be laid out on the ground in a straight line between the end stations.

These are poles of circular section 2m, 2.5m or 3m long, painted with characteristic red and white bands which are usually 0.5m long and tipped with a pointed steel shoe to enable them to be driven into the ground. They are used in the measurement of lines with the tape, and for marking any points which need to be seen.



Two men are required for chaining operation; The chain man at the forward end of chain is called the leader while the other man at the rear end is known as the follower.

Duties of leader &follower

Leader:

1) To put the chain forward
2) To fix arrows at the end of chain
3) To follow the instruction of the followers.

Follower:

1) To direct the leader to the line with the ranging rod.
2) To carry the rear end of the chain.
3) To pick up the arrows inserted by the leader.

Chaining

1) The follower holds the zero handle of the chain against the peg &directs the leader to be in line of the ranging rod.
2) The leader usually with to arrows drags the chain alone the line.
3) Using code of signals the follower directs the leader as required to the exactly in the line.
4) The leader then fixes the arrows at the end of chain the process is repeated.

Ranging

1) Place ranging rods or poles vertically behind each point
2) Stand about 2m behind the ranging rod at the beginning of the line.
3) Direct the person to move the rod to right or left until the three ranging rods appear exactly in the straight line.

4) Sight only the lower portion of rod in order to avoid error in non-vertically.
5) After ascertaining that three rods are in a straight line, ask the person to fix up the rod.

- **Setting Out Horizontal Angles**

Ensure instrument is set to measure angles in the appropriate direction. Unclamp both vertical and upper horizontal clamps. Ensure lower horizontal clamp (if fitted) is locked. Use target finder to locate reference target station keeping one hand on horizontal clamp. Clamp in smooth operation when target located. Look through telescope and bring target into focus. Start with focussing ring turned fully one way then will avoid “missing” focal point. Use Horizontal and Vertical tangent screws to bring stadia lines over target. Ensure that target is vertical or use the lowest point visible

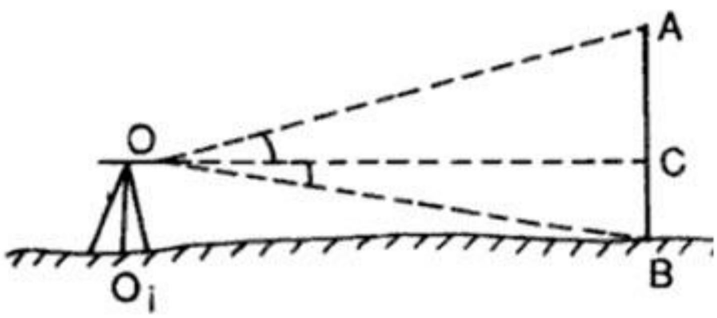
- **Measurement of Horizontal Angle**

Procedure: to measure a Horizontal Angle ABC between BA & BC the following procedure is followed.

1. Set up, Centre and level the theodolite over the ground point B.
2. Loosen the upper plate, set the vernier to read zero and clamp the upper clamp.
3. Loosen the lower plate and swing the telescope until the left point A is sighted. Tighten the lower clamp. Accurate bisection of the arrow held on the Point A is done by using the lower tangent screw. Read both the vernier and take the mean of the reading.
4. Unclamp the upper plate and swing the telescope in clockwise direction until point C is brought in the field of view. Tighten the upper clamp and bisect the mark of C accurately, using the upper clamp tangent screw.
5. Read both the verniers and take the mean of readings. The difference of the means of the reading to C to A is the required angle ABC.
6. Change the face of the instrument and repeat the show procedure, the measure of the angle is again obtained by taking the difference of the means of the readings to C&A on face right.
7. The mean of the two measures of the angle ABC on two faces is the required value of the angle ABC.

- **Vertical angle measurement**

1. The theodolite is set up at O. It is centred and levelled properly. The zeros of the vernires (generally C and D) are set at the 0° - 0° mark of the vertical circle (which is fixed to the telescope). The telescope is then clamped.
2. The plate bubble is brought to the centre with the help of food screws (in the usual manner). Then the altitude bubble is brought to the centre by means of a clip screw. At this position the line of collimation is exactly horizontal.
3. To measure the angle of elevation, the telescope is raised slowly to bisect the point A accurately. The readings on both the verniers are noted, and the angle of elevation recorded.



4. The face of the instrument is changed and the point A is again bisected. The readings on the verniers are noted. The mean of the angles of the observed is assumed to be the correct angle of elevation.
5. To measure the angle of depression, the telescope is lowered slowly and the point B is bisected. The readings on the verniers are noted for the two observations (face left and face right). The mean angle of the observation is taken to be the correct angle of depression.

- **Levelling.**

Levelling is defined as “an art of determining the relative height of different points on, above or below the surface”.

Levelling refers to height measurements for representing the relative difference in height (altitude) between various points on the earth’s surface.

- Principle of Levelling, the principle of levelling is to obtain horizontal line of sight with respect to which vertical distances of the points above or below this line of sight are found.
- The objective of Levelling

- To Find the elevation of given point with respect to some assumed reference line called datum.
- To establish point at required elevation respect to datum.

All vertical height measurements from the ground or other points under consideration are referred to a plane of reference known as the HORIZONTAL PLANE of COLLIMATION. This is the line of sight through the telescope of an optical level. The difference between such measurement would indicate differences in height or level.
Basic equipment
(a) A device which gives a truly horizontal level (the Level).
(b) A suitably graduated staff for reading vertical heights (the Levelling Staff).

Bench Mark and Reference Datum
In order to calculate the heights of points a datum is required, i.e. a reference level. This is usually the mean sea levels. For this purpose, the use of Bench Marks is necessary, and these are classified as follows:
Bench Mark (BM) – a point with known height above mean sea level (or other reference datum). These are permanent points (e.g. unchanged by weather conditions) and are provided by the Department of Lands and Surveys.
Temporary Bench Mark (TBM) – a point of known height above a pre-defined level. This level is not absolute and is defined locally by the surveyor for the purpose of the survey. Based on the TBM the survey may then later be reduced to absolute levels if the level of TBM is known.
The height of any target point is referred to as Reduced Level (RL), because it is reduced to a known datum.

- Common sources of errors in levelling

1. Instrument not correctly levelled.
2. Telescope not correctly focused.
3. The wrong cross-hair reading recorded (e.g. top instead of middle).
4. Staff incorrectly read or not held vertical.
5. Staff incorrectly booked.

All the above are mistakes (blunders) and cannot be corrected unless the work is repeated. A systematic error in levelling is the collimation error of the level which is discussed later in detail.

- Levelling operations

Level readings can be taken either from one location (one set-up levelling) or from various stations, if some points of interest are not visible. A level survey can be used for setting-out purposes, the presentation of soil profiles etc.

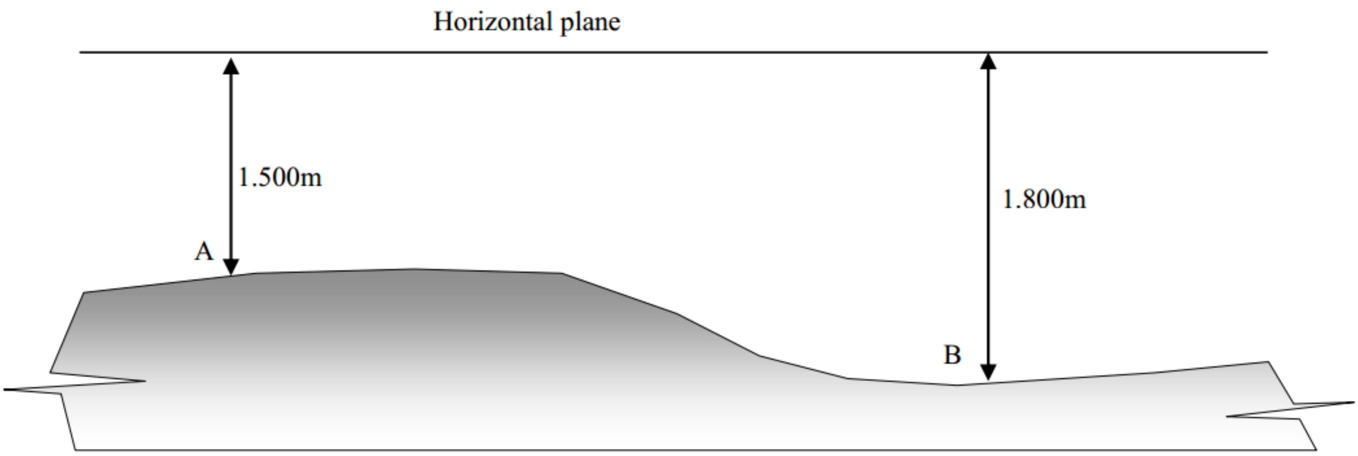
- Basic definitions

Backsight (BS): first staff reading taken immediately after setting up the instrument.

Foresight (FS): last staff reading taken before moving the instrument to another location.

Intermediate sight (IS): all readings taken between a BS and a FS.

So, if the instrument is set up at one location only, there will be just one BS (first reading to a TBM), one FS (last reading) and several IS.



It can be seen in the above figure that point B is lower than point A and the difference in the measurement of 0.300m tells us the difference in level.
Mathematically we have subtracted the height at point A from the height at point B. (i.e. 1.800 – 1.500 = 0.300)
From a Surveying point of view, we have taken the level at point A, say 20.000m and added the vertical distance to the horizontal plane to give a level (or height) for the horizontal plane. We can obtain the level at point B by subtracting the vertical distance from the value of the level for the horizontal plane. The difference in levels between A and B is then apparent.
Level at A = 20.000m (say)
Level of horizontal datum = 20.000 + 1.500 = 21.500m
Level at B = 21.500 - 1.800 = 19.700m

Hence
Difference in level between A and B = 20.000 – 19.700 = 0.300m

- **Optical distance measurement.**

Optical measurement method is also known as tacheometry method or stadia method. Optical measurement is inspection of measurement with the help of telescope and then calculations are solved using triangulation method to find out the distance. The instrument tacheometer is considered as important in this method. Other than these, level staff which is a graduated wooden or aluminium rod needed to carry out optical measurement. Before the electronic distant measurement method this method is more famous ad accurate for a particular distance. This is a suitable method to survey a hill country and counter lines.

The common equation to obtain the distance, d between the instrument and levelling staff is,

$d = k \times s + c$

Here, s is the levelling staff interval; k and c are multiplicative and additive constants. In most of the instrument the k is 100 and c is 0.

- **Controlling verticality.**

Checking verticality works would encounter during building construction at several stages such as during installing vertical formworks of columns and transferring levels up successive floors of multi storey structures. Various methods which to control or check verticality works during building construction are discussed.

Theodolite Method

Theodolite is substantially powerful instrument which can be used to check verticality works during construction with great precision and accuracy.

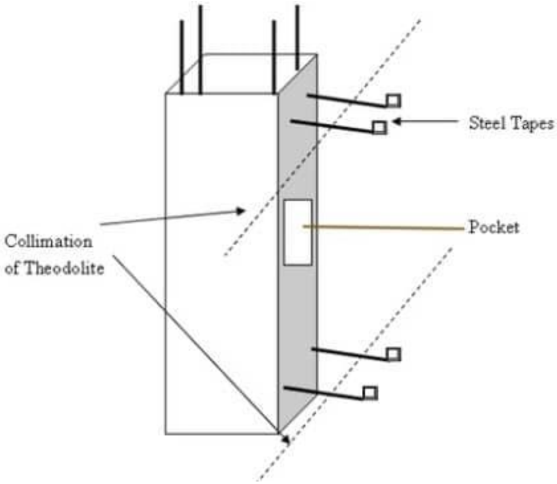
It is suitable for checking or controlling verticality of towers as shown in Figure 8, wall, foundation and columns; specifically, large number of columns along a one grid line.

It is possible to measure the slope of out of plumb line of the member by using Theodolite in combination with a tape.

The procedure used to check column verticality includes:

1. Setting up the digital Theodolite centered on a peg that installed 500 mm from the column grid.
2. After Theodolite set up accurately the laser beam will be turned on and focused it to the steel tape which is held to the formwork.
3. Take the reading of the steel tape through the telescope.
4. Take the readings of two positions at the same level on both top and bottom levels of the formwork. By taking two readings at the same level any curvature on the surface can be identified. These steps are illustrated in Figure 9.

Fig.6: Checking Verticality Using Theodolite



Checking Column Verticality Using Theodolite

- **Care and maintenance**

Surveying instruments, which include theodolites, levels, total stations, electronic measuring devices, and GPS receivers, are designed and constructed to provide years of reliable use. The shafts, spindles, pendulums, and electronics of precision instruments, although constructed for rugged field conditions, can be damaged by one careless act, or continued inattention to prescribed procedures for use, care, and adjustment of the instrument.

- Before making the first set up of the day, visually inspect the instrument for damage. Check the machined surfaces and the polished faces of the lenses and mirrors. Try the clamps and motions for smooth operation
- Clean the exterior of the instrument frequently. Any accumulation of dirt and dust can scratch the machined or polished surfaces and cause friction or sticking in the motions. Remove dirt and dust with a clean, soft cloth or with a brush. Clean non-optical parts with a soft cloth or clean chamois
- Clean the external surfaces of lenses with a fine lens brush and, if necessary, use a dry lens tissue. Do not use silicone-treated tissues because they can damage coated optics. The lens may be moistened before wiping it, but do not use liquids for cleaning. Do not loosen or attempt to clean the internal surfaces of any lens
- After an instrument has been used in damp or cold situation, use special precautions to prevent condensation of moisture inside the instrument. If the instrument is used in cold weather, leave it in the carrying case in the vehicle during non-working periods rather take it into a heated room. If you store the instrument in a heated room overnight, remove it from the carrying case. If the

instrument is wet, bring it into a warm, dry room, remove it from its case and leave it at room temperature to dry it

Some general guidelines for the care of instruments are:

1. Lifting - Instruments should be removed from the case with both hands, gripping the micrometer knob standard and base on the older instruments. Newer instruments are equipped with a carrying handle; the other hand should support the base. One hand should continually support the instrument until the tribrach lock is engaged and the tripod fixing screw secured.
2. Carrying a Tripod - In most cases, the instrument should be removed and re-cased for transportation to a new point. If the point is nearby, the instrument should be carried in the vertical position (tripod legs pointing straight down). An instrument should never be "shouldered" or carried horizontally.
3. Adjusting Collimation - The collimation error of theodolites is determined by following the procedure outlined in the user’s manual. If the collimation error is found to be consistently in excess of ten seconds on the horizontal and twenty seconds on the vertical, the instrument should be adjusted. The collimation adjustment should be made in the field only by a specially trained individual. Otherwise, the instrument should be returned to an authorized repair shop.

b. Field work Caring for a Digital Theodolite and Helpful Hints

- Do not "shoulder" or carry a tripod mounted theodolite or electronic distance measuring equipment (EDM). These instruments should always be removed from the tripod and secured in their carrying cases when moved.

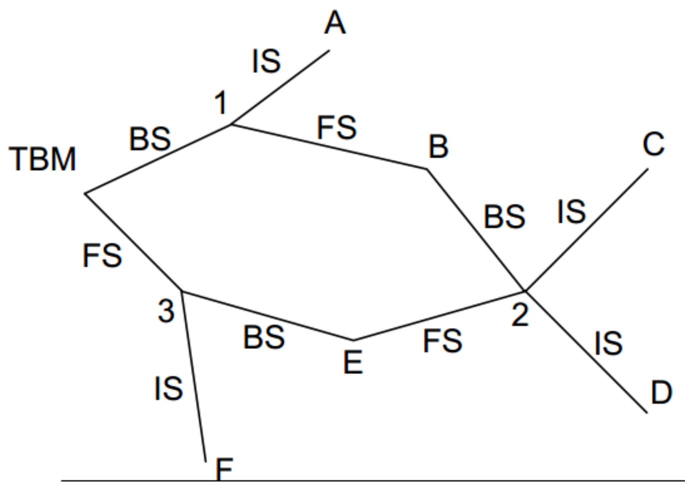
These precautions are necessary because the centre spindle (centre spigot or standing axis) of a theodolite is hollow and relatively short. When carried horizontally while on the tripod, the alidade's weight is an excessive load for the hollow centrepiece to bear. Instrument damage can result if the above precautions are ignored. Also, the instrument fastener can break, causing the theodolite to fall.

- Whenever possible, select instrument stations where operation is not dangerous to the instrument operator, the crew, or the instrument. Select stable ground for the tripod feet. Do not set an instrument closely in front of, or behind, a vehicle or equipment which is likely to move. Take a safe route to all setups.
- At the site, firmly plant the tripod with its legs widespread. Push along the legs, not vertically, downward. On smooth surfaces, use some type of tripod leg restrained to keep the legs from sliding outward.
- Always have the tripod firmly set over the point before removing the instrument from its carrying case. Immediately secure the instrument to the tripod with the instrument fastener.
- Never leave an instrument or its tribrach on the tripod without securing either to the tripod.
- Moderate pressure on the fastener screw is sufficient.
- Excessive tightening causes undue pressure on the foot screws and on the tribrach spring plate.
- Make sure the tribrach clamp is in the lock position.
- Do not submerge instrument in water or any other chemical.
- Do not drop instrument.
- Make sure theodolite is locked in its case while transporting.
- When raining, use cover over instrument.
- Do not look directly into the sunlight through the telescope on the instrument.
- Using a wooden tripod can protect the instrument from vibrations better than an aluminium tripod would.

- Using the sunshade attachment is important; any sudden temperature changes can cause incorrect readings.
- Never hold the instrument by the telescope.
- Always have a substantial level of battery power on your instrument.
- Always clean the instrument after using.
- Dust in the case or on the instrument can cause damage.
- If the theodolite is damp or wet, allow it time to dry out before storing it in its case.
- When storing, make sure that the telescope on the instrument is in the vertical position.

- **Booking and Reduction Methods**

The two common methods are presented below using the same example. For vertical control the level survey should start and close on points of known height (same point or different). If the survey starts and closes on the same point (e.g. a TBM), as below, this is termed as a closed level survey.



RL(TBM) = +50.000m
Instrument stations: 1, 2, 3.
Target points: TBM, A, B, C, D, E, F.

(a) Rise & Fall method

(BOOKING)					(REDUCTION)		
Station	**Point**	**BS**	**IS**	**FS**	**Rise**	**Fall**	**RL**
1	**TBM**	1.000					**+50.000**
1	A		1.580			0.580	+49.420
1	**B**			1.420	0.160		+49.580
2	**B**	0.900					(+49.580)
2	C		1.100			0.200	+49.380
2	D		1.450			0.350	+49.030
2	**E**			1.300	0.150		+49.180
3	**E**	1.355					(+49.180)
3	F		1.585			0.230	+48.950
3	**TBM**			1.320	0.265		+49.215

(All heights in m)

Sum (Σ) **3.255** **4.040** **0.575** **1.360**

(Note that a FS always follows a BS in order to connect the survey with subsequent stations. Target points B and E are change points for the instrument.)

Arithmetic checks (necessary for checking the reduction)
Σ (BS) - Σ (FS) = 3.255 – 4.040 = - 0.785m
Σ (RISES) – Σ (FALLS) = 0.575 – 1.360 = - 0.785m => OK
LAST (RL) – FIRST (RL) = +49.215 – 50.000 = -0.785m => OK.

Since this is a closed survey the value calculated is the misclosure error (for perfect measurements it should have been zero since TBM is the same point!)

(b) Height of Plane of Collimation (HPC) method

This method is simpler but with one check less, so care should be taken in reduction. The booking part is the same. You should always remember that the HPC is constant for the same instrument station, so needs to be calculated only once.

For each station, HPC = (known RL) + BS , and each RL = HPC – (IS or FS)

(BOOKING)					(REDUCTION)	
Station	**Point**	**BS**	**IS**	**FS**	**HPC**	**RL**
1	**TBM**	1.000			+51.000	**+50.000**
1	A		1.580		(+51.000)	+49.420
1	**B**			1.420	(+51.000)	+49.580
2	**B**	0.900			+50.480	**+49.580**
2	C		1.100		(+50.480)	+49.380
2	D		1.450		(+50.480)	+49.030
2	**E**			1.300	(+50.480)	+49.180
3	**E**	1.355			+50.535	**+49.180**
3	F		1.585			+48.950
3	**TBM**			1.320		+49.215

(All heights in m)

Sum (Σ) 3.255 4.040

Arithmetic checks (necessary for checking the reduction)
Σ (BS) - Σ (FS) = 3.255 – 4.040 = - 0.785m
LAST (RL) – FIRST (RL) = +49.215 – 50.000 = -0.785m => OK.
So we can see that both methods give the same results for the RL of the target points. It is required to know and understand both methods of reduction.

LO 3.3 – Accurate recorded data during measurement

- **Topic 1. Description of Accurate recorded data during measurement**

➢ **Requirements of a Data Collector**

Data Collector – Individual employed by a company or him/herself for the purpose of examining the nature of the ground.

Requirements:

- data collector must be trained person
- data collector must have a skill on theodolite
- data collector must know how to interpret staff readings
- data collector must know how to care instrument
- data collector must know surveying communication language
- data collector must be to interpret data
- data collector must know how to record data

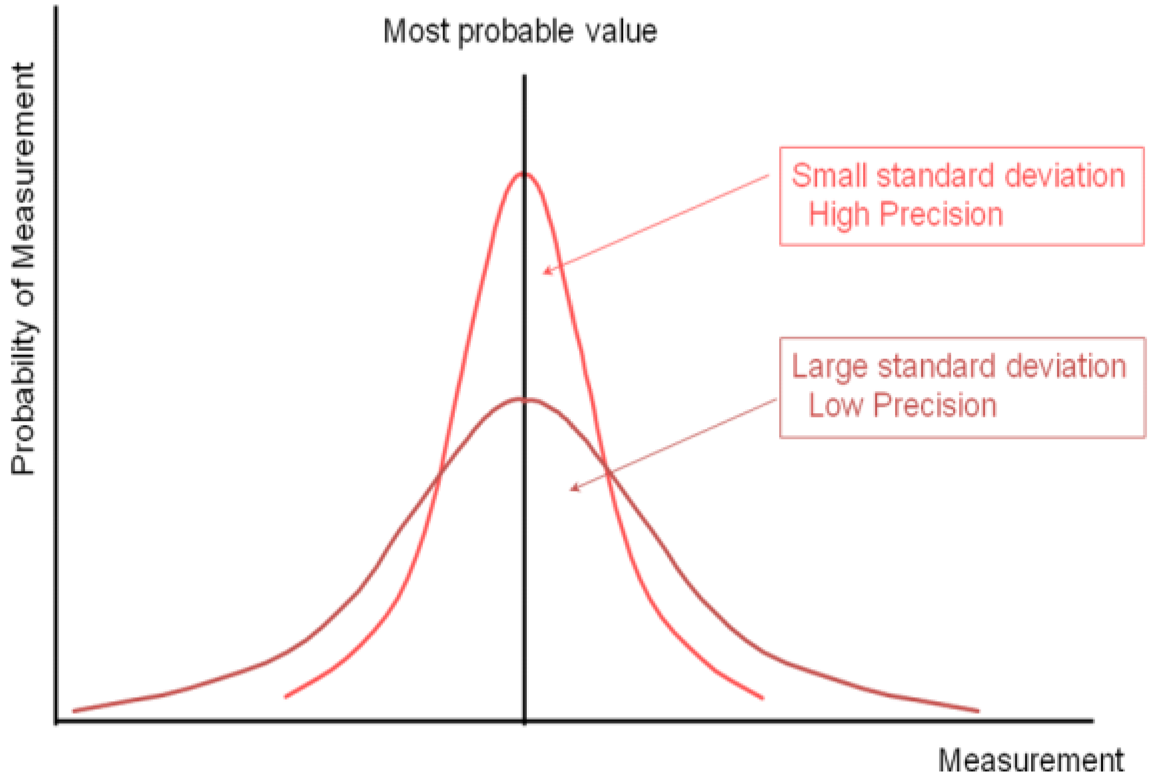
➢ **Accuracy and precision**

These terms are used frequently in engineering surveying both by manufacturers when quoting specifications for their equipment and on site by surveyors to describe results obtained from field work.

Accuracy allows a certain amount of tolerance (either plus or minus) in a measurement, while; Precision demands exact measurement. Since there are no such things as an absolutely exact measurement, a set of observations that are closely grouped together having small deviations from the sample mean will have a small standard error and are said to be precise.

❖ Precision
  ➢ Degree of perfection used in the survey
  ➢ represents the repeatability of a measurement and is concerned only with random errors.

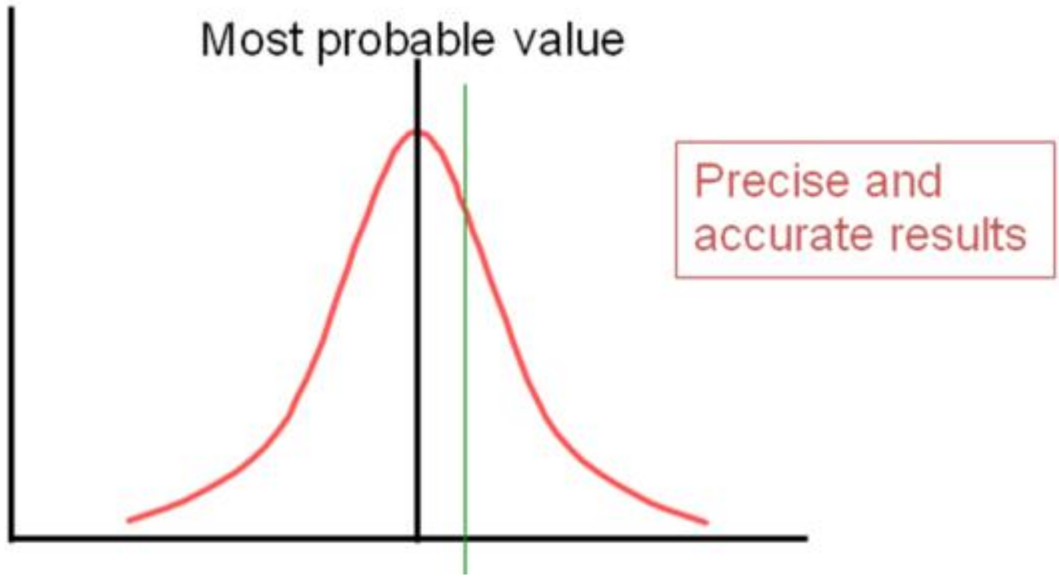
Observations closely grouped together with a small deviation form a sample mean (small standard error) are said to be Precise.

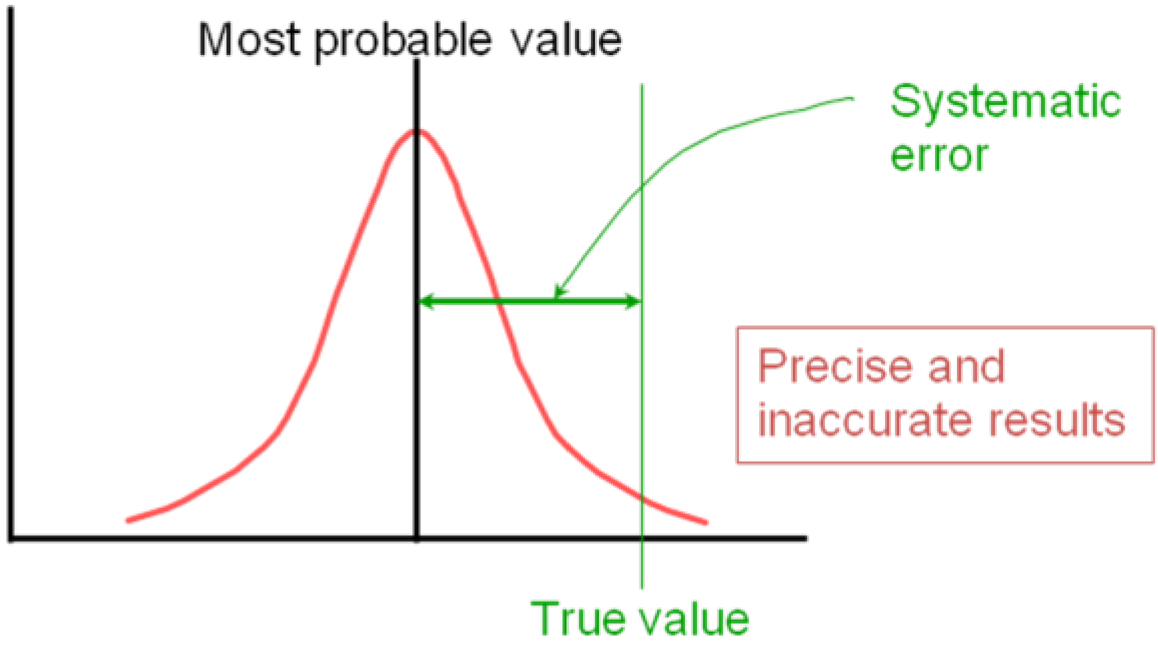


- Accuracy is: the degree of perfection obtained in the measurement (results) and depends on
  1. Accurate instruments- which simplifies the work, save time and provide economy
  2. Precise methods –reduces the effect of all types of small errors
  3. Good planning –includes the choice of proper choice and arrangement of survey control and proper choice of instruments and methods

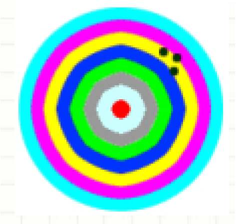
The difference between a MEASUREMENT and TRUE VALUE of the quantity measured is the true error of the measurement and is never known since the true value of the quantity is never known.

Discrepancy is the difference between two measured values of the same quantity. It is not an error

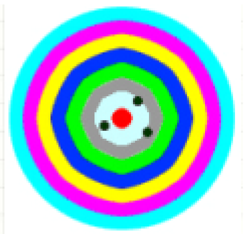




Precision: An indication of the uniformity or reproducibility of a result.



Accuracy: the degree of conformity with a standard (the"truth")



- The accuracy of an analytical measurement is how close a result comes to the true value. Determining the accuracy of a measurement usually requires calibration of the analytical method with a known standard.
- Precision is the reproducibility of multiple measurements and is usually described by the standard deviation, standard error, or confidence interval.

- **Topic 2: identification of errors during data measurement**

Types of Errors

Errors are classified into the following three types

a. Mistake

b. Systematic Errors

c. Random (Accidental) Errors

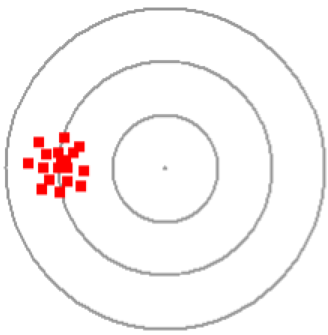
(1) Mistakes are sometimes called gross errors, but should not be classified as errors at all. They are blunders, often resulting from fatigue or the inexperience of the surveyor.

(2) Systematic errors can be constant or variable throughout an operation and are generally attributable to known circumstances. The value of these errors can be calculated and applied as a correction to the measured quantity.

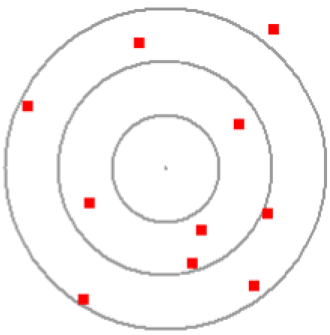
They can be the result of natural conditions, examples of which are:

refraction of light rays, variation in the speed of electromagnetic waves through the atmosphere, expansion or contraction of steel tapes due to temperature variations.

(3) Random errors are those variates which remain after all other errors have been removed. They are beyond the control of the observer and result from the human inability of the observer to make exact measurements, for reasons already indicated above.



Systematic Error



Random Error

Sources of Error

The sources of error fall into three broad categories, namely:

a. Natural Errors

b. Instrument Error

c. Personal Errors

a) Natural errors caused by variation in or adverse weather conditions, refraction, gravity effects, etc.

Natural Errors

- Wind
- Temperature effects
- Refraction
- Tripod settlement

b) Instrumental errors caused by imperfect construction and adjustment of the surveying instruments used.

Instrumental errors

- Plate bubble out of adjustment
- Horizontal axis not perpendicular to vertical axis
- Axis of sight not perpendicular to horizontal axis
- Vertical circular index error
- Eccentricity of centres
- Circle graduation errors
- Errors caused by peripheral equipment

c) Personal errors caused by the inability of the individual to make exact observations due to the limitations of human sight, touch and hearing.

Personal Errors

- Instrument not set up exactly over point
- Bubbles not centred perfectly
- Improper use of clamps and tangent screws
- Poor focusing
- Overly careful sights
- Careless plumbing and placement of rod

- **Mistake and error**

No measurement can be perfect or exact because of the physical limitations of the measuring instruments as well as limits in human perception.

The difference between a measured distance or angle and its true value may be due to mistakes and/or errors.

These are two distinct terms.

• Blunders

A blunder is a significant mistake caused by human error.

It may also be called a gross error.

• Systematic and Accidental Errors

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