MINE SURVEY-I

Semester: 3RD

STUDY MATERIAL

MINE SURVEY

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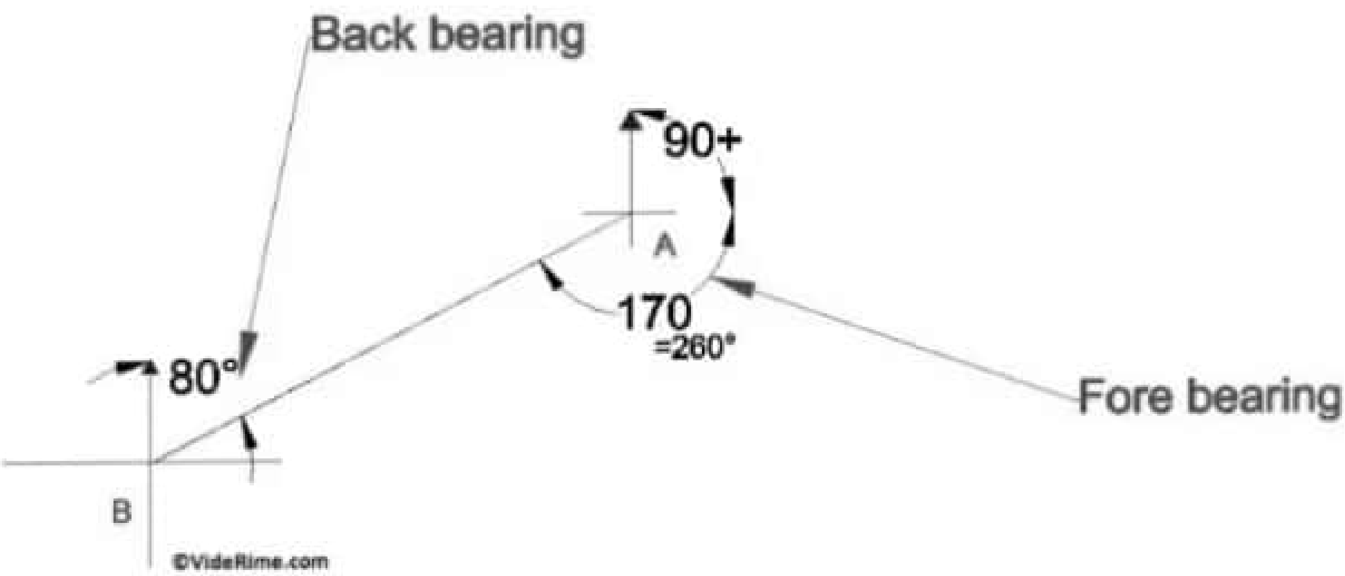
Fore Bearing (F.B)

- Fore bearing is the bearing of the line in the forward direction of surveying.
- The formula used to calculate the fore bearing of the progressive line $F.B = B.B \pm 180°$ { + sign when B.B less than 180° and – sign when B.B more than 180°}.

Back Bearing (B.B)

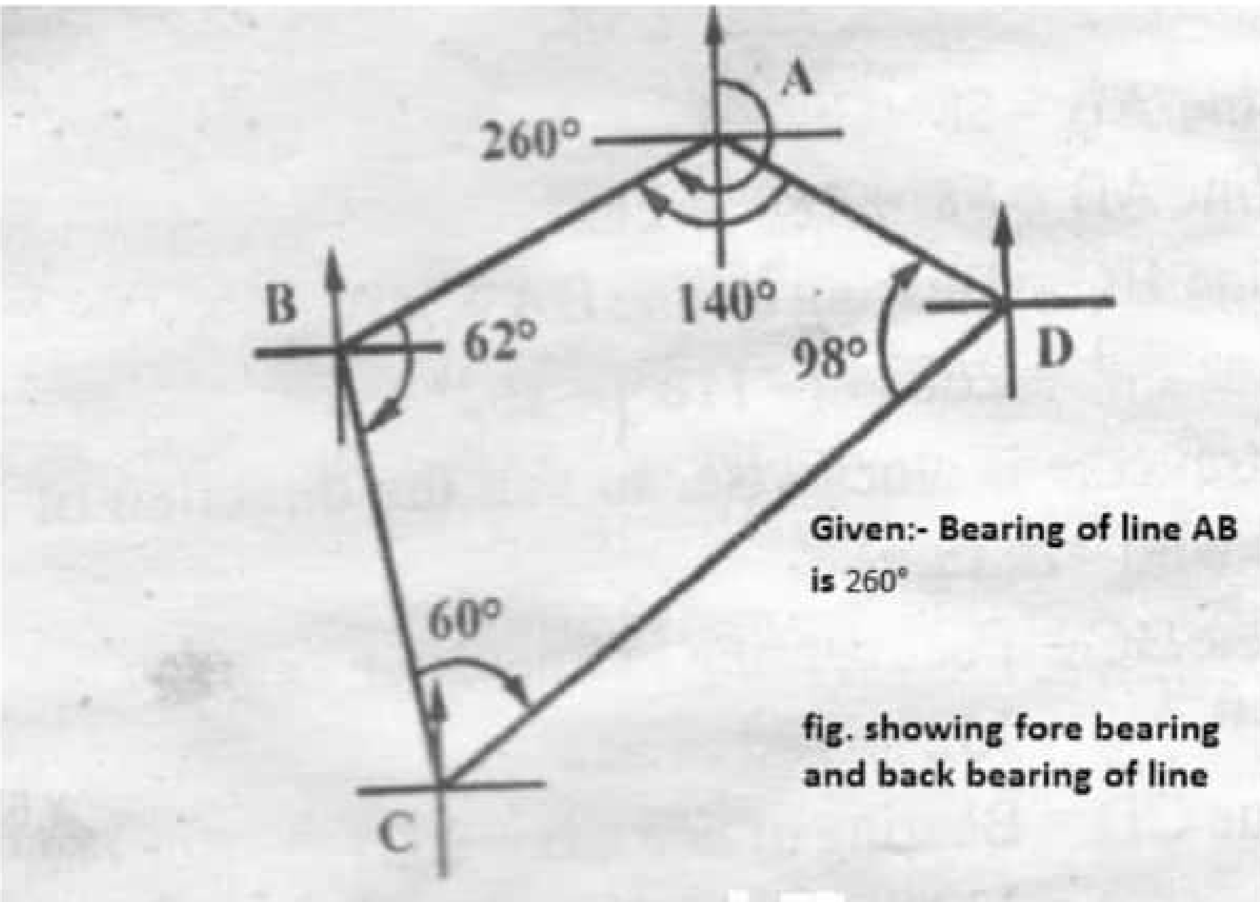
- Back bearing is the bearing of the line in the opposite direction of surveying.
- The formula used to calculate the back bearing of line B.B = F.B ± 180° { + sign when F.B less than 180° and – sign when F.B more than 180° }.



*If the difference of F.B and B.B is 180° then consider no error in measurements.
*If the difference of F.B and B.B is not 180° then consider error means affected by local attraction.

Read Carefully:Bearing represents a measurement of angles w.r.t clockwise(examples: S 77° W or N 89°45 E) or anticlockwise(S 69° E and N 55° W) direction or angles w.r.t clockwise direction in surveying, where angle simply represent a degree in geometry.

Example:-



Fore bearing of line AB = 260° (given above) and included angles are also given.

Back bearing of line AB (means BA) = 260°- 180°= 80°

Fore bearing of line BC = Bearing of line BA + angle B

= 80° + 62° = 142°

Back bearing of BC= 142° +180° =**322°**

Fore bearing of line CD= Bearing of line CB +angleC

=322° +60° =382°

Therefore, Fore Bearing of line CD=382° -360° = 22°

Back bearing of line CD =22° +180° =**202°**

Fore bearing of line DA=Bearing of line DC+ angleD

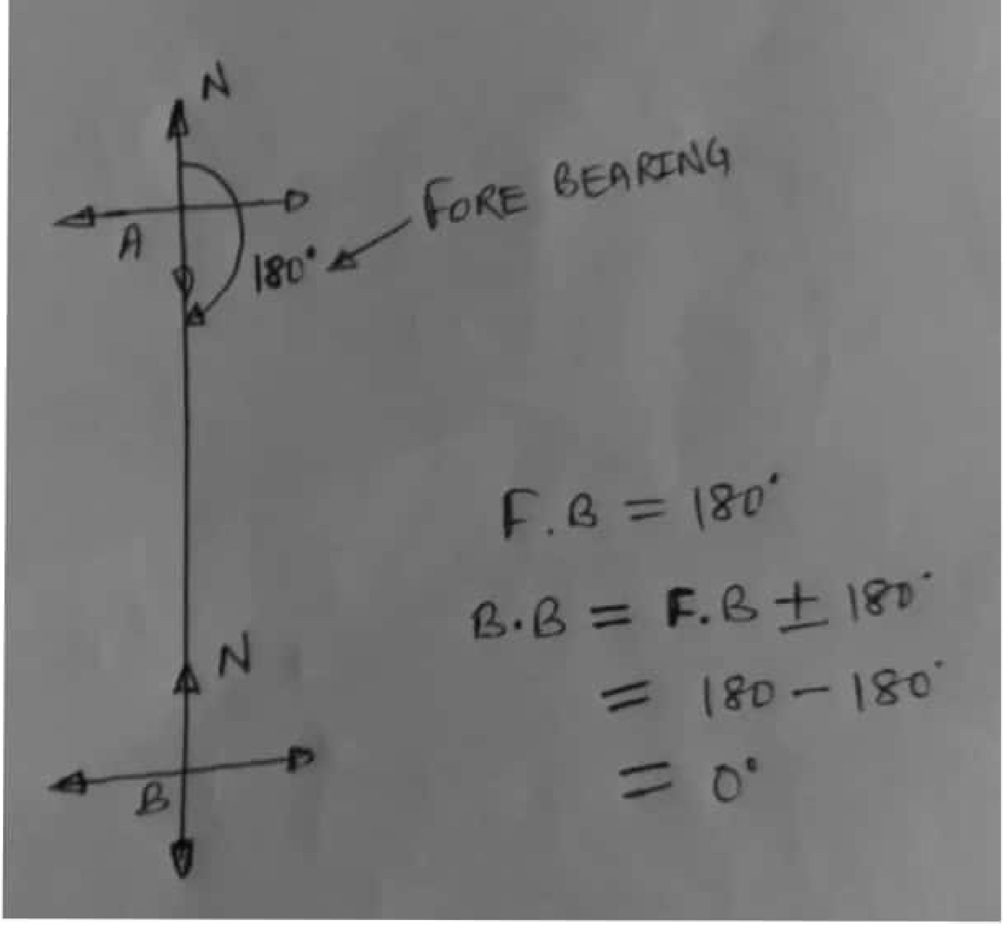
=202° +98° =**300°**

Back Bearing of line DA= 300° -180° =**120°**

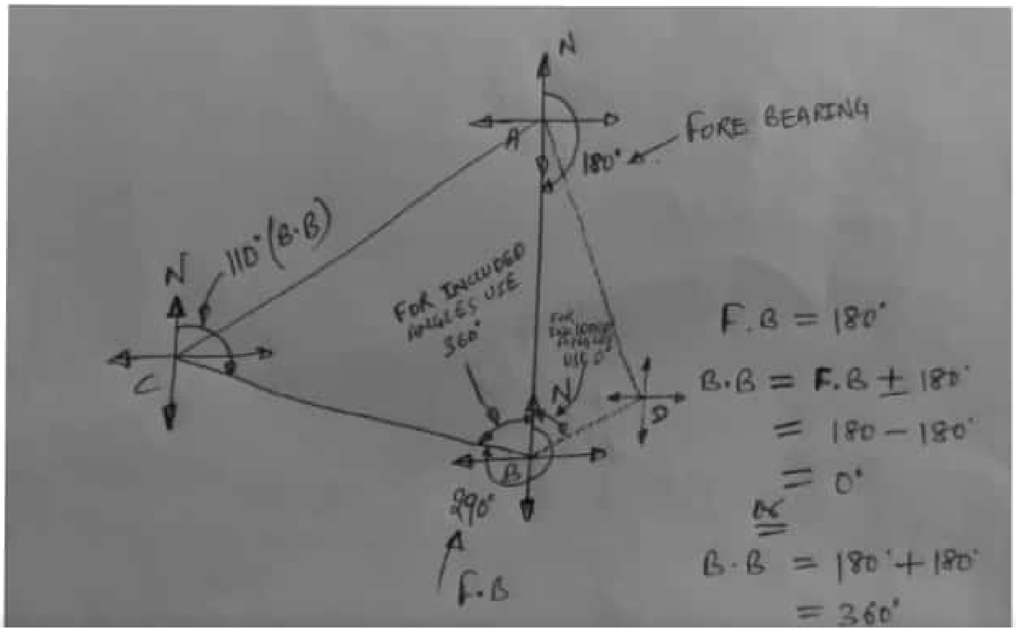
Question asked in comments:

if B.B or F.B is 180° then how we calculate:

Well friends, as we sight through compass from A to B point, we already came to know what is fore bearing.



As the line is straight then Back Bearing at B point it is 0°. Here, if we use + sign then B.B will become 360°. Here two traverse were shown i.e. one at L.H.S(ABC) and other at R.H.S(ABD). If not understood please consult your teachers.



Geographical Positioning System (GPS)

Introduction —

The Global positioning system (GPS) is a satellite-based navigation & surveying system for determination of precise position & time, using radio signals from the satellites, in real time or in post-processing mode. GPS is being used all over the world for numerous navigational & positioning applications, including navigation on land, in air & on sea, determining the precise coordinates of important geographic features as an essential input to mapping & Geographical Information system (GIS).

The Navigation Satellite Timing & Ranging Global positioning System (NAVSTAR GPS) developed by the U.S. department of Defence (DOD) to replace the TRANSIT Navy Navigation satellite system (NNSS) by mid 90's, is an all weather high accuracy radio navigation & positioning system which has revolutionised the fields of modern surveying, navigation & mapping.

The GPS which consists of 24 satellites in near circular orbits at about 20,000 km altitude, now provides full coverage with signals from minimum 4 satellites available to the user, at any place on the Earth. By receiving signals transmitted by minimum 4 satellites simultaneously the observer can determine his geometric position (lattitude, longitude & height), coordinated Universal Time (UTC) & velocity vectors with higher accuracy, economy & in less time compared to any other technique available today.

GPS Segments :—

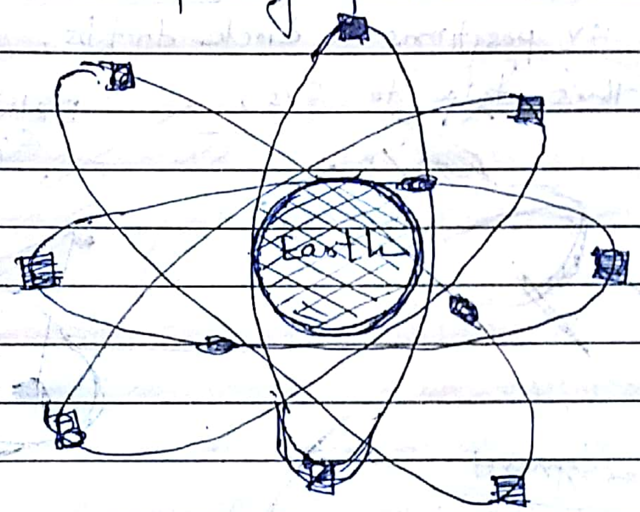
The Global positioning system basically consists of 3 segments —

- The Space segment
- The Control "

- The User segment

* Space Segment :-

The Space segment contains 24 satellites, in 12-hours near circular orbits & at altitude of about 20,000km with inclination of orbit 55°. The constellation ensures atleast 4 satellites in view from any point on the earth at any ~~point on~~ time for 3-D positioning & navigation on world-wide basis. The three axis controlled earth-positioning satellites continously transmit navigation & system data comprising predicted satellite emphemeri's.



GPS Nominal constellation, 24 satellites in 6 orbital planes
4 satellites in 6 orbital planes, 4 satellites in each plane
20,200 km Altitudes, 55 degree inclination

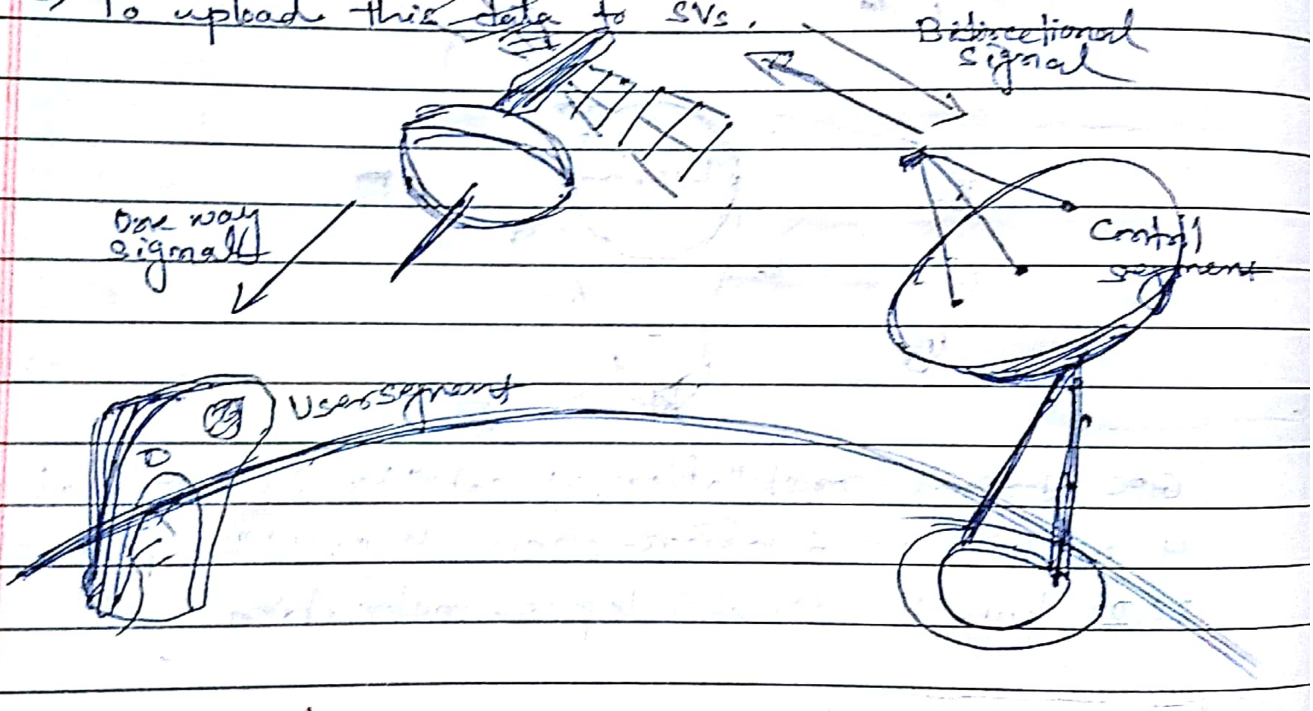
* Control Segment :-

It has a Master Control station (MCS), few monitor stations (MSs) & an up load station (ULS). The MSs are transportable shelters with receivers & computers which passively track satellites, accumulating ranging data from navigation signals. This is transferred to MCS for processing by computer to provide best estimates of satellite position, velocity & clock drift relative to system time. The data thus processed generates refined information of gravity field influencing the satellite motion, solar presence parameters, positions clock bias & electronic delay characteristics of ground stations & other observable system influences. Future navigation message are generated from this & located into satellite memory once a day via ULS which has a parabolic antenna, a transmitter & a computer. Thus role of control segment is :—

-> To estimate satellite [space vehicle (SV)] ephemerides & atomic clock behaviour.

-> To predict SV positions & clock drifts.

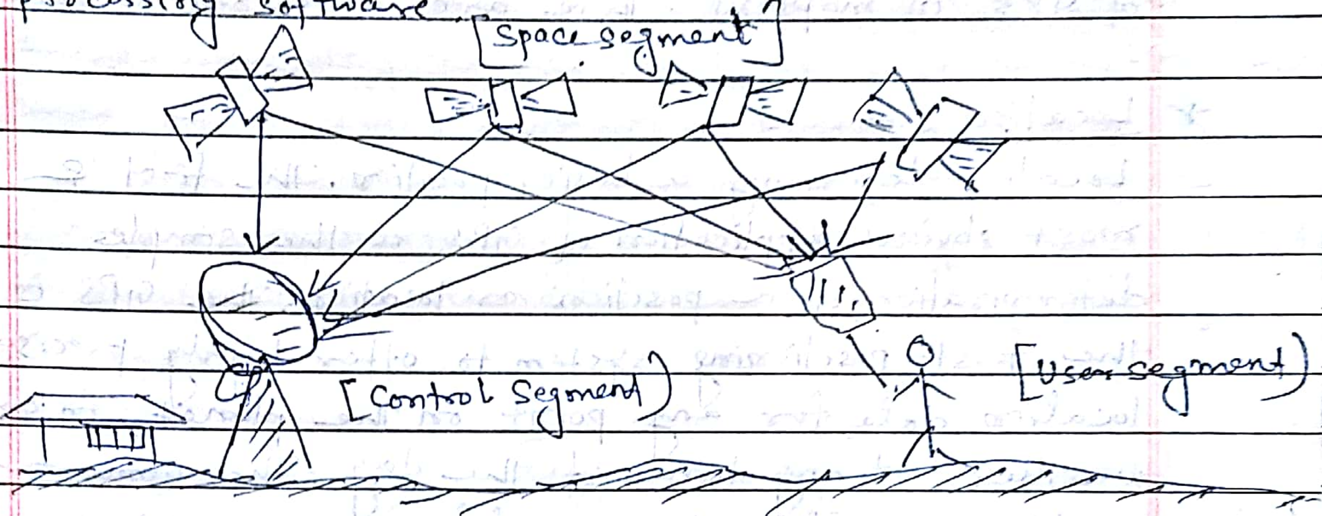
-> To upload this data to SVs.



* User Segment :—

The user segment consists of an antenna, a receiver, a data-processor with software & a control/display unit. The GPS receiver measures the pseudo-range, phase & other data using navigation signals from minimum 4 satellites & computes the 3-D position, velocity & system time. The position is in geocentric coordinates in the basic references coordinate

system.
World Geodetic reference system (1984) (WGS 84) which are converted & displayed as geographic UTM, grid, or any other type of coordinates. Corrections like delay due to ionospheric & tropospheric refraction, clock errors, etc are also computed & applied by the user equipment / processing software.



Application of GPS in Mapping :-

The GPS has a variety of applications on land, at sea, & in the air. Basically GPS allows us to record or create locations from places on the earth & helps us navigate to & from those spots. The GPS can be used everywhere except where it is impossible to receive the signal such as inside buildings, in caves, parking garages & other subterranean locations & underwater.

A vital role of GPS is to help in navigation & positioning of remote sensing satellite.

The original motivation for satellite navigation was for milletary applications currently GPS-guided misiles are being used in wars.

The GPS technology has matured into a resource that goes far beyond its original design goals,

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Now-a-days scientists, sportsmen, farmers, soldiers, pilots, surveyors, hikers, delivery driver, sailor, dispatcher, lumberjacks & people from so many other walks of life are using GPS in ways that make their work even easier, more productive, safer, & sometimes even easier.

There are several real-world applications of GPS in mapping. These are described below:—

* Location :—

Location — determing a basic position. The first & most obvious application of GPS is the simple determination of a position or location. The GPS is the first positioning system to offer highly precise location data for any point on the planet, in any weather, at any time of the day. This alone would be sufficient to qualify it as a major utility.

* Navigation :—

Navigation — getting from one location to another. The GPS helps us to determine exactly where we are, but sometimes important to know how to get elsewhere.

* Tracking :→

Tracking — monitoring the movement of people & things. The GPS used in conjuction with communication links & computers can be used for tracking any moving vehicle (on the water, on the land & in the air). Transport, police department & traffic departments are also rapidly adopting GPS-based tracking.

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* Mapping :—

Mapping – creating maps of the world or part of it. It is a big world out there & using GPS to survey & map precisely saves timea & money in this most stringent of all application. Now-a-days GPS makes it possible for a signal survey or to accomplish in a day what used to take weeks with an entire team. And they can do their work with a higher level of accuracy than ever before. The ~~&~~ GPS pioneered the technology which is now the method of choice for performing control surveys & the effect on surveying in general has been considerable.

* Timing —

Timing – bringing precise timming to the world. Although GPS is well known for navigation, tracking & mapping, it is also used to desseminate precise time, time intervals & fequency, time is a powerful commodity, & exact time is still more powerful. The GPS satellite carry highly accurate atomic clocks. In order for the system to work, our GPS receivers here on the ground synchronize themselves to these clocks this implies that every GPS receiver is in essence an atomic accuracy, clock & can provide time information in an accuracy of nanosecond.

Theodolite:

The theodolite is the most intricate and accurate instrument used for measurement of horizontal and vertical angles. It consists of telescope by means of which distant objects can be sighted. The telescope has two distinct motions on in the horizontal plane and the other in the vertical plane. The former being measured on a graduated Horizontal vertical circle of two verniear.

1) Transit theodolite

2) Non-transit theodolite

A theodolite is called transit theodolite when its telescope can be resolved through a complete revolution about its horizontal axis. In a vertical plane. The transit type is largely used.

<u>Various parts of transit theodolite</u>

1) Telescope:

It is an integral part and is mounted on the spindle known as horizontal axis or turn on axis. Telescope is either internal or external focusing type.

2) The leveling head:

It may consists of circular plates called as upper and lower Parallel plates. The lower parallel plate has a central aperture through which a plumb bob may be suspended. The upper parallel plate or tribranch is supported by means of four or three leveling screws by which the instrument may be leveled.

3) To lower plate or screw plate:

It carries horizontal circle at its leveled screw. It carries a lower clamp screw and tangent screw with the help of which it can be fixed accurately in any desired position.

4) The upper plate or vernier plate:

It is attached to inner axis and carries two vernier and at two extremities diametrically opposite.

5) Compass:

The compass box may be either of circular form or of a rough type. The former is mounted on the vernier plate between the standards while the latter is attached to the underside of the scale or lower plate or screwed to one of the standards. Modern theodolite is fitted with a compass of the tubular type and it is screwed to one of the standards.

6) Vertical circle:

The vertical circle is rigidly attached to the telescope and moves with it. It is silvered and it is usually divided into four quadrants.

7) Index bar or T-frame:
The index bar is T shaped and centered on horizontal axis of the telescope in front of the vertical axis. It carries two vernier of the extremities of its horizontal arms or limbs called the index arm. The vertical leg called the clip or clipping screws at its lower extremity. The index arm and the clipping arm are together known as T-frame.

8) Clamps and tangent screws
There are two clamps and associated tangent screws with the plate. These screws facilitate the motion of the instruments in horizontal plane. Lower clamp screw locks or releases the lower plate. When this screw is unlocked both upper and lower plates move together. The associated lower tangent screw allows small motion of the plate in locked position. The upper clamp screw locks or releases the upper vernier plate. When this clamp is released the lower plate does not move but the upper vernier plate moves with the instrument. This causes the change in the reading. The upper tangent screw allows the fine adjustment

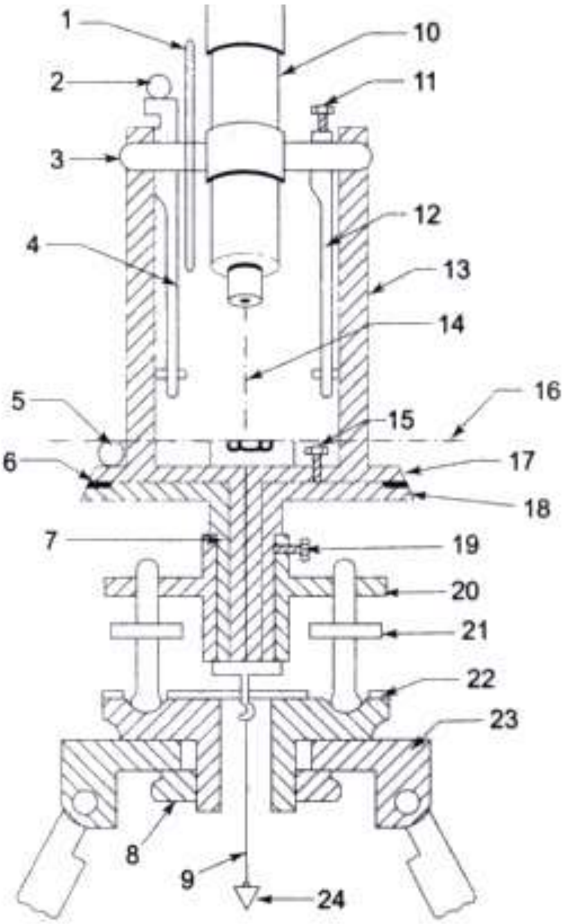
9) Vertical circle clamp and tangent screw (11):
Clamping the vertical circle restrict the movement of telescope in vertical plane.

10) Altitude level (2):
A highly sensitive bubble is used for levelling particularly when taking the vertical angle observations.

11) Plumb bob:
To center the instrument exactly over a station mark, a plumb bob is suspended from the hook fitted to the bottom of the central vertical axis.

Trasit theodolite and parts:

1. Vertical Circle
2. Altitude bubble
3. Horizontal axes
4. Vernier Arm
5. Plate bubble
6. Graduated Arc
7. Levelling Head
8. Clamping Nut
9. Vertical Axis
10. Telescope
11. Vertical circle clamping screw
12. Arm of the vertical circle clamp
13. Standard 14.Line of sight
15. Upper plate clamping screw
16. Axis of plate bubble
17. Upper plate
18. Lower plate
19. Lower plate clamping screw
20. Tribrach
21. Foot screw
22. Trivet
23. Tripod top
24. Plumb bob



Important Definition

Face Right: When the vertical circle of a theodolite is on right of the observer, the position is called face right and observation made is called face right observation.

Face Left: When the vertical circle of a theodolite is on left of the observer, the position is called face left and observation made is called face left observation. By taking the mean of both face readings, the collimation error is eliminated.

Telescope Normal: The telescope is said to be normal or direct when its vertical circle is to the left of the observer and bubble is up.

Telescope Inverted: The telescope is said to be inverted when its vertical circle is to the right of the observer and the bubble is down.

Changing face: Revolve the telescope by 180°in vertical plane about horizontal axis. Again revolve the telescope in horizontal plane about vertical axis.

Temporary adjustments of theodolite

Centering: This involves setting the theodolite exactly over the station mark or on the station peg. It is done by the following steps.

1) The plub bob is suspended from a small hook attached to the vertical axis of the theodolite.
2) The instrument is placed over the station mark with the telescope at a convenient height and with the tripod legs set well apart.
3) Two legs of the tripod are set firmly into the ground and the third leg is moved radially to bring the plumb bob exactly over the station mark. Then the third leg is also pushed into the ground.
4) If the instrument has a shifting head , the instrument is roughly centered over the station mark and then by means of the shifting head ,the plumb bob is brought exactly over the station mark.

Levelling: Having centered and approximately leveled the instrument is accurately leveled with reference to the plate level by means of leveling (or foot) screws. So that the vertical axis is made truly vertical, to lead the instrument.

(a) Loosen all the clamps and turn the instrument about either of its axis until the longer plate level is parallel to the pair of foot screws, the other plate level will then be parallel to the line joining the third screw and the midpoint of the line joining the first pair.

(b) Bring the long bubble to the center of its run by turning both screws equally either both inwards or both outwards.

(c) Similarly bring to the other bubble to the center of its run by turning third leveling screw or the other pair of leveling screws.

(d) Repeat the process until finally both bubbles are exactly centered.

If the vertical angles are to be measured the instrument should be levelled with reference to the altitude level fixed on the index arm. To do this,

a) First level the instrument by the plate levels. Then turn the telescope. So that the altitude level is parallel to the line joining a pair of foot screws. Bring the bubble to the center of its run by means of these srews.
b) Turn the telescopr through 90° and bring the bubble exactly to the mid position by the third leveling screw. Repeat until the bubble remains central in these two positions.

Focussing: This is done in two steps.

1) Focussing the eyepiece for distinct version of the cross hairs at diaphragm.

2) Focussing the object glass for bringing the center of the object on the plane of the diagram.

(1)Focussing the eyepiece:

Point the telescope towards the sky or hold a sheet of white paper in front of the object glass ,and move the eyepiece in and out until the cross hairs are seen quite distinctly and clearly (appear sharp and black)

(2) Focussing the object glass:

There will be an apparent movement of the image relatively to the cross hairs when the observer moves his eyes. The apparent movement being called the parallax. To eliminate it, direct the telescope towards the object and turn the telescope towards the object and turn the focusing screw until the image appears clear and sharp.

Experiment No- 1

Aim: - To measure the horizontal and vertical angles by reiteration method.

Instruments used:-Theodolite, ranging rods and arrows.

Theory:-

Reiteration is a method of measuring horizontal angles with high precision. It is less tedious and is generally preferred when there are several angles to be measured at a station. Several angles are measured successively and finally the horizon is closed. Closing the horizon is the process of measuring the angles around a point to obtain a check on their sum which should be equal to 360^0.

Procedure:-

1. Select a station point O.
2. Set the theodolite at O and do the temporary adjustments. The telescope is adjusted for right face right swing.
3. Set the vernier A to zero using upper clamp. Loosen the lower clamp, direct the telescope to the station point A and bisect A exactly by using the lower clamp and lower tangent screw.
4. Note the vernier readings (A and B).
5. Loosen the upper clamp and turn the telescope clockwise until the point B is exactly bisected.
6. Note the vernier readings (A and B).
7. The mean of the two vernier readings gives the value of <AOB.
8. Bisect all the points successively and note the readings of both verniers at each bisection.
9. Finally close the horizon by sighting the station point A. The A vernier should be 360^0. If not, note the closing error.
10. Adjust the telescope for left face left swing.
11. Repeat the whole process by turning the telescope in anticlockwise direction.
12. Distribute the closing error proportionately the several observed angles.
13. Take the average of face left and face right observations to give the corresponding horizontal angles.

OBSERVATIONS AND CALCULATIONS.

Observation station	Target station	Face left reading	Face right reading	Accepted mean angle
	A	00 00 00	179 59 38	
	B	18 28 12	198 28 05	
		18 28 12	18 28 27	18 28 19.5

Observation station	Target station	Face left reading	Face right reading	(360-FRR)	mean angle
	A	83 32 23	276 26 26	83 33 34	83 32 58.5
	B	99 02 36	261 13 28	98 46 32	98 54 34

The vertical angle of A = 90 - 83 32 58.5 = 06 27 01.5

The vertical angle of B = 90 - 98 54 34 = - 08 54 34

Theodolite

COMPONENTS OF A THEODOLITE

INTRODUCTION

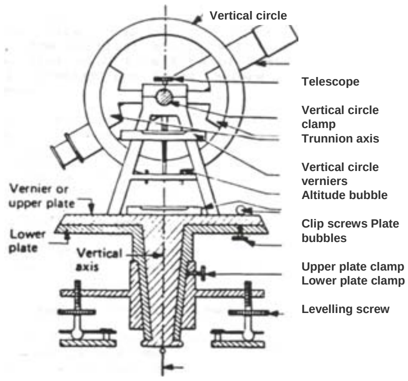
- The theodolite is used to measure horizontal and vertical angles. The **accuracy** with which these angles can be measured **ranges from 5mins to 0,1 secs**. It is a very important instrument in plane surveying.
- Its essential components are:
  - a **telescope** which can rotate or transit through 360° about a transverse horizontal axis.

  - The bearings for this horizontal or trunnion axis are mounted in two vertical pillars or **standards**. The standards are mounted on a **horizontal upper plate**.

  - The upper plate rotates through 360° about a **vertical** or alidade axis, the bearing for the alidade axis is mounted in a **lower horizontal plate**.

  - Rotation of the upper plate about the alidade axis is known as **traversing** the instrument. The horizontal plates can be levelled by means of three **foot screws** located beneath the lower plate, in a similar way to a level.

Simplified Diagram Of An Early Vernier Theodolite
Showing Most Of The Main Components



DESCRIPTION OF MAIN COMPONENTS

1. Telescope

- It has the same features as in a level graticule with eyepiece and internal focussing for the telescope itself. The same precautions for focussing the eyepiece and eliminating parallax should be applied.

DESCRIPTION OF MAIN COMPONENTS

2. Vertical Scale (or Vertical Circle)

- The **vertical circle** is a full 360° scale. It is mounted within one of the standards with its centre co-linear with the trunnion axis. It is used to measure the angle between the line of sight (collimation axis) of the telescope and the horizontal. This is known as the **vertical angle.**

- Note that the side of the instrument where the standard containing the scale is found is referred to as the **face** of the instrument.

DESCRIPTION OF MAIN COMPONENTS

3. Vertical Clamp and Tangent Screw

- In order to hold the telescope at a particular vertical angle a vertical clamp is provided. This is located on one of the standards and its release will allow free transiting of the telescope. When clamped, the telescope can be slowly transited using another fine adjustment screw known as the vertical tangent screw.

DESCRIPTION OF MAIN COMPONENTS

4. Upper Plate

- The upper plate is the base on which the standards and vertical circle are placed. Rotation or **transiting** of the upper plate about a vertical (alidade) axis will also cause the entire standards/telescope assembly to rotate in an identical manner. For the instrument to be in correct adjustment it is therefore necessary that the upper plate must be perpendicular to the alidade axis and parallel to the trunnion axis. Also, before the instrument is used, the upper plate must be "levelled". This is achieved by adjustment of three **foot screws** and observing a precise tube bubble. This bubble is known as the **plate bubble** and is placed on the upper plate.

DESCRIPTION OF MAIN COMPONENTS

5. The Lower Plate

- The lower plate is the **base** of the whole instrument. It houses the foot screws and the bearing for the vertical axis. It is rigidly attached to the tripod mounting assembly and does not move.

DESCRIPTION OF MAIN COMPONENTS

6. Horizontal Scale (or Horizontal Circle)

- The horizontal circle is a full 3600 scale. It is often placed **between the upper and lower plates** with its centre co-linear with the vertical axis. It is capable of full independent rotation about the trunnion axis so that any particular direction may be arbitrarily set to read zero.

- It is used to define the horizontal direction in which the telescope is sighted. Therefore a horizontal angle measurement requires two horizontal scale readings taken by observing two different targets.

- The difference between these readings will be the horizontal angle subtended by the two targets at the theodolite station.

DESCRIPTION OF MAIN COMPONENTS

7. The Upper Horizontal Clamp and Tangent Screw.

- The upper horizontal clamp is provided to clamp the upper plate to the horizontal circle. Once the clamp is released the instrument is free to traverse through 360° around the horizontal circle. When clamped, the instrument can be gradually transited around the circle by use of the upper horizontal tangent screw. It is the upper clamp and tangent screw which are used during a sequence or "round" of horizontal angle measurements.

DESCRIPTION OF MAIN COMPONENTS

8. The Lower Horizontal Clamp and Tangent Screw.

- The lower horizontal clamp is provided to clamp the horizontal circle to the lower plate. Once the clamp is released the circle is free to rotate about the vertical axis. When clamped, the horizontal circle can be gradually rotated using the lower-horizontal tangent screw. The lower clamp and tangent screw must only be used at the start of a sequence or "round" of horizontal angle measurements to set the first reading to zero (if so desired).

DESCRIPTION OF MAIN COMPONENTS

9. Circle Reading and Optical Micrometer

- Modern instruments usually have one eyepiece for reading both circles. It is usually located on one of the standards. The vertical and horizontal circles require illumination in order to read them. This is usually provided by small circular mirrors which can be angled and rotated to reflect maximum light onto the circles.

DESCRIPTION OF MAIN COMPONENTS

10. Optical Plumb

- Unlike optical levels, theodolites must be set up over fixed control stations, often defined by wooden pegs and nails. Positioning of the instrument must be achieved to nail head accuracy. Modern instruments have an optical plumb to achieve this. It consists of an eyepiece set in the lower plate. The line of sight through the eyepiece, which is reflected vertically downwards beneath the instrument by means of a prism, is precisely in line with the vertical axis.

DESCRIPTION OF MAIN COMPONENTS

Comments

1. Horizontal Clamps and Tangent Screws.

- Great care must be taken not to confuse the upper and lower horizontal clamps and tangent screws. With the upper clamp released, the instrument rotates around the horizontal circle. With the lower released, the instrument and circle rotate around the lower plate.

DESCRIPTION OF MAIN COMPONENTS

Comments

1. Horizontal Clamps and Tangent Screws.

- Great care must be taken not to confuse the upper and lower horizontal clamps and tangent screws. With the upper clamp released, the instrument rotates around the horizontal circle. With the lower released, the instrument and circle rotate around the lower plate.

- The upper tangent screw moves the instrument relative to the circle, the lower tangent screw moves the instrument and circle relative to the lower plate. Tangent screws only work when the clamps are tightened, they have ***limited travel and must not be forced.***

DESCRIPTION OF MAIN COMPONENTS

Comments

2. Instrument Station.

- Since the function of the instrument is to measure vertical and horizontal angles subtended at the instrument, the position of the instrument is important (unlike the position of a level). Theodolites are therefore set up over ***control stations*** which are permanent locations. The art of setting up a theodolite over a station <to nail head accuracy) and getting it level is best demonstrated rather than described.

DESCRIPTION OF MAIN COMPONENTS

Comments

3. Familiarisation

- On a modern theodolite there should be the following controls (silver knobs):
  - Telescope focussing
  - Vertical clamp
  - Vertical tangent screw
  - Vertical circle fine adjustment screw (if not an automatic indexing instrument)
  - Microptic adjustment
  - Upper horizontal clamp
  - Lower horizontal clamp (note that on some instruments the two horizontal clamps are combined into one).
  - h) Upper Horizontal tangent screw
  - i) Lower horizontal tangent screw.

DESCRIPTION OF MAIN COMPONENTS

Comments

- When one considers additional features such as illuminating mirrors, eyepiece focussing, a precise plate bubble (possibly a vertical circle precise bubble), an approximate circular bubble), optical plumb and foot screws, one realises that a theodolite is a ***complicated*** **and** ***very expensive*** i ns t rument.

- So regarding the practical side:
  Make sure you understand ***the function of every control.*** Different types of instrument will have different features.

- Treat the instrument with great care. Never force screws. Never force the instrument into its box. Always thoroughly dry the instrument with tissues if it gets wet. Never replace a wet instrument in its box. Report any accidents or faults.

OPERATION OF A THEODOLITE

Before operating, the theodolite needs to be placed directly over the station (so called nail accuracy), and then level it. This has to be done at the same time as described below. (*this is better done in practice than describe in words!*)

OPERATION OF A THEODOLITE

A. Precise levelling and positioning of theodolite

1. Set tripod *and* instrument with optical plumb *almost* over the station.
2. Unclamp one of the horizontal clamp (either will do) and traverse the instrument so that the plate bubble is parallel to two of the footscrews.
3. Adjust those two footscrews until the plate bubble is level.
4. Traverse the instrument so that the bubble is perpendicular to the already adjusted footscrews.
5. Re-level using the third footscrew.

OPERATION OF A THEODOLITE

A. Precise levelling and positioning of theodolite

6. Traverse the instrument in the same direction and re-align parallel to the first two footscrews.
7. Repeat stage 3 and then traverse as in 4. Then repeat stages 5-7, until the best mean level bubble is obtained (to one division accuracy).
8. Unclamp the base of the instrument and while viewing through optical plumb, slide the instrument across the tripod base until it is exactly over the station. Do not rotate the instrument about the tripod base. (Note that it might be necessary to repeat stages 1-7!!).

OPERATION OF A THEODOLITE

B. Zeroing the Horizontal circle

1. Unclamp the Upper Horizontal clamp.
2. Traverse the instrument until the horizontal circle reads *approximately* zero.
3. Re-clamp the Upper Clamp.
4. Adjust the Upper Horizontal Tangent Screw until the reading is approximately zero.
5. Select a target whose direction you wish to assign a zero scale reading.
6. Unclamp the Lower Horizontal clamp.

OPERATION OF A THEODOLITE

B. Zeroing the Horizontal circle

7. Traverse the instrument (and circle) until the telescope is pointing approximately at the selected target.
8. Re-clamp and, sighting through the telescope, align the vertical graticule precisely onto the target using the Lower Horizontal Tangent Screw. It is important that you approach the target in the direction in which you intend to continue to traverse to the next target. This is to minimize errors and is dealt with in more detail later.

   The instrument is now correctly sighted onto the target and is reading zero. The lower horizontal clamp and lower tangent screw should not be touched again until this particular ‘round’ of readings has been completed.

OPERATION OF A THEODOLITE

C. “FACE” and “SWING”

- As defined earlier in the subject, the standard which houses the vertical circle is called the Face of the instrument. If, when sighting through the telescope, this standard (the face) is on your left, then FACE LEFT is recorded for all readings taken. If on the right, then we record FACE RIGHT.
- The Swing of the instrument is defined as the direction in which the theodolite is traversed (i.e. rotated about vertical axis). If, when traversing, the telescope lens moves to the left we record readings as SWING LEFT. If on the right, we record readings as SWING RIGHT.
- Every horizontal circle reading must be booked with the face and swing identified. Usually it is conventional to work with opposite face and swing, i.e. FL/SR and FR/SL.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings
The following procedure would normally be adopted to measure the horizontal angle subtended at the theodolite station T by the two targets A and B.

1. Set Horizontal scale to zero and ensure both clamps are tightened.
2. Select Face (L or R) by transiting the telescope (if necessary).
3. Release the lower horizontal clamp. Traverse the instrument to approach target A using the appropriate Swing direction (L or R) stopping just short of the target.
4. Clamp the lower clamp.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings
The following procedure would normally be adopted to measure the horizontal angle subtended at the theodolite station T by the two targets A and B.

5. Adjust the lower horizontal tangent screw to complete the swing movement and bring the graticule cross precisely in line with target A. Do not "overshoot"!
6. Read and book the horizontal scale reading (which should be zero).
7. Now unclamp the Upper horizontal clamp. Traverse the instrument to approach target B using the same swing as before, stopping just short of target. Re-tighten (clamp) the upper clamp.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings
The following procedure would normally be adopted to measure the horizontal angle subtended at the theodolite station T by the two targets A and B.

8. Adjust the upper horizontal tangent screw to complete the swing movement and bring the graticule cross in line with target B.
9. Read and book the horizontal scale reading.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings

- Now if we transit the telescope by approximately 180º, this will be facing away from target B. By repeating stages 8-10 above (opposite swing now), another reading is recorded for target B and then at A (continuing traverse).
- This round of readings is now complete and will give us two versions of the same angle. Depending on the nature of the work and the accuracy required we may produce more rounds of readings, using opposite faces and swings or different positions on the horizontal circle producing 4 or even 8 versions of the same angle.
- The reason for this systematic approach using different combinations of face, swing and osition on the horizontal circle is to minimise systematic errors.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

An example, based on the description in D, is given below. Note that face left and face right readings on the same target differ by approximately 180º, if the instrument is in precise adjustment.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

Instrument Station (I.S.)	Target	Face/Swing	Horiz.Circle (° ′ ″)	Reduced Angle (° ′ ″)
T	A	L/R	000-00-00	136-34-20
T	B	L/R	136-34-20	
T	B	R/L	316-34-40	136-34-30
T	A	R/L	180-00-10	

The mean value is 136º- 34′- 25″.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

- Note that the horizontal scale is always graduated so that readings increase in a clockwise sense. Also, the reduced angle is clockwise from A to B (i.e. reading at B minus reading at A or say RB-RA).
- However, consider the case of reducing as RA-RB .This would have represented the clockwise rotation from B to A and the booking should have been as follows.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

Instrument Station (I.S.)	Target	Face/Swing	Horiz.Circle (° ′ ″)	Reduced Angle (° ′ ″)
T	A	L/R	360-00-00	223-25-40
T	B	L/R	136-34-20	
T	B	R/L	316-34-40	223-25-30
T	A	R/L	180-00-10	

The mean value is 223º- 25′- 35″.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

- Both reductions are equally acceptable, but the important question is: which angle has been obtained? It is easy to work out with common sense by visualizing the real situation. This approach is good enough when angles are close to 90º but will not necessarily work for angles close to 180º!

Errors in Theodolite

Instrument Errors :

Non-adjustment of plate bubble :

- The axis of the plate bubble may not be perpendicular to vertical axis. So. When the plate level are centered, the vertical axis may not be truly vertical.

  In such a case, the horizontal circle would be inclined and the angle will be measured in an inclined plane. The would cause an error in angle measured.

- This error may be eliminated by leveling the instrument with reference to the altitude bubble.

Line of collimation not being perpendicular to horizontal axis :

- In this case, a cone is formed when the telescope is revolved in the vertical plane, and this causes an error in the observation.
- This error is eliminated by reading the angle from both the faces (left and right) and take the average of the reading.

Horizontal axis not being perpendicular to vertical axis :

- If the horizontal axis is not perpendicular to the vertical axis, there is an angular error. This is ~~elimal~~ eliminated by reading the angle from both the faces.

Line of collimation not being parallel to axis of telescope :

- If the line of collimation is not parallel to the axis of telescope, there is an error in the observed vertical angle. This error is eliminated by taking reading from both faces.

Eccentricity of Inner and Outer axes :

- This condition causes an error in vernier readings. This area is eliminated by taking reading from both the vernier and considering the average readings.

Graduation not being Uniform :

- The error due to this condition is eliminated by measuring the angles several times on different parts of the circle.

Vernier being Eccentric :

- The zeros of the vernier should be diametrically opposite to each other. When vernier A is set at 0°, vernier B should be at 180°, But in some cases, this condition may not exist.
- This error is eliminated by reading both verniers and taking the average.

Personal Errors :

- The centering may not be done perfectly, due to carelessness. The levelling may not be done carefully according to usual procedure. If the clamp screws are not properly fixed, the instrument may slip. The proper tangent screw may not be operated. The focusing in order to avoid parallax may not be perfectly done.

- The object of ranging rod may not be bisected accurately. The vernier may not be set in proper place.
- Error would also result if the verniers are not read because of oversight.

Natural Errors:

- High temperature causes error due to irregular refraction.
- High wind causes vibration in the instrument, and this may lead to wrong readings on the verniers.

Methods of Levelling:

1. Height of Collimation Method
2. Rise and Fall Method

1. Collimation Method:

It consist of finding the elevation of the plane of collimation (H.I.) for every set up of the instrument, and then obtaining the reduced level of point with reference to the respective plane of collimation.

1. Elevation of plane of collimation for the first set of the level determined by adding back side to R.L. of B.M.
2. The R.L. of intermediate point and first change point are then obtained by starching the staff reading taken on respective point (IS & FS) from the elation of the plane collimation. [H.I.]
3. When the instrument is shifted to the second position a new plane collimation is set up. The elevation of this plane is obtained by adding B.S. taken on the C.P. From the second position of the level to the R.L. C.P. The R.L. of successive point and second C.P. are found by subtract these staff reading from the elevation of second plane of collimation Arithmetical check

Sum of B.S. – sum of F.S. = last R.L. – First R.L.

This method is simple and easy.

Reduction of levels is easy.

Visualization is not necessary regarding the nature of the ground.

There is no check for intermediate sight readings

This method is generally used where more number of readings can be taken with less number of change points for constructional work and profile leveling.

2.Rise and Fall Method:

It consists of determining the difference of elevation between consecutive points by comparing each point after the first that immediately preceding it. The difference between there staff reading indicates a rise fall according to the staff reading at the point. The R.L is then found adding the rise to, or subtracting the fall from the reduced level of preceding point.

Arithmetic check

Sum of B.S. – sum of F. S. = sum of rise – sum of fall = last R. L. – first R.L.

This method is complicated and is not easy to carry out.

Reduction of levels takes more time.

Visualization is necessary regarding the nature of the ground.

Complete check is there for all readings.

This method is preferable for check levelling where number of change points are more.

Basic definitions

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 level. 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.

Reduced Level

The height of any target point is referred to as Reduced Level (RL), because it is reduced to a known datum.

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.

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.

Levelling operations

Now consider Figure 2 below. The level is set up as shown, and using the staff at points A and B, height readings are recorded. This is just the height read through the telescope horizontal line of sight (known as line of collimation). If no reduced level is known only the difference in height can be found between A and B, not their absolute levels.
Staff Reading at A is 1.135m
Staff Reading at B is 1.875m
If we know that RLA = +120.000m (above datum), then RLB = 120.00 – 0.740 = +119.260m i.e. a fall
from A. If RLB was known we would calculate a rise in level. Hence, the following can be defined:

Rise – staff reading is less than previous reading.

Fall – staff reading is greater than previous reading.

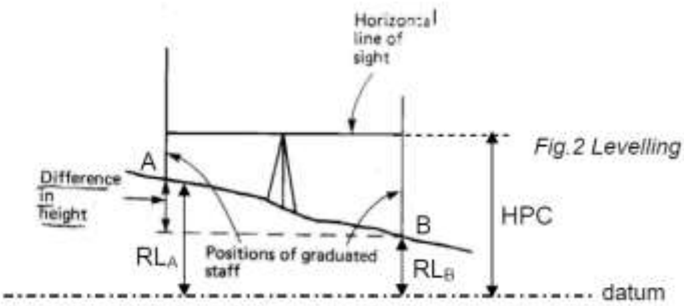


Fig.2 Levelling set-up and height calculation

Experiment (Rise & Fall method):

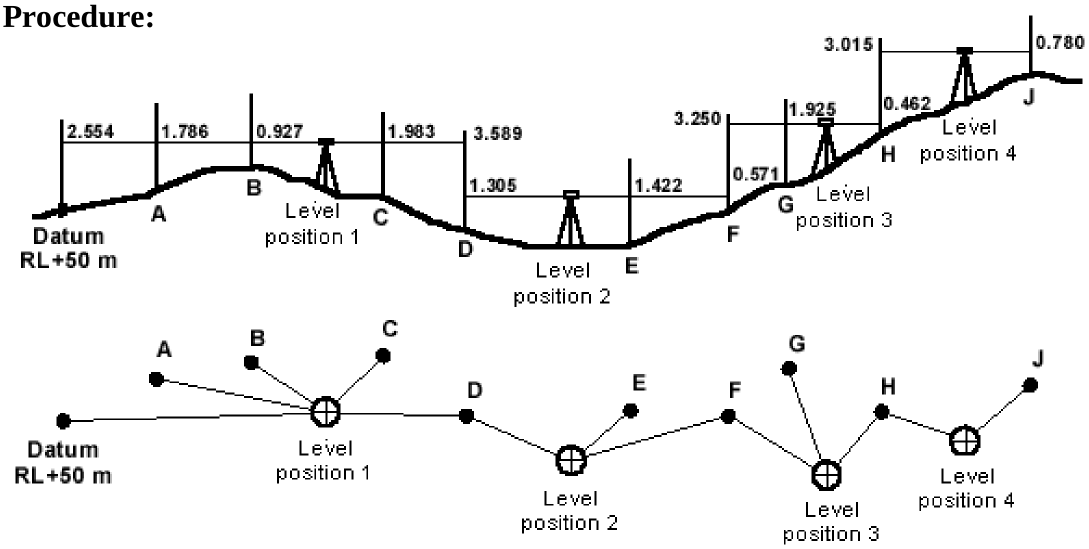
Aim:

To determine the required level of given points by Rise and fall method

Apparatus Required:

Automatic level, Tripod and Levelling staff

Procedure:

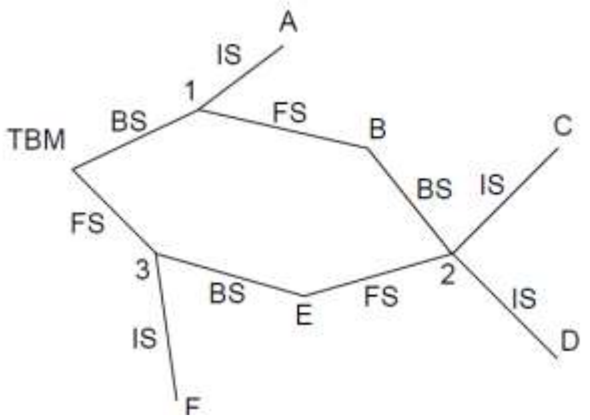


1. Set up the leveling instrument at Level position 1.
2. Hold the staff on the Datum (RL+50 m) and take a reading. This will be a backsight, because it is the first staff reading after the leveling instrument has been set up.
3. Move the staff to **A** and take a reading. This will be an intermediate 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 changeplate 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 (see Table 1)
8. Set up the level at Level position 2 and leave the staff at **D** on the changeplate. 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 changeplate.

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

Field procedures for leveling

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) = +430.000m
Instrument stations: 1, 2, 3.
Target points: TBM, A, B, C, D, E, F.

(BOOKING)					(REDUCTION)		
Station	**remark**	**BS**	**IS**	**FS**	**Rise**	**Fall**	**RL**
1	**BM**						
1	**A**						
1	**B**						
2	**B**						
2	**C**						
2	**D**						
2	**E**						
3	**E**						
3	**F**						
3	**BM**						
Sum							

Arithmetic checks (necessary for checking the reduction)

Σ (BS) - Σ (FS) =
Σ (RISES) – Σ (FALLS) =
LAST (RL) – FIRST (RL) =
Allowable misclosure = ±5 √n mm ; where n = no. of instrument positions

Levelling Staffs

- These are scales on which these distances are measured.
- These are of two types :- Self reading staff
  - Target staff

Self Reading Staff :

- The self reading staff can be read directly by the level man looking through the telescope.
- Common types of self reading staffs :- Ordinary staff
  - Folding staff
  - Sop-with telescopic staff

i) Ordinary staff :

The one length staff, is solid and made of seasoned wood, it is 3 meters long and graduated in the same way as the telescopic staff.

ii) Folding staff :

The folding staff is made up of well seasoned timber such as Cyprus. It consists of two 2 meters wooden pieces with a joint assembly. Each piece of the staff is made of one longitudinal strip without any joint. The folding joint is of the detachable type with a locking device at the back. The staff is joined together in such a way that the staff may be folded from one another when required.

The staff has brass cap at the bottom. It has two folding handles, with spring action. It is provided with a circular bubble fitted at the back.

iii) Sop-with Telescopic Staff :

Such a staff is arranged in three lengths placed one into the other. It can be extended to its full length by pulling. The top portion is solid and the central box is hollow the total length of staff is 4 m.

The staff is graduated in such a way that smallest division is of 5 mm. the value in 'm' are marked in red on the left and those in decimels are in black on the right.

Target staff :

- For ~~every~~ very precise works and sight target staff are used. A movable target is provided in this staff.
- A vernier is provided on target to give precise reading. In target staff level man directs the staff man to move the target up and down untill it bisects by the line of sight. The staff man observe the staff reading.

A total station is composed of four main components; EDM (Electronic Distance Measurement), electronic theodolite, microprocessor and electronic display.

For all intents and purposes the EDM's main function is to measure distance from the total station to a reflector. It uses electromagnetic (EM) energy to determine the length of a line. There are different kinds of EMs; electro-optical (infrared or laser) and microwave. The nature of the reflector is dependent on the type of EM used. A passive medium (prism) is used with electro-optical EM but if microwave is used a second receiver/transmitter is required.

An EDM does not determine distance by measuring the time of travel of the EM signal. Instead, it uses the signal structure and determines the phase shift. The EM signal has a sinusoidal wave form. The wave form repeats every 360°. The distance between waveform ends is the wavelength. However, reflector-less total stations measures travel times of the laser pulses and from that can determine the total instrument-surface-instrument distance. This is because they use short pulses of high energy laser light which are capable of bouncing off surfaces.

The function of the theodolite is to measure horizontal and vertical angles. A standalone theodolite works by combining the optical plummet, level bubble and calibrated circles to find the said angles. The optical plummet ensures the theodolite is placed vertically above the survey point. The bubble level makes sure the device is level to the horizon. The calibrated circles, one vertical and one horizontal, enable the user to read out the angles in both axes.

However, when integrated in a total station one does not get to see the calibrated circles. Same case applies to an electronic theodolite. The horizontal and vertical angles are measured and communicated to the electronic display.

Before the advent of the micro-processor, surveyors had a lot of mathematical calculations on their hands. Since the distance measured by an EDM is slope distance, the surveyor had to manually reduce it to horizontal distance for every measurement observed. That's not all, before the theodolite and EDM were combined to form the total station instrument, surveyors would first measure the vertical angle with a theodolite, dismount the theodolite and replace it with the EDM to measure the slope distance (often on the same tribrach). Such mounting and dismounting introduced offset errors.

The micro-processor therefore saved the surveyor a lot of work. It typically performs the following functions but the inherent program varies widely from manufacturer to manufacturer;

· Averages multiple angle measurements

· Averages multiple distance measurements

· Computes horizontal and vertical distances

· Provides corrections for temp, pressure and humidity

· Computes inverses, polars and resections

· Computes X, Y and Z coordinates

The final piece of the puzzle is the elec-

The final piece of the puzzle is the electronic display. Basically its function is to provide a visual of what is happening in the total station. Depending on the button pressed it helps the user navigate to the various menu items. It also enables input of instrument and reflector heights as well as access to the stored data. It displays horizontal distance, vertical distance, horizontal and vertical angles, difference in elevations of two observed points and all the three coordinates of the observed points (XYZ).

The total station has come a long way in terms of its technological complexities. Nowadays, with robotic total stations and Automatic Target Recognition (ATR), only one user is needed since the surveyor can remotely control his device (although this is debatable since the instrument on occasion loses its target and goes through a series of about-turns in an attempt to auto-find the reflector). Moreover, the line of sight predicament is being overcome with total stations that come integrated with GPS receivers. The future of the total