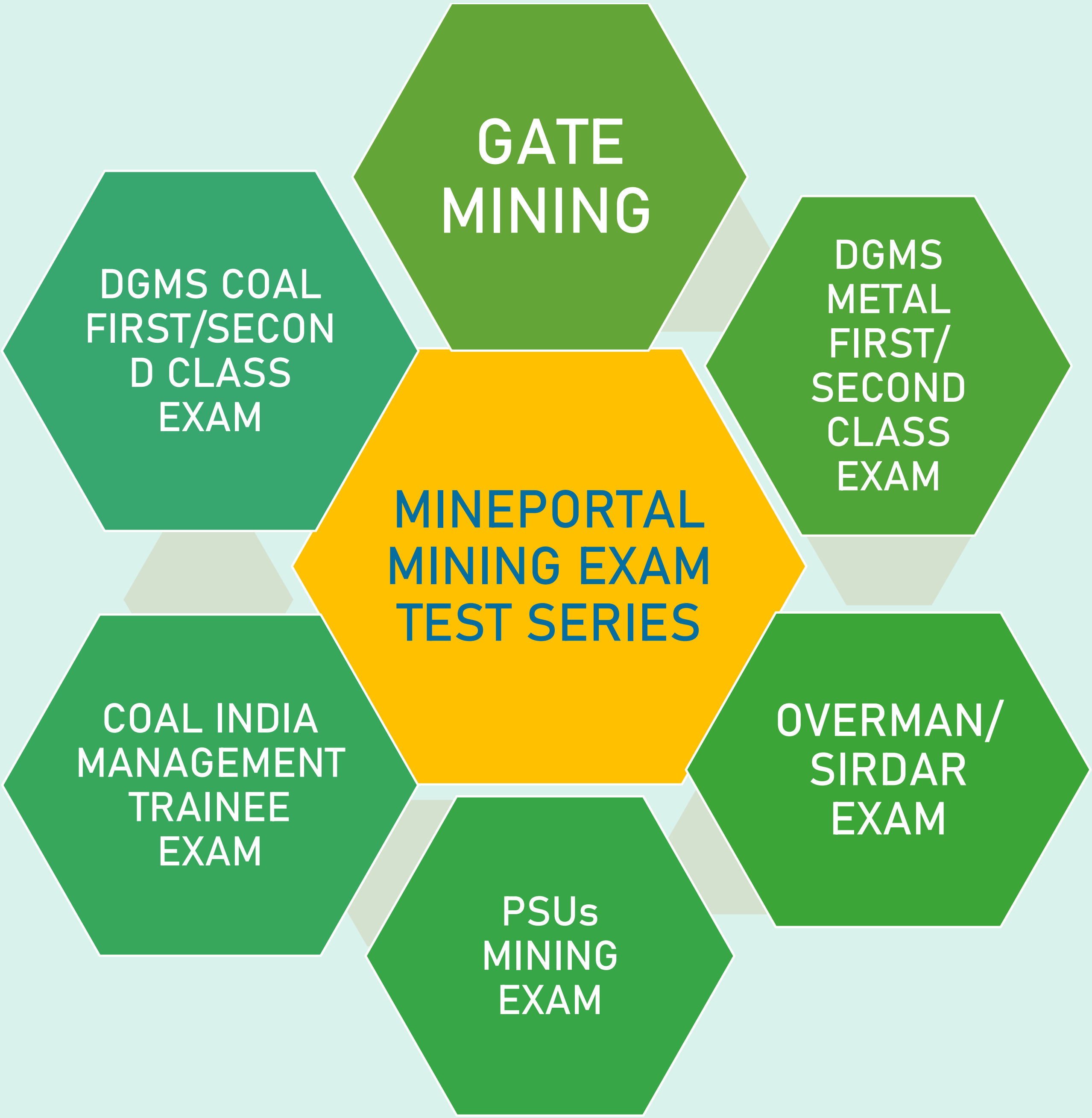
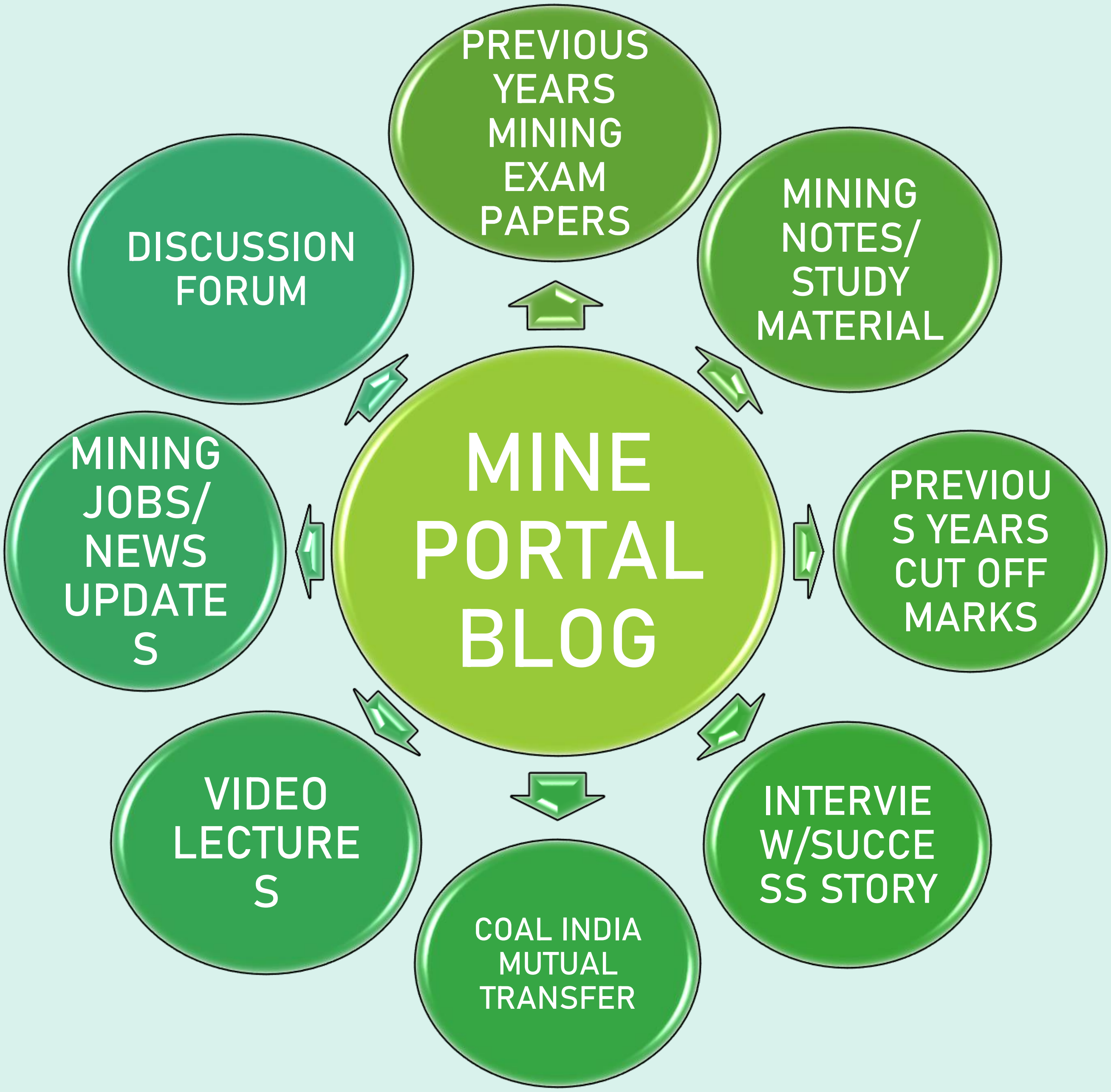
www.MINEPORTAL.in





CALL/WHATSAPP- 8804777500

MINE PORTAL NOTES ON SURVEYING WITH CMR/MMR & DGMS CIRCULARS

CLICK ON THE LINKS TO JOIN VARIOUS MINING EXAM PREPARATION TELEGRAM GROUP

METAL FIRST/SECOND CLASS EXAM TELEGRAM GROUP

COAL FIRST/SECOND CLASS EXAM TELEGRAM GROUP

MINE OVERMAN/SIRDAR EXAM TELEGRAM GROUP

GATE MINING EXAM TELEGRAM GROUP

STUDY MARERIAL/NOTES TELEGRAM GROUP

MINING JOBS TELEGRAM GROUP

MINING MATE/FOREMAN/BLASTER GROUP

MINE SURVEYOR EXAM GROUP

DISCUSSION FORUM

COAL INDIA LTD EMPLOYEES' SUBSIDIARY MUTUAL TRANSFER FORUM

USER NOTES

INDEX

SURVEY - I

SURVEY - I

Distance Measurement

Distance measurement is a critical aspect of mine surveying as it is essential to accurately determine the location of different points in the mine. There are several methods of distance measurement used in mine surveying, including chains, tapes, electronic distance measurement, and total station.

Different methods are adopted for measuring the distance between any two given points. Three methods used are

- Direct distance measurement
- Optical distance measurement
- Electromagnetic distance measurement

Direct Distance Measurement: The direct distance measurement is actually measured on the ground. Chain or tapes are used for this method. Other instruments which are used are

- Passometer
- Pacing
- Chaining
- Odometer
- Speedometer

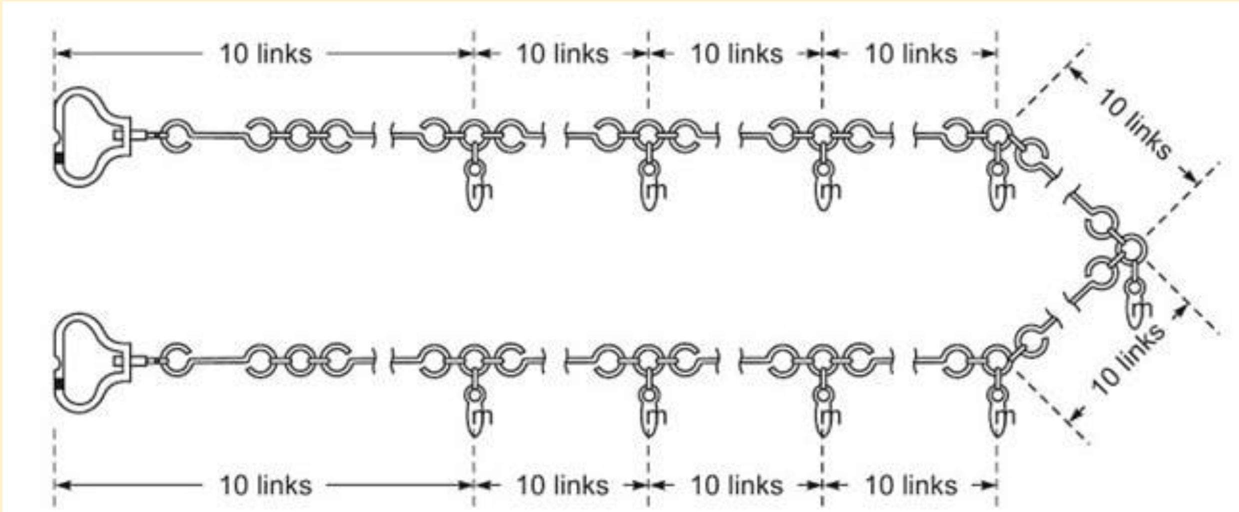
Chaining can be used for work of normal precision and for higher precision tapes can be used. Chaining is the basis of surveying.

Optical Distance Measurement: This method of measurement uses a tachometer or telemetric method. These are very rapid and convenient. But its precision is less compared to chaining. Although these are more suitable in steep, swap, etc.

Electromagnetic Distance Measurement (Edm): Electronic distance measurement is surveying equipment that is used for measuring the distance between two points. The principle behind the EDM is electromagnetic waves. These rely on the generation, propagation, reflection, and reception of electromagnetic waves.

Chain Surveying
Types of chains

Gunter’s Chain: The Gunter’s chain is 66 ft. Long and is divided into 100 links each 0.66 ft. Long. It is very convenient for measuring distances in miles and furlongs and for measuring land when the unit of area is an acre, on account of its simple relation to the mile and the acre.



(a) 100 link chain

Revenue Chain: The revenue chain is commonly used for measuring fields in cadastral survey. It is 33 ft. Long divided into 16 links.

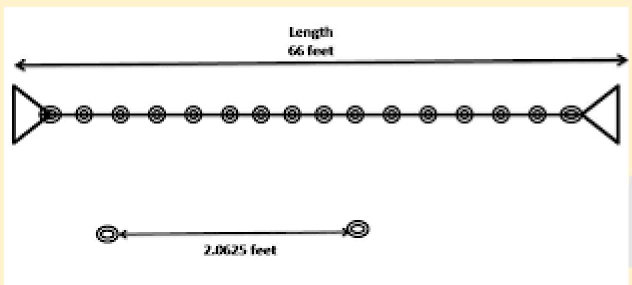


Fig. Revenue Chain

Engineers' Chain: The engineers' chain is 100 ft. Long and is divided into 100 links each one foot in length.

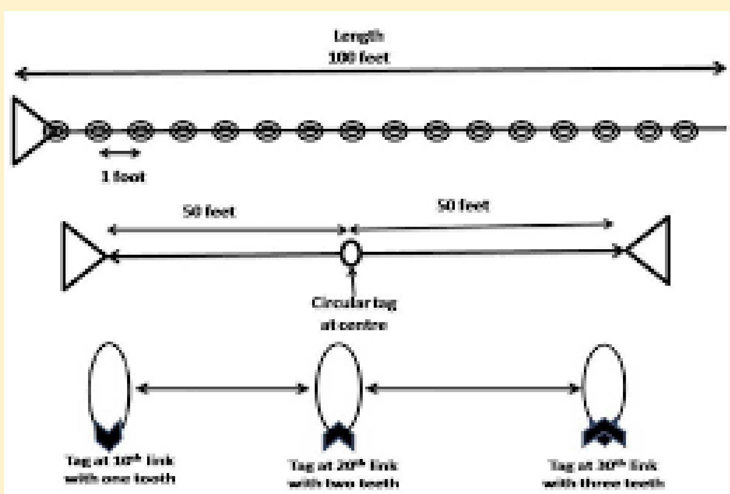


Fig. Engineer's Chain

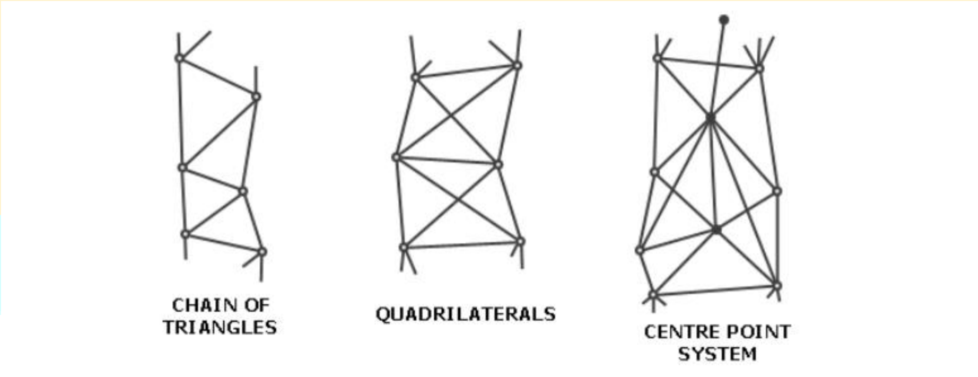
Equipment used in chain surveying:

- a chain and to arrows
- a 20 m metallic tape

- Ranging rods 12 nos.
- An offset rod
- An optical square or a cross staff
- A plumb bob
- A survey field book
- Pegs
- 2 pencils of good quality and penknife
- A good field glass
- Sundries such as chalk, hammer, nails etc.

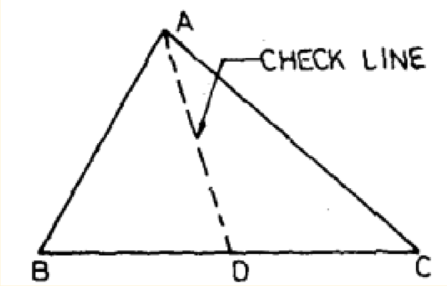
Principle of Chain surveying

The principle of a chain survey is triangulation. It consists of the arrangement of framework of triangles, since a triangle is the only simple plane figure, which can be plotted from the lengths of its sides alone. The three sides of a triangle being equally liable to error, each of the three angles of a triangle should be nearly 60o , i.e. the triangle should be equilateral.



Base Line: The longest of the chain lines used in making a survey is generally regarded as the base line. It is generally the most important line. It fixes up the directions of all other lines, as on the base line is built up the framework of a survey.

Check line: A check line is measured to check the accuracy of the framework, as the length of a check line as measured on the ground should agree with its length on the plan.



Survey station and Main station

A Survey Station is a point of Importance at the beginning and end of a chain line. There are two main types of stations namely Main station and Subsidiary or Tie station.

Main station: Main stations are the ends of the lines which command the Boundary of the survey, and the lines joining the main stations are called main Survey or Chain lines.

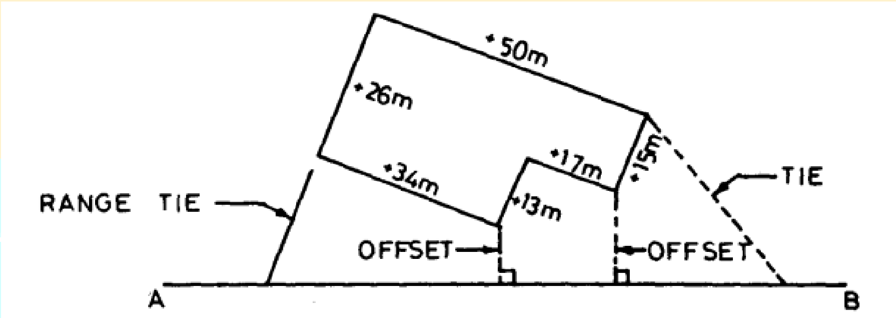
Subsidiary or tie station: Any Point selected on the main survey line where it is necessary to run the auxiliary lines to locate the interior details such as fences, hedges, buildings, etc., when they are at some distance from the main survey lines are known as Subsidiary or Tie stations .

Tie line: The lines joining such stations are known as tie line or subsidiary line. A tie line usually fulfils a dual purpose, viz. It checks the accuracy of the framework and enables the surveyor to locate the interior details which are far away from the main chain lines.

OFFSETS: In a survey the positions of the details such as boundaries, building, fences, rods, nallas etc. are located with respect to the survey (r chain) lines by means of lateral measurements (i.e. distances measured from the chain lines) to such objects right or left of the chain lines. These lateral measurements are called offsets. There are two kinds of offsets:

1. perpendicular offsets: In the strict sense, offsets are always taken at right angles to the survey line. They are also called perpendicular or right-angled offsets.

2. oblique offsets: The measurements which are not made at right angles to the survey line are called oblique offsets or tie-line offsets.



Taking Offsets: Every offset involves two measurements

1. the distance along the chain line called chainage, and

2. the length of the offset (perpendicular or oblique). These are taken and noted in a field book. This operation is known as taking offset.

RANDOM LINE: In a linear measurement when end stations are not visible from any intermediate point, random line method is used. In this method, a random line is drawn in the estimated direction up to the point from which the other end point is visible.

Errors and Mistakes in Chaining

Errors in chaining may be caused due to variation in temperature and pull, defects in instruments, etc. They may be either

- compensating, or
- cumulative

Compensating Errors: Errors which may occur in both directions (i.e. both positive and negative) and which finally tend to compensate are known as compensating errors. These errors do not affect survey work seriously. They are proportional to , where L is the length of the line. Such errors may be caused by

- Incorrect holding of the chain,

- Horizontality and verticality of steps not being properly maintained during the stepping operation,
- Fractional parts of the chain or tape not being uniform throughout its length, and
- Inaccurate measurement of right angles with chain and tape.

Cumulative Errors: Errors which may occur in the same direction and which finally tend to accumulate are said to be cumulative. They seriously affect the accuracy of the work, and are proportional to the length of the line (L). The errors may be positive or negative.

Positive Errors: When the measured length is more than the actual length (i.e. when the chain is too short), the error is said to be positive.

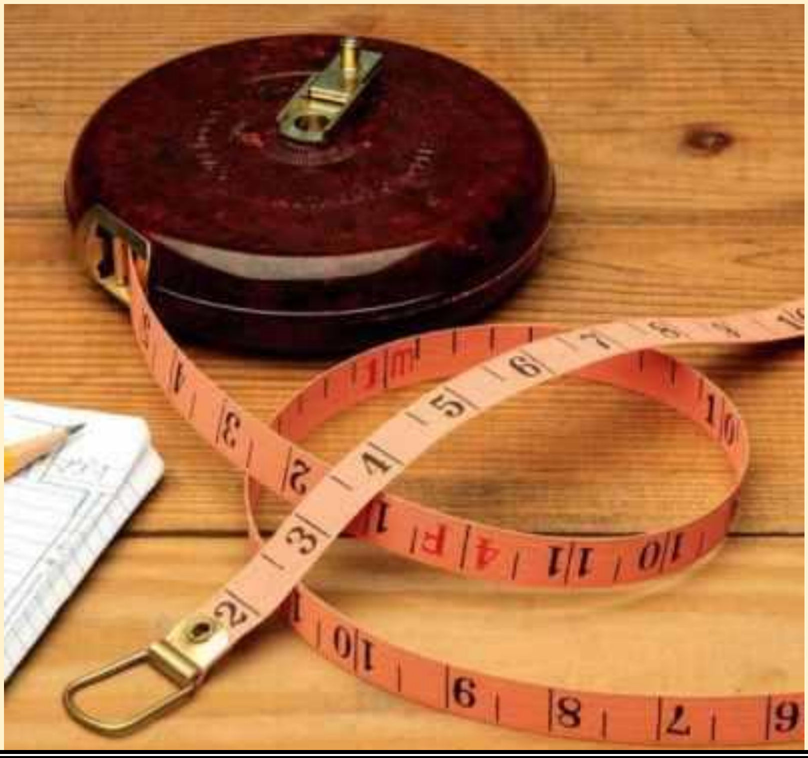
Negative Errors: When the measured length of the line is less than the actual length (i.e. when the chain is too long), the error is said to be negative. These errors occur when the length of the chain or tape is greater than the standard length.

TAPES

Surveying tapes are used to measure distances, heights, and other dimensions in surveying and related fields. Here are some of the most common types of tapes used in surveying:

- Linen Tape.
- Woven Metallic Tape.
- Steel Tape.
- Synthetic Tape.
- Invar Tape.

Linen Tape: Linen tape, also known as cloth tape is a varnished strip made of closely woven linen. The width of the strip is about 12 to 16 mm. It is available in different lengths such as 10m, 20m, 30m, and 50m. Both ends of the linen tape are provided with metallic handles and the whole tape is wounded in leather or metal case.



Linen tapes are light in weight and easy to handle. These tapes may shrink when exposed to water and also elongate when pulled. Hence, these tapes are not suitable for accurate surveying measurements. These are generally used for measuring offsets and for ordinary works.

Woven Metallic Tape: The metallic woven tape is an improved version of linen tape. Brass or copper made wires are used as reinforcement for the linen material. Hence, it is more durable than normal linen tape. A brass ring is provided at the end of the tape which is included in the length of the tape.

These tapes are available in different lengths of 2m, 10m, 15m, 20m, 30m, and 50m. These are used for survey works such as topographical survey works where minor errors are not taken into consideration.

Steel Tape: A steel tape is made of steel or stainless steel. It consists of a steel strip of 6mm to 16mm wide. It is available in lengths of 1m, 5m, 8m, 10m, 20m, 30m and 50m. Meters, decimeters, and centimeters are graduated in the steel strip. Steel tapes generally came up with the metal case with automatic winding device. The tape is withdrawn from the case by using a hand during measuring and it is rewound into the case by just pressing button provided on the case.

Synthetic Tape: Synthetic tapes are made of glass fibers coated with PVC. These are light in weight and flexible. They are available in lengths of 5m, 10m, 20m, 30m, and 50m. Synthetic tapes may stretch when subjected to tension. Hence, these are not suitable for accurate surveying works. However, synthetic tapes are recommended in place of steel tapes where it is essential to take measurements in the vicinity of electric fences and railway lines, etc.

Invar Tape: Invar tapes are made of an alloy which consists of 36% of nickel and 64% of steel. Invar tape contains a 6mm wide strip and is available in different lengths of 30m, 50m, 100m.

The coefficient of thermal expansion of invar alloy is very low. It is not affected by changes in temperature. Hence, these tapes are used for high precision works in surveying such as baseline measurement, triangulation surveys, etc. Invar tapes are expensive than all the other types of tapes. These tapes should be handled with care otherwise bends or kinks may be formed.

Tape corrections

Correction for Slope

Correction $C_g = D - L = -L(1 - \cos\theta) = -2L \sin^2 \theta/2$

where D = horizontal equivalent, L = slope distance and θ is angle of slope.

Alternatively $C_g = \sqrt{(L^2 - h^2)} - L$

where h is difference in elevation of the end points.

Correction for Pull

The correction for pull (Cp) is given by

$$C_p = \frac{(P - P_0)L}{AE}$$

where P is pull applied during measurement (N), P0 is standard pull (N), L is measured length, A is cross sectional area of the tape and E is Young's modulus of elasticity (for steel E = 2 x 105 N/mm2 or 2 x 105 MPa).

Correction for Temperature

The temperature correction is given by

$$C_t = \alpha(T - T_0)L$$

where α is coefficient of linear expansion, T is mean temperature of the tape (^{0}C) and T_0 is standard temperature (^{0}C). The sign of Ct is directly given by above equation.

Correction for Sag

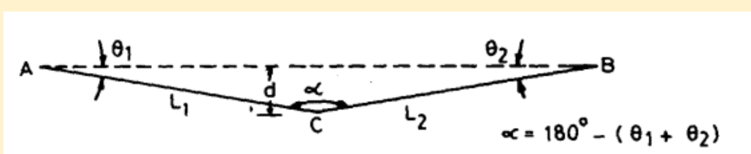
Correction for sag is given by

$$C_s = -\frac{l_1(wl_1)^2}{24P^2}$$

where w is weight of tape per unit length (N/m), P is applied pull (N) and l1 is length of the tape suspended between the supports (m).

Correction for Misalignment

If the survey line is not accurately ranged out, the error due to misalignment occurs. The measured distance is always greater than the correct distance, and hence the error is positive and the correction is negative.



The correction due to misalignment is given by

$$C_m = (L_1 \cos\theta_1 + L_2 \cos\theta_2) - (L_1 - L_2)$$

or $$C_m = \sqrt{L_1{}^2 + L_2{}^2 - 2L_1L_2\cos\alpha} - (L_1 + L_2)$$

or $$C_m = \left[\sqrt{L_1{}^2 - d^2} + \sqrt{L_2{}^2 - d^2}\right] - (L_1 + L_2)$$

Questions

Example

A steel tape 30 m long was standardized with a pull of 65 N. If the pull at the time of measurement was 45 N, find the correction per tape length. The tape weighs 10 N. Take E = 2 x 10^5 N/mm2 and weight of 1 m3 of steel as 77.10 kN.

Solution

Let A be the cross sectional area of the tape in mm^2.

Weight of 1 mm^2 steel = 77.10 x $10^3/10^9$ = 77.1 x 10^{-6} N

Therefore A x (30 x 10^3) x 77.1 x 10^{-6} = 10

or A = 4.323 mm^2

Now $C_p = \frac{(45-65)}{4.323 \times 2 \times 10^5} = -6.93 \times 10^{-4}\ m = -0.693\ mm$

Example

Determine the sag correction for a 30 m steel tape under a pull of 80 N in 3 bays of 10 m each. The area of the cross section of the tape is 8 mm^2 and the unit weight of steel may be taken as 77 kN/m^2 .

Solution

Weight of the tape per metre = (77 x $10^3/10^9$) x 8 x 10^3 = 0.616 N/m

Now sag correction per bay will be

$$\frac{l_1(wl_1)^2}{24P^2} = -\frac{10x(0.616x10)^2}{24\,x\,(80)^2} = -2.470 \times 10^{-3}\ m$$

Total correction for 3 bays = -3 x 2.470 x 10^{-3} = -7.411 x 10^{-3} m

Example

A metallic tape originally 20 m is now found to be 20.2 m long. A house, 30 m x 20 m is to be laid out. What measurements must be made using this tape ? What should the diagonal read?

Solution

True distance = length to be measured x (Incorrect length of tape L'/Correct length of tape L)

30 = Length to be measured x 20.2 / 20

Length to be measured = 30 x 20/20.2 = 29.802 m

Hence measurements to be made with 20.2 m tape instead of 20 m tape are 29.703 x 19.802m

Diagonal measurement = $\sqrt{}(29.703)^2 + (19.802)^2 = 35.7$ m

Example

A mining land was measured with an incorrect 30 m chain and a plan was drawn. From these measurements the area on the plan was measured and calculated and was found to be 16.25 km^2 . Find to correct area of the mining land, if the length of the chain was 30.06 m.

Solution

True area = $(L/30)^2$ x 16.25 km^2 = $(30.06/30)^2$ x 16.25 km^2 = 16.315 km^2

Example

Find the maximum length of offset so that the displacement of a point on the paper should not exceed 0.025 cm, given that the offset was laid out 3^0 from its true direction and the scale was 10 m to 1 cm.

Solution

Let l = the limiting length of offset in m.

α = the angular error in direction.

Then,

Displacement of the point on the ground = l sin α = l sin 30^o

Since the scale is 10 m to 1 cm, its displacement on the paper

= l sin $3^o/10$ cm and this should equal 0.025 cm.

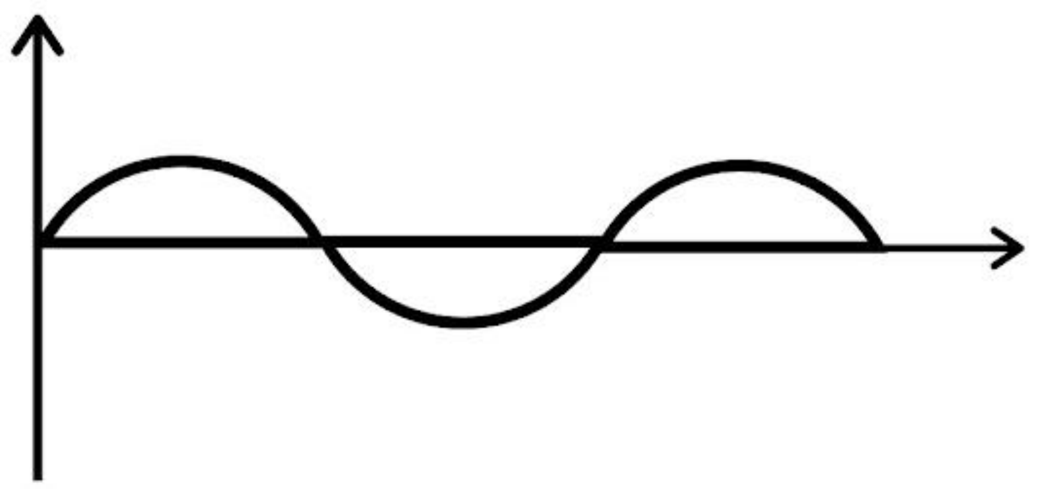
l sin $3^o/10$ = 0.025 or l = 4.78 m.

Electronic Distance Measurement (EDM)

Electronic distance measurement (EDM) is a method of determining the length between two points using electromagnetic waves. EDM is commonly carried out with digital instruments called theodolites.

EDM instruments are highly reliable and convenient pieces of surveying equipment and can be used to measure distances of up to 100 kilometers. Each piece of EDM equipment available at Engineer Supply provides dependably accurate distance measurements displayed on an easy-to-read digital screen.

Principles of EDM.



The EDM uses the electromagnetic waves, the type of waves generated depends on various factors such as frequency, wavelength, and period. These are represented in the form of periodic sinusoidal waves.

Frequency is defined as the number of times the waves complete one cycle. It is represented in hertz(Hz).

The length traveled by the waves in one cycle is known as wavelength. It is represented in meters.

The time period is the inverse of frequency. That is the time takes to complete one cycle. It is represented by seconds.

The velocity of the electromagnetic waves depends on the medium. While the properties may vary according to the source.

$f = c / \lambda = 1 / T$

Where

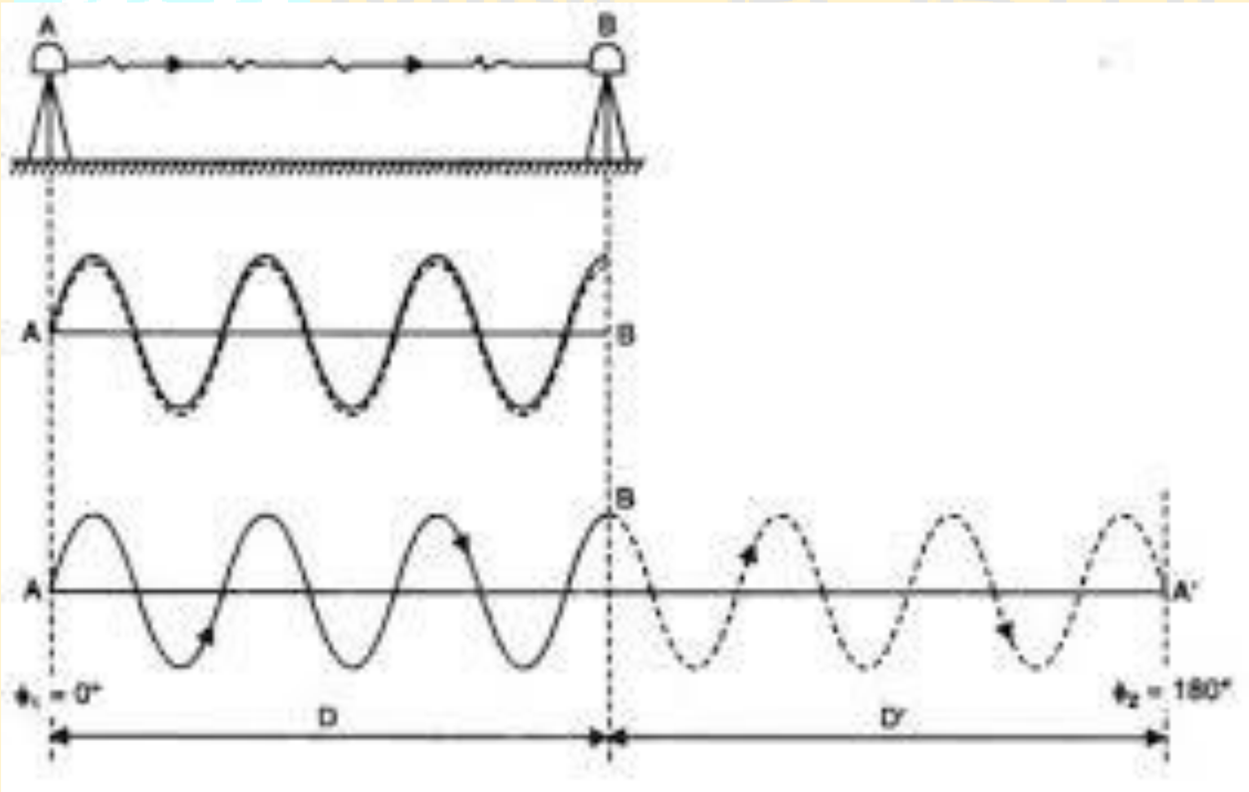
c is the speed of light in a vacuum.

T is the time period

f is the frequency

λ is the wavelength

Working of EDM



The distance between two points is calculated based on the propagation of electromagnetic waves.

Consider two points A and B, and we have to calculate the distance between them. First, a transmitter is placed at point A. Then a receiver and a timer are placed at another point B. Now an Electromagnetic wave is propagated from A to B, the timer is kept on. The time at which the receiver accepted the wave is noted and this time is called Transit time.

Here we know the velocity and transit time of the wave propagated. But measuring the transit time is a little tougher. Therefore a reflector is placed at B. The point a acts as a transmitter and receiver. Thus the double transit time is calculated.

Now the distance is measured by the phase difference between the transmitted and received signals.

The distance covered by the wave is

$2D = n\lambda + \Delta\lambda$

Where,

D is the distance

$n\lambda$ is resolving the ambiguity of the phase comparison

$\Delta\lambda$ is the fraction of wavelength travelled by the wave

This is solved automatically by the EDM device and the result is displayed

Here are the three types of instruments that are used for electronic distance measurement, which are based on the methods being used:

Microwave Instruments — Also called tellurometers, these instruments use microwaves. And they have been around since the 1950's.

Infrared Wave Instruments — Uses prism reflectors that pick up amplitude modulated infrared waves at the end of a line.

Visible Light Wave Instruments — Uses modulated light waves to measure up to a specific range.

Advantages of Electronic Distance Measurement

When compared to other measuring methods EDM has many advantages. Since it is an electronic device manual work power is less. Horizontal and vertical angles, Horizontal and vertical distance are automatically measured and recorded in EDM.

- High accuracy.
- Field work can be done fastly
- Reduces errors.
- Less manual work
- Obstacles to chaining can be over comes
- Less calculation needed and more precise
- Convenient and reliable methods.

EDM instruments are subject to various errors that can affect the accuracy and precision of the measurements. These errors can be classified into three categories: **instrumental errors, personal errors, and natural errors** [2].

- Instrumental errors are caused by the imperfections or malfunctions of the instrument, such as:

- **Instrument constant error:** This is a constant error that arises from the differences between the electronic and mechanical centres of the instrument and the reflector. It can be determined by measuring a known distance with the instrument and applying the correction to all subsequent measurements [2][3].

- **Scale error:** This is a proportional error that arises from the drift in frequency of the quartz crystal oscillator in the instrument or the errors in the measured atmospheric conditions that affect the velocity of the signal. It can be determined by measuring a known distance with different settings of the instrument and applying a correction factor to all subsequent measurements [2][3].

- **Cyclic error:** This is a periodic error that arises from the non-linearity in amplitude modulation of the signal or the phase measurement. It can be determined by measuring a known distance with different positions of the reflector and applying a correction function to all subsequent measurements [2][3].

- Personal errors are caused by the human factors involved in operating the instrument, such as:

- **Alignment error:** This is an error that arises from the misalignment of the instrument or the reflector with respect to the line of sight. It can be minimized by using optical devices such as telescopes or prisms to align the instrument and the reflector [2][3].

- **Reading error:** This is an error that arises from the incorrect reading or recording of the instrument display or the reflector position. It can be minimized by using digital displays or automatic recording devices and by checking for consistency and reasonableness of the readings [2][3].

- Natural errors are caused by the environmental factors that affect the propagation of the signal, such as:

- **Atmospheric refraction:** This is an error that arises from the bending of the signal due to variations in air density, temperature, pressure, and humidity. It can be minimized by measuring and applying corrections for these atmospheric conditions or by using instruments that compensate for them automatically [2][3].

- **Atmospheric absorption:** This is an error that arises from the attenuation of the signal due to absorption by water vapor, dust, or other particles in the air. It can be minimized by using instruments that operate at wavelengths that are less affected by absorption or by using reflectors that enhance the signal strength [2][3].

Selection of instrument in EDM depends on several factors, such as:

- **Accuracy requirement:** Different types of EDM instruments have different levels of accuracy and precision, ranging from millimetres to centimetres. The accuracy requirement depends on the purpose and specifications of the survey project [1].

- **Distance range:** Different types of EDM instruments have different ranges of distance measurement, ranging from meters to kilometres. The distance range depends on the length and terrain of the survey lines [1].

- **Cost and availability:** Different types of EDM instruments have different costs and availability, depending on their complexity, functionality, and demand. The cost and availability depend on the budget and resources of the survey project [1].

Questions

1. What is the purpose of electronic distance measurement (EDM)?

a) To determine the length between two points using electromagnetic waves.

b) To measure the angle between two points using digital instruments.

c) To calculate the area of a surveying project.

d) To record and analyze environmental factors affecting measurements.

Answer: a) To determine the length between two points using electromagnetic waves.

2. Which of the following is NOT a type of instrument used for electronic distance measurement?

a) Microwave Instruments

b) Infrared Wave Instruments

c) Ultraviolet Wave Instruments

d) Visible Light Wave Instruments

Answer: c) Ultraviolet Wave Instruments

3. What is the advantage of using electronic distance measurement (EDM) over other measuring methods?

a) High accuracy

b) Faster field work

c) Reduced errors

d) All of the above

Answer: d) All of the above

4. Which category of errors in EDM is caused by imperfections or malfunctions of the instrument?

a) Instrumental errors

b) Personal errors

c) Natural errors

d) Environmental errors

Answer: a) Instrumental errors

5. What is the purpose of measuring a known distance with the instrument in EDM?

a) To determine the accuracy requirement

b) To calculate the scale error

c) To minimize alignment error

d) To apply correction factors to subsequent measurements

Answer: d) To apply correction factors to subsequent measurements

6. Which type of error in EDM is caused by the misalignment of the instrument or the reflector?

a) Instrument constant error

b) Scale error

c) Cyclic error

d) Alignment error

Answer: d) Alignment error

7. Which type of error in EDM is caused by the bending of the signal due to variations in air density, temperature, pressure, and humidity?

a) Instrument constant error

b) Scale error

c) Atmospheric refraction

d) Atmospheric absorption

Answer: c) Atmospheric refraction

8. The distance covered by the wave in EDM is calculated using which formula?

a) $D = n\lambda + \Delta\lambda$

b) $f = c / \lambda = 1 / T$

c) $2D = n\lambda + \Delta\lambda$

d) $D = cT$

Answer: c) $2D = n\lambda + \Delta\lambda$

9. Which factor does the selection of an EDM instrument depend on?

a) Accuracy requirement

b) Distance range

c) Cost and availability

d) All of the above

Answer: d) All of the above

10. What is the purpose of using reflectors in EDM measurements?

a) To enhance the signal strength

b) To compensate for atmospheric conditions

c) To minimize instrumental errors

d) To measure the accuracy requirement

Answer: a) To enhance the signal strength

Angular Measurement

Prismatic Compass

A prismatic compass is a type of magnetic compass that is used for navigation and surveying purposes. It is designed to measure the bearing of a line or an object with respect to the magnetic north.

It consists of a circular metal box with a glass top, a magnetic needle, a graduated ring, a prism, and two vanes. Here are some features and functions of a prismatic compass:

- The metal box protects the compass from dust, rain, and shock. It also has a tripod socket at the bottom for mounting the compass on a stand.

- The magnetic needle is balanced on a pivot at the center of the box. It has two ends that point towards the magnetic north and south poles when freely suspended. The needle can be lifted from the pivot by a lifting pin and lever mechanism to prevent damage when not in use.

- The graduated ring is fixed to the magnetic needle and rotates with it. It has markings from 0° to 360° in clockwise direction. The ring is divided into four quadrants: NE, SE, SW, and NW. Each quadrant has 90° and each degree has 20 divisions. The smallest division is equal to 3 minutes.

- The prism is attached to the box by a hinge and can be moved up and down by a sliding arrangement. It has two faces: one is perpendicular to the line of sight and the other is inclined at an angle of 45° to it. The prism acts as a reflector and a magnifier for reading the graduated ring.

- The vanes are two vertical plates fixed to the box at opposite sides. One is called the eye vane and the other is called the object vane. The eye vane has a slit and a hairline for sighting the object. The object vane has an open sight or a peep hole for aligning with the eye vane.

To use the prismatic compass, the user has to hold it in hand or mount it on a tripod stand. Then, the user has to adjust the prism so that it is close to the eye and parallel to the eye vane. Next, the user has to align the object vane with the object whose bearing is to be measured. Finally, the user has to look through the slit of the eye vane and read the bearing from the graduated ring through the prism.

A prismatic compass has some advantages and disadvantages over other types of compasses. Some of the advantages are:

- It is simple, portable, and easy to use.

- It allows simultaneous sighting and reading of bearings.

- It has a high accuracy of up to 10 minutes.

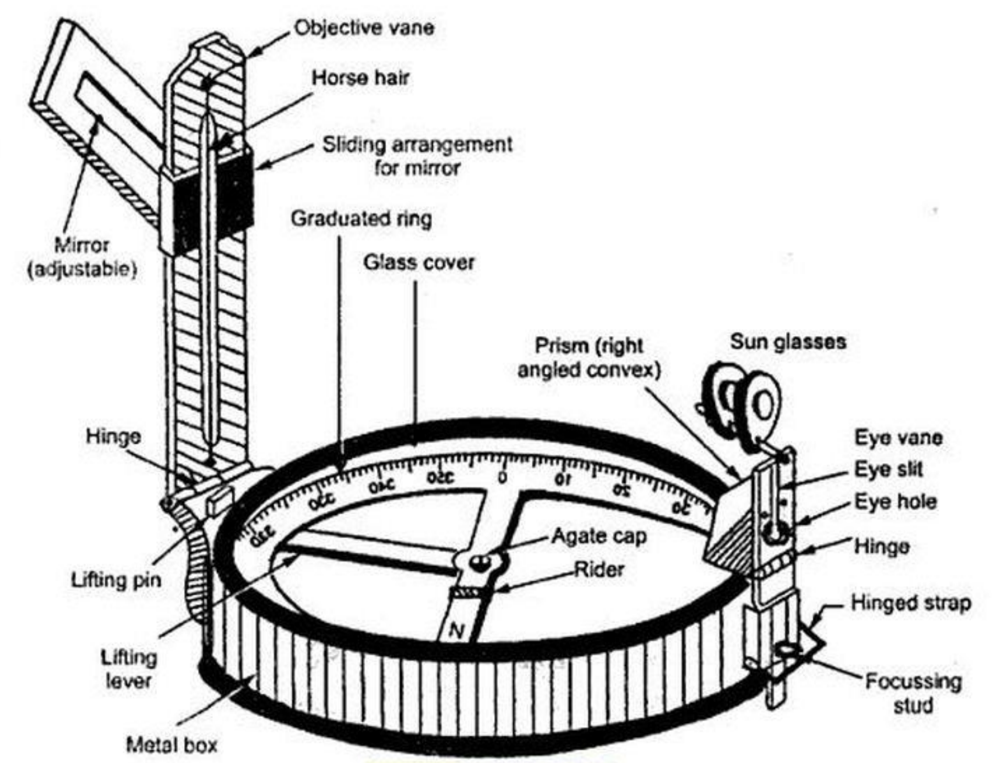
- It can be used for both direct and indirect methods of surveying.

Some of the disadvantages are:

- It is affected by local attraction, which is the deviation of the magnetic needle due to nearby magnetic substances or electric currents.

- It is affected by atmospheric refraction, which is the bending of light rays due to variations in air density, temperature, pressure, and humidity.

- It requires frequent adjustments and corrections for errors.



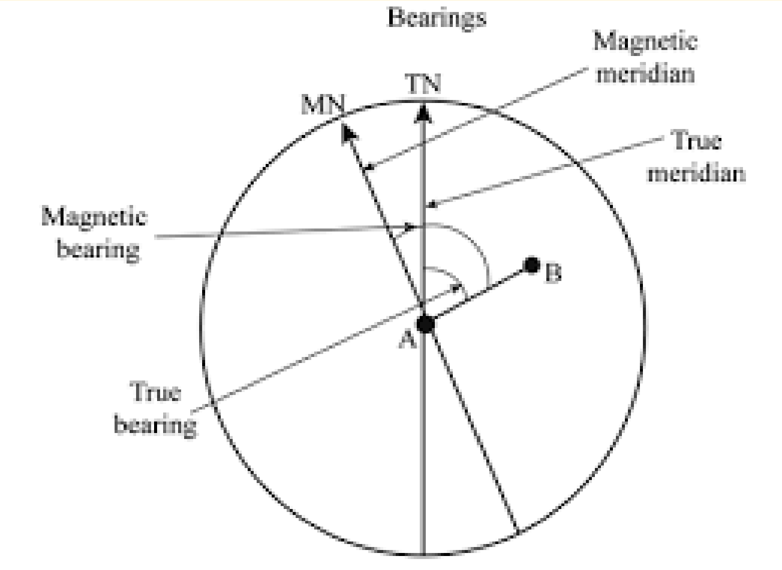
Prismatic compass parts

Bearing of Line

Bearing of a line is the angle that the line makes with a reference direction, usually north. Bearings are measured in degrees, from 0 to 360, clockwise from the reference direction. Bearings can be either true or magnetic bearings.

-**True bearing** of a line is the angle measured clockwise from true north, which is the direction of the geographic north pole. True bearings are used to measure the orientation of a line relative to some fixed point or object on the earth's surface. True bearings are also called azimuths.

- **Magnetic bearing** of a line is the angle formed by that line and magnetic north, which is the direction of the magnetic north pole. Magnetic bearings are used to measure the direction of a line using a magnetic compass or a similar device. Magnetic bearings are affected by local attraction, which is the deviation of the magnetic needle due to nearby magnetic substances or electric currents.



These are two different systems of measuring the direction of a line or an object with respect to the magnetic north.

The whole circle bearing is the angle measured clockwise from the magnetic north to the line or object. The value of the whole circle bearing ranges from 0° to 360°. For example, if a line makes an angle of 45° with the magnetic north in the clockwise direction, its whole circle bearing is 45°.

The Quadrantal bearing, also known as reduced bearing, is the angle measured either eastward or westward from the magnetic north or south, whichever is closer to the line or object. The value of the quadrantal bearing ranges from 0° to 90°.

To convert from whole circle bearing to quadrantal bearing: -

- If the whole circle bearing is less than 90°, then the quadrantal bearing is N (whole circle bearing) E.

- If the whole circle bearing is between 90° and 180°, then the quadrantal bearing is S (180° - whole circle bearing) E.

- If the whole circle bearing is between 180° and 270°, then the quadrantal bearing is S (whole circle bearing - 180°) W.

- If the whole circle bearing is between 270° and 360°, then the quadrantal bearing is N (360° - whole circle bearing) W.

To convert from quadrantal bearing to whole circle bearing: -

- If the quadrantal bearing is N(angle)E, then the whole circle bearing is (angle).

- If the quadrantal bearing is S(angle)E, then the whole circle bearing is 180° - (angle).

- If the quadrantal bearing is S(angle)W, then the whole circle bearing is 180° + (angle).

- If the quadrantal bearing is N(angle)W, then the whole circle bearing is 360° - (angle).

Magnetic Declination

Magnetic declination is the angle between magnetic north and true north on the horizontal plane. It is not constant and varies depending on the location and time on the Earth's surface. We use the lowercase Greek letter δ (delta) as the symbol for magnetic declination and we also call it magnetic variation.

The relationship between true bearing and magnetic bearing of a line or an object can be expressed by the following formula:

True bearing = magnetic bearing ± declination (δ)

The sign of the declination depends on whether magnetic north is east or west of true north. By convention, declination is positive when magnetic north is east of true north, and negative when it is west.

Questions

1)If the magnetic bearing of a line is 120° and the magnetic declination is 10°E, what is the true bearing of the line?

Ans:

True bearing = magnetic bearing ± declination

True bearing = 120° - 10°

True bearing = 110°

2) If the true bearing of a line is 270° and the magnetic declination is 15°W, what is the magnetic bearing of the line?

Ans:

True bearing = magnetic bearing ± declination

Magnetic bearing = true bearing + declination

Magnetic bearing = 270° + 15°

Magnetic bearing = 285°

3) If the magnetic declination at a place is 5°W in 2020 and it changes by 0.1°E per year, what will be the magnetic declination at that place in 2025?

Ans:

Magnetic declination = initial declination + rate of change × time

Magnetic declination = 5°W + 0.1°E × 5 years

Magnetic declination = 5°W + 0.5°E

Magnetic declination = 4.5°W

4) If the magnetic declination at a place is 12°E in January and it varies sinusoidally with an amplitude of 2° and a period of 12 months, what will be the magnetic declination at that place in July?

Ans:

Magnetic declination = mean declination + amplitude × sin (2π × time / period)

Magnetic declination = 12°E + 2° × sin (2π × 6 / 12)

Magnetic declination = 12°E + 2° × sin(π)

Magnetic declination = 12°E + 0°

Magnetic declination = 12°E

5) Convert the whole circle bearing 210° to a quadrantal bearing.

a) 30°

b) 180°

c) 270°

d) 360°

Ans: To convert a quadrantal bearing to a whole circle bearing, we subtract 180° to the whole circle bearing.

Quadrantal bearing:210° - 180° = 30°

So Quadrantal bearing= S 30° W

Miners' dials and other compass instruments

A miner’s dial is a type of surveying instrument that was used by underground miners to measure and set out angles and determine magnetic north. It consists of a magnetic compass surrounded by a graduated circle, and it has fixed sights and spirit levels. It is mounted on a tripod stand and has a circular cover to protect it from dust and moisture. A miner’s dial is also known as a circumferentor1.

A miner’s dial was an essential tool for mining engineers and surveyors, who needed to plan and monitor the direction of the mine shafts and tunnels. By using the miner’s dial, they could map out the underground layout of the mine and calculate the distance, depth, and elevation of different points. The miner’s dial also helped them to avoid obstacles and hazards, such as water, gas, or faults.

There are different types of miners’ dials that were used in mines, depending on the purpose and the accuracy required. Some of the common types are:

Plain dial: This is the simplest type of miner’s dial, which consists of a magnetic compass with a graduated circle and a pair of sights. It is used for rough surveys and setting out directions. It has no spirit levels or tripod stand, and it is usually held by hand or placed on a wooden block.

Improved dial: This is a more accurate type of miner’s dial, which has a spirit level attached to the compass box and a tripod stand for stability. It also has a vernier scale for reading smaller divisions of the circle. It is used for more precise surveys and measurements.

Theodolite dial: This is the most advanced type of miner’s dial, which has two spirit levels at right angles to each other and a telescope instead of sights. It also has a vertical circle for measuring angles of elevation and depression. It is used for trigonometric surveys and calculations.

Dialing

Dialing in mines performed by surveyor is a process of measuring and setting out angles and directions in underground mining operations. It involves using a special instrument called a dial, which is a type of compass with a graduated circle and sights. The dial helps the surveyor to determine the magnetic north and the horizontal angle of any line in the mine. The dial also helps the surveyor to map out the layout of the mine and to avoid any obstacles or hazards.

Dialing steps: -

1. The surveyor first sets up the tripod stand over a fixed point in the mine, such as a peg or a nail.
2. The surveyor then levels the box using the spirit levels attached to it.
3. The surveyor then opens the cover and observes the needle pointing to the magnetic north.
4. The surveyor then rotates the box until one of the sights is aligned with the line to be measured.
5. The surveyor then reads the angle from the graduated circle, which is called the bearing or azimuth of the line.
6. The surveyor then repeats this process for other lines in the mine.

The dial is a simple but useful instrument for mining surveying. However, it has some limitations and sources of error.

For example,

- The dial can be affected by magnetic interference from iron tools or ore deposits in the mine, which can cause the needle to deviate from the true north.
- The dial can also be affected by mechanical wear and tear, which can cause errors in reading or setting out angles.
- The dial can also be affected by human errors, such as misreading or mis-recording angles.

Loose and fast needle surveying

Loose and fast needle surveying are two methods of traversing, which is a technique of measuring and setting out angles and directions in underground mining operations. They both use a special instrument called a dial, which is a type of compass with a graduated circle and sights. The dial helps the surveyor to determine the magnetic north and the horizontal angle of any line in the mine. The dial also helps the surveyor to map out the layout of the mine and to avoid any obstacles or hazards.

The main difference between loose and fast needle surveying is how they measure the magnetic bearings of the traverse lines. A magnetic bearing is the angle between the magnetic north and the direction of a line. The magnetic north is the direction that a compass needle points to, which is not the same as the true north (the direction of the geographic north pole).

Loose needle surveying

The steps involved in the loose needle method are as follows[1]:

- The surveyor sets up the dial over a fixed point in the mine, such as a peg or a nail, and levels it using the spirit levels attached to it.

- The surveyor opens the cover of the dial and observes the needle pointing to the magnetic north. The surveyor then rotates the box until one of the sights is aligned with the line to be measured. The surveyor then reads the angle from the graduated circle, which is called the bearing or azimuth of the line.

- The surveyor then moves to the next station along the line and repeats the process. The surveyor measures the bearing of each line independently by establishing the direction of the magnetic meridian at each station.

- The surveyor records all the readings in a field book, along with the linear measurements taken with a chain or a tape. The surveyor also notes any local attraction or magnetic interference that may affect the accuracy of the readings.

- The surveyor then calculates the errors due to local attraction and compensates them by applying corrections to the bearings. The surveyor also checks for any mistakes or discrepancies in the readings by comparing them with the included angles (the angles between adjacent lines).

- The surveyor then plots the traverse on a map using a protractor and a scale. The surveyor also calculates the coordinates of each station using trigonometry or geometry.

The loose needle method is simple but not very accurate, as it can be affected by magnetic variation, mechanical wear and tear, and human errors. Therefore, it is usually used for rough surveys and setting out directions. For more precise surveys and measurements, a more advanced method called fast needle method is used, which involves measuring only one magnetic bearing and using a more accurate instrument called a theodolite.

Fast needle surveying

The steps involved in the fast needle method are as follows[1]:

- The surveyor sets up the dial over a fixed point in the mine, such as a peg or a nail, and levels it using the spirit levels attached to it.

- The surveyor opens the cover of the dial and observes the needle pointing to the magnetic north. The surveyor then rotates the box until one of the sights is aligned with the first line to be measured. The surveyor then reads the angle from the graduated circle, which is called the bearing or azimuth of the first line. This is the only line whose magnetic bearing is measured by the compass.

- The surveyor then moves to the next station along the line and sets up the dial again. The surveyor then rotates the box until one of the sights is aligned with the previous line. The surveyor then transits (reverses) the dial, which means turning it 180 degrees around its vertical axis. The surveyor then aligns the other sight with the next line to be measured. The surveyor then reads the angle from the graduated circle, which is called the included angle (the angle between adjacent lines). This is repeated for all other lines in the traverse, except for the last one.

- The surveyor records all the readings in a field book, along with the linear measurements taken with a chain or a tape. The surveyor also notes any local attraction or magnetic interference that may affect the accuracy of the readings.

- The surveyor then calculates the errors due to local attraction and compensates them by applying corrections to the bearings. The surveyor also checks for any mistakes or discrepancies in the readings by comparing them with the closing error (the difference between the sum of included angles and 360 degrees for a closed traverse).

- The surveyor then plots the traverse on a map using a protractor and a scale. The surveyor also calculates the coordinates of each station using trigonometry or geometry.

The fast needle method is more accurate and reliable than the loose needle method, as it reduces the errors due to magnetic variation, mechanical wear and tear, and human errors. Therefore, it is usually used for precise surveys and measurements.

Questions

1. What is the purpose of a miner's dial?

a) To measure and set out angles and determine magnetic north in underground mining operations.

b) To calculate the distance, depth, and elevation of different points in a mine.

c) To map out the layout of the mine and avoid obstacles and hazards.

d) All of the above.

Answer: d) All of the above.

2. Which type of miner's dial is the simplest and used for rough surveys and setting out directions?

a) Plain dial

b) Improved dial

c) Theodolite dial

d) None of the above.

Answer: a) Plain dial.

3. What is the purpose of dialing in mines?

a) To determine the magnetic north and horizontal angle of any line in the mine.

b) To map out the layout of the mine and avoid obstacles and hazards.

c) To measure and set out angles and directions in underground mining operations.

d) All of the above.

Answer: d) All of the above.

4. What are the steps involved in dialing using the loose needle method?

a) Set up the dial, observe the needle pointing to magnetic north, rotate the box, read the angle, repeat for other lines.

b) Set up the dial, level it, observe the needle pointing to magnetic north, rotate the box, read the angle, repeat for other lines.

c) Set up the dial, level it, observe the needle pointing to magnetic north, rotate the box, read the angle, record the readings.

d) Set up the dial, level it, observe the needle pointing to magnetic north, rotate the box, read the angle, calculate the errors.

Answer: b) Set up the dial, level it, observe the needle pointing to magnetic north, rotate the box, read the angle, repeat for other lines.

5. Which method of surveying is more accurate and precise?

a) Loose needle surveying

b) Fast needle surveying

c) Both methods have the same level of accuracy.

d) It depends on the type of mine and surveying requirements.

Answer: b) Fast needle surveying.

6. What is the purpose of transiting the dial in the fast needle method?

a) To align the sights with the next line to be measured.

b) To reverse the dial and align the sights with the previous line.

c) To calculate the errors due to local attraction.

d) To check for mistakes or discrepancies in the readings.

Answer: b) To reverse the dial and align the sights with the previous line.

7. Which type of surveying method involves measuring only one magnetic bearing?

a) Loose needle surveying

b) Fast needle surveying

c) Both methods involve measuring multiple magnetic bearings.

d) It depends on the type of mine and surveying requirements.

Answer: b) Fast needle surveying.

8. What is the purpose of calculating the closing error in the fast needle method?

a) To determine the linear measurements taken with a chain or tape.

b) To compensate for errors due to local attraction.

c) To check for mistakes or discrepancies in the readings.

d) To plot the traverse on a map using a protractor and scale.

Answer: c) To check for mistakes or discrepancies in the readings.

9. Which type of miner's dial is used for trigonometric surveys and calculations?

a) Plain dial

b) Improved dial

c) Theodolite dial

d) None of the above.

Answer: c) Theodolite dial.

10. What are some limitations and sources of error in using a miner's dial?

a) Magnetic interference, mechanical wear and tear, and human errors.

b) Atmospheric conditions, alignment errors, and reading errors.

c) Instrumental errors, personal errors, and natural errors.

d) All of the above.

Answer: a) Magnetic interference, mechanical wear and tear, and human errors.

Total Station

Total stations are the primary survey instrument used in mining surveying.

A total station is used to record the absolute location of the tunnel walls, ceilings (backs), and floors as the drifts of an underground mine are driven. The recorded data are then downloaded into a CAD program, and compared to the designed layout of the tunnel.

The survey party installs control stations at regular intervals. These are small steel plugs installed in pairs in holes drilled into walls or the back. For wall stations, two plugs are installed in opposite walls, forming a line perpendicular to the drift. For back stations, two plugs are installed in the back, forming a line parallel to the drift.

A set of plugs can be used to locate the total station set up in a drift or tunnel by processing measurements to the plugs by intersection and resection.

A total station is an electronic theodolite that measures angles and distances between points. It's the most advanced surveying instrument today, capable of measuring horizontal and vertical angles to ±3 seconds.

A total station has two associated devices used during surveying: a digital distance meter which measures distance, and an angle sensor or right-angle optical prism, which measures the horizontal or vertical angle.

Like the word "total" means, this instrument can do many measurements; a Total Station is a telescope mounted on wheels or a tripod. It can measure distances and angles between lines, heights of points on an object, area and volume of an object from its sides, slope angle between two directions on the ground, etc.

Types of total station

For total surveying stations, there are different types of full stations. The most popular form is a total handheld station, available with an internal or external antenna and for photogrammetric processing.

Another type is the mobile station attached to a motorized platform that gives it mobility. Lastly, the fixed station is mounted on a tripod and provides continuous service from a stationary point.

As per Trimble Geospatial, there are the following four types of Total Stations;

- Scanning Total Stations
- Robotic Total Stations
- Autolock Total Stations
- Total Mechanical Stations

Working principle of the total station in surveying

The entire station allows surveyors to create a map of a spot in three instead of two dimensions, as was generally the case with surveying instruments.

The term 1–Point reflects this capability; each point that a full surveying method measures is considered one dimension and describes an independent position on the ground. A total station has high accuracy and range due to its lenses, adjustable vertical laser levels, and bubble axes.

A total station is a tool used for surveying. The equipment heavily relies on geo-radar and time signals to calculate the levels and distances of points it is set over.

The measurement of heights or portions of objects is done by the prism used to determine the angles partaking in triangulation and rapid positioning.

The application of the total station in surveying covers a vast range of activities related to engineering and construction.

Function

Angle measurement

Most total station instruments measure angles by means of electro-optical scanning of extremely precise digital bar-codes etched on rotating glass cylinders or discs within the instrument. The best quality total stations are capable of measuring angles to 0.5 arc-second. Inexpensive "construction grade" total stations can generally measure angles to 5 or 10 arc-seconds.

Distance measurement

Measurement of distance is accomplished with a modulated infrared carrier signal, generated by a small solid-state emitter within the instrument's optical path, and reflected by a prism reflector or the object under survey. The modulation pattern in the returning signal is read and interpreted by the computer in the total station. The distance is determined by emitting and receiving multiple frequencies, and determining the integer number of wavelengths to the target for each frequency. Most total stations use purpose-built glass prism (surveying) reflectors for the EDM signal. A typical total station can measure distances up to 1,500 meters (4,900 ft) with an accuracy of about 1.5 millimeters (0.059 in) ± 2 parts per million.

Reflectorless total stations can measure distances to any object that is reasonably light in color, up to a few hundred meters.

Coordinate measurement

The coordinates of an unknown point relative to a known coordinate can be determined using the total station as long as a direct line of sight can be established between the two points. Angles and distances are measured from the total station to points under survey, and the coordinates (X, Y, and Z; or easting, northing, and elevation) of surveyed points relative to the total station position are calculated using trigonometry and triangulation.

To determine an absolute location, a total station requires line of sight observations and can be set up over a known point or with line of sight to 2 or more points with known location, called free stationing.

For this reason, some total stations also have a Global Navigation Satellite System receiver and do not require a direct line of sight to determine coordinates. However, GNSS measurements may require longer occupation periods and offer relatively poor accuracy in the vertical axis.

Data processing

Some models include internal electronic data storage to record distance, horizontal angle, and vertical angle measured, while other models are equipped to write these measurements to an external data collector, such as a hand-held computer.

When data is downloaded from a total station onto a computer, application software can be used to compute results and generate a map of the surveyed area. The newest generation of total stations can also show the map on the touch-screen of the instrument immediately after measuring the points.

Errors in Total Station

A total station is subject to various errors that can affect the quality and reliability of the measurements. These errors can be classified into three categories: instrumental errors, natural errors, and personal errors:

Instrumental errors are caused by the imperfections or malfunctions of the instrument or its components, such as:

Circle eccentricity error: This is an error that arises when the center of the measuring circle does not coincide with the center of the mechanical axis of the instrument. It can be corrected by measuring in both faces (opposite sides of the circle) and using the mean as a result.

Horizontal collimation error: This is an error that arises when the optical axis of the instrument is not perpendicular to the telescope axis. It can be corrected by adjusting the collimation screws or using electronic calibration procedures.

Vertical index error: This is an error that arises when the vertical circle does not read zero when the telescope is horizontal. It can be corrected by adjusting the index screw or using electronic calibration procedures.

Tilt axis error: This is an error that arises when the tilt axis of the instrument is not perpendicular to the vertical axis. It can be corrected by adjusting the tilt axis screws or using electronic calibration procedures.

Prism constant error: This is an error that arises when the distance measured by the instrument does not match the actual distance due to the use of a prism as a reflector. It can be corrected by entering the prism constant value in the instrument settings or using electronic calibration procedures.

Natural errors are caused by the environmental factors that affect the propagation of light or electromagnetic waves, such as:

Atmospheric refraction error: This is an error that arises when the light or electromagnetic waves bend due to variations in air density, temperature, pressure, and humidity. It can be corrected by measuring and applying corrections for these atmospheric conditions or using instruments that compensate for them automatically.

Atmospheric absorption error: This is an error that arises when the light or electromagnetic waves lose intensity due to absorption by water vapor, dust, or other particles in the air. It can be corrected by using instruments that operate at wavelengths that are less affected by absorption or using reflectors that enhance the signal strength.

Earth curvature and refraction error: This is an error that arises when the light or electromagnetic waves deviate from a straight line due to the curvature of the Earth's surface and the refraction of the atmosphere. It can be corrected by applying a standard correction factor or using instruments that compensate for it automatically.

Personal errors are caused by the human factors involved in operating the instrument or interpreting the data, such as:

Sighting error: This is an error that arises when the instrument or the reflector is not properly aligned with the line of sight. It can be minimized by using optical devices such as telescopes or prisms to sight the object and by checking for consistency and reasonableness of the readings.

Reading error: This is an error that arises when the instrument display or the data recorder is not correctly read or recorded. It can be minimized by using digital displays or automatic recording devices and by checking for consistency and reasonableness of the readings.

Calculation error: This is an error that arises when the data is not correctly processed or analyzed. It can be minimized by using reliable software or methods and by checking for consistency and reasonableness of the results.

To ensure the accuracy and precision of the measurements, a total station needs to be properly adjusted and calibrated before and during use. Some of the common adjustments and calibrations are:

Centering: This is the process of placing the instrument over a known point on the ground and leveling it with a plumb bob or a laser plummet.

Leveling: This is the process of making the vertical axis of the instrument perpendicular to the horizontal plane using a circular level or a plate level.

Focusing: This is the process of adjusting the eyepiece and the objective lens of the telescope to obtain a clear image of the object.

Zero setting: This is the process of setting the horizontal and vertical circles to zero when the telescope is pointing to a reference direction, such as magnetic north or a known azimuth.

Compensation: This is the process of activating or checking the electronic devices that automatically correct for tilt axis error, atmospheric refraction error, earth curvature and refraction error, etc.

Calibration: This is the process of testing and correcting for instrumental errors, such as circle eccentricity error, horizontal collimation error, vertical index error, prism constant error, etc.

Application

A total station has many applications in various fields, such as:

- **Surveying**: A total station can be used to perform different types of surveys, such as topographic survey, cadastral survey, engineering survey, hydrographic survey, etc. It can measure distances, angles, coordinates, elevations, and slopes of points, lines, areas, and volumes on the ground or on a map.

- **Construction**: A total station can be used to perform different tasks in construction projects, such as setting out, layout, alignment, monitoring, quality control, etc. It can help to establish and verify the position, orientation, shape, size, and elevation of structures, such as buildings, bridges, roads, tunnels, etc.
- **Geodesy**: A total station can be used to perform different studies in geodesy, which is the science of measuring and representing the shape and gravity field of the Earth. It can help to determine geodetic coordinates, geoid heights, gravity anomalies,
- **Archaeology**: A total station can be used to perform different investigations in archaeology, which is the study of human history and culture through the analysis of material remains. It can help to document and map archaeological sites, features, and artifacts.
- **Forensics**: A total station can be used to perform different analyses in forensics, which is the application of scientific methods to solve legal problems. It can help to reconstruct crime scenes, accidents, or disasters by measuring and recording the location and orientation of evidence.

Solved Previous Year Questions

1. The base line is defined as

(1) The tie line joining two tie stations on chain line

(2) The longest line in the triangulation

(3) The shortest line in the triangulation

(4) The offset line drawn from the chain line

(5) None of the Options

Ans(2)
In surveying, a baseline is **a line between two points on the earth's surface and the direction and distance between them**. In a triangulation network, at least one baseline between two stations needs to be measured to calculate the size of the triangles by trigonometry. It is the longest line in the triangulations.

2. The straightness and accuracy of the any one of the following gives the accuracy of the whole chain surveying

(1) Straight line

(2) Base line

(3) Plotting line

(4) Check line

(5) Tie line

Ans(2)

Chain surveying is **the branch of surveying in which only linear measurements are made in the field**. This is suitable for the survey of small areas with simple details and an area that is fairly flat. It derives its name from the fact that the principle equipment commonly used is the chain. The accuracy and straightness of base line gives the accuracy of the whole chain surveying.

3. Which of these is not an instrument for measuring distances

Options:

(1) Chain

(2) Steel tape

(3) MetallicTape

(4) lnvar Tape

(5) Gyromat

Correction Answer : Option No.(5)

4. If the radius of a simple curve is R. the length of the chord for calculating offsets by the method of chords produced, should not exceed

(1) R/10

(2) R/15

(3) R/20

(4) R/25

(5) None of the Options

Ans(3)

Offset is the **perpendicular distance taken from either side of the chain line running in a particular direction**. The purpose of offset is to locate the objects which lie in the vicinity of the main survey line. If the radius of a simple curve is R, the length of the chord for calculating offsets by the method of chords produced, should not exceed. **R/20.**

5. Number of links per metre length of a chain are

(1) 2

(2) 5

(3) 8

(4) 10

(5) None of the Options

Ans(2)

Metric chains are available in 5 m, 10 m, 20 m, and 30 m.

In the metric chain for 1 m length 5 links are present.

For 30 m metric chain, Number of links = 30 × 5 = **150 links**

Following are the various types of chain in common use in surveying:

Type	Length	No. of links	Length of one link
Metric chain	**20 m or 30 m**	**100 or 150**	**20 cm**
Engineering chain	100 ft	100	1 ft
Gunter chain	66 ft	100	0.66 ft
Revenue chain	33 ft	16	$2\frac{1}{16}$

6. If a 30 m chain diverges through a perpendicular distance d from its correct alignment, the error in length, is

(1) $d^2/60$

(2) d^2/so

(3) d/30

(4) d/60

(5) None of the Options

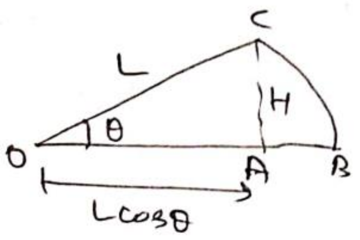
Ans(1)

required error in length

$= AB$

$= \frac{H^2}{2L}$ [formula]

$= \frac{d^2}{2 \times 30} = \frac{d^2}{60}$ Answer



7. When total station is sighted to the target, which of the operations acts first

a) Rotation of optical axis
b) Rotation of vertical axis
c) Rotation of horizontal axis
d) Rotation of line of collimation
e) None of these

Ans A

A Total Station is **a modern surveying instrument that integrates an electronic theodolite with an electronic distance meter**. A theodolite uses a movable telescope to measure angles in both the horizontal and vertical planes. At the time of sighting the instrument towards the target, first step involves the **rotation of the instrument's optical axis from the instrument north in horizontal plane**.

8. Modern EDM uses which among the following waves

a) Visible rays
b) Thermal infra- red
c) Modulated infra-red
d) Radio waves
e) None of these

Ans C

The **electronic distance meter (EDM) is an essential surveying tool**. The principle of operation is the same among various EDM devices such as the stand alone EDM device, the theodolite mounted EDM unit and the coaxial design integrated with a total station. Modern EDM uses the **modulated infra-red waves**, which are capable of receiving the reflected waves from a distance of 100km.

9. Remote elevation measurement of Total station used for

a) objects which are nearer

b) objects which are too far and not visible
c) object which are too far, visible and accessible
d) visible and inaccessible objects where it is difficult
e) none of the options

Ans D

The process of finding the height of objects without actually going to the top of the object is known as Remote Elevation Measuring (REM) i.e., a total station placed remotely (faraway) from the object is used to measure the heights.

10. Which of the following indicates the correct set of the combination of total station

a) Theodolite, compass
b) Theodolite, EDM
c) Electronic theodolite, EDM
d) EDM, GPS
e) GPS

Ans C

Concept:

A total station, also known as an electronic tachometer, is an optical instrument.

It is a combination of an electronic theodolite for measuring **horizontal and vertical angles**, an electromagnetic distance measurement (EDM) device for measurement of **slop distances,** and onboard software to convert the raw observed data to three-dimensional coordinates.

Thus with a total station, one may determine the actual positions (X, Y, and Z or northing, easting, and elevation of surveyed points or the position of the instrument from known points in absolute terms. Further, the EDM that measures the slop distance can calculate and display horizontal distance and difference in level.

This is accomplished with the help of a microprocessor normally working concentric with the telescope eyepiece and generally housed in a casting that forms part of the telescope.

11. Modern EDM uses which among the following waves :

a) Visible rays
b) Thermal infra-red
c) Modulated infra-red
d) Radio waves
e) None of these

Ans C

Modern EDM uses which among the following waves? Explanation: Modern EDM uses the **modulated infra-red waves**, which are capable of receiving the reflected waves from a distance of 100km.

12. Which of the following represents the correct sequences for the basis of EDM propagation.

a) Propagation, generation, reflection and reception
b) Generation, reception, reflection and propagation
c) Generation, propagation, reception and reflection

d) Generation, propagation, reflection and reception
e) None of these

Ans D

The creation, propagation, reflection, and later reception of electromagnetic waves are used in the electronic distance measurement method. The type of electromagnetic waves produced is determined by a number of elements, the most important of which is the nature of the electrical signal used to generate the waves. It continues in the above-mentioned order with no interruptions.

13. For ranging a line, the number of ranging rods required is

(1) At least two

(2) At least three

(3) At least four

(4) At least five

(5) At least one

Ans(2)

If the length of the line is greater, the survey lines have to be divided by certain intermediate points, before conducting the chaining process. This process is called ranging. For ranging a line, the minimum number of ranging rods required is three.

14. Which kind of EDM has operability in fog or moderate rain, day and right as well as longer range?

a) Microwave instruments
b) Inferred instruments
c) Electro-optical instruments
d) Modulation instruments
e) None of the above

Ans A

Types of EDM Instruments:

Depending on the types of carrier wave employed, EDM instruments can be classified under the following three heads :

- Microwave Instruments
- Infrared Instruments
- Visible Light Instruments

1. Microwave Instruments:

- These instruments make use of microwaves. Such instruments were invented as early as 1950 in South Africa by Dr. T.L. Wadley and named them as Tellurometers.
- The instrument needs only 12 to 24 V batteries. Hence they are light and highly portable.
- Tellurometers can be used in day as well as in night.
- **The range of these instruments is up to 100 km.**

2. Infrared Wave Instruments:

- In this instrument amplitude modulated infrared waves are used. Prism reflectors are used at the end of line to be measured.
- These instruments are light and economical and can be mounted on theodolite. With these instruments accuracy achieved is ± 10 mm.
- **The range of these instruments is up to 3 km.**

3. Visible Light Wave Instruments:

- These instruments rely on propagation of modulated light waves. This type of instrument was first developed in Sweden and was named as Geodimeter.
- **During night its range is up to 2.5 km while in day its range is up to 3 km.**

15. The distance between two points A & B was measured with EDM. Find out the distance between A & B.

Given : Wave length (A) = 30 m, no. of complete wave cycle (n) = 20. (α1= 0^0 and α 2= 90^0)

(1) 303.75 m

(2) 607.50 m

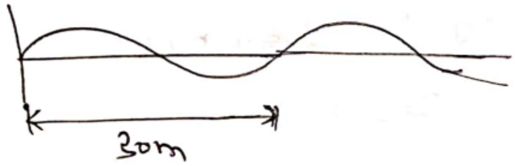
(3) 600 m

(4) 300 m

(5) None 0fthe Options

Ans(1)

Totae distance
Covered by
wave



$= 30 \times 20$

$= 600m$

From $\alpha_1 = 0°$ to $\alpha_2 = 90°$,

length $= \frac{1}{4} \times 30 = 7.5m$

$\therefore d$ = total distance $= 600 + 7.5 = 607.5m$

$\therefore$ Since wave goes and return from target,

$\therefore$ Distance b/w A & B $= \frac{607.5}{2} = 303.75m$

Levelling

What Is Leveling?

Levelling or leveling is a branch of surveying, the object of which is to establish or verify or measure the height of specified points relative to a datum. It is widely used in cartography to measure geodetic height, and in construction to measure height differences of construction artifacts. Leveling is the general term applied to any of the various processes by which elevations of points or differences in elevation are determined.

Levelling Terms

- **Vertical line:** A line that follows the local direction of gravity as indicated by a plumb line.
- **Level surface:** A curved surface that, at every point is perpendicular to the local plumb line (the direction in which gravity acts).
- **Level line:** A line lying in a level surface is a level line. It is thus a curved line normal to the plumb at all points. In field surveying, it is defined by the direction of a freely suspended plumb-bob.
- **Horizontal plane:** A plane perpendicular to the local direction of gravity. In plane surveying, it is a plane perpendicular to the local vertical line.
- **Horizontal line:** A line in a horizontal plane. In plane surveying, it is a line perpendicular to the local vertical.
- **Vertical datum:** Any level surface to which elevations are referenced. This is the surface that is arbitrarily assigned an elevation of zero.
- **Elevation:** The distance measured along a vertical line from a vertical datum to a point or object.
- **Benchmark (BM):** A relatively permanent object, natural or artificial, having a marked point whose elevation above or below a reference datum is known or assumed.
- **Station:** A point where the leveling staff is kept.
- Height of instrument: It is the elevation of the plane of sight with respect to assumed datum. It is also known as plane of collimation.
- **Back sight (BS):** It is the sight taken on the level staff, of a known elevation with the intention to obtain the elevation of plane of collimation. It is called PLUS sight because it is added to elevation of that point to get height of instrument or plane of collimation.
- **Intermediate sights (IS):** These are the sight taken after back sight and before sighting the final point. These are called MINUS sights. These are subtracted from plane of collimation to find the reduced level of different points.
- **Fore sight (FS):** The last reading taken from the instrument. This is also a MINUS sight.

- **Change point (CP) or turning point(TP):** The point at which both BS and FS are taken.
- **Reduced level (RL):** The elevations of the points with respect to assumed datum.

Types of Leveling in Surveying

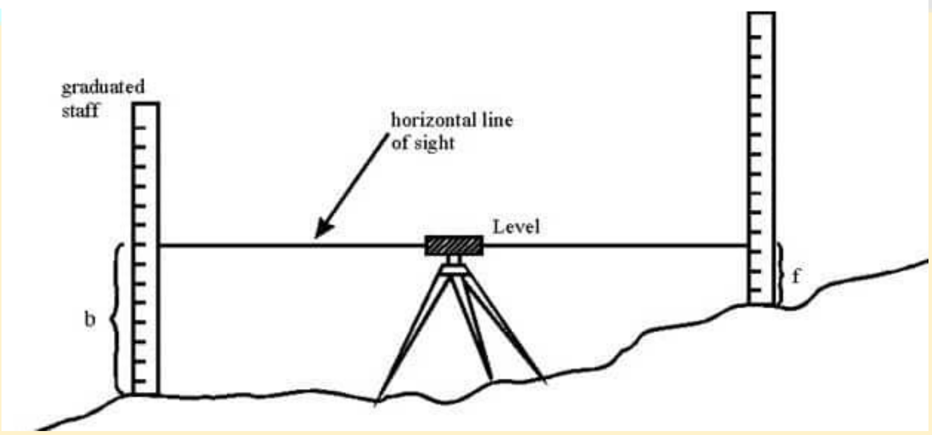
- Direct leveling
- Trigonometric leveling
- Barometric leveling
- Stadia leveling

Direct Leveling

It is the most commonly used method of leveling. In this method, measurements are observed directly from leveling instrument. Based on the observation points and instrument positions direct leveling is divided into different types as follows:

- Simple leveling/geometric leveling
- Physical leveling
- Differential leveling
- Fly leveling
- Profile leveling
- Precise leveling
- Reciprocal leveling

Simple Leveling/geometric leveling: It is a simple and basic form of leveling in which the leveling instrument is placed between the points at which elevation is to be find. Leveling rods are placed at those points and sighted them through leveling instrument. It is performed only when the points are nearer to each other without any obstacles.

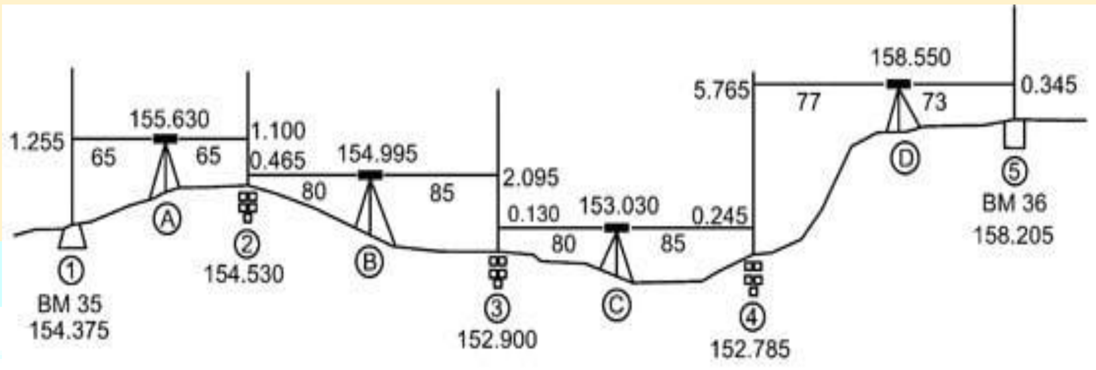


Physical Leveling: Physical levelling in survey is a term that is sometimes used to refer to geometric levelling, which is a method of determining the elevation or height difference of points on the earth's surface relative to a reference datum. It involves using a level instrument, which is a device that can produce a horizontal line of sight, and a level staff, which is a graduated rod that can be read by the level instrument. The level instrument is usually mounted on a tripod and can be adjusted to make it horizontal using a spirit level or an automatic compensator. The level staff is held vertically on the point whose elevation is to be measured or set.

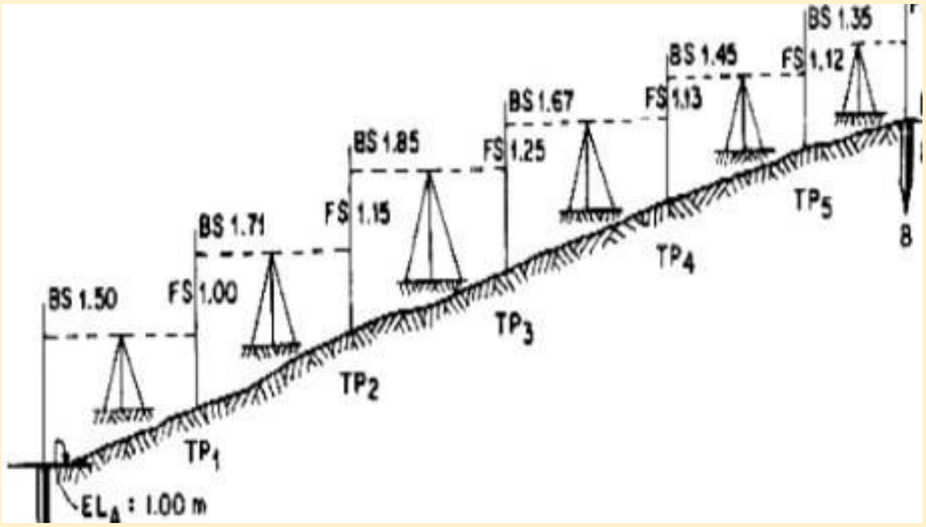
Physical levelling in survey can be done in two ways: simple levelling and differential levelling. Simple levelling is used to determine or set the elevation of a single point with respect to a known datum. Differential levelling is used to determine or set the elevation of several points with respect to a known datum by using intermediate points along the way.

Physical levelling in survey is a reliable and accurate method for measuring height differences, but it can be slow and laborious. It can also be affected by errors due to refraction, curvature, collimation, temperature, etc. Therefore, it requires careful observation and correction to ensure high precision.

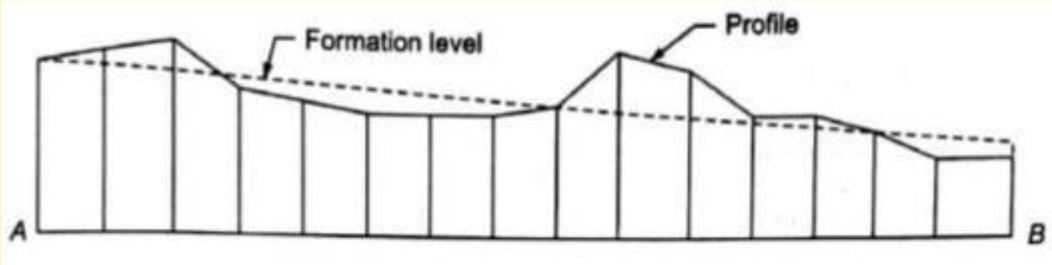
Differential Leveling: Differential leveling is performed when the distance between two points is more. In this process, the number of inter stations are located and instrument is shifted to each station and observed the elevation of inter station points. Finally the difference between original two points is determined.



Fly Leveling: Fly leveling is conducted when the benchmark is very far from the workstation. In such a case, a temporary benchmark is located at the workstation which is located based on the original benchmark. Even if it is not highly precise it is used for determining the approximate level.

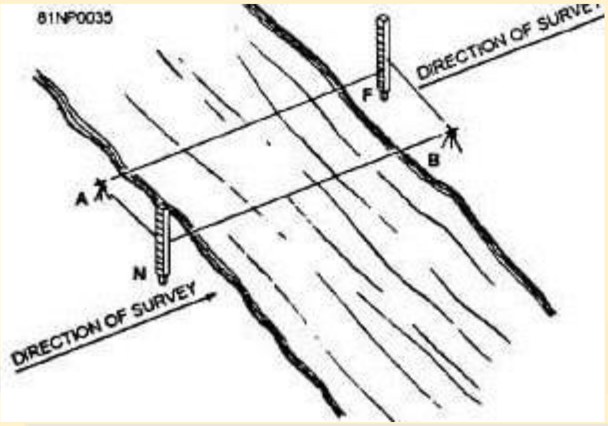


Profile Leveling: Profile leveling is generally adopted to find elevation of points along a line such as for road, rails, or rivers etc. In this case, readings of intermediate stations are taken, and reduced level of each station is found. From this cross section of the alignment is drawn.



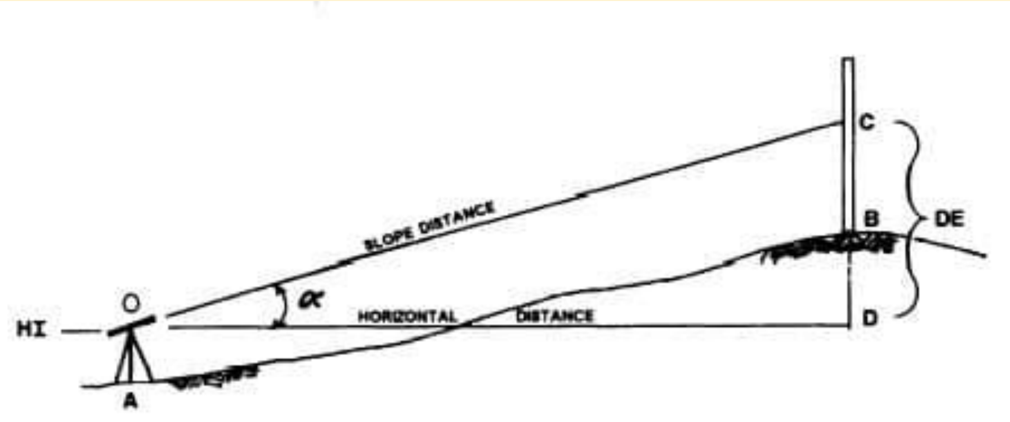
Precise Leveling: Precise leveling is similar to differential leveling but, in this case, higher precise is wanted. To achieve high precision, serious observation procedure is performed. The accuracy of 1 mm per 1 km is achieved.

Reciprocal Leveling: When it is not possible to locate the leveling instrument in between the inter visible points, reciprocal leveling is performed. This case appears in case of ponds or rivers etc. in case of reciprocal leveling, instrument is set nearer to 1st station and sighted towards 2nd station.



Trigonometric Leveling

The process of leveling in which the elevation of point or the difference between points is measured from the observed horizontal distances and vertical angles in the field is called trigonometric leveling.

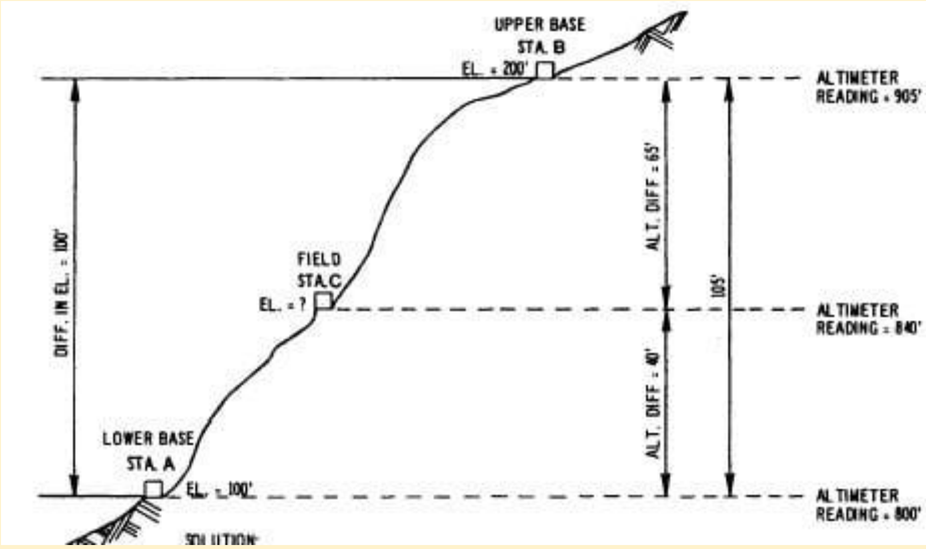


.

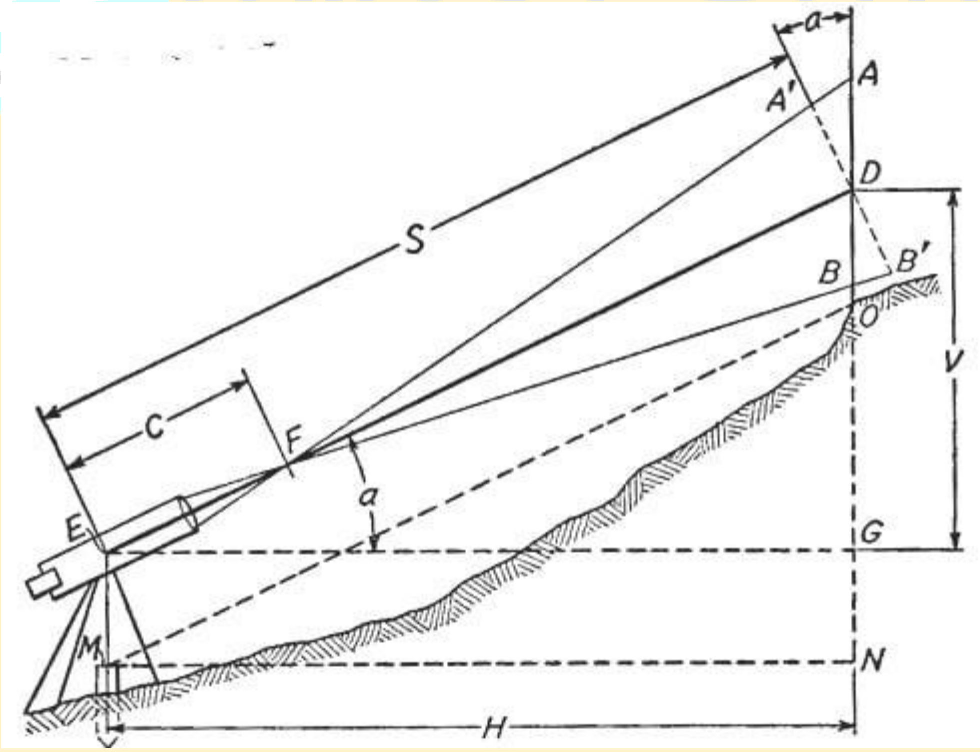
In this method, trigonometric relations are used to find the elevation of a point from angle and horizontal distance so, it is called trigonometric leveling. It is also called indirect leveling.

Barometric Leveling

A barometer is an instrument used to measure atmosphere at any altitude. So, in this method of leveling, atmospheric pressure at two different points is observed, based on which the vertical difference between two points is determined. It is a rough estimation and used rarely.



Stadia Leveling



It is a modified form of trigonometric leveling in which the Tacheometer principle is used to determine the elevation of point. In this case the line of sight is inclined from the horizontal. It is more accurate and suitable for surveying in hilly terrains.

Types of Levels Used in Leveling

Following are the types of different levels used for leveling in surveying:

Dumpy Level

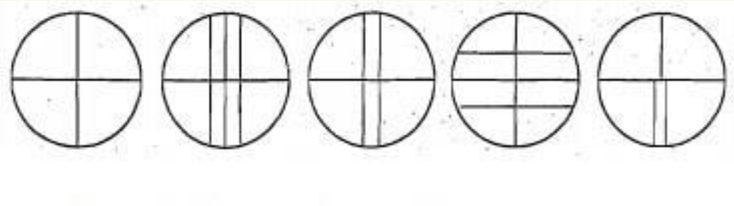
Dumpy level is the most commonly used instrument in leveling. In this level the telescope is restricted against movement in its horizontal plane and telescope is fixed to its support. A bubble tube is provided on the top of the telescope. But however, the leveling head can be rotated in horizontal plane with the telescope. The telescope is internal focusing telescope is a metal tube contains four main parts as given below.

- Objective lens
- Negative lens
- Diaphragm
- Eye-piece

Objective Lens: Objective lens should be made as the combination of crown glass and flint glass. Because of this some defects like spherical aberration and chromatic aberration can be eliminated. A thin layer coating which has smaller refractive index than glass is provided on the objective lens to reduce the loss due to reflection.

Negative Lens: Negative lens located co axial to the objective lens. So, the optical axis for both lenses is same.

Diaphragm: Diaphragm is fitted inside the main tube which contains cross hairs (vertical and horizontal) and these are adjusted by capstan headed screws. The cross hairs are made of dark metal as filament wires which are inserted in diaphragm ring in exact position. For stadia leveling purposes, extra two horizontal cross hairs are provided above and below the horizontal wire.



different types of cross-hairs

Eyepiece: Eyepiece lens enable the ability to sight the object together with cross hairs. The image seen through eye piece is magnified and inverted. Some eyepieces erect the image into normal view and those are called as erecting eyepieces.

Y Level

Y level or Wye-level consists y-shaped frames which supports the telescope. Telescope cane be removed from the y-shaped supports by releasing clamp screws provided. These y-shaped frames are arranged to vertical spindle which helps to cause the rotation of telescope. Compared to dumpy level, adjustments can be rapidly tested in y- level. But, there may be a chance of frictional wear of open parts of level.

Cushing’s Level

In case of Cushing’s level, the telescope is restricted against rotation in its longitudinal axis and it is non-removable. But, the object end and eye piece end can be interchangeable and reversible.

Tilting Level

Tilting level consist a telescope which enabled for the horizontal rotation as well as rotation about 4 degree in its vertical plane. Centering of bubble can be easily done in this type of level. But, for every setup bubble is to be centered with the help of tilting screw. The main advantage of tilting level is it is useful when the few observations are to be taken with one setup of level.

Cooke’s Reversible Level

Cooke’s reversible level is the combination of dumpy level and y-level. In this instrument, the telescope can be reversed without rotation the instrument. Collimation error can be eliminated in this case because of bubble left and bubble right reading of telescope.

Automatic Level

Automatic level is like the dumpy level. In this case the telescope is fixed to its supports. Circular spirit can be attached to the side of the telescope for approximate leveling. For more accurate leveling, compensator is attached inside the telescope.

Compensator can help the instrument to level automatically. Compensator is also called as stabilizer which consists two fixed prisms and it creates an optical path between eye piece and objective. Due to the action of gravity, the compensator results the optical system to swing into exact position of line of sight automatically. But before the process of leveling, compensator should be checked.

To check the compensator, just move the foot screws slightly if the leveling staff reading remains constant then compensator is perfect. If it is not constant, then tap the telescope gently to free the compensator. Automatic level is also called self-adjusting level.

Temporary and Permanent Adjustment of Levels

Temporary adjustment of levels are the adjustments that are made for every setting of a level instrument before taking any readings. They are done by the surveyor in the field, and they do not involve any alteration in the instrument. The purpose of temporary adjustment of levels is to make the instrument ready for use and to eliminate any errors due to improper setting or focusing. The temporary adjustment of levels usually includes:

Setting up the level: This involves placing the instrument on a tripod stand over a convenient location and fixing it firmly. The instrument should be roughly leveled by adjusting the tripod legs and bringing the circular bubble (if present) to the center.

Leveling up: This involves making the vertical axis of the instrument truly vertical by using the foot screws and the spirit level attached to the instrument. The instrument should be leveled such that the bubble remains in the center of its run for all positions of the telescope.

Elimination of parallax: This involves focusing the eyepiece and the objective lens of the telescope such that the crosshairs and the staff image are clearly visible without any relative movement. Parallax is an apparent displacement of an object due to a change in the position of observation. It can cause errors in reading if not eliminated.

Permanent adjustment of levels are the adjustments that are made to correct any defects or errors in the instrument itself. They are done by an expert, or a manufacturer and they involve some alteration in the instrument. The purpose of permanent adjustment of levels is to establish or restore the fixed relationships between the fundamental lines or parts of the instrument, such as:

- The axis of the bubble tube should be perpendicular to the vertical axis.
- The line of collimation (the line joining the center of crosshairs and objective lens) should be parallel to the axis of the bubble tube.
- The line of sight (the line passing through crosshairs and staff image) should coincide with the line of collimation.

booking and reduction methods

Booking and reduction methods are techniques of recording and calculating the elevation or height difference of points on the earth's surface using a level instrument and a level staff.

There are two common methods of booking and reducing levels: the height of collimation method and the rise and fall method.

(A) Height of Instrument Method: -

The basic equations are: -

- Height of instrument for the first setting= RL of BM + BS (at BM)
- Subtract the IS and FS from HI to get RL of intermediate stations and change points.
- Checking: ∑BS - ∑FS = Last RL – First RL. This is –ve for FALL and +ve for RISE.

(B) Rise and Fall method: -

- In this method the difference of the present staff reading is subtracted from the previous staff reading.
- Previous reading – present staff reading = +ve, denotes RISE
- Previous reading – present staff reading = -ve, denotes FALL

- Checking: ∑BS - ∑FS = Last RL – First RL= ∑Rise - ∑Fall

Curvature correction (Cc)

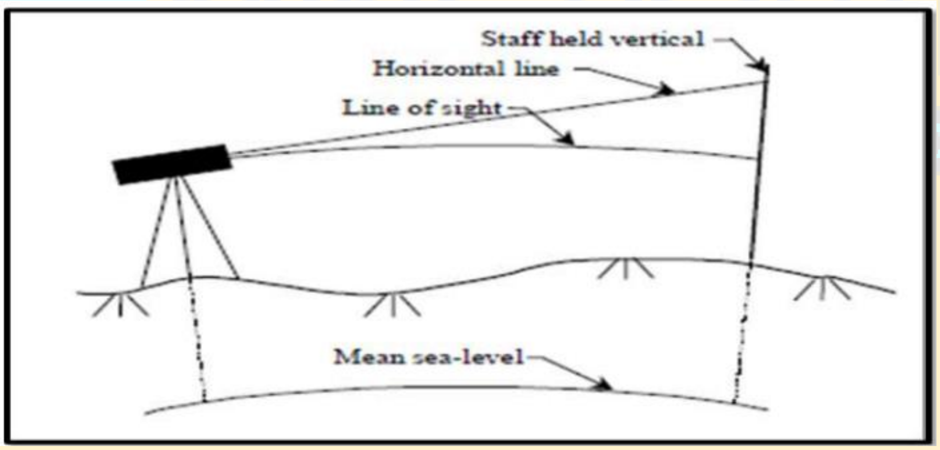
- Cc is always negative.
- A properly adjusted instrument takes the readings with respect to horizontal line.
- So, something has to be subtracted from the staff reading to get actual reading.
- Cc= $d^2/2R$ and -ve
- D is distance of the staff from the point of tangency and R is the radius of the Earth = 6370km
- Cc= $-7.849 \times 10^{-8} \times d^2$ meters if d is in meters. And
- Cc= $-0.0785 \times d^2$ meters, if d is in kilo meters (km).

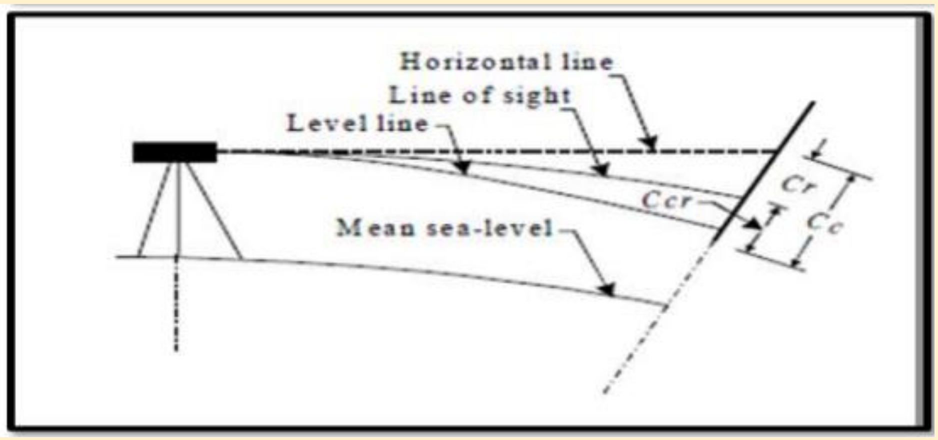
Effect of refraction (Cr)

- Air is denser near the earth and becomes thinner as we go far from the surface of the earth. This causes refraction.
- Cr = $(1/7) \times (d^2/2R)$ and +ve
- Cr = $0.0112 \times d^2$ meters, if d is in kilo meters (km).

Combined effect

Cc + Cr = $-(6/7) \times (d^2/2R) = -6.728 \times 10^{-8} \times d\ 2$ meters, if d is in meters = $-0.0673 \times d^2$ meters, if d is in kilo meters (km).





Contours And Contour Lines

Contour: Contour An imaginary line on the ground surface joining the points of equal elevation is known as contour. It facilitates depiction of the relief of terrain in a two-dimensional plan or map. In other words, contour is a line in which the ground surface is intersected by a level surface obtained by joining points of equal elevation. This line on the map represents a contour and is called contour line. Contouring is the science of representing the vertical dimension of the terrain on a two-dimensional map.

Contour Map: A map showing contour lines is known as Contour map. A contour map gives an idea of the altitudes of the surface features as well as their relative positions in plan serves the purpose of both, a plan and a section.

Contouring: The process of tracing contour line on the surface of the earth is called Contouring.

Contour Line: A Contour line is an imaginary outline of the terrain obtained by joining its points of equal elevation.

Contour Interval (CI): It is the vertical distance between any two consecutive contours. Suppose a map includes contour lines of 100m, 98m ,96 m and so on. The contour interval here is 2 m.

This interval depends upon

- the nature of the ground (i.e. whether flat or sleep).
- The scale of the map.
- the purpose of the survey.

Contour intervals for flat country are generally small, e g. 0.25 m, 0.5 m, 0.75m. etc.

Contour interval for a steep slope in a hilly area is generally greater. e.g. 5m. 10 m, 15 m etc.

It should be remembered that the contour interval for a particular map is Constant.

CHARACTERISTICS OF CONTOURS

- All points in a contour line have the same elevation.
- Flat ground is indicated where the contours are widely separated and steep-slope where they run close together.
- A uniform slope is indicated when the contour lines are uniformly spaced.
- A plane surface when they are straight, parallel and equally spaced.
- A series of closed contour lines on the 80 map represent a hill 75, if the higher values are inside.
- A series of closed contour lines on the map indicate a depression if the higher values are outside.

Method of Contouring

- Direct method
- Indirect method

Direct Method of Contouring: It consists in finding vertical and horizontal controls of the points which lie on the selected contour line.

For vertical control levelling instrument is commonly used. A level is set on a commanding position in the area after taking fly levels from the nearby bench mark. The plane of collimation/height of instrument is found and the required staff reading for a contour line is calculated.

The instrument man asks staff man to move up and down in the area till the required staff reading is found. A surveyor establishes the horizontal control of that point using his instruments. After that instrument man directs the staff man to another point where the same staff reading can be found. It is followed by establishing horizontal control.

Thus, several points are established on a contour line on one or two contour lines and suitably noted down. Plane table survey is ideally suited for this work. After required points are established from the instrument setting, the instrument is shifted to another point to cover more area. The level and survey instrument need not be shifted at the same time. It is better if both are nearby to communicate easily.

For getting speed in levelling sometimes hand level and Abney levels are also used. This method is slow, tedious but accurate. It is suitable for small areas.

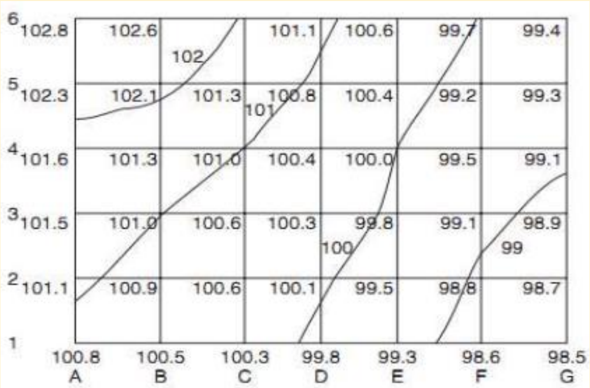
Indirect Method of Contouring: In this method, levels are taken at some selected points and their levels are reduced. Thus in this method horizontal control is established first and then the levels of those points found.

After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points.

For selecting points any of the following methods can be used:

- Method of squares
- Method of cross-section
- Radial line method

Method of Squares: In this method area is divided into a number of squares and all grid points are marked (Fig.).



Commonly used size of square varies from 5 m × 5 m to 20 m × 20 m. Levels of all grid points are established by levelling. Then grid square is plotted on the drawing sheet. Reduced levels of grid points marked and contour lines are drawn by interpolation Fig.

Method of cross-section: In this method cross-sectional points are taken at regular interval. By levelling the reduced level of all those points are established. The points are marked on the drawing sheets, their reduced levels (RL) are marked and contour lines interpolated.

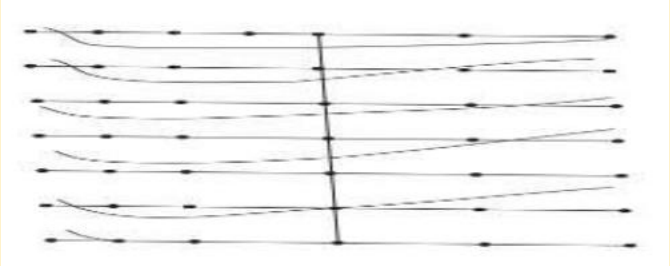
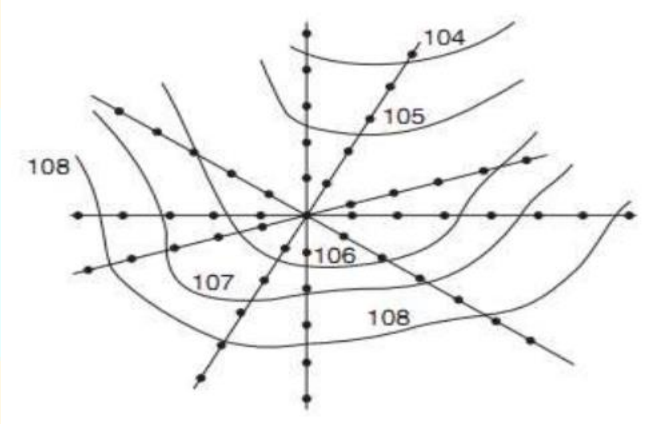


Figure shows a typical planning of this work. The spacing of cross-section depends upon the nature of the ground, scale of the map and the contour interval required. It varies from 20 m to 100 m. Closer intervals are required if ground level varies abruptly.

The cross- sectional line need not be always be at right angles to the main line. This method is ideally suited for road and railway projects.

Radial Line Method: In this method several radial lines are taken from a point in the area. The direction of each line is noted. On these lines at selected distances points are marked and levels determined. This method is ideally suited for hilly areas. In this survey theodolite with tacheometry facility is commonly used.



Questions

1. What is a level line?

a) A line perpendicular to the local plumb line

b) A line lying in a level surface

c) A line parallel to the local vertical

d) A line connecting two benchmark points

Answer: b) A line lying in a level surface

2. What is a benchmark (BM)?

a) A line perpendicular to the local plumb line

b) A line lying in a level surface

c) A line parallel to the local vertical

d) A relatively permanent object with a known elevation

Answer: d) A relatively permanent object with a known elevation

3. What is the purpose of precise leveling?

a) To achieve high precision in leveling measurements

b) To measure elevations in hilly terrains

c) To perform serious observation procedures

d) All of the above

Answer: d) All of the above

4. Which type of level is commonly used in leveling?

a) Dumpy level

b) Y level

c) Tilting level

d) Automatic level

Answer: a) Dumpy level

5. What is the purpose of the objective lens in a level?

a) To magnify and invert the image

b) To eliminate spherical aberration and chromatic aberration

c) To restrict the movement of the telescope

d) To enable sighting of objects with cross hairs

Answer: b) To eliminate spherical aberration and chromatic aberration

6. What is the purpose of the eyepiece lens in a level?

a) To magnify and invert the image

b) To eliminate spherical aberration and chromatic aberration

c) To restrict the movement of the telescope

d) To enable sighting of objects with cross hairs

Answer: a) To magnify and invert the image

7. What is the characteristic feature of a tilting level?

a) Horizontal rotation capability

b) Vertical rotation capability

c) Reversible telescope

d) Self-adjusting capability

Answer: a) Horizontal rotation capability

8. What are temporary adjustments of levels?

a) Adjustments made for every setting of the level instrument

b) Adjustments made to eliminate errors due to refraction and curvature

c) Adjustments made to determine the elevation of benchmark points

d) Adjustments made by the manufacturer to correct defects in the instrument

Answer: a) Adjustments made for every setting of the level instrument

9. What is the curvature correction (Cc) used for in leveling?

a) To determine the actual reading on the staff

b) To compensate for errors due to refraction

c) To eliminate errors caused by curvature of the Earth

d) To check for mistakes or discrepancies in the readings

Answer: c) To eliminate errors caused by curvature of the Earth

10. What is the combined effect of curvature correction (Cc) and refraction correction (Cr)?

a) To determine the actual reading on the staff

b) To compensate for errors due to refraction and curvature

c) To eliminate errors caused by curvature of the Earth

d) To check for mistakes or discrepancies in the readings

Answer: b) To compensate for errors due to refraction and curvature

Tacheometry

Tacheometry is a branch of angular surveying in which the horizontal and vertical distances are obtained by optical means as opposed to the ordinary process of chain and tape. This is done with the help of two special type of instruments- transit theodolite and stadia rod. On the other hand, other conventional surveying methods like chain surveying or traverse surveying need the surveyor to take a linear measurement on the field by a tape or a chain. These are relatively slower processes and also tiresome.

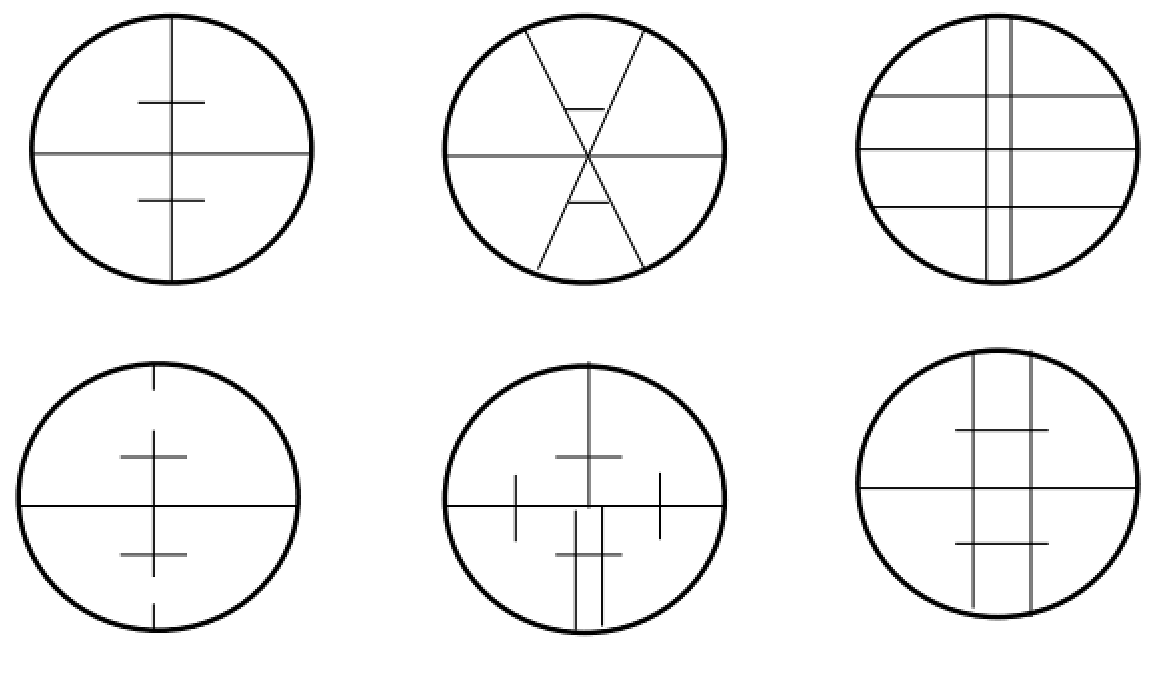
Tacheometric Surveying Instruments

Tacheometric Surveying is done with the help of Tacheometer and Stadia Rod. To read details of the tacheometric surveying instruments click the following link:

- Tacheometer
- Stadia Rod
- Anallatic lens

Tacheometer: A transit theodolite fitted with special stadia diaphragm is known as tacheometer. It is the main instrument of tacheometric surveying. Its telescope contains two horizontal hairs called stadia hairs in addition to the regular crosshairs. The stadia hairs are equidistant from the central cross-hairs and they are specially termed as stadia lines or stadia webs.

The common types of stadia diaphragms are shown below:



In general, the telescopes used in stadia surveying are of three kinds:

- The simple external-focusing telescope which is also known as the stadia theodolite
- The external-focusing anallatic telescope (Porro's telescope). This is usually known as the tacheometer
- The internal-focusing telescope

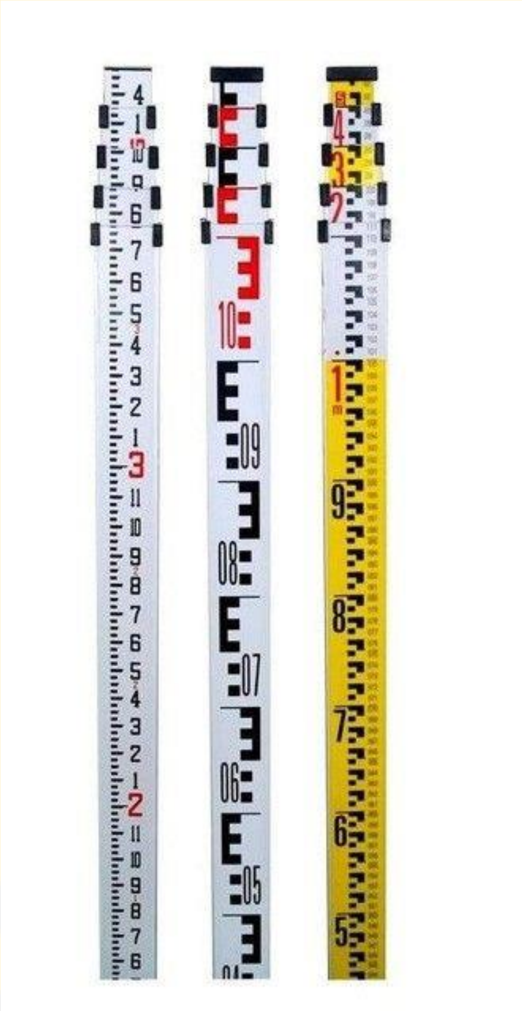
The second type has advantages over first and third kind because of zero additive constants of the instrument (more of constants will be discussed in the latter sections).

Major Features of Techeometer

A tacheometer must essentially incorporate the following features:

- The multiplying constant should have a nominal value of 100 and the error contained in this value should not exceed 1 in 1000.
- The axial horizontal line should be equidistant from the upper and lower stadia hairs.
- The telescope should be anallactic which means the additive constant should be zero.
- The telescope should be powerful magnification property.

Stadia Rod: For small distances (up to 100 meters) a level staff may be used for tacheometric surveying. But for greater distances stadia rod is needed. Stadia rod is of one piece having 3 to 5 meters length. The smallest subdivision is usually 5 mm.



Anallatic lens: is an additional lens used in the instrument. It is a special lens which is placed between the object glass and the eyepiece of the telescope in order to eliminate the additive constant (f+d). This is done to make the expression for the distance between instrument station and staff position more simplified. The lens in only provided in an external focusing telescope but not in the internal focusing.

Different Methods of Tacheometric Measurements

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

- The Stadia System
    - Fixed Hair Method
    - Movable Hair Method, or Subtense Method
- The Tangential System
- Measurements by means of Special Instruments

A brief description of these methods is given below.

Fixed Hair Method

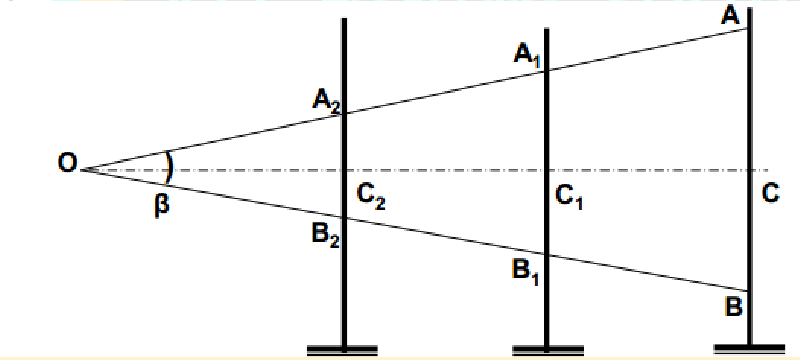
- In this method, the angle at the instrument at A subtended by a known short distance along a staff kept at B is made with the help of a stadia diaphragm having stadia wires at fixed or constant distance apart.
- The readings are on the staff corresponding to all the three wires taken.
- The staff intercept which means the difference of the readings corresponding to the top and bottom stadia wires will, therefore, depend on the distance of the stadia/level staff from the tacheometer
- When the staff intercept is more than the length of the staff, the only half intercept is read.
- This is the most common method is tacheometry and the same 'stadia method' generally bears reference to this method.

Subtense Method

- This method is almost same as the stadia method except that the stadia interval is variable.
- A suitable arrangement is made to vary the distance between the stadia hair as to set them against the two targets on the staff kept at the point under observation.
- Thus, in this 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 hair is variable.
- As in the case of fixed hair method, inclined sights may also be taken.

Stadia Method

As in the field of tacheometric surveying 'Stadia Method' is the most widely used procedure so we will discuss the principle behind it. The stadia method follows the principle that in similar isosceles triangles the ratio of the perpendicular to the base is constant.

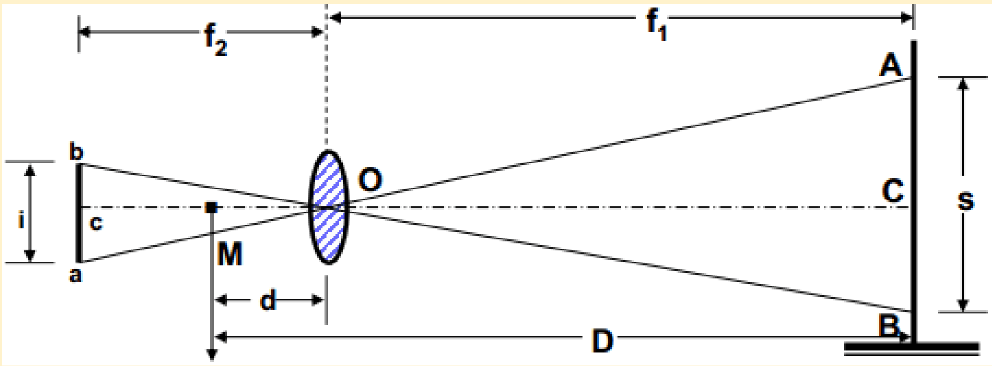


In fig. let two rays be equally inclined to the central ray. Here central ray is shown as OC. A_2B_2, A_1B_1, and AB are staff intercepts i.e difference between upper and lower stadia reading.

Evidently, $OC_2/A_2B_2 = OC_1/A_1B_1 = OC/AB =$ *constant* $K = 0.5\cot(\beta/2)$

This constant depends entirely on the angle β. Let, the constant is found to be 100. It means the distance between the staff and the point O will be 100 times the staff intercept.

The Distance-Elevation Formulae For Horizontal Sight



Suppose,

the interval between stadia hairs is given by i=ab,

staff intercept is s,

f is the focal length of the objective,

D is the horizontal distance of the staff from the vertical axis of the instruments.

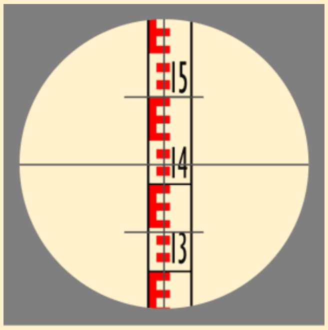
The horizontal distance between the axis and the staff is given by the following equation

$D = f_1 + d = f_1 = (s/i)*f+(f+d)$

This is the distance equation. Staff intercept is found by subtracting the reading of the upper and lower stadia reading.

The constant k = f/i is called the multiplying constant or stadia interval factor and the constant *(f + d) =C* is known as the additive constant of the tacheometer but the latter one is made zero by using an anallatic lens in the instrument.

Determination of Tacheometric Constants on Field



In most cases, we do not really know the value of f (focal length of the objective) so we have to determine the constant k and C on the field with a different approach as below:

- Measure a line (about 100m long) on the fairly level ground and drive pegs at some interval, say 50 meters.
- Keep the staff on the previously determined station and observe the corresponding staff intercepts (upper and lower stadia reading) with horizontal sight.
- Knowing the values of D and s for different points, a number of simultaneous equations can be formed by substituting the values of D and s in equation D = k.s + C. The simultaneous

solution of successive pairs will give the values of k and C, and the average of these can be found.

Followings are the advantages of tacheometric surveying

- It is one of the fastest methods of surveying.
- The accuracy of tacheometric surveying in uneven or difficult terrain is quite satisfactory.
- Does not require any tedious jobs with tapes and chains.
- Cost efficient with relative to time.
- Useful where chain survey or plane table survey cannot be conducted (hilly areas, hydrographic sites).
- It can be used to gain a better check for previously done chain surveying results.

Solved Previous Year Questions

1. The error in levelling to determine mine surface bench marks shall not exceed

(1) 3 cm per km

(2) 5 cm per km

(3) 2 cm per km

(4) 1 cm per km

(5) None of the Options

Ans(3)

A benchmark is a point of reference by which something can be measured. In surveying, a "bench mark" (two words) is **a post or other permanent mark established at a known elevation that is used as the basis for measuring the elevation of other topographical points**. The error in levelling to determine mine surface bench marks shall not exceed 2 cm per km.

2. Parallax are eliminated by

A) Focusing the eye piece

B) Levelling up

C) Focusing the objective

D) Centering

(1)A&C

(2)A&B

(3) B&C

(4) C&D

(5) None

Ans(1)

Parallax is a displacement or difference in the apparent position of an object viewed along two different lines of sight.

The temporary adjustments of a theodolite are:

i) Setting over the station

ii) Levelling up

iii) Elimination of parallax

Elimination of parallax:

Focusing the eye-piece: To focus the eye-piece for distinct visions of the cross-hairs, hold a sheet of white paper in front of objective and move eyepiece in and out till the cross hairs are seen sharp and distinct.

Focusing the objective: The Telescope is now directed towards the object to be sighted and the focusing screw is turned till the image appears clear and sharp.

3. The main purpose of precise levelling in mines is

(1) Establishment of Bench Mark

(2) Correlation Survey

(3) Subsidence monitoring

(4) dump movement monitoring

(5) Monitoring of subsidence and dump movement

Ans(5)

Precise Leveling is used for establishing bench marks with **high precision at widely distant points**.

- It requires the use of highly modern instruments and greatest care in the field.
- A high grade level equipped with tilting screw, stadia wires and coincidence level etc. and an invar precision leveling staff are commonly required.
- The parallax should be entirely eliminated by correct focusing.
- The staff should be exactly vertical.
- The bubble should be exactly in the centre of its run at the time of taking readings.
- Lengths of sights are limiting to about 100 m.
- The back sight and fore sight distances should be exactly equal. Stadia readings may be taken for this purpose.
- **To avoid error due to settlement of tripod and staff, the back sights and the following fore sights should be taken in quick successions** and the order of taking readings is interchanged at alternate set up i.e. at first setting, the back sight is observed first and then the fore sight while at the 2nd setting, the foresight is taken first and then the back sight and so on.

Rod readings are taken against the two horizontal hairs of the diaphragm. This is done in Tachometry Survey in which horizontal and vertical distances are taken.

4. Inaccurate bisection of signal, errors due to wrong bookings, errors in reading verniers are ________ errors.

a) Instrumental
b) Manipulation
c) Observational
d) Natural
e) All the above

Ans C

Observational or Personal Errors:

Inaccurate Centering:

- This is very common error and is introduced in all angles measured at a given station. Its magnitude depends upon the length of the sight. It varies inversely as the length.
- The error is much reduced by carefully centering the instrument over the station-mark.

Inaccurate Levelling:

- The effect of this error is similar to that of the error due to non-adjustment of plate levels. The error is serious when horizontal angles between points at considerably different elevations are to be measured.
- The error can be minimised by levelling the instrument carefully with reference to the altitude level.

Slip:

- The slip may occur if the instrument is not firmly screwed to the tripod-head or the shifting head is not sufficiently clamped or the lower clamp is not properly tightened. As a result, the observations will be in error. This can be prevented by proper care.

Working wrong tangent screw:

- This is a common mistake on the part of a beginner. This can be avoided by proper care and experience. Always operate the lower tangent screw for a back sight and the upper tangent screw for a foresight.

Parallax:

- This error arises due to imperfect focussing. The parallax can be eliminated by properly focussing the eye-piece and the object-glass.

Inaccurate bisection of the point sighted and non-verticality of the ranging rod:

- Care should be taken to bisect the lowest point visible on the ranging rod. In case of short sights, the point of a pencil or the blub- line may be used instead of a ranging rod. The error varies inversely with the length of sight.

Other errors such as:

  - Mistake in setting the verniers,
  - Mistake in reading the scales and verniers,
  - Mistake in reading wrong verniers, and
  - Mistake while booking the readings can be prevented by habitual checks and precautions.

5. Which of the following statements is wrong in terms of Levelling?

(1) The rise-and-fall method of booking is recommended as it is affbrds a complete arithmetical check on all the observations

(2) Although the Height of Collimation method appears superior where there are a lot of intermediate sights, there is no simple straightforward check on their reduction

(3) Height of Collimation method is useful when setting out levels on site

(4) The compensator has a wide working range. Even If the circular bubble is too much out of adjustment, it will not result in tilt of the line of collimation

(5) None of the Options

Ans.(4)

Rise and Fall Method:

- It is adopted whenever the number of intermediate stations is less and also if the number of shifting of instruments is more
- The difference between the levels of consecutive staff points is calculated
- The rise and fall method for obtaining the reduced levels of points provides a **check on foresight, backlight & intermediate sight.**
- Generally used for fly leveling, profile leveling or to establish BMs
- **∑BS - ∑FS = Last R.L – First R.L = ∑Rise - ∑Fall**

Collimation Method or Height of instrument method:

- This method is generally adopted if there are lot many numbers of intermediate stations and also if the number of shifting of instruments is less
- **It does not provide a check on Intermediate sights**
- Height of instrument is calculated at each set up of the instruments
- Generally used in contour survey, in small areas
- **Checks: ∑BS - ∑FS = Last R.L – First R.L**

6. A line of levels was run from a bench mark no. 1 of elevation 858.304 for a longitudinal section in the course of which an intermediate sight 0.952 was taken on a bench mark No. 2 of R.L. 852.588. The sum of back sights from the commencement to this point was 12.345 and that of the fore sights was 17.100. Find the error of closure on the second bench mark.

a) 0.009
b) 0.007
c) 0.006
d) 0.005
e) 0.008

Ans A

$$\Sigma F.S - \Sigma B.S = 17.100 - 12.345 = 4.755$$

$$RL(B.M_1 - B.M_2) = 858.304 - 852.588 = \cancel{4.755}\ 5.716$$

$\therefore$ Error of close on second BM

$$= 5.716 - 4.755 - 0.952$$
$$= 0.009.$$

7. The fundamental lines of a transit are

a) The vertical axis
b) The axis of plate levels
c) The line of collimation
d) The horizontal axis
e) All of these

Ans E

Explanation:

There are **five** fundamental lines in a Theodolite:

1. **Vertical axis (Azimuth axis):** It is the axis about which the instrument rotates in the **horizontal plane**.

2. **Horizontal Axis (Trunnion axis):** It is the axis about which the instrument rotates in the **vertical plane.**

3. **Line of Collimation (Line of Sight):** It is the line that passes through the intersection of horizontal and vertical crosshairs and the optical center of the object glass.

4. **Bubble Line (Level tube axis or Altitude level axis):** It is a straight line tangential to the longitudinal curve of the level tube at its center. It is horizontal when the bubble is in the center.

5. **Plate level axis:** It is perpendicular to the vertical axis when the bubble is at the center.

∴ **All the above statements are true.**

8. The elevation of a point is its _____ distance above or below the datum, it is also known as _____

a) horizontal, bench mark
b) vertical, bench mark
c) vertical, reduced level
d) inclined distance, height of instrument
e) none of the above

Ans C

Elevation is the **distance above sea level of a given location** and impacts a location's temperature, the amount of precipitation it receives, and as a result of those two, the ecosystems that form there.

9. A theodolite was set up at distance of 150 m from a tower. The angle of elevation to the top of the parapet was $10^0 8'$ while the angle of depression to the foot of the wall was $3^0 12'$. The staff reading on the B.M. of R.L. 50, 217 with the telescope horizontal was 0.880. find the height of the lower and reduced level of the top of the parapet.

a) Height of the tower = 35.19 m and R.L of the top of the parapet = 77.900
b) Height of the tower = 53.19 m and R.L of the top of the parapet = 57.901
c) Height of the tower = 38.19 m and R.L of the top of the parapet = 57.902
d) Height of the tower = 39.19 m and R.L of the top of the parapet = 70.903
e) Height of the tower = 25.19 m and R.L of the top of the parapet = 87.904

Ans A

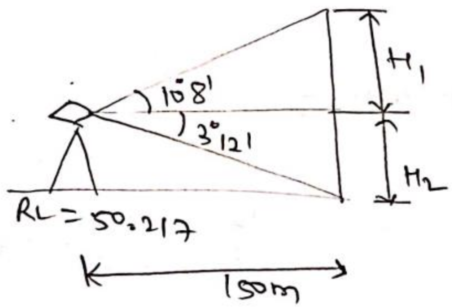
From figure:

$H_1 = 150 \times \tan(10^\circ 8')$

$= 26.80$

$H_2 = 150 \times \tan(3^\circ 12')$

$= 8.386$



$\therefore$ Height of tower $= H_1 + H_2$

$= 35.186$ m

Also,

RL of top $= 50.217 + 0.880 + 26.80 = 77.900$ m

10. The height or depth of any points above or below any datum is called :

a) MSL
b) Datum line
c) Bench marks
d) Reduced level
e) None of these

Ans D

Explanation:

To check the levelling data, following check should be done:

∑ Back sight - ∑ Fore sight = Last Reduced level – First Reduced level = ∑ Rise - ∑ Fall

Reduced level: Height of any point with respect to mean sea level is known as reduced level.

Back sight: All the first readings taken from an instrument location after setting up instrument is known as Back sight.

Fore sight: All the first readings taken from an instrument at location is known as fore sight.

11. In leveling survey the point of known reduced level is known as _____

a) Bench mark
b) Back sight
c) Fore sight
d) Permanent mark
e) None of the options

Ans A

In surveying, a "bench mark" (two words) is **a post or other permanent mark established at a known elevation that is used as the basis for measuring the elevation of other topographical points**.

12. The correction for Sag is

a) always additive
b) always subtractive
c) always zero
d) sometime additive sometime subtractive
e) none of the above

Ans B

Concept:

Sag correction is given by:

$$C_s = -\frac{(wL)^2 L}{24\ P^2}$$

Where,

l = the length of the tape (in metres) suspended between supports

P = Pull applied in kg or N

W = weight of the tape in kg or N per metre run

C_s = Sag correction in metres for length (l)

wL = weight of tape suspended between the supports.

Therefore,

i) Sag correction is directly proportional to the square of the weight of the tape (kg per metre run)

ii) Sag correction is inversely proportional to the pull applied.

13. Calculate the combined correction for curvature and refraction for a distance of 500m,

a) 0.020 m
b) 0.017 m
c) 0.022 m
d) 0.050 m
e) 0.025 m

Ans B

combined correction for curvature and refraction

$$= \frac{6}{7} \times \frac{D^2}{2R} \quad \left[\text{where } R = \text{radius of earth (km)} \right]$$

$$= \frac{6}{7} \times 0'.0785\, D^2$$

$$= 0.06728\, D^2 \quad [\text{where, } D = \text{distance in km})$$

∴ required combined correction $= 0.06728\,(0.5)^2$

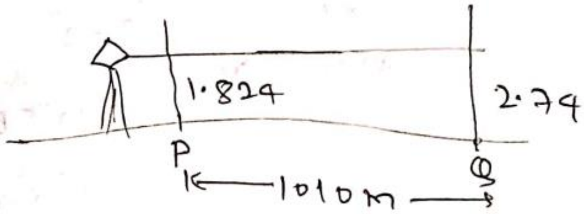
$$= \underline{0.01682}$$

14. When the instrument is a P the staff readings on P is 1.824 and on Q is 2.74 B. When the instrument at Q the staff readings on P is 0.928 and Q is 1.606. Distance between P and Q is 1010 meters RL of P is 126, 386 find true R.I and Q

a) 125.555
b) 125.565
c) 125.575
d) 125.585
e) 125.595

Ans D

Combined correction for PQ



$= 0.06728\, D^2$

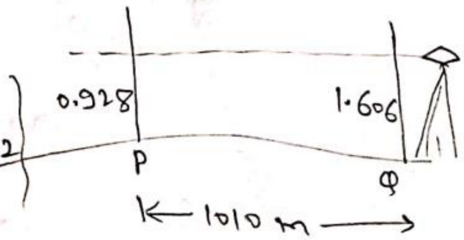
$= 0.06728 \times (1.01)^2 = 0.06863$

$Q_1 = 2.74 - 0.06863 = 2.67137$

$P_1 = 1.824$

$P_1 = 0.928 - 0.06863 = 0.85932$

$Q_1 = 1.606.$



$\therefore e = \dfrac{(2.67137 - 1.824) + (1.606 - 0.85932)}{2} = 0.797025$

$\therefore$ RL of Q $= 126.386 - 0.797025 = \underline{125.588}$

15. Find a correction for curvature for a distance of 800 m

a) 0.10 m
b) 0.08 m
c) 0.8 m
d) 0.05 m
e) 0.18 m

Ans D

correction for curvature $= 0.0785\, D^2$ {where, D = distance in km}

$= 0.0785\,(0.8)^2$

$= \underline{0.05024}$

16. In which of the following methods of levelling. the error due to curvature of earth is eliminated?

(1) Reciprocal levelling

(2) Differential levelling

(3) Pro>le levelling

(4) Trigonometric level ling

(5) None of the Options

Ans(1)

Reciprocal levelling is adopted to accurately determine the level difference between two points which are separated by obstacles like a river, ponds, lakes, etc.

It eliminates the following errors:

i) error in instrument adjustments

ii) the combined effect of Earth's curvature and the refraction of the atmosphere

iii) variation in the average refraction

Important Points:

Reciprocal leveling eliminates the **error due to collimation** and **error due to curvature** of Earth completely, but as the refraction depends upon the atmosphere which may change every minute;

∴ Error due to refraction cannot be eliminated completely but it is reduced.

17. Which of the following statements is wrong?

(1) On a topographic map the vertical distances are represented by contour lines

(2) On a plan generally only horizontal distances and directions are shown

(3) The scale of Plan is generally large as compared to Map

(4) Scale of Map is generally large as compared to Plan

(5) None of the Options

Ans(3)

The scale of a map is the ratio of a distance on the map to the corresponding distance on the ground. This simple concept is complicated by the curvature of the Earth's surface, which forces scale to vary across a map. Because of this variation, the concept of scale becomes meaningful in two distinct ways. On a topographic map the vertical distances are represented by contour lines. On a plan generally only horizontal distances and directions are shown. The scale of Plan is generally smaller as compared to Map.

18. The Contour Interval for town planning is kept in between

(1) 0.5-1

(2) 01-2

(3) 0.2-0.5

(4) 171.5

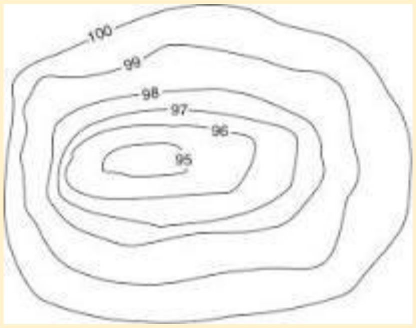
(5) None of the Options

Ans(1)

The following are the common values of the contour interval adopted for various purposes:

(a) For large scale maps of flat country, for building sites for detailed design work and for calculation of quantities of earth work: 0.2 to 0.5 m.

(b) For reservoirs and town planning schemes: 0.5 to 2 m.



19. What is contour interval

(1) difference in R.L. between any two consecutive Contours

(2) horizontal distance between two consecutive Contour lines

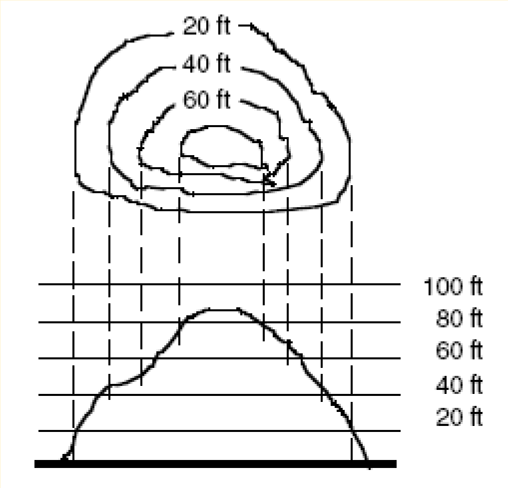
(3) slope distance between two consecutive Contours

(4) spacing between two successive contour labels

(5) None of the Options

Ans(1)

A contour interval is the vertical distance or difference in elevation between contour lines. Index contours are bold or thicker lines that appear at every fifth contour line. If the numbers associated with specific contour lines are increasing, the elevation of the terrain is also increasing.



20. Identify the correct statement with respect to Tacheometry survey, from the following :

Statement (1) : The stadia method has the advantage of rapidly in the field work.

Statement (2) : Stadia method is suitable for long sights

Statement (3) : The subtense method is unsuitable for long sights.

a) Statement (1) only
b) Statement (2) only
c) Statement (3) only
d) Statement (1) & (2) only
e) All the above statement are correct

Ans E

The stadia method is a surveying method for determination of distances and differences of elevation by means of a telescopic instrument having two horizontal lines through which the marks on a graduated rod are observed also. For short sights of about 100 m or less, an ordinary levelling staff may be used. For long sights, special staff called stadia rod is generally used.

Subtense tachometry method:

- The substance bar is an instrument used for **measuring the horizontal distance between the instrument station and a station where the substance bar is to be set up**. Subtense the method is an indirect method of distance determination. This method is consists of measuring the angle subtended by two ends of a horizontal rod of fixed length.

Tacheometer:

(i) This is another method of surveying wherein the horizontal distance and the difference in elevations are determined indirectly by an instrument called as tacheometer.

(ii) Tacheometer is nothing but a transit theodolite fitted with a stadia diaphragm.

(iii) The stadia diaphragm generally consists of two stadia hairs, one above and one below and equidistant from central horizontal hair.

Major Characteristics of a Tacheometer:

(i) The **multiplying constant (k)** of the tacheometer is usually a round figure and mostly it is **100.**

(ii) The additive constant (C) of the tacheometer is kept very small and mostly it is kept zero.

(iii) An **additional convex lens is provided between eyepiece and object glass at a fixed distance and known as anallactic lense to make additive constant zero.**

(iv) The magnifying power of the eyepiece is kept high to make the staff graduations clearly visible even at a large distance.

(v) The **aperture of the objective** is kept usually **35 mm to 45 mm** to make the image sharp.

21. In Surveying contours are lines of equal

(1) Length

(2) Elevation

(3) Bearing

(4) Latitude

(5) None of the Options

Ans(2)

Contour lines are lines drawn on a map with equal **elevation points**, so elevation would be constant if you followed the contour line physically. The elevation and terrain shape of the contour lines shows. It is useful because they show the form of the land surface on the map–its topography.

22. Tacheometry is used to determine

(1) Horizontai and verticai distances

(2) Horizontai distances

(3) Horizontai angles

(4) Vertical angles

(5) None of the Options

Ans(1)

Tachometer:

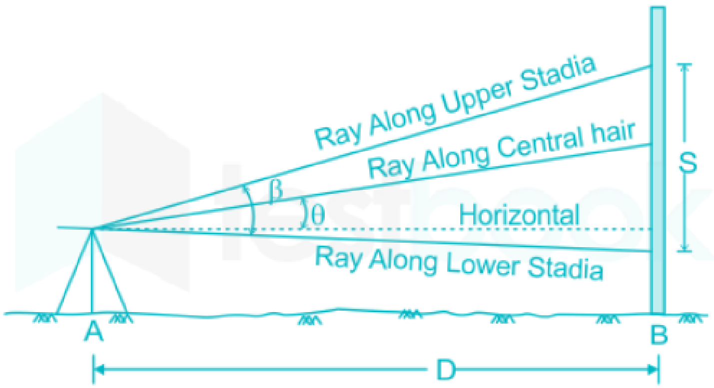
- (i) Tacheometer is nothing but a transit theodolite fitted with a stadia diaphragm.
- (ii) The stadia diaphragm generally consists of two hairs, one above and one below and equidistant from a central horizontal hair.

Systems of Tacheometric measurements:

- Stadia system
- Tangential system
- Subtense bar system

(a) Stadia system:

- In the stadia system of tacheometry of, the tacheometer is set up station A and staff at station B.
- The staff intercept between the upper and lower stadia is measured along with vertical angle θ made with horizontal.
- The horizontal distance D between the instrument station A and staff station B and the difference of elevation between stations A and B are determined from the staff intercept (s) and the vertical angle.
- Refraction correction may occur during measurement.
- **In stadia Method Fixed stadia method is commonly used.**



Traversing

Traversing is that type of survey in which a number of connected survey lines form the framework and the directions and lengths of the survey lines are measured with the help of an angle measuring instrument and tape or chain respectively.

Types of Surveying

There are two types of traverse surveying. They are:

- **Closed traverse**: When the lines form a circuit which ends at the starting point, it is known as a closed traverse.
- **Open traverse:** When the lines form a circuit ends elsewhere except starting point, it is said to be an open traverse.

Suitability

The closed traverse is suitable for locating the boundaries of lakes, woods, etc and for a survey of large areas. the open traverse is suitable for surveying a long narrow strip of land as required for a road of the canal or the coastline.

Methods of Traversing

There are several methods of traversing, depending on the instruments used in determining the relative directions of the traverse lines. The following are the principal methods:

- Chain traversing
- Chain and compass traversing
- Transit type traversing

  a) By fast needle method
  b) By measurement of angles between the lines

- Plane table traversing

Brief descriptions of these traverse surveying methods are given below.

Adjustment of Traverse.

Adjustment of traverse is a technique of correcting the errors in the measurements of angles and distances in a traverse, which is a series of connected lines whose lengths and directions are measured.

Temporary adjustment: Temporary adjustment of traverse is the adjustment that is done for each setting of the instrument before taking any readings. It involves making the instrument ready for use and eliminating any errors due to improper setting or focusing. Temporary adjustment of traverse usually includes:

- Setting up the instrument: This involves placing the instrument, such as a theodolite or a compass, on a tripod stand over a convenient location and fixing it firmly. The instrument should be roughly levelled by adjusting the tripod legs and bringing the circular bubble (if present) to the center.

- Leveling up: This involves making the vertical axis of the instrument truly vertical by using the foot screws and the spirit level attached to the instrument. The instrument should be leveled such that the bubble remains in the center of its run for all positions of the telescope.
- Elimination of parallax: This involves focusing the eyepiece and the objective lens of the telescope such that the crosshairs and the staff image are clearly visible without any relative movement. Parallax is an apparent displacement of an object due to a change in the position of observation. It can cause errors in reading if not eliminated.

Permanent adjustment: Permanent adjustment of traverse is the adjustment that is done to correct any defects or errors in the instrument itself. It involves some alteration in the instrument by an expert or a manufacturer. Permanent adjustment of traverse aims to establish or restore the fixed relationships between the fundamental lines or parts of the instrument, such as:

- The axis of the bubble tube should be perpendicular to the vertical axis.
- The line of collimation (the line joining the center of crosshairs and objective lens) should be parallel to the axis of the bubble tube.
- The line of sight (the line passing through crosshairs and staff image) should coincide with the line of collimation.

Chain Traversing

The method in which the whole work is done with chain and tape is called chain traversing. No angle measurement is used and the directions of the lines are fixed entirely by linear measurements Angles fixed by linear or tie measurements are known as chain angles. The method is unsuitable for accurate work and is generally used if an angle measuring instruments such as a compass, sextant or theodolite is available.

Chain and Compass Traversing

In chain and compass traversing, the magnetic bearings of the survey lines are measured by a compass and the lengths of the lines are measured either with a chain or with a tape. The direction of the magnetic meridian is established at each traverse station independently. The method is also known as a tree or loose needle method.

Traversing by Fast Needle Method

The method in which the magnetic bearings of traverse lines are measured by a theodolite fitted with s compass is called traversing by fast needle method. The direction of the magnetic meridian is not established at each station but instead, the magnetic bearings of the lines are measured with a reference so that direction of the magnetic meridian established at the first station. There are three methods of observing the bearings of lines by fast needle method.

- Direct method with transiting,
- Direct method without transiting,
- Back bearing method.

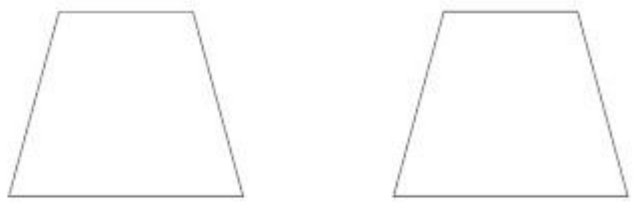
Traversing By Direct Observation Of Angles

In this method, the angles between the lines are directly measured by a theodolite and the magnetic bearing of other lines can be calculated in this method. The angles measured at different stations may be either

- Included Angles and
- Deflection Angles

Traversing by Included Angle

An included angle at a station is either of the two angles formed n\by two survey lines meeting there and these angles should be measured clockwise. The method consists simply in measuring each angle directly from a back sight on the preceding station. The angled may also be measured by repetition. The angles measured from the back station may be interior or exterior depending on the direction of progress.



In Fig(a) the direction of progress is counter-clockwise and so the angles measured clockwise are the interior angle. In Fig(a) the direction of progress is clockwise and so the angles measured clockwise are the exterior angle.

Traverse by Deflection Angles

A deflection angle is an angle in which a survey line makes with the prolongation of the preceding line. It is designated as right (R) or left (L) as it is measured clockwise or anti-clockwise from the prolongation of the previous line. This type of traversing is more suitable for the survey of roads, railways, pipe-lines, etc where the survey lines make small deflection angles.

Errors in Traversing

The errors involved in closed traversing are two kinds:

- Linear Error and
- Angular Error

The most satisfactory method of checking the linear measurements consists in chaining each survey line a second time, preferably in the reverse direction on different dates and by different parties. The following are checks for the angular work:

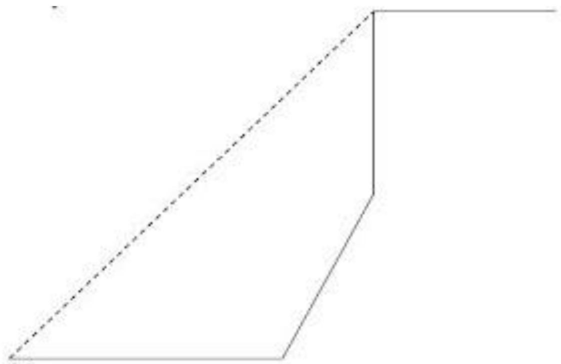
A. **Travers by included angles:**

- The sum of measured interior angles should be equal to (2N-4), where N=number of sides of the traverse.
- If the exterior angles are measured, their sum should be equal to (2N=4)p/2

B. **Travers by deflection angles:** The algebraic sum of the deflection angles should be equal to 360°, taking the right hand and deflection angles as a positive and left-hand angle as negative.
C. **Traversing by direct observation of bearings:** The force bearing of the last line should be equal to its back bearing ±180° measured from the initial station.

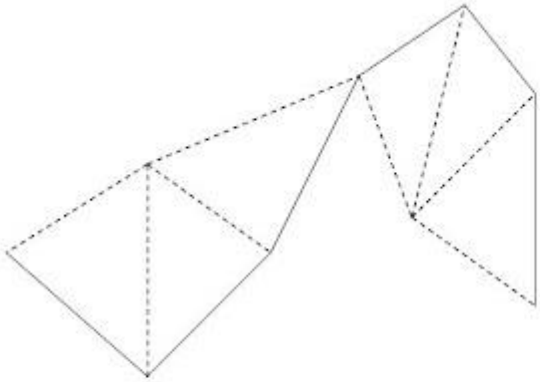
Checks in Open Traverse

No direct checks of angular measurement are available. So indirect checks can be made. As illustrated in Fig(a) the addition to the observation of bearing of AB at station A, bearing of AD can also be measured., if possible. Similarly, at D, the bearing of DA can be measured and check applied. If the two bearings differ by 180°, the work may be accepted as correct.



(a)

Another method, which furnishes a check when work is plotted is shown as in Fig (b) and consists of reading the bearing to any prominent point P from each of the consecutive stations. The check-in plotting consists in laying off the lines AP, BP, CP, etc and noting whether the lines pass through one point.



(b)

Plotting a Traverse Survey

There are two principal methods of traverse survey:

- Angles and distance method: This method is of three types.

  - By protractor
  - By the tangent of the angle
  - By the chord of the angle.

- Co-ordinate method.

Solved Previous Year Questions

1. Which of the following is a not a method of correlation survey through single shaft

(1) Weiss Quadrilateral method

(2) Weisbach Triangle method

(3) Triangulation and Traversing

(4) Exact Alignment Method

(5) Gyro—laser and Nadir plummet method

Ans(3)

Triangulation is a surveying method that measures the angles in a triangle formed by three survey control points. Using trigonometry and the measured length of just one side, the other distances in the triangle are calculated.

Traversing is that type of survey in which a number of connected survey lines form the framework and the directions and lengths of the survey lines are measured with the help of an angle measuring instrument and a tape or chain respectively.

2. If the angular measurement are more practice than its linear measurement, balancing of the traversing is done by

a) Transit rule
b) Simpson's rule

c) Empirical rule
d) None of these

Ans A

Explanation

Transit Rule:

- The transit rule may be employed where **angular measurements are more precise than linear measurements.**
- According to this rule, the total error in latitudes and in departures is distributed in proportion to the latitudes and departure of the sides.
- It is claimed that the angles are less affected by corrections applied by the transit method than those by Bowditch's method.

Bowditch's rule:

- This method is based on **assumption that the errors in the linear measurements** are proportional to √l and that the errors in angular measurements are inversely proportional to 1/√l where l is the length of a line.

3. The error of closure in closed traverse in underground shall not exceed

(1) 1 in 2000

(2) 1 in 2500

(3) 1 in 3000

(4) 1 in 5000

(5) None of the Options

Ans(2)

The ratio of distance by which a survey fails to close to the perimeter of the tract surveyed is termed as Closing Error. Also, the sum of the angles of a traverse as measured minus the true sum required by geometry is termed as Closing Error. The error of closure in closed traverse in underground shall not exceed 1 in 2500.

4. Sum of the internal angles in a closed traverse is given by

(1) (n-4)x 90°

(2) (2n-4)x 90°

(3) (2n+4)x 90°

(4) (2n+2)x 90°

(5) None of the Options

Ans(2)

Closed traverse:

When the lines form a circuit that ends at the starting point, it is known as a closed traverse. **There should be a minimum of 3 no. of sides for closed traversing.**

Properties of closed traverse:

The sum of measured **interior angles** should be equal to **(2N - 4) × 90°**, where N=number of sides of the traverse.

The sum of measured **exterior angles** should be equal to **(2N + 4) × 90°**, where N=number of sides of the traverse.

5. If the adjusted values of latitude and departure for a traverse line obtained in a field survey are 238.65 m and 119.38 m respectively, the length and azimuth of the line are

(1) 266.84 m, 63.42^0

(2) 266.84 m,26.57^0

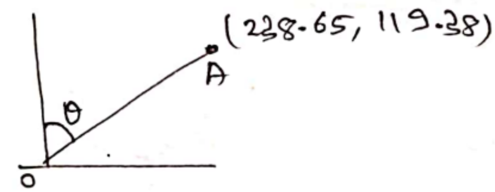
(3) 358.03 m, 63.42^0

(4) 358.03 m, 26.57^0

(5) None of the Options

Ans(2)

$$\tan\theta = \frac{\text{Departure}}{\text{Latitude}}$$



$$\Rightarrow \tan\theta = \frac{119.38}{238.65}$$

$$\Rightarrow \theta = 26.\underline{57}^\circ$$

Also, Length $= OA = \sqrt{(238.65)^2 + (119.38)^2}$

$= 266.84\underline{m}$

6. The closing error in a closed traverse is adjusted by

(1) Lehmann's rule

(2) Slide rule

(3) Bowditch's rule

(4) Simpson’s rule

(5) Trapezoidal rule

Ans(3)

Bowditch’s rule or Compass Rule- A widely used rule for adjusting a traverse that assumes the precision in angles or directions is equivalent to the precision in distances. This rule distributes the closure error over the whole traverse by changing the northings and eastings of each traverse point in proportion to the distance from the beginning of the traverse. More specifically, a correction factor is computed for each point as the sum of the distances along the traverse from the first point to the point in question, divided by the total length of the traverse. The correction factor at each point is multiplied by the overall closure error to get the amount of error correction distributed to the point's coordinates

7. Bowditch rule is applied to

a) An open traverse for graphical adjustment
b) A closed traverse for adjustment of closing error
c) Determine the effect of local attraction
d) For magnetic declination
e) None of the above

Ans B

Bowditch rule is applied to a closed traverse for adjustment of closing error. Bowditch rule is also known as the compass rule, which is used when linear measurement and angular measurement both take equal degree of precision. It is applied to a closed traverse for adjustment of closing error.

Every traverse made to determine of check the position of an underground survey station or check the position of the main roadways of a mine shall be made with a theodolite the smallest reading of which does not exceed ______ seconds of arc and all measurement shall be made with a steel tape not less than _____ metres in length.

a) 10, 20
b) 20, 30
c) 10, 25
d) 30, 30
e) 10, 30

Ans B

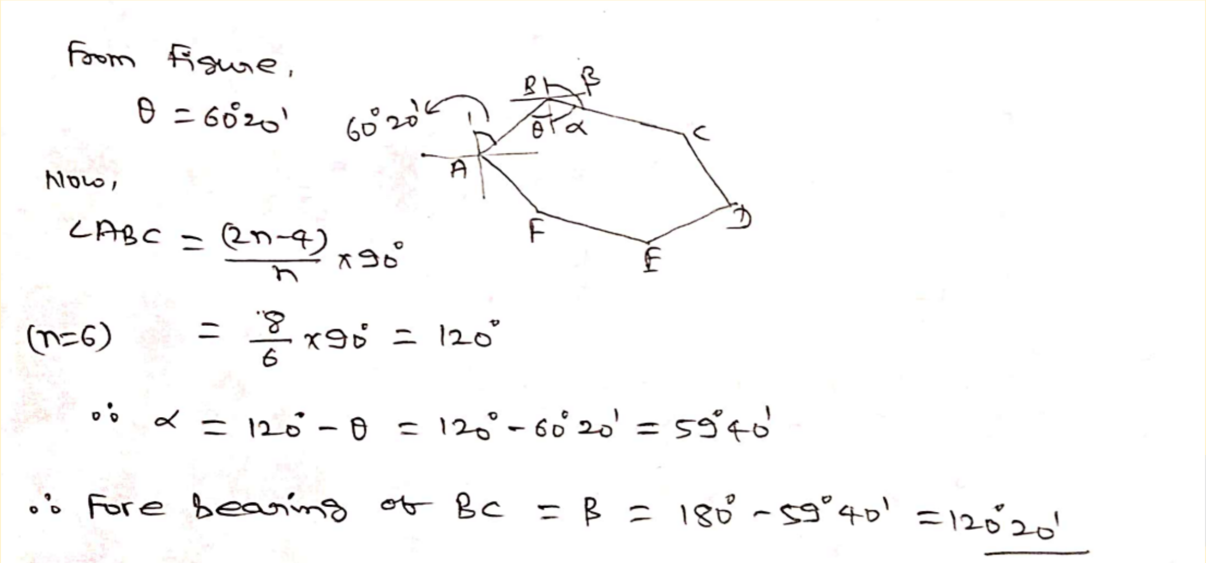
Least count of theodolite is 20 seconds.

- Least count of an instrument is minimum reading that can be measured by instrument. ...
- Total station and theodolite are used to measure horizontal angles as well as vertical angles in a plane.
- Prismatic compass and surveyors compass are used to measure only horizontal angles.

8. In a compass traverse, ABCDEFA is in the form of regular Hexagon. The F.B. of line AB $60^0 20^0$. The fore bearing of line BC is

a) $120^0 20^0$
b) $60^0 20^0$
c) $130^0 40^0$
d) $120^0 40^0$
e) None of the options

Ans A



9. For a closed traverse the omitted measurements may be calculated :

a) Length of one side only
b) Bearing of one side only
c) Both length and batting of one side
d) All of the above
e) None of these

Ans D

Omitted measurement depends on all the above condition. Sometime, error in close traverse so that every side & bearing may be calculated. Yes, Some time error in close traverse. Maximum omitted measurements in closed traverse = 2.

10. Identify the wrong statement from the following

Statement (1) : The Bowditch rule is commonly used to balance a transverse where linear and angular measurements are of equal precision.

Statement (2) : Transit method may be applied where linear measurements are more precise than the angular measurements.

Statement (3) : Axis method is adopted when the angles are measured very accurately.

a) Statement (1) only

b) Statement (2) only
c) Statement (3) only
d) Statement (1) & (2) only
e) Statement (2) & (3) only

Ans B

Bowditch's Rule: This method of traverse adjustment is suitable where linear and angular measurements are made with equal precision. This method is usually used for balancing a compass traverse but can be used for theodolite traverse also provided angular and linear measurement is done with the same precision. Axis method: (i) This method is used to balance a traverse where angles are measured more precisely than the lengths and thus this axis method is used for correction of lengths only.

Transit Rule: The transit rule may be employed where angular measurements are more precise than linear measurements. According to this rule, the total error in latitudes and in departures is distributed in proportion to the latitudes and departure of the sides.

Triangulation and Trilateration

What is Theodolite?

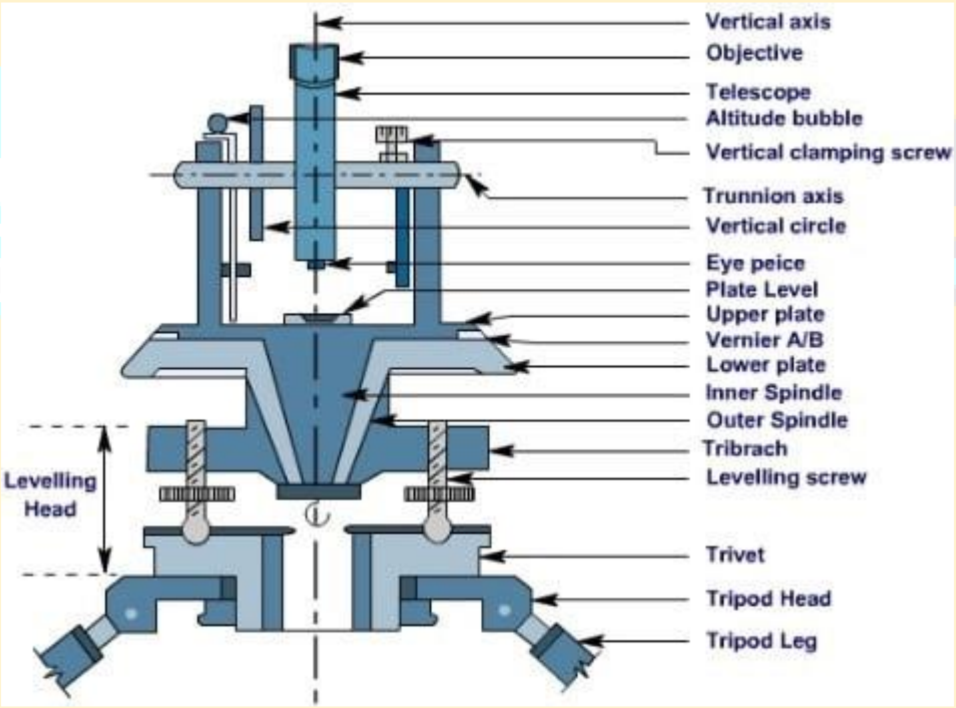
Theodolite is a measurement instrument utilized in surveying to determine horizontal and vertical angles with the tiny low telescope that may move within the horizontal and vertical planes.

It is an electronic machine which looks sort of a tiny telescope. It is extensively used for the measurement of vertical and horizontal angles for scaling functions and within the housing industry. The accuracy with that these angles may be measured ranges from 5mins to 0.1 secs. It is utilized in triangulation networks.

Theodolites are employed everyplace from construction sites to main road points. It measures angles using age-old principles of pure mathematics and assists surveyors in establishing precise locations.

Parts of a Theodolite

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



- Telescope
- Horizontal plate (Circle)
- Vertical Circle
- Index frame
- The standards
- The upper plate
- The lower palte
- Plate level
- The leveling head
- The shifting head

- Magnetic compass
- Tripod
- Plumb bob

These theodolite parts are discussed briefly below.

- **Telescope:** It is used to see the object. It rotates about a horizontal axis in the vertical plane. It can be up to an accuracy of 20 degrees.
- **Horizontal plate (Circle):** It is used for measuring the horizontal angle.
- **Vertical Circle:** It is used for measuring the vertical angle.
- **Index frame:** The frame consists of horizontal and vertical wings. This frame is additionally called a t-frame or vernier frame. The horizontal wing helps to require the measurement of vertical angles and the vertical wing helps to grip the telescope at the wanted level.
- **The standards:** Standards look like 'A' shaped and for that, it is known as A-frame. The standards’ frames support the telescope and allow it to spin about the vertical axis.
- **The upper plate:** It is the bottom on that standard and vertical settled. It also helps to rotate the standards and telescope regularly for correct measurement. the upper plate must be horizontal to the alidade axis and coordinate to the trunnion axis. The instrument must be leveled and this leveled is achieved by adjustment of three-foot screws and perceptive an explicit tube bubble. The bubble is understood as a plate bubble and located within the upper plate.
- **The lower pale:** The lower plate is that the base of the entire instrument. It homes the foot screws and the carrying for the vertical axis. it is strictly connected to the tripod-escalating assembly and does not modifier or shift. Horizontal angles are measured with this plate.
- **Plate level:** Plate levels are lifting by the upper plate that is the proper angles to every different with one they are coordinate to trunnion axis. Plate levels facilitate the telescope to mend incorrect vertical points.
- **The leveling head:** The leveling head consists of two parallel triangular plates called tribrach plates. The upper one is called as upper tribrach plate and is used to level the upper plate and telescope with the help of equalizing screws provided at its three ends. The lower one is called a lower tribrach plate and is connected to the tripod stand.
- **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.
- **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.
- **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 leveling head is screwed.

- **Plumb bob:** To center the instrument precisely over a station mark, a plumb bob is suspended from the hook fitted to the rock bottom of the central vertical axis.

The theodolite has other more parts are - Level tube, Foot Plate, Standard Frame, Upper Clamp, Trunnion Axis, Lower Clamp, Vernier Frame, Inner Axis, Outer Axis, Altitude Level, Leveling Screw, Clamp Screw, Tangent Screw.

Uses of Theodolite in Surveying

Theodolite uses for many purposes, but mainly it is used for measuring angles, scaling points of constructional works. For example, to determine highway points, huge buildings' escalating edges theodolites are used. Depending on the job nature and the accuracy required, theodolite produces more curved readings, using paradoxical faces and swings or different positions for perfect measuring survey.

Followings are the major uses of theodolite:

- Measuring horizontal and vertical angles
- Locating points on a line
- Finding the difference in the level
- Prolonging survey lines
- Ranging curves
- Setting out grades
- Tachometric surveying

The theodolite helps us a good within the engineering field. This instrument plays a major role in measurement horizontal angles, vertical angles, bearing, etc. To use theodolite, it is necessary to know about theodolite parts, types of theodolite, and for what it is used wisely in the field.

Modern Micro-Optic Theodolites

Modern micro-optic theodolites are a type of surveying instrument that use optical and electronic components to measure angles and distances with high precision and accuracy.

A modern micro-optic theodolite consists of a movable telescope mounted on two perpendicular axes: the horizontal axis and the vertical axis. The telescope can rotate around these axes and provide angular readouts on digital displays. The telescope also has a built-in laser or infrared distance meter that can measure the distance to the target object. The theodolite is usually mounted on a tripod stand and can be adjusted to make it level and vertical using spirit levels or automatic compensators.

A modern micro-optic theodolite works by combining optical and electronic principles to measure angles and distances. The optical principle involves using a lens system to magnify the image of the target object and project it onto a reticle or crosshair in the eyepiece. The electronic principle involves using light-emitting diodes (LEDs) and photodetectors to read the angular position of the telescope on glass plates with engraved scales. The angular readings are then converted into digital signals and displayed on LCD screens.

A modern micro-optic theodolite has several advantages over traditional mechanical or optical theodolites. Some of these advantages are:

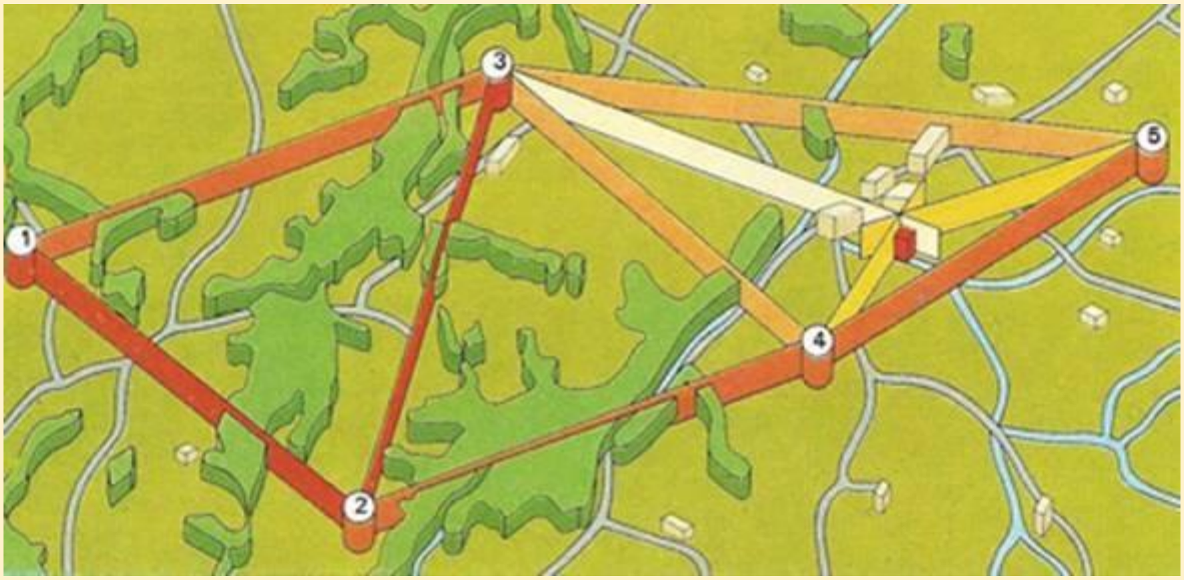
Higher accuracy and resolution: Modern micro-optic theodolites can measure angles with accuracies up to arc-second (≈ 0.005 mrad) levels, which is much higher than mechanical or optical theodolites that have accuracies of arcminute (≈ 0.3 mrad) levels. Modern micro-optic theodolites can also measure distances with accuracies up to millimeter levels, which is much higher than optical theodolites that have accuracies of centimeter levels.

Faster and easier operation: Modern micro-optic theodolites have automatic features that make them faster and easier to operate than mechanical or optical theodolites. For example, modern micro-optic theodolites have automatic leveling, focusing, indexing, zero-setting, etc., which reduce the time and effort required for manual adjustments. Modern micro-optic theodolites also have digital displays that show the angular and distance readings directly, which eliminate the need for reading scales or verniers.

More functions and features: Modern micro-optic theodolites have more functions and features than mechanical or optical theodolites. For example, modern micro-optic theodolites have memory storage, data processing, wireless communication, etc., which enable them to store, analyze, transfer, and display data in various formats. Modern micro-optic theodolites also have accessories such as cameras, scanners, GPS receivers, etc., which enhance their capabilities and applications.

Triangulation

Triangulation surveying is the tracing and measurement of a series or network of triangles to determine distances and relative positions of points spread over an area, by measuring the length of one side of each triangle and deducing its angles and length of other two sides by observation from this baseline. Triangulation surveying was first introduced by a Dutch man named Sneli.



Triangulation is preferred for hills and undulating areas, since it is easy to establish stations at reasonable distances apart, with intervisibility. In plane and crowded areas it is not suitable as the intervisibility of stations is affected. The difficulty is overcome by building towers which is quite expensive. The main disadvantage of triangulation is the accumulation of error in the lengths and direction of lines, since both of them, for successive lines, depend upon the computations for those of the preceding line, which necessitates the check bases. In triangulation, entire area to be surveyed is covered with a framework of triangles. For the triangle, the length of the first line, which is measured precisely is known as Base line. The other two Computed sides are used as new baselines for two other triangles interconnected with the first triangle. By extending this process, a chain or network of triangles can be spread over the entire area.

Operations in Triangulation Survey

The field work of a triangulation is carried out in the following well defined operations:

- Reconnaissance
- Station preparation
- Baseline measurement
- Measurement of angles

Besides field work, triangulation consists of the specifications, the design of stations and signals, and the reduction and adjustment of the observations.

Applications of Triangulation Surveying

- Establishing accurately located control points for plane and geodetic surveys of large areas.
- Establishing accurately located control points in connection with aerial surveying

- Accurate location of engineering projects such as Centre lines, terminal points and shafts for long tunnels, and Centre lines and abutments for long span bridges.

Triangulation Systems

A system consisting of triangulation stations connected by a chain of triangles. The complete fig is called triangulation system or triangulation figure. The most common type of figures used in a triangulation system are

- Triangles
- Quadrilaterals
- Polygons

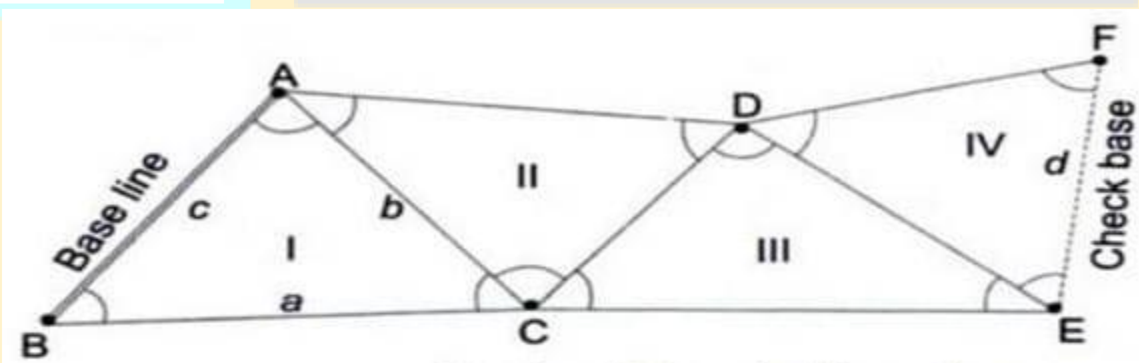
Geometric conditions to be fulfilled by above figures in triangulation system are:

- The sum of interior angles should be $(2n-4) \times 90^o$, where n = no. of sides of the figure
- If all the angles are measured at a station, their sum should be 360^o.
- The length of sides calculated through more than one routes should agree.

It is impossible to fulfil all the geometric conditions, owing to the errors, until the field measurements have been adjusted.

Triangles

- A chain of triangles is very rapid and economical when a narrow strip of terrain is to be surveyed.
- Angles less than 30^o or more than 120^o are not permitted
- For well-conditioned triangles, angles should not be less than 30^o or more than 120^o.



Chain of simple triangles

Advantages of triangles:

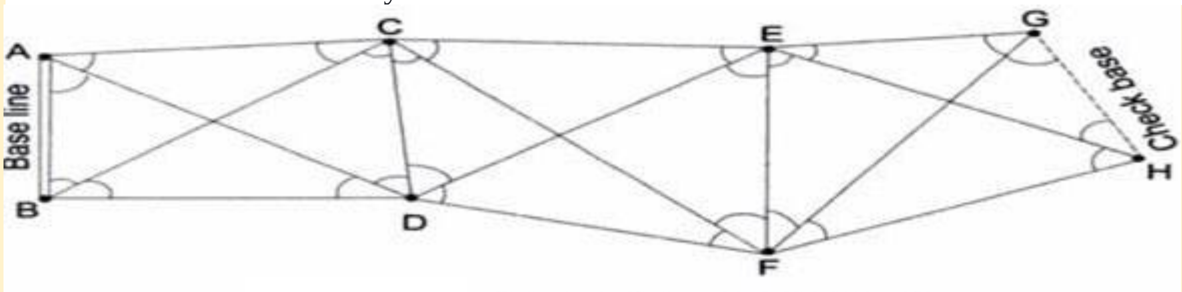
- This is simple and rapid
- Economical method

Disadvantages:

- Since it is used to survey a long narrow strip, a no.of base lines must be introduced frequently to reduce the accumulation of errors. Therefore, a single chain of triangles is never permitted in high order triangulation.
- Least accurate method

Quadrilaterals

- These afford an excellent system since the various combinations of sides and angles can be used to compute the lengths of required sides, and checks can be made frequently
- The best quadrilateral is square. A quadrilateral with both diagonals having no station at their intersection is usually employed.
- This is best suited for hilly areas.



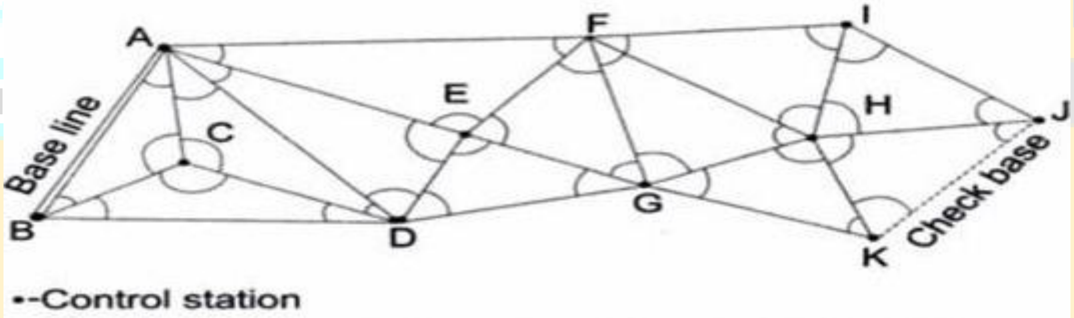
Braced quadrilaterals

Advantages

- Most accurate system as the number of checks are more.

Polygons

- When areas that are very wide in proportion to their lengths are to be surveyed then pentagonal or hexagonal figures may be economical.
- These may or may not have a central station.



Polygons with central points

Advantages

- This is also more accurate as the desired number of checks are more.

Control Point Framework

A control survey provides a framework of survey points, whose relative positions, in two or three dimensions, are known to specified degrees of accuracy. The areas covered by these points may extend over a whole country and form the basis for the national maps of that country. Alternatively the area may be relatively small, encompassing a construction site for which a large-scale plan is required. Although the areas covered in construction are usually quite small, the accuracy may be required to a very high order. The types of engineering project envisaged are the construction of long tunnels and/or bridges, deformation surveys for dams and reservoirs, three-dimensional tectonic ground movement for landslide prediction, to name just a few. Hence control networks provide a reference framework of points for:

- Topographic mapping and large-scale plan production.
- Dimensional control of construction work.
- Deformation surveys for all manner of structures, both new and old.
- The extension and densification of existing control networks.

The methods of establishing the vertical control have already been discussed in Chapter 3, so only two-dimensional horizontal control will be dealt with here. Elements of geodetic surveying will be dealt with in Chapter 8 and so we will concentrate upon plane surveying for engineering control here.

The methods used for control surveys are:

- Traversing.
- Intersection and resection.
- Least squares estimation of survey networks.
- Satellite position fixing

Satellite station

Satellite station triangulation is a technique used to determine the location of a satellite by measuring the angle of arrival (AOA) or time of arrival (TOA) of signals received from the satellite at multiple ground-based stations with known locations. By using the principles of trigonometry and geometry, the position of the satellite can be determined based on the measured angles or times of arrival at the different stations.

Satellite station triangulation is commonly used in satellite communication systems, such as satellite television, satellite navigation (e.g., GPS), and satellite tracking applications. It allows ground-based stations to determine the location of a satellite with high accuracy, which is crucial for satellite operations, orbit determination, and tracking.

The process of satellite station triangulation typically involves the following steps:

Signal Reception: Ground-based stations receive signals from the satellite using antennas or receivers that are designed to operate at the frequency bands used by the satellite.

Angle or Time Measurements: The received signals are used to measure the angle of arrival (AOA) or time of arrival (TOA) of the satellite signal at each ground-based station. The AOA can be determined by measuring the direction or bearing of the incoming signal using techniques such as phased array antennas or mechanical tracking systems. The TOA can be determined by measuring the time delay between the transmitted and received signals.

Data Exchange: The measured angles or times of arrival are typically exchanged among the ground-based stations to allow for the calculation of the satellite's position.

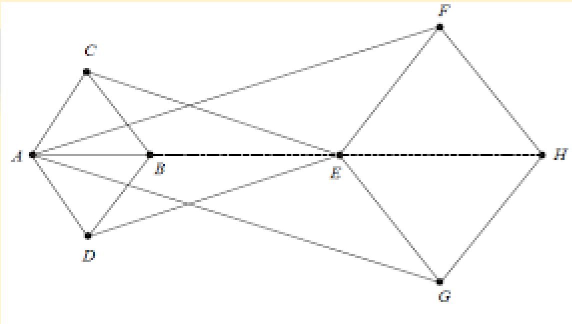
Triangulation Calculation: Using the measured angles or times of arrival from multiple stations with known locations, the satellite's position can be calculated using trigonometric or geometric methods. These calculations involve using the angles or times of arrival to form triangles, where the satellite's position is at the intersection of the triangles. The more stations involved in the triangulation, the higher the accuracy of the satellite's position determination.

Satellite Position Determination: Once the triangulation calculations are completed, the satellite's position can be determined with high accuracy. This information can be used for various purposes, such as tracking the satellite's orbit, controlling the satellite's operations, and providing precise satellite location data for satellite communication or navigation systems.

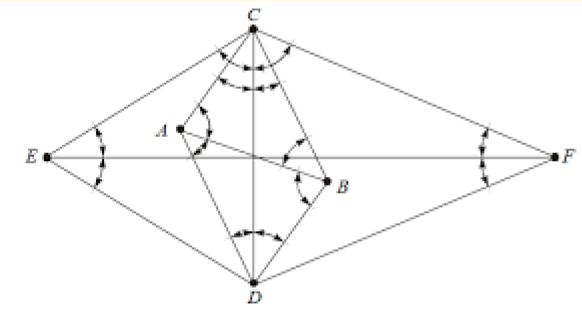
Extension and double extension of base

Extension and double extension are techniques used to enhance the accuracy and reliability of triangulation results, especially in situations where high precision is required. They are commonly used in geodetic surveys, precise positioning applications, and other scenarios where accurate positioning is critical. However, these techniques may also require additional equipment, resources, and expertise to implement, and the choice to use them depends on the specific requirements and constraints of the triangulation application.

Extension: Extension in triangulation involves increasing the length of the baseline by adding additional measurement points, typically in a linear or chain-like configuration. This is done to increase the accuracy of the triangulation by obtaining more precise measurements and a larger baseline angle. The additional measurement points are typically placed in a straight line, and the baseline is extended by measuring the angles or distances between these points and the target object.



Double Extension: Double extension is a technique used in triangulation that involves extending the baseline in two directions from the original measurement points. This is typically done to further increase the accuracy and reliability of the triangulation results by creating a larger baseline angle and reducing potential measurement errors. Double extension is commonly used in situations where high precision is required, such as in geodetic surveys or precise positioning applications.

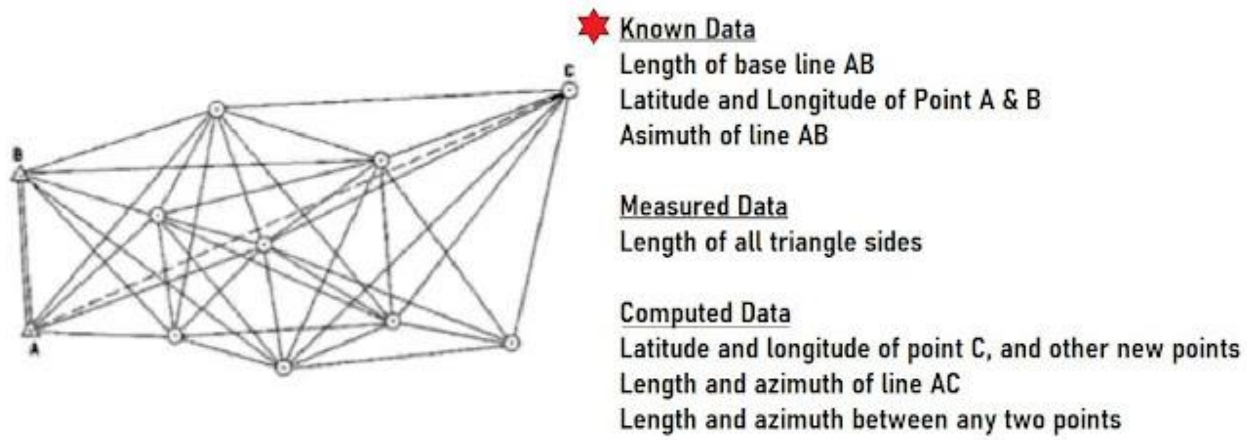


Trilateration

Trilateration is a surveying method used to determine the horizontal positions, in addition to other methods like triangulation, intersection, resection and satellite positioning. Trilateration is a method that work with distances and is the major working principle followed in Global Positioning System (GPS) Surveying.

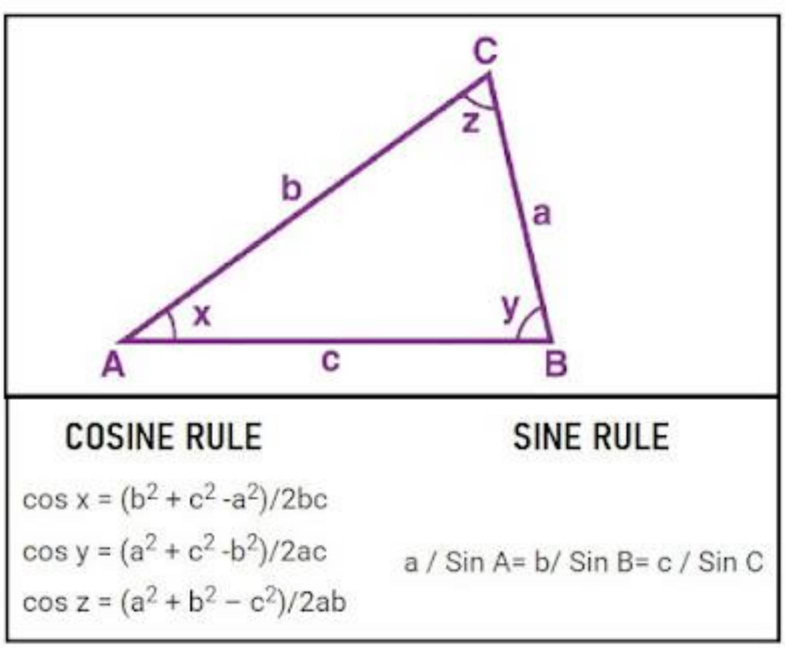
Trilateration employs electronic distance measuring instruments (EDMs) to measure the lengths of the triangle sides rather than horizontal angles in triangulation. Trilateration consist of series of joined or overlapped triangles that forms polygons or quadrilaterals, with a supplemental horizontal angle observation to provide azimuth control or check the angles.

Trilateration has become more practical with the development of EDMIs, as it is highly accurate and precise for expanding and establishing horizontal control.



Principle of Trilateration in Surveying

- Trilateration measures distance and not angles unlike triangulation method. Initially, the area to measured is turned into triangles and the length of all the sides of the triangles are measured. It can also be polygons, or quadrilateral or any combination of them. The distances are measured using an electronic instrument or a suitable instrument.
- The angles of the triangles and the coordinates of their vertices are determined using trigonometric computations. Sine rule and cosine rule are used to determine the angles.



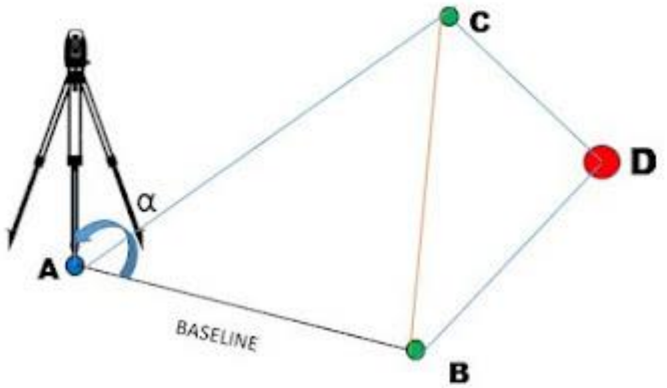
- This means, the method, does not involves measurement of angles.
- In order to check the accuracy of determined angles from the trigonometric observations, horizontal angles are sometimes measured.
- Once the angles of the triangles are computed, the trilateration is adjusted and the coordinates of the stations are determined.
- When trilateration is used for navigation, astronomy, engineering or mapping, azimuths are also determined. Azimuth is an angular measurement in a spherical coordinated system, that is measured in degrees. Watch Explained v

How to Locate a Point Using Trilateration Surveying

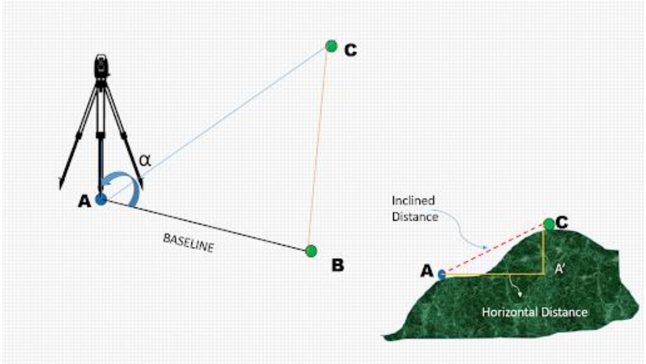
Trilateration is an alternative to triangulation that rely only on distance measurement. EDMs make trilateration a cost-effective positioning technique for control surveys.

If a point A exists, another point B is established using open traverse. Using a total station with EDM device, the distance AB is measured and its azimuth (α) is determined. This like AB becomes the **baseline** for trilateration purpose.

This is performed by placing the total station on A by an operator and a reflector on B. Based on the requirements of control survey, the accuracy of the calculated position B may be conformed by the astronomical observation.



The distance AC and BC is measured using total station. Both forward and backward measurements are taken. After the measurements, the slope distances are converted into horizontal distances.



After this, cosine rule is used to determine the interior angles of the triangle, and the coordinates of C can be fixed.

The accuracy of the fixed coordinated is checked by plotting triangle ABC nd evaluating the error of closure.

Next, the trilateration network is extended to measure the distance CD and BD, and then fix the coordinates of location D.

Applications of Trilateration in Surveying

- In areas that is subjected to seismic activity, trilateration is employed to study the gradual and secular movement in earth's crust. This study helps to construction high-precision engineering projects with defense and scientific facilities.
- Trilateration is also used in control expansion or densification for future metropolitan growth; coastline control; inland waterways; control extension; densification for land subdivisions and construction; and deformation surveys of dams, geothermal areas, structures, regional/local tectonics, and landslides.
- Used for simple low-order topographic survey
- Used for global positioning surveying systems
- Used to extend topographic mapping control from small local tracts to regional areas
- Accuracy increase with the use of EDMs making it suitable for special-purpose precise surveys.

Advantages of Trilateration in Surveying

- Achieve rapid control expansion with utmost accuracy
- Earns good cost-benefit ratio and potential
- Less expensive compared to triangulation
- Accurate for most conditions
- Permits control over large and small geographical areas with minimum number of personnel.
- Provide necessary scale control that is lacking in triangulation
- Proper execution make it superior than triangulation and traversing method

Computation of Coordinates

In mine measurement and surveying, coordinates play a crucial function. Two measurements are required (a) for horizontal bearings and (b) for horizontal distance in order to calculate coordinates.

The vernier theodolite was used for angle measurement in the past, but today, total stations and digital theodolites are utilised to measure angles. Chain, tape, and a total station should be used for horizontal measurements.

Coordinates come in two different types:

consecutive coordinates: Consecutive coordinates are the latitude and departure of any point with relation to the recording point.

Independent coordinates, often known as total coordinates, are the coordinates of any point with respect to a shared origin.

Latitude and departure must be calculated to find out coordinates of a line.

Solved Previous Year Questions

1. In a theodolite the line passing through the center of the cross-wires and optical center of the objective lens and its continuation is known as

(1) Trunion line

(2) Horizontai line

(3) Line of Collimation

(4) Axis of level tube

(5) None of the Options

Ans(3)

Trunnion axis: It is the axis about which the telescope rotates in the verticle plane. It is also called the horizontal axis and transverse axis.

Optical axis: This axis is the imaginary line passing through the optical center of the object-glass and the optical center of the eyepiece.

Line of collimation: It is an imaginary line passing through the intersection of crosshairs on the diaphragm and the optical center of the objective.

2. A Theodolite measures

(1) Horizontal angle only

(2) Vertical angle only

(3) Horizontal and Vertical angles

(4) both angle and distance

(5) None of the Options

Ans.(3)

Theodolite:

The theodolite is the most precise instrument designed for the **measurement of horizontal and vertical angles.**

Theodolite is one of the surveying instruments which has very wide applicability such as

- Laying of horizontal angles
- Locating point on the line
- Determining differences in elevation
- Setting out curves
- Establishing grades, etc.

3. Slow motion to a theodolite is given using the

(1) Tangent screw

(2) Capstan screw

(3) Clamping screw

(4) Foot screw

(5) None of the Options

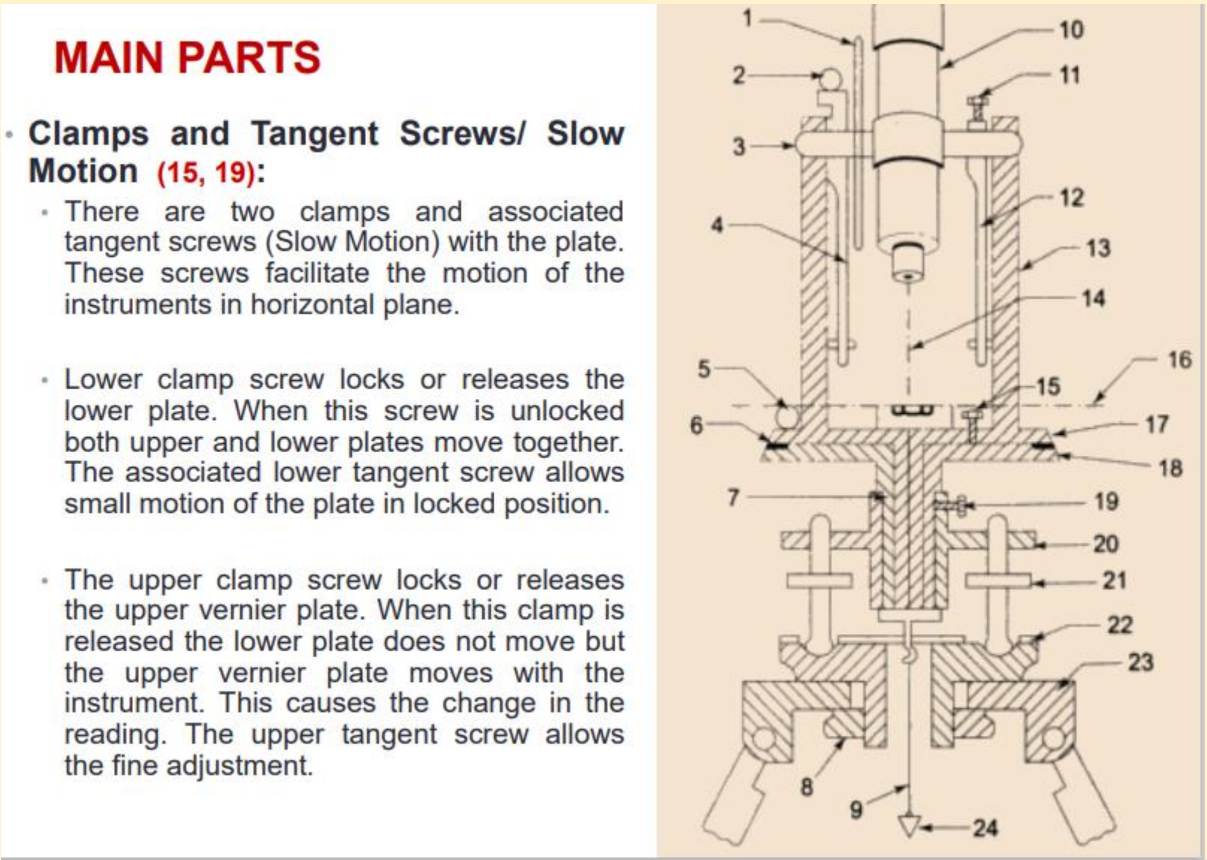
Ans(1)

The tangent screw ia a very fine, slow-motion screw giving a tangential movement for making the final setting to a precision surveying instrument (such as for completing the alignment of sight on a theodolite or transit by gentle rotation of the reading circle about its axis).

4. A very fine slow motion for making the final setting to a theodolite is given using the _____

a) Tangent screw
b) Captain screw
c) Clamping screw
d) Foot screw
e) None of the above

Ans A



5. Which of the following is not a permanent adjustment of Theodolite?•

(1) Adjustment of plate level

(2) Adjustment of line of sight

(3) Adjustment of reversing point

(4) Adjustment of altitude bubble

(5) Adjustment of pivot

Ans 5

The adjustments in transit Theodolite are of two types:

1. Permanent Adjustments.

2. Temporary Adjustments.

The **permanent adjustment are** made to establish the fixed relationships between the fundamental lines of the instrument, and once made, they last for long time. The following are the permanent adjustments in transit Theodolite:

1. **Adjustment of the Horizontal Plate Levels.**
2. **Collimation Adjustment: Axis of the telescope level adjusted to parallel to the line of collimation.**
3. **Horizontal Axis Adjustment: Horizontal axis is perpendicular to vertical axis when the instrument is leveled.**
4. Adjustment of the Telescope Level or the Altitude level.
5. Vertical Circle Index Adjustment

The temporary adjustments are made at each set up of the instrument before starting taking observations with the instrument. The following are the temporary adjustments in transit Theodolite:

1. Setting up the Theodolite over the station.
2. Leveling up the Theodolite.
3. Elimination of the parallel.
4. Focusing.

6. The GPS works based on the principle of ________

a) Triangulation
b) Trilateration
c) Two point problem
d) Three point problem
e) Traversing

Ans B

The working/operation of the Global positioning system is based on the 'trilateration' mathematical principle. The position is determined from the distance measurements to satellites. From the figure, the four satellites are used to determine the position of the receiver on the earth.

7. In colliery triangulation an accuracy of ………………. for calculate because between two station should be attained

a) 1 in 10,000
b) 1 in 1,000
c) 1 in 5,000
d) 1 in 2,000
e) 1 in 3,000

Ans A

The triangulation Survey is classified into three types on the basis of triangulation of a line of length and azimuth with accuracy.

The general specifications of these three types of surveys are given below in the tabulated form:

Parameter	**Primary Triangulation**	**Secondary Triangulation**	**Tertiary Triangulation**
Average triangle closure	**Less than a Second**	**Less than 3 Seconds**	**Less than 6 Seconds**
Maximum triangle closure Length	Less than 3 seconds	Less than 8 seconds	Less than 12 seconds
Length of the sides of triangles	30 to 150 kms	8 to 65 kms	1.5 to 10 kms
Actual error of base	1 in 300000	1 in 150000	1 in 75000
Probable error of base	1 in 1000000	1 in 5000000	1 in 250000

7. The principle of triangulation survey is working from ……………. to ……………..

a) Whole, part
b) Part, whole
c) Whole, whole
d) Part, part
e) None of these

Ans A

Explanation:

- In **whole to part**, the error is **localized as it prevents accumulation of error** and,
- In **part to whole,** the **error** is **expanded**.

The fundamental principles of plane surveying are:

1. Location of a point by measurement from two point of reference: Two control points are selected in an area and the distance between them is measured accurately.

2. Working from whole to the part: Major control points are selected and measured first with high degree of precision, minor details can be collected later on even with less degree of precision. In this manner, errors involved in minor detailing will be compensating and will not affect the major dimensions.

Note:

- The **main idea of working from whole to part** is **to localise errors** and **prevent their accumulation**.
- On the contrary, **working from part to whole,** the **errors accumulate and expand to a greater magnitude** and the survey work becomes uncontrollable at the end.

8. The bearing of a line AB is $150^0 20'$ and angle ABC is $124^0 38'$. What is the bearing of BC?

a) Bearing of BC = $94^0 58'$
b) Bearing of BC = $86^0 58'$
c) Bearing of BC = $66^0 58'$
d) Bearing of BC = $76^0 58'$
e) Bearing of BC = $99^0 28'$

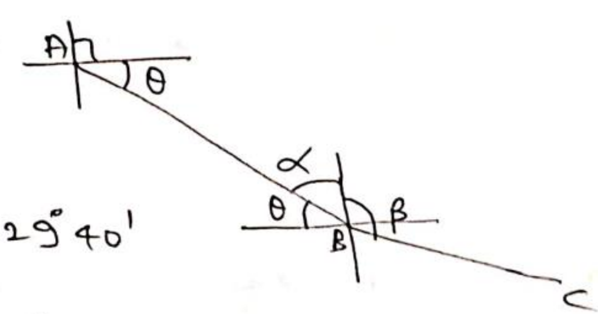
Ans A

Given,

$90 + \theta = 150^\circ 20'$

$\Rightarrow \theta = 60^\circ 20'$

$\therefore \alpha = 90^\circ - 60^\circ 20' = 29^\circ 40'$



$\therefore \beta = 124^\circ 38' - 29^\circ 40'$

$= 94^\circ 58'$

$\therefore$ Bearing of BC $= \underline{94^\circ 58'}$

9.The geometrical figures used in a triangulation system are

a) Triangles
b) Quadrilaterals

c) Pentagons
d) Hexagons
e) All of these

Ans E

The common figures or system used in triangulation system are:

- Single Chain of Triangles.
- Double Chain of Triangles.
- Central Point Figures.
- Quadrilaterals.
- Combination of all the system.

10. In triangulation figure, the angle of every triangle should not be less than ………. and not more than ………

a) 30”, 120”
b) 50”, 160”
c) 60”, 160”
d) 50”, 130”
e) 45”, 140”

Ans A

Well conditions triangle of a triangular system.

- The arrangement of a triangle in the layout and the magnitude of the angles in the individual triangles, affect the accuracy of the triangular system.
- The shape of the trianglein which any error in the angular measurement has a minimum effect upon the length of the computed sides is known as a well conditional triangle.
- Hence, **the best shape of a triangle is an isosceles triangle whose base angle is 56°14'.**
- But, for all practical purposes, an equilateral triangle may be treated as a well conditional triangle.

Note:

The triangle, whose angles are less than **30^0** or more than **120^0**, should be avoided in the chain of triangles.

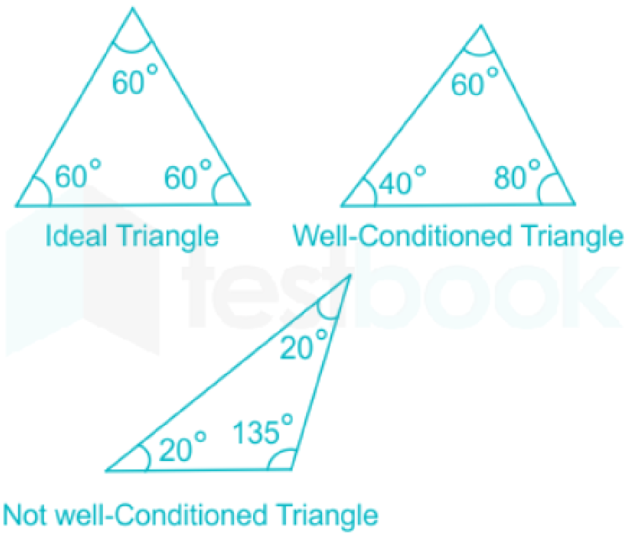
11. The best conditioned triangle in a triangulation survey is

a) Right angled triangle
b) Equilateral triangle
c) Isosceles triangle whose base angle are $56^0$14’ each
d) Scalene triangle
e) None of the above

Ans B

In chain surveying,

- A **triangle** is said to be **well-conditioned** if it can be plotted accurately by the intersection of arcs from the end of baseline.
- **An equilateral triangle is the best well-conditioned triangle or ideal triangle possible.**
- If not possible to have an equilateral triangle, it must ensure that **no angle is less than 30° and greater than 120°**.



Note:

Well-conditioned triangles are preferred because their **apex points are very sharp** and **can be located by a single 'dot'**. In such a case, there is **no possibility of relative displacement** of the plotted point.

12. The GPS works based on the principle of ________

f) Triangulation
g) Trilateration
h) Two point problem
i) Three point problem
j) Traversing

Ans B

The working/operation of the Global positioning system is based on the 'trilateration' mathematical principle. The position is determined from the distance measurements to satellites. From the figure, the four satellites are used to determine the position of the receiver on the earth.

13. The base line is defined as

(1) The tie line joining two tie stations on chain line

(2) The longest line in the triangulation

(3) The shortest line in the triangulation

(4) The offset line drawn from the chain line

(5) None of the Options

Ans(2)

In surveying, a baseline is a line between two points on the earth's surface and the direction and distance between them. In a triangulation network, at least one baseline between two stations needs to be measured to calculate the size of the triangles by trigonometry. It is the longest line in the triangulations.

14. Prismatic compass gives the

(1) Quadrantal Bearing

(2) Reduced Bearing

(3) Whole circle Bearing

(4) Quadrantal and Reduced Bearing

(5) None Of the Options

Ans(3)

Sol-Whole Circle Bearing (WCB) The magnetic bearing of a line measured clockwise from the north pole towards the line, is known as the 'whole circle bearing', of that line. Such a bearing may have any value between 00 and 360^0. The whole circle bearing of a line is obtained by prismatic compass.

Quadrantal Bearing (QB)The magnetic bearing of a line measured clockwise or counter clockwise from the North Pole or South Pole (whichever is nearer the line) towards the East or West, is known as the 'quadrantal bearing' of the line. Quadrantal bearings are obtained by the surveyor's compass.

15. ABCD is a regular parallelogram plot of land whose angle BAD is 60°. If the bearing of the line AB is 30°, the bearing of CD, is

(1) 90°

(2) 120°

(3) 210°

(4) 270°

(5) 180°

Ans.(3)

From figure,

By corresponding angle :

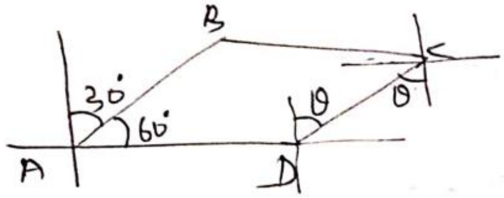
$\theta = 30°$

∴ True bearing of CD

$= 180° + \theta$

$= 180° + 30°$

$= \underline{210°}$



16. If the reduced bearing of a line AB is N 60° W and length is 100 m, then the latitude and departure respectively of the line AB will be

(1) tt50 m, 1186.6 m

(2) tt86.6 m, Âť 50 m

(3) tt50 m, ~ 86.6 m

(4) tt70.? m. - 50 m

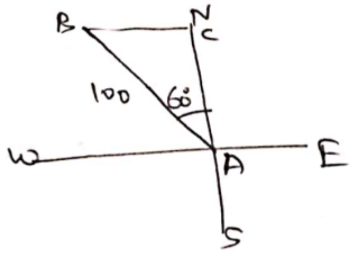
(5) None of the Opfions

Correcfion Answer : Opfion No.(3)

$AC = 100 \times \cos 60°$

$= 100 \times \frac{1}{2}$

$= 50 m$



$BC = 100 \times \sin 60°$

$= 86.60$

∴ (latitude, departure) ≃ $\underline{(50, 86.6)}$

17. The whole circle bearing of a line with Quadrantal bearing of S 19° 30’ E is

(1) 19° 30’

(2) 109° 30’

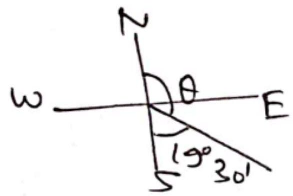
(3) 160° 30’

(4) 199° 30’

(5) None of the Options

Ans.(3)

Whole circle Bearing



$= \theta$

$= 180° - 19°30'$

$= 179°60' - 19°30'$

$= \underline{160°30'}$

18. The magnetic bearing of a line is S30° 20’E. What will be the true bearing of the line if the magnetic declination is 4° 10’ East?

(1) 145° 30‘

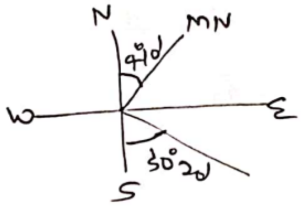
(2) 153° 50’

(3) 63° 50’

(4) 65° 30’

(5) None of the Options

Ans.(2)



Magnetic bearing of line

$= 180° - 30°20'$

$= 149°40'$

$\therefore$ True bearing of line $= 149°40' + 4°10'$

$= \underline{153°50'}$

19. The multiplicative constant in a tacheometer with focal length fand stadia wire interval i. is

(1) i/f

(2) f/i

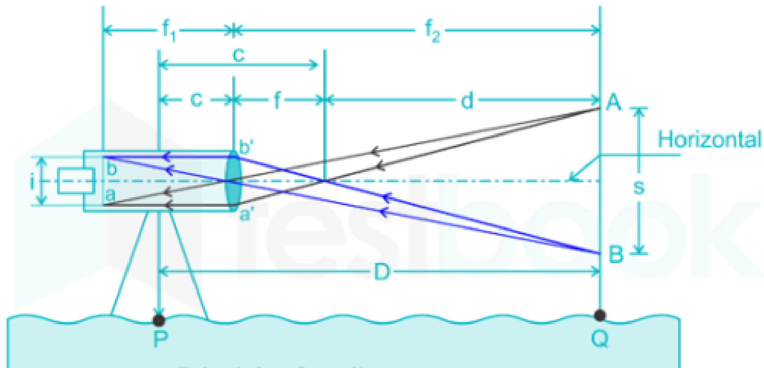
(3) i+f

(4) I x f

(5) None of the Options

Ans(2)

Tachometer: It's a transit theodolite fitted with a stadia diaphragm which gives both horizontal and vertical control with an accuracy of 1 in 1000.



Principle of stadia measurement

From the above figure, the horizontal distance is given by -

D = kS + C

This formula involves the computation of two constants i.e. **multiplying constant (k) and additive constant (c)**.

$k = \frac{f}{i}$ and $c = f + d$

Where,

f = Focal length of the objective lens

i = Distance between the stadia wires

d = distance of the objective from the center of the instrument.

20. A tacheometer is calibrated as D= 100s + 0.30. The stadia readings to a staff station are 3.84 m, 2.67 m and 1.5 m. Find the horizontal distance between two stations.

a) 246.30 m
b) 238.4 m
c) 234.30 m
d) 243.3 m
e) None of the above

Ans C

Given, $S_1 = 3.84m$

$S_2 = 2.67m$

$S_3 = 1.5m$

$\therefore \; S = S_1 - S_3 = 3.84 - 1.5 = 2.34m$

$\therefore$ Horizontal distance $= D = 100S + 0.30$

$= 100 \times 2.34 + 0.30$

$= \underline{234.30\,m}$

Field Astronomy

Field astronomy is a branch of astronomy that involves observing and measuring celestial objects chronometers. Field astronomers often work in remote locations, away from light pollution and atmospheric interference, to obtain accurate data for various purposes, such as navigation, surveying, geodesy, and timekeeping.

Astronomical terms are words and phrases that are used to describe the concepts and phenomena related to astronomy and its subfields. Some common astronomical terms are:

- **The celestial sphere:** An imaginary sphere of infinite radius that surrounds the Earth and on which all celestial objects appear to be located. The center of the Earth may be taken as the center of celestial sphere.

- **Zenith:** the point on the upper portion of the celestial sphere marked by plumb line, above the observer or the point on the celestial sphere immediately above the observer's station.

- **Nadir:** the point on the lower portion of the celestial sphere marked by plumb line, below the observer. Or the point on the celestial sphere vertically below the observer's station.

-**Great circle**: is a section of a sphere when the cutting plane passes through the center of the sphere.

- **The celestial Horizon / True Horizon/ Geocentric Horizon:** It is the great circle traced upon the celestial sphere by the plane which is perpendicular to the Zenith-Nadir line and which passes through the center of the earth.

- **The Terrestrial Poles:** The Terrestrial Poles are the two points in which the Earth's axis of rotation meets the earth's sphere. Terrestrial poles are the points where the Earth's surface and Earth axis of rotation meets.

- **The Terrestrial Equator:** The Terrestrial Equator is the great circle of the Earth, the plane of which is at right angles to the axis of rotation. The two poles are equidistant from it.

- **The Celestial Poles:** If the Earth's axis of rotation is produced indefinitely, it will meet the celestial sphere in two points called the North and South celestial poles.

-**The Celestial Equator:** It is the Great circle of the celestial sphere in which it is intersected by the plane of celestial equator.

-**The Sensible Horizon:** The circle in which a plane passing through the Earth's surface and point of observations and tangential to the earth's surface or (normal to the Zenith-nadir line) intersects with celestial sphere is called the sensible Horizon. The line of sight of an accurately levelled telescope lies in this plane.

-**The Visible Horizon:** The circle of contact with the Earth surface of the visible rays passing through the point of observation is called as visible horizon. Visible Horizon is a small circle of Earth.

-**The Vertical Circle:** A vertical circle of the celestial sphere is a Great circle passing through the Zenith (Z)and Nadir (Z'). All the vertical circle cut the celestial Horizon at Right Angles.

-**The Observer's Meridian:** The Meridian of any Particular point is that circle which passes through the Zenith (Z)and Nadir (Z') and Poles P and P 1 of the point as well as through the poles. It is thus a vertical circle.

-**The Prime Vertical/ Prime Control**: It is Vertical Circle at 90° to observer's meridian on celestial sphere and passes through the East and West points of the horizon is called as prime vertical.

-**The Latitude (Axaans)**: The angle between the direction of a plumb line at the place and the plane of the celestial Equator is called as latitude. It is denoted by 'θ'. It can also be defined as the angle between the celestial equator and Zenith.

-**The longitude**: Longitude measures distance east or west of the prime meridian. Lines of longitude, also called meridians, are imaginary lines that divide the Earth. They run north to south from pole to pole, but they measure the distance east or west.

Purposes of Field Astronomy

• Determine absolute location/ position and direction of any line on the surface of the Earth.

• Determine absolute location of any points / object - astronomical observation to celestial bodies such as Moon, Sun, Star, and planets.

• Used to find Angular position of Stars.

• Determination of the position of Points on the Earth

• Determination of Orientation.

Determination of True Bearing by the Equal Altitude Method

The determination of true bearing by the equal altitude method is a technique used in celestial navigation to find the true bearing or azimuth of a celestial body, such as the Sun or a star. This method involves measuring the altitude of the celestial body at two different times when it is at the same azimuth or bearing. By comparing the two altitudes and the time difference between the measurements, the true bearing of the celestial body can be calculated.

To perform the equal altitude method, a navigator needs a sextant to measure the altitude of the celestial body above the horizon accurately. The process involves the following steps:

1. **Choose a celestial body:** Select a celestial body that is visible and has a known declination (the celestial equivalent of latitude).

2. **Measure the altitude:** Using a sextant, measure the altitude of the celestial body when it is at a certain azimuth or bearing. This is the first altitude measurement.

3. **Wait for a time interval:** Wait for a specific time interval, usually around 1 to 2 hours, depending on the celestial body and the desired accuracy.

4. **Measure the altitude again:** Take a second altitude measurement of the celestial body when it is at the same azimuth or bearing as before. This is the second altitude measurement.

5. **Calculate the true bearing:** The true bearing can be calculated using the two altitude measurements and the time difference between them. The calculation involves trigonometry and spherical geometry.

To calculate the true bearing using the equal altitude method, you will need the following information:

1. First altitude measurement (h_1): The altitude of the celestial body at the first observation.
2. Second altitude measurement (h_2): The altitude of the celestial body at the second observation.
3. Time difference (Δt): The time difference between the two observations in hours.
4. Declination (δ): The known declination of the celestial body.

The calculation involves trigonometry and spherical geometry. Here's the step-by-step process:

1. Convert the altitudes to zenith distances:

   Zenith distance (Z) = 90° - Altitude (h)

   $Z_1 = 90° - h_1$

   $Z_2 = 90° - h_2$

2. Convert the zenith distances to co-latitudes:

   Co-latitude (C) = 90° - Zenith distance (Z)

   $C_1 = 90° - Z_1$

   $C_2 = 90° - Z_2$

3. Calculate the hour angle (H) using the time difference:

   Hour angle (H) = 15° per hour × Time difference (Δt)

4. Calculate the latitude (L) using the co-latitudes and the hour angle:

   Latitude (L) = $(C_1 + C_2) / 2$

5. Calculate the azimuth (A) using the latitude, co-latitudes, and hour angle:

   Azimuth (A) = $\arctan(\sin(H) / (\cos(L) * \tan(C_1) - \sin(L) * \cos(H) * \tan(C_2)))$

6. Convert the azimuth to true bearing:

True bearing = 360° - Azimuth (A) if A > 180°

True bearing = Azimuth (A) if A ≤ 180°

Gyro Theodolites

A gyro theodolite is a device that combines a gyroscope and a theodolite to measure the true north direction of a survey line. It is mainly used in situations where other methods of determining the direction, such as astronomical observations or GPS, are not feasible or accurate enough. For example, it can be used in mine surveying, tunnel engineering, shipbuilding, or other projects that require high precision in orientation.

Gyro theodolite works by using the principle of gyroscopic precession, which is the tendency of a spinning object to align itself with the axis of rotation of the Earth. The gyroscope is mounted on a sphere that is connected to the vertical axis of the theodolite. The gyroscope is spun at a high speed by an electric motor until it becomes a north-seeking gyroscope.

The operator then uses an optical system to align the zero mark on the attachment with the spin axis of the gyroscope. By tracking the spin axis as it oscillates about the meridian, the operator can record the azimuths of the extreme stationary points of the oscillation and calculate the midpoint, which represents an estimate of the true north direction. The accuracy of this estimate depends on several factors, such as the quality of the gyroscope, the alignment of the zero torque of the suspension, and the measurement errors of the oscillation extremes.

Determination of the Gyro North Using a Gyro Theodolite

For determining the gyro north using a gyro theodolite is as follows:

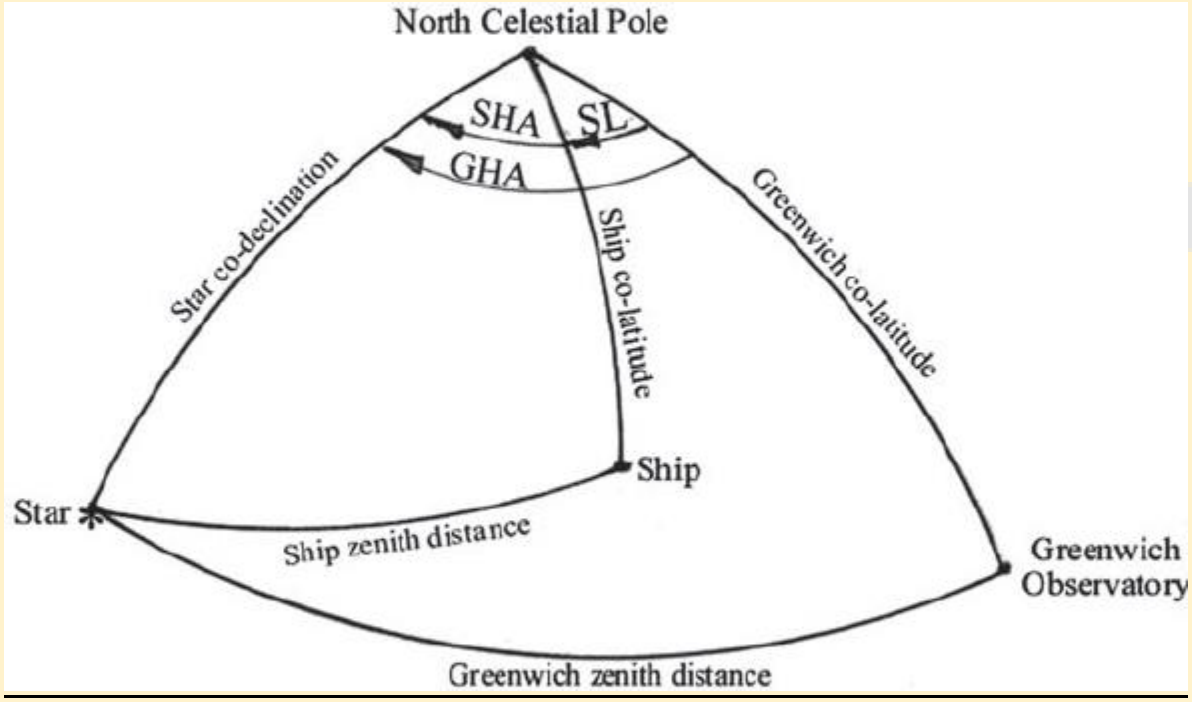
- Step 1: Set up the gyro theodolite on a stable tripod over a survey point and level it using the bubble levels. Make sure the gyroscope is mounted on the sphere that is connected to the vertical axis of the theodolite.
- Step 2: Turn on the electric motor to spin the gyroscope at a high speed until it becomes a north-seeking gyroscope. This may take several minutes depending on the model and type of the gyro theodolite.
- Step 3: Use the optical system to align the zero mark on the attachment with the spin axis of the gyroscope. This will ensure that the gyroscope is free to oscillate about the meridian without any external torque.
- Step 4: Track the spin axis of the gyroscope as it oscillates about the meridian using the crosshairs of the telescope. Record the azimuths of the extreme stationary points of the oscillation using the horizontal circle of the theodolite. These are called A1 and A2, where A1 is clockwise from A2.
- Step 5: Calculate the midpoint of A1 and A2, which represents an estimate of the true north direction. This can be done by adding A1 and A2 and dividing by 2, or by subtracting A1 from A2 and dividing by 2, depending on whether A1 is greater than or less than A2. The result is called Z, which is the true bearing of the celestial body from your position

- Step 6: Adjust the horizontal circle of the theodolite to read Z as zero. This will set your reference direction as true north. You can then use the gyro theodolite to measure other directions relative to true north.

Astronomical Triangle

An astronomical triangle is a spherical triangle on the celestial sphere formed by the intersection of the great circles joining a celestial body, the observer's zenith, and the north or south celestial pole. It is used to transform between equatorial and horizontal coordinate systems, and to calculate the azimuth, altitude, hour angle, and parallactic angle of the celestial body.

The sides of the astronomical triangle are equal to the zenith distance, the polar distance, and the co-latitude of the observer. The angles of the astronomical triangle are equal to the azimuth, the hour angle, and the parallactic angle of the celestial body. The relationships between the sides and angles of a spherical triangle are given by the spherical law of cosines and the spherical law of sines. These can be used to solve for any unknown side or angle of the astronomical triangle given enough information.



Different Time Systems

Time is the interval which lapses between any two instances. The time taken by one apparent revolution of the Sun about the Earth is known as **Solar Day**. The time taken by the Sun apparently to make a complete circuit of the ecliptic is equal to **one Tropical Year**.

The Earth made 366.2422 revolutions during a tropical year. The Sun travels through a total hour angle of 360° or 244 Hours in tropical year. The Sun apparently made 365.2422 revolutions about the Earth. Hence, apparently there are 365.2422 days in a solar year. The time interval between successive upper transits of the vernal equinox (first point of Aries) is known as a sidereal day. Thus, in a year, there are 366.2422 sidereal days.

Thus.

365.2422 solar days = 366.2422 sidereal days

1 solar day = 1.0027379 sidereal days

1 sidereal day = 0.9972696 solar days

Sidereal time is suitable for astronomers while solar time is convenient for everyday use.

The following systems are used for measuring time:

1. Sidereal time
2. Solar apparent time
3. Mean solar time
4. Standard time

1. Sidereal Time

The sidereal day is the interval of time between two successive upper transits of the first point of Aries. The sidereal day is divided into 24 hours, each hour is divided into 60 minutes and each minute into 60 seconds.

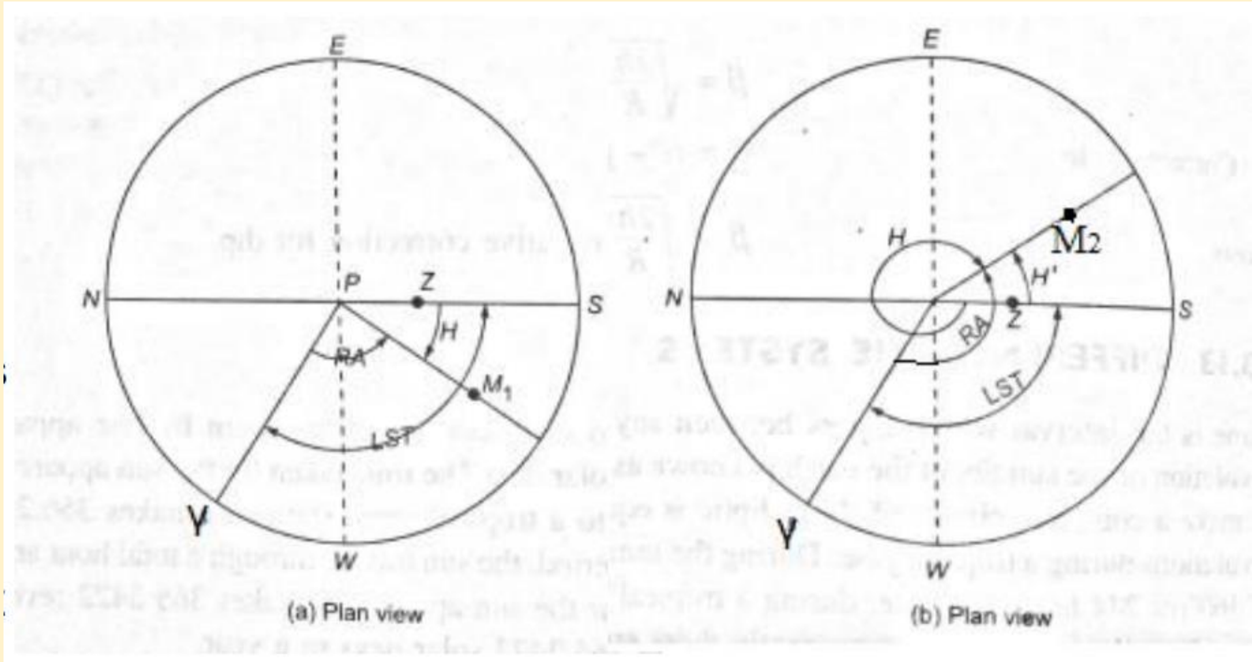
Local Sidereal Time

Local sidereal time (LST) is the time interval that has elapsed since the transit of the first point of Aries to the meridian of the observer.

Fig. shows the plan view of celestial sphere seen from the pole and thus: LST = $\angle ZP\gamma$

In fig. (a) NPZS shows the observers meridian. PM1 shows Hour circle of star M1 Thus Star's hour angle +Star's Right Ascension = LST

In fig. (b) LST = RA - H' It may also be noted that when the star is on the observer's meridian LST = RA (Since hour angle is zero).



The interval of the time between two successive lower transits of the mean sun is known as mean solar day. The duration of a mean solar day is the average of solar days of the year. The mean solar day begins at midnight and ends on next midnight. The zero hour of the mean solar day is at the local mean mid-night (LMM). The instant when the mean sun crosses the upper transit is known as local mean noon (LMN). The local mean time (LMT) is given by the hour angle of the mean sun reckoned westward from 0 to 24 hours.

Standard Time

Local mean time changes from place to place. So, to avoid confusion of using different local time in a country, local mean time of a particular place is used as the standard mean time in the entire country. The standard meridian of a country is generally selected such that its distance from Greenwich is in whole number of hours without any fraction.

However, India is an exception to this as its standard meridian is 5½ hours (82° 30') east of Greenwich. It passes near Allahabad. Though the standard mean time is followed through in a country, if required local mean time may be found with the formula below.

Local mean time = Standard mean time ± difference in longitudes in hours

Plus, sign is used if the place is east of standard meridian and minus sign is used for the places west to the standard meridian. World has accepted local mean time of Greenwich in U. K. as universal time (UT) or Greenwich mean time (GMT). Indian Standard Time = GMT+5½ Hours.

In general, hour angle and RA is measured in (hour, minute, second) , then following relation may be used for conversion:

24 hours = 360°

1 hour = 15°

1 min. = 15'

1 Sec. = 15"

The difference between the local sidereal time of two different places is equal to the difference of their longitudes expressed in terms of hours.

Solar Apparent Time

The time based on apparent motion of the sun around the Earth is known as solar apparent time. The time interval between two successive lower transits of the Sun over the observer's meridian is called apparent solar day. The reason for selecting lower transits of the Sun is to see that the day changes only at midnight not at noon.

The solar apparent day is not uniform throughout the year since the orbit around the Earth is not circular but elliptic and due to the apparent diurnal path of the Sun. The local apparent days are longer in summer and shorter in winter. Due to the non-uniformity of the apparent solar day, the clock cannot be used to give us solar time. Sun dials can be used to get apparent solar time.

Mean Solar Time

To overcome the difficulty of non-uniformity of the Sun's apparent motion in recording of the time, a fictitious sun is assumed to move at a uniform rate along the equator. ▪ The fictitious sun is called mean sun and start, and arrival of the mean sun and the true sun are assumed to be same at the vernal equinox.

Relationship between difference in longitudes and time interval

360°of longitude is equal to 24 hours of time interval. Hence

360° = 24 hours

1 hour = 15°

1 min. = 15'

1 Sec. = 15"

Conversion of local time to standard time

Since the apparent motion of the Sun is from east to west, local time of the place towards the east of standard meridian is more and if place is towards west local time is less.

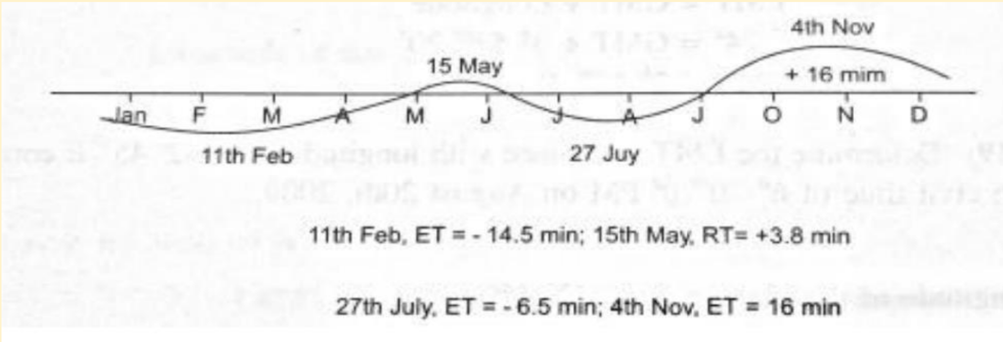
Local time = Standard time ± Difference in longitudes (use +ve for E; -ve for West).

Conversion apparent solar time to mean solar time.

The difference of apparent solar time (local apparent time, LAT) and mean solar time (local mean time, LMT) is known as equation of time, ET. Thus,

ET = LAT – LMT

The value of ET varies from 0 to 16 min. It is zero four times in a year. The Nautical Almanac gives the values of equation of time (ET) for everyday in a year. The values given are at the instant of apparent midnight for the Greenwich meridian. For any other day ET may be linearly interpolated. The ET is the same for all the places.



Conversion of sidereal time interval to mean solar time interval.

366.2424 sidereal days = 365.2422 mean solar days

Sidereal time to mean solar time:

1sidereal day = $\frac{365.2422}{366.2422}$

= $\left(1 - \frac{1}{366.2422}\right)$ mean solar day

or Sidereal Day-Mean solar day = $-\frac{1}{366.2422}$ hours

= $-\frac{1}{366.2422}\times 24\times 60\times 60$

= -235.909 seconds

or sidereal hour - Mean solar hour = $-\frac{235.909}{24}$ = - 9.8296 seconds.

or sidereal hour = (Mean solar hour - 9.8296) seconds.

Mean solar time to Sidereal time:

1 mean solar day= $\frac{366.2422}{365.2422}$ = $\left(1 + \frac{1}{365.2422}\right)$ sidereal day.

or mean solar day-Sidereal day = $\frac{1}{365.2422}$ hours = $\frac{1}{365.2422}$ ×24×60×60= 236.555 seconds.

or sidereal hour-Mean solar hour = $\frac{236.555}{24}$ 9.8565 seconds.

or Mean solar hour = (sidereal hour+9.8565) seconds.

Determination of azimuth by astronomical methods

The PZS Triangle and six parts:

Co Ø = 90° - LAT

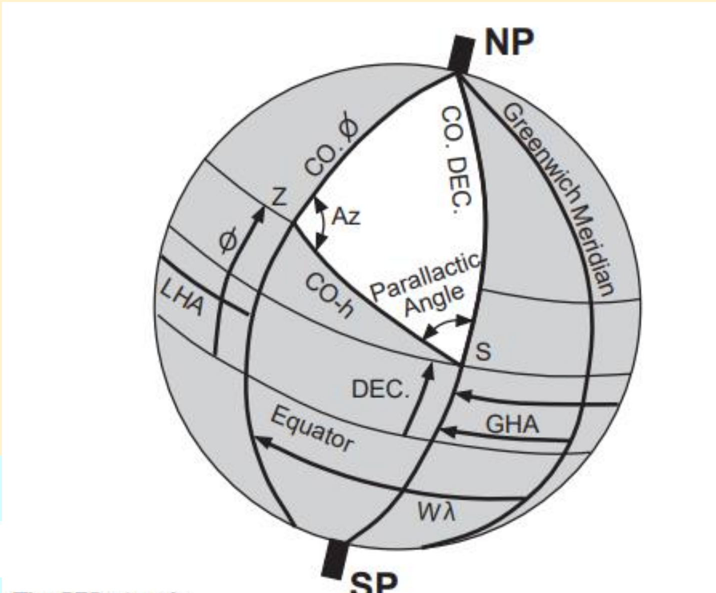
CoDEC = 90° - DEC

Co h = 90° - h

NP = North Pole

Z = Zenith

S = Sun or star



The PZS triangle.

Azimuth by Solar Observation

Azimuth can be determined using following 2 methods by solar observation:

1-hour angle method

2-altitude method

hour angle method

$$\text{AZIMUTH} = \tan^{-1} \frac{\sin \text{LHA}}{\sin \text{LAT} \cos \text{LHA} - \cos \text{LAT} \tan \text{DEC}}$$

Where:

LHA = local hour angle of sun

Dec = declination of sun

LAT = latitude of observe

AZ = Azimuth of sun

To normalize AZ, add correction		
LHA	corr	corr
0-180	180(+AZ)	360(-AZ)
180-360	0(+AZ)	180(-AZ)

Altitude method

Z = $\cos^{-1} \frac{\sin DEC - \sin LAT \sin h}{\cos LAT \cos h}$

Where:

AZ = Z (when sun is east of the local meridian)

AZ = 360 - Z (when sun is west of the local meridian)

DEC = declination of sun

LAT = latitude of observer

h = vertical angle to the sun corrected for parallax and refraction

<u>Azimuth by Observation of Polaris</u>

The equation given for hour angle method for the sun can be used, or the following:

Z = $\frac{p \sin LHA}{\cos h}$

Where:

h = (true altitude of Polaris)

p = 90° - declination

Z is west of north when 0o ≤ LHA ≤ 180°

Z is east of north when 180^o ≤ LHA ≤ 360°

AZ = Z (when Z is east of north)

AZ = 360 - Z (when Z is west of north)

Questions

1. What is the purpose of the equal altitude method in field astronomy?

   a. To measure latitude

   b. To determine the true bearing of celestial bodies

c. To calculate the altitude of the celestial equator

d. To find the azimuth of the North Star

Answer: b. To determine the true bearing of celestial bodies

2. Which instrument is used in the equal altitude method for celestial navigation?

a. Gyro theodolite

b. Sextant

c. Telescope

d. Chronometer

Answer: b. Sextant

3. In field astronomy, what is the primary function of a gyro theodolite?

a. To measure the altitude of celestial bodies

b. To determine the azimuth of celestial bodies

c. To find the declination of stars

d. To calculate the latitude of the observer

Answer: b. To determine the azimuth of celestial bodies

4. What is the purpose of an astronomical triangle?

a. To calculate the altitude of the North Star

b. To measure the zenith distance of celestial bodies

c. To transform between equatorial and horizontal coordinate systems

d. To determine the observer's longitude

Answer: c. To transform between equatorial and horizontal coordinate systems

5. What is the relationship between the sides and angles of an astronomical triangle determined by?

a. The Pythagorean theorem

b. The law of cosines and the law of sines

c. The law of gravitation

d. The celestial sphere's curvature

Answer: b. The law of cosines and the law of sines

6. Which time system is suitable for astronomers due to its uniformity?

a. Solar apparent time

b. Mean solar time

c. Standard time

d. Sidereal time

Answer: d. Sidereal time

7. What is local sidereal time (LST) in field astronomy?

a. The time elapsed since midnight

b. The time interval between two successive solar transits

c. The time interval between two successive upper transits of the first point of Aries

d. The time difference between standard time and solar apparent time

Answer: c. The time interval between two successive upper transits of the first point of Aries

8. What is the difference between mean solar time and apparent solar time called?

a. Equation of time

b. Sidereal time

c. Solar declination

d. Time correction

Answer: a. Equation of time

9. Which time system is used universally as a reference point for timekeeping?

a. Sidereal time

b. Solar apparent time

c. Mean solar time

d. Standard time

Answer: d. Standard time

10. In the conversion of local time to standard time, what sign is used for places east of the standard meridian?

a. +ve

b. -ve

c. x

d. /

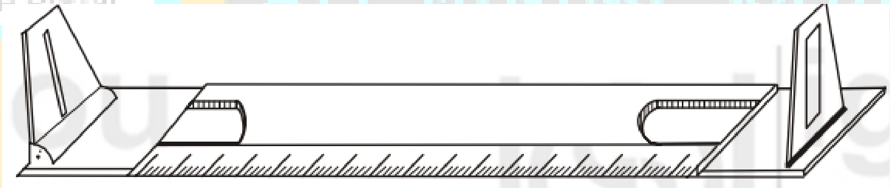
Answer: a. +ve

Plane Table Surveying

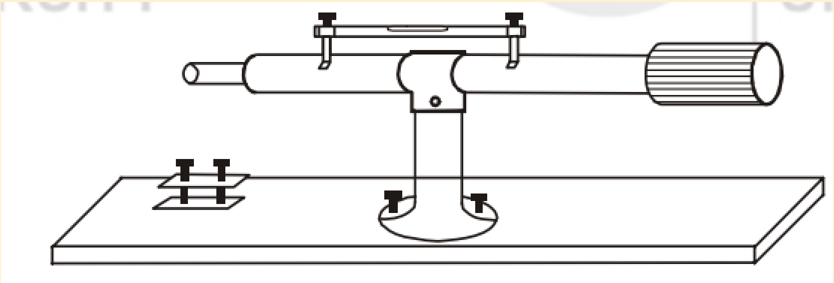
The plane table is an instrument used for surveying by a graphical method in which the field work and plotting are done simultaneously. In plane table surveying, an unknown point of interest is established by measuring its directions from known points. The main advantage of plane tabling is that the topographic features to be mapped are in full view. Plane table surveying is most suitable for small and medium scale mapping.

Basic Principle: For quick and approximate surveying, when great precision and accuracy is not needed, plane table surveying techniques is very suitable. It is particularly convenient for filling the details between the stations already fixed and surveyed by more precise method of triangulation or theodolite traversing. For small area surveys, plane table is recommended. The great advantage of this technique is that field work and map plotting is achieved simultaneously by use of graphical surveying. The principle used in plane table surveying is that an unknown point of interest can be established by measuring its directions from known points.

Equipment: The plane table essentially consists of a simple drawing board mounted on a tripod similar to a compass or a level. The drawing board usually made from well seasoned teak or pine wood. The size can vary from 400 × 300 mm to 750 × 600 mm. Sometimes square boards of 500 × 500 mm or 600 × 600 mm are also used but size of square boards is rather uncommon. Another important constituent of plane table is a straight edge called Alidade. It is made of a metal (brass or gunmetal) or seasoned wood about 500 mm long with a straight ruled edge which is bevelled. This edge is termed "fiducial" edge. It may be provided with sight vanes, at both ends in a plain alidade with a telescope for better accuracy. In plain alidade one of the sight vanes is provided with a narrow slit and the other is provided with cross and stadia wires. Like a level, two bubble tubes placed orthogonally are provided for keeping the plane table horizontal. The bevelled edge is graduated so that it can be used as a scale for plotting distances directly on the map.

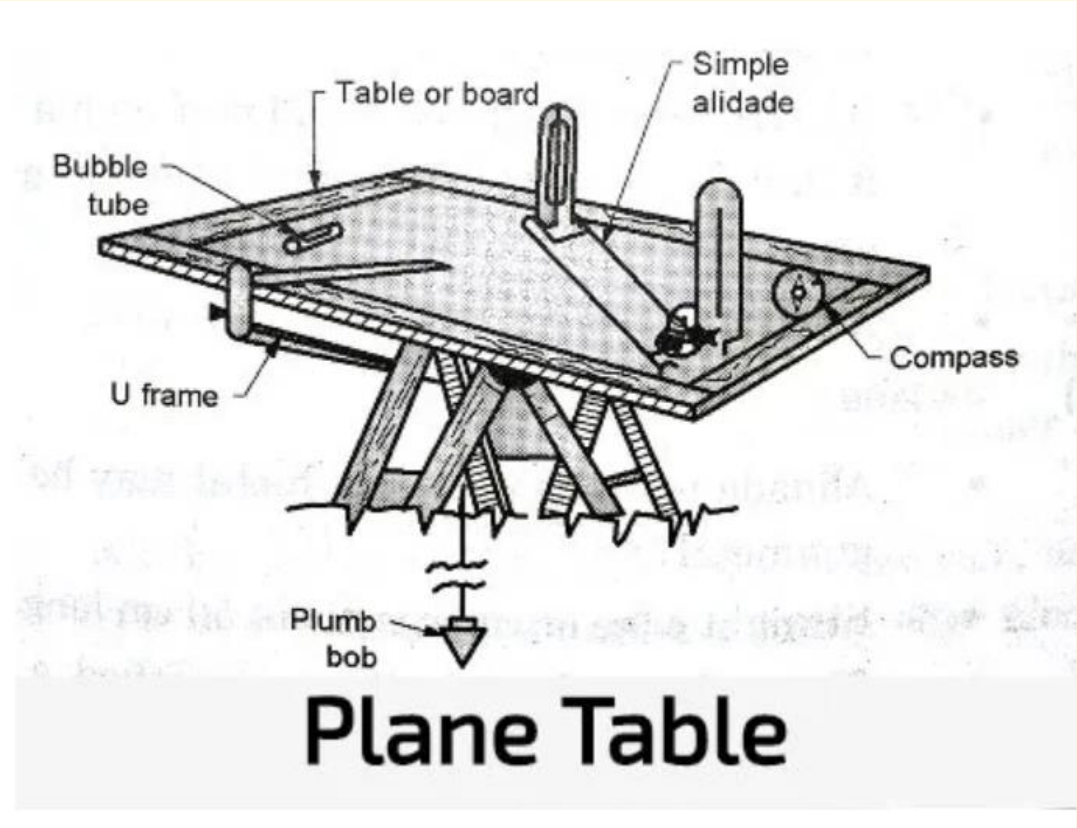


(a)



(b)

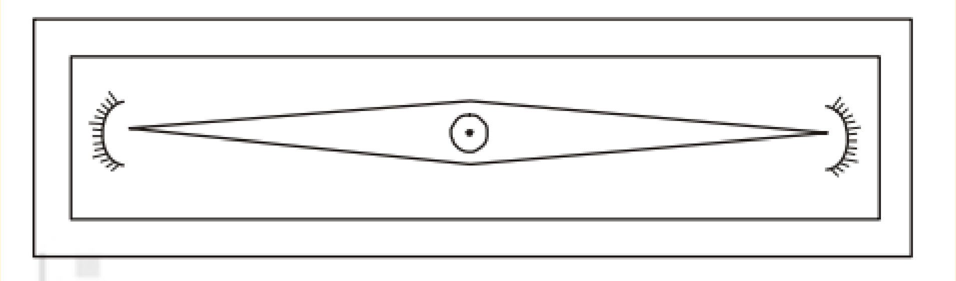
Fig: (a) and (b) : Equipment of Plane Table



Accessories

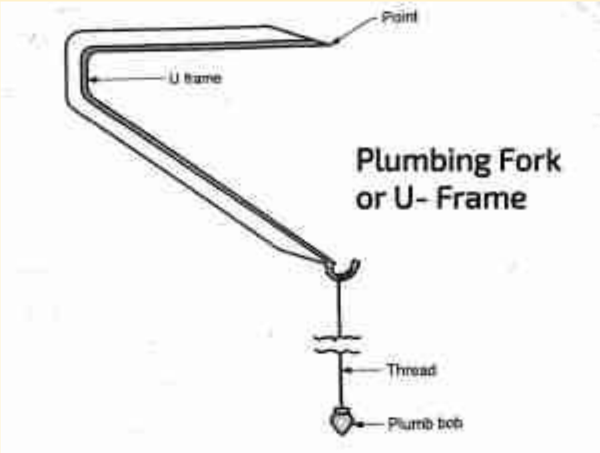
The additional equipment to be used for surveying with plane table could be as given below:

- **Trough Compass:** It is usually 15 cm long, shown in Figure 5.2(a), and is provided to plot the magnetic meridian (N-S direction) to facilitate orientation of the plane table in the magnetic meridian.



- **Spirit Level:** Circular spirit level is used to check the level of the board and make it horizontal by placing it on the board in two positions mutually at right angles and centering the bubble in each position.
- **Plumbing Fork**: It is also known as U frame. It is a hairpin shaped brass frame having two arms of equal length. One end of the frame is pointed and is kept over the drawing sheet touching the plotted position of the instrument station. The other end of the frame

carries a plumb bob. The position of the plane table is adjusted until the plumb bob hangs over the station occupied by the instrument.



- **Drawing Sheet**: Drawing paper should be of best quality and well seasoned to minimize the effect of climatic variations. The paper should be tinted green or grey for reducing glaring in sun and eye strains. Drawing paper is fixed on board with drawing pins, clamps etc. For drawing rays and other detail quality pencils, dustless rubber and precision scales are used. A water-proof cover is also an essential accessories to protect drawing paper from dampness and rain.

Advantages and Disadvantages

Advantages

a. Plane table survey is most suitable for preparing small-scale maps. It is most rapid.
b. The field book is not necessary as plotting is done in field concurrently with the field work, and hence the mistakes in booking the field notes are avoided.
c. The surveyor can compare the plotted work with the actual features of the area surveyed and, thus, cannot overlook any essential features.
d. There is no possibility of omitting the necessary measurements as the map is plotted in the field.
e. Errors of measurements and plotting may be readily detected by check lines.
f. Contours and irregular objects may be represented accurately, since the tract is in view.
g. It is particularly advantageous in magnetic area where compass survey is not reliable.
h. It is less costly than a theodolite survey.
i. No great skill is required to prepare a satisfactory map.

Disadvantages

a. The plane table is essentially a tropical instrument. It is not suitable for work in a wet climate.
b. It is heavy, cumbersome, and awkward to carry.
c. There are several accessories to be carried and, therefore, they are likely to be lost.

d. It is not intended for accurate work.
e. If the survey is to be re-plotted to a different scale or quantities are to be computed, it is of great inconvenience in absence of the field notes.

Methods of Plane Table Surveying

1. Radiation
2. Intersection
3. Traversing
4. Resection.

The first two methods are used for locating details while the other two methods are used for locating position of plane table station on drawing sheet.

1) Radiation Method :

In this method the instrument is setup at a station and rays are drawn to various stations which are to be plotted. The distances are cut to a suitable scale after actual measurements. This method is suitable only when the area to be surveyed is small and all the stations are visible and accessible from the instrument station. The scope of the method is increased when the distances are measured by a tacheometer. In the field it is sometimes used to locate the details of the area it conjunction with the method of traversing.

2) Traversing Method :

This method is similar to compass of theodolite traversing. The table is set at each of the stations in succession. A foresight is taken to the next station and the distance is cut to a suitably choosen scale. It is most suited when a narrow strip of terrain is to be surveyed, e.g survey of roads, railways, etc. This method can be used for traversing both the open as well as close traverses.

3) Intersection Method :

In this method two stations are so selected that all the other stations to be plotted are visible from these. The line joining these two stations is called base line. The length of this line is measured very accurately. This method is very commonly used for plotting details. It is referred when the distance between the stations is too large or the stations are inaccessible or the ground is undulating. The most suitable example is of broken boundaries which can be very conveniently plotted by this method.

4) Resection Method :

It is a method of orientation employed when the table occupies a position not yet located on the drawing sheet. It is defined as the process of locating the instrument station occupied by the plane table by drawing rays from the stations whose positions have already been plotted on the drawing sheet.

This method is employed when during surveying the surveyor feels that some important details can be plotted easily by choosing any station other than the triangulation stations. The position of such a station is fixed on the drawing sheet by resection.

- Resection after orientation by compass.
- Resection after orientation by back sighting.
- Resection after orientation by two points (two-point problem)

- Resection after orientation by three points (three-point problem)

Two-point Problem

The back ray method requires drawing the ray from preceding stations (O1 and O2) to the station to be occupied by plane table (say O3). Errors of centering thus are inevitable.

The two-point problem consists of locating the position of a plane table station on the drawing sheet by observation of two well defined points, whose positions have already been plotted on plan. The procedure of resection after orientation by two points is given below.

(a) Let O1 O2 be the two stations plotted as o1 and o2 on the drawing sheet. It is required to plot station O3 for plane tabling work.

(b) An auxiliary point A on ground is selected such that AO3 is approximately parallel to O1 O2 and the angle O3 O1 A and O3 O2 A are balanced angles, i.e. these are neither too acute or too obtuse. The table is set and levelled at A, and so oriented that line O1 O2 on ground is nearly parallel to line o1 o2 plotted on table map.

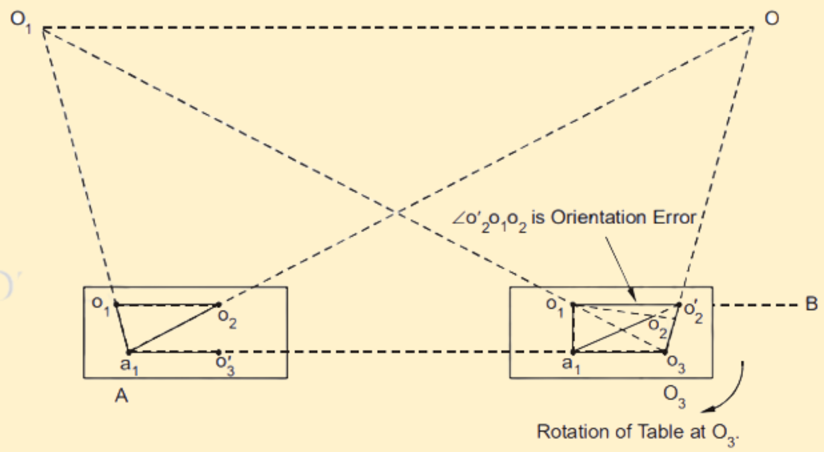
(c) Alidade, touching o2 and sighting O2 on ground, a ray is drawn through o2. In the same way, draw a ray by touching alidade to o1 and sighting O1 on ground. This ray will intersect the first ray at a1 on the map.

(d) With alidade touching a1, sight O3 and draw the ray a1 o3. Mark the estimated position of O3 on the map as o′3.

(e) The table is removed from A and set at O3 with marked position of o3 over O3, properly levelled and similarly oriented. This is achieved by back sighting A from O3.

(f) Now with table at O3, keep alidade touching o1 and sight O1 and draw a back ray resecting the line a1 o′3 in o3. Here o3 is the point 102 representing the station O3 with reference to the approximate orientation made at A.

(g) With alidade touching o3, sight O2 and draw a ray to O2. If the ray passes through the plotted point o2, the orientation of the table is correct and o3 is the correct position of O3. Whereas, if this



ray cuts the previously plotted line a1 o2 at some other point, say o′2, then the position o3 is not the correct position of O3.

(h) The orientation error will be equal to 212 ∠o oo ′ between the lines o1 o2 and o1 o2´. This error can be eliminated by rotating the table through the angle o2´ o1 o2. This table rotation can be achieved by taking the following steps.

i. The alidade is placed along line o1 o2´ and a ranging rod B is fixed in line with o1 o2´, far away from the plane table.
ii. Alidade is now kept along true line o1 o2 and table is rotated so that ranging rod B is bisected. The table is clamped in new position.
iii. The true location of O3 on map is now marked by :

- orienting alidade along o1 O1 and drawing the ray o1 O1 and,
- orienting alidade along o2 O2 and drawing the ray o2 O2. The point of intersection of the two rays will give the correct position of O3 (the new table position) on map.

The new position of table station O3 is, thus, correctly marked on map with the help of two previous table stations O1 and O2 already marked on map. The procedure followed is termed two-point problem in plane table survey.

Three-point Problem

The position of new plane table station on the map can be correctly located with the help of three well defined points on ground whose positions are already plotted on map. Such a procedure is called three-point problem. It is obvious that locating the position of table by this process is more accurate. However, it is more involved and complex. 103 Let there are three ground stations A Plane Table Surveying , B and C whose positions are marked as a, b and c on the plan map and let these stations are visible from new table station O. It is required to plot the position of O on map as o. This can be achieved by any of the following methods :

(a) Tracing Method

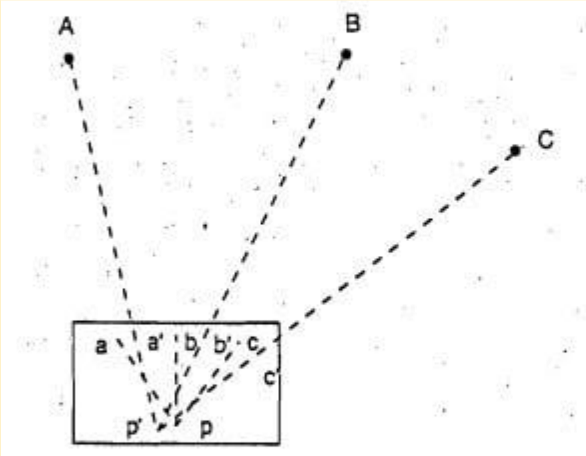
(b) Lehmann Method

(c) Analytical Method

(d) Graphical Method

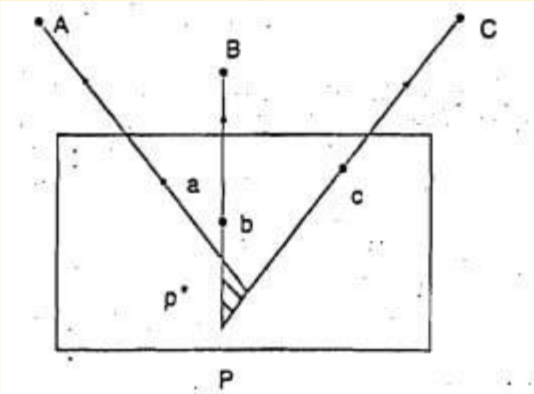
(a) Tracing Method in Plane Table Surveying

In the tracing method, the plane table is located at a point from where three points are visible. The table is oriented with respect to the plotted lines of those three points. Place the tracing paper on the drawing sheet and again sight the three points and plot the radiating lines. The tracing paper is then moved above the drawing sheet until the three radiating lines pass through corresponding points previously plotted on the map. Finally, the position of the plane table is marked.



(b) Lehmann Method

In this method, Plane table is located at a point P and sight the station A, B and C and plot the rays Aa, Bb, and Cc. The rays form small triangle which is called triangle of error. Another point P1 is chosen to reduce the error and sight the point A from P1 similarly to B and C. which will give another triangle of error. Repeat this procedure until error becomes zero.



(c) Analytical Methods

There are many analytical methods are developed in three-point problem condition. In this method, from station P A, B and C are sighted and note the values of angles and lengths. From these values determine the position of unknown points by using analytical formulae.

(d) Graphical Method

In graphical method also, angles and lengths are determined and represented it on a graph and determines the location of plane table.

Questions

1. What is the primary advantage of plane table surveying?

a. High precision

b. Simultaneous fieldwork and plotting

c. Suitable for large-scale mapping

d. Requires minimal accessories

Answer: b. Simultaneous fieldwork and plotting

2. Which of the following is NOT an essential accessory for plane table surveying?

a. Trough Compass

b. Spirit Level

c. Theodolite

d. Plumbing Fork

Answer: c. Theodolite

3. Which method of plane table surveying is suitable for narrow strips of terrain, such as roads or railways?

a. Radiation Method

b. Intersection Method

c. Traversing Method

d. Resection Method

Answer: c. Traversing Method

4. What is the purpose of the resection method in plane table surveying?

a. To measure distances accurately

b. To locate details between known points

c. To orient the plane table at an unknown station

d. To plot magnetic meridian lines

Answer: c. To orient the plane table at an unknown station

5. In the two-point problem, how is the orientation error eliminated?

a. By changing the drawing paper

b. By adjusting the bubble level

c. By rotating the plane table

d. By using a different alidade

Answer: c. By rotating the plane table

6. What is the advantage of using the three-point problem in plane table surveying?

a. It requires fewer measurements.

b. It provides higher accuracy.

c. It is suitable for large-scale mapping.

d. It eliminates the need for accessories.

Answer: b. It provides higher accuracy.

7. Which method involves using tracing paper to determine the position of the plane table in three-point problem solving?

a. Lehmann Method

b. Analytical Method

c. Graphical Method

d. Tracing Method

Answer: d. Tracing Method

8. What is the purpose of the triangle of error in the Lehmann Method?

a. To locate three known points

b. To estimate the precision of measurements

c. To reduce orientation errors

d. To measure the angles between stations

Answer: c. To reduce orientation errors

9. Which method of three-point problem solving involves using mathematical formulas to determine the unknown point's position?

a. Lehmann Method

b. Analytical Method

c. Graphical Method

d. Tracing Method

Answer: b. Analytical Method

10. In plane table surveying, what is the primary disadvantage of the method?

a. Requires complex mathematical calculations

b. Unsuitable for small-scale mapping

c. Limited accuracy

d. Inconvenient for fieldwork

Answer: c. Limited accuracy

ERRORS IN PLANE TABLING

The main sources of errors in a plane table survey can be broadly classified as follows:

(a) Due to faulty instrument adjustments

(b) Due to quality of drawing paper used in map plotting

(c) Human errors of surveyor in centering and orienting the table

(d) Surveyor's error in observing and plotting.

Surveyor's Errors in Table Setting

There can be primarily two types of errors which are : (a) inaccurate centering of table, and (b) inaccurate orientation of table. Inaccurate Centering The position of instrumentation station on map shall be exactly over the station on ground it represents. The importance of accurate centering can be best emphasized by explaining the nature and impact of error on survey accuracy. When the table is set at new instrument station, the correct orientation is rather more important than correct centering.

The position of instrument station should be accurately corresponding to its plotted position on the map. The survey details already plotted on the map from previous instrument stations can synchronize with details to be plotted on map from new instrument station only when the plane table is accurately centered and oriented in new position. The correct orientation can be achieved by checking the orientation by two-point or three-point problem as described in Sections 5.6.2 and 5.6.3.

Preferably the orientation of the table should be checked from as many stations as possible by sighting two distant and prominent reference stations which are already plotted on the map, thereby eliminating the triangle of errors. The orientation of table shall also be checked after observations, preferably after recording each observation to eliminate any chance rotation of table during the observation process due to improper clamping of table.

Surveyor's Error in Observing and Plotting

Human error can be introduced during observation and plotting of details by the surveyor. These could be due to

• objects not being sighted and bisected in sight vanes accurately,

• the centering of alidade on the desired station point on paper may not be accurate,

• the radiating ray towards the desired object may not be correctly drawn through the referred station point, and

• plotting of details may not be properly done or recorded. Care should be exercised during observation process to eliminate these types of errors. Random rechecking of some details recorded at referred instrument station is desirable.

Methods contouring using plane table and micro-optic alidade.

Contouring is a technique of representing the three-dimensional shape of a surface on a two-dimensional plane by using lines of equal elevation, called contours. Contouring can be used for various applications, such as mapping, engineering, geology, and mining.

One of the methods of contouring is using a plane table and a micro-optic alidade. A plane table is a device that consists of a drawing board mounted on a tripod, and an alidade is a ruler with a sighting device that can measure horizontal angles. A micro-optic alidade is an alidade that has a small telescope with crosshairs and a micrometer screw for precise measurements.

The procedure of contouring using a plane table and a micro-optic alidade is as follows:

- Set up the plane table at a convenient point on the ground and level it using a spirit level.
- Draw a north line on the paper and orient the plane table using a magnetic compass or by sighting two known points.
- Select a point on the paper to represent the station point and mark it with a dot.
- Sight the points on the ground whose elevations are known or assumed and mark their positions on the paper using the alidade.
- Draw rays from the station point to these points and label them with their elevations.
- Move the plane table to another station and repeat the steps above, making sure that at least two points from the previous station are visible and plotted.

- After plotting all the stations, join the points of equal elevation with smooth curves to form contours.
- Label the contours with their elevations and indicate the direction of slope with arrows.

The advantages of contouring using a plane table and a micro-optic alidade are:

- It is simple, fast, and economical.
- It does not require any calculations or measurements of distances.
- It gives a direct and accurate representation of the ground features.
- It can be used for any scale and any terrain.

The disadvantages of contouring using a plane table and a micro-optic alidade are:

- It requires good visibility and clear weather conditions.
- It is affected by magnetic disturbances and errors in leveling and orientation.
- It is not suitable for large areas or complex surfaces.

Solved Previous Year Questions

1. Detailed plotting is generally done by:
A) Radiation B) Traversing
C) Resection D) All of the above

Ans A

Detailed plotting is generally done by the radiation method. The radiation method is a type of surveying in which the location of a point is determined by measuring angles and distances from a fixed reference point called the origin. The position of the point is calculated by using trigonometry to solve a set of equations that relate the measured angles and distances to the coordinates of the point. This method is particularly useful for laying out points or features that are not on a straight line, such as curves or irregular boundaries. Traversing and resection methods are also used in surveying, but they are typically used for larger-scale surveys or for locating features that are further away. Therefore, option A is the correct answer.

2. Two-point problem and three-point problem aremethods of:
A) Resection B) Orientation
C) Traversing D) Resection and orientation

Ans D

The two-point problem and three-point problem are methods of resection and orientation in surveying.

Resection is the process of determining the position of an unknown point by measuring angles and distances from two or more known points. The two-point problem and three-point problem are methods of resection that are used to determine the position of an unknown point based on measurements from two or three known points, respectively.

Orientation, on the other hand, refers to the process of establishing the true north direction on a survey site, which is necessary for accurate mapping and surveying. While resection and orientation are related, they are not the same thing.

Therefore, option D is the correct answer.

3. Which of the following methods of Plane Table surveying is used to locate the position of an inaccessible point:

A) Radiation B) Intersection
C) Traversing D) Resection

Ans B

The method used to locate the position of an inaccessible point in Plane Table surveying is intersection. In this method, two or more lines of sight are taken from different points on the plane table to the inaccessible point, and the intersection of these lines gives the location of the point. This method is useful when it is not possible to access a point directly due to obstacles such as buildings, lakes, or other physical features. The accuracy of the intersection method depends on the number of lines of sight taken and the accuracy of the measurements made.

4. Under which regulation of CMR 2017, duties andresponsibilities of Surveyor are given:

A) Regulation No. 49 B) Regulation No. 50
C) Regulation No. 52 D) Regulation No. 53

Ans D

Regulation No. 53. : Duties and responsibilities of surveyor.– (1) The surveyor shall – (a) make such accurate surveys and levellings, and prepare such plans and sections and tracings thereof, as the manager may direct or as may be required by the Act or by the regulations or orders made thereunder, and shall sign the plans, sections and tracings and date his signature; (b) be responsible for the accuracy of any plan and section, or tracings thereof that has been prepared and signed by him. (2) The surveyor shall record in a bound paged book kept for the purpose – (a) the full facts when working of the mine have approached to about 120 meters from the mine boundary, or from disused or waterlogged workings; (b) any doubts which may arise or exist concerning the accuracy of the plans and sections prepared under these regulations; (c) any other matter relating to the preparation of the plans and sections that he may like to bring to the notice of the manager, and every entry in the book shall be signed and dated by the surveyor and countersigned and dated by the manager: Provided that where in any mine two or more surveyors are employed, each of the surveyors shall make the entries aforesaid in respect of the workings in his jurisdiction or of the plans and sections in his charge.

5. Which of the following methods of Plane Table Surveying is also known as graphic triangulation.

Options:

(1) Resection

(2) intersection

(3) interpolation

(4) Radiation

(5) None ofthe Options

Correction Answer : (2]

Plane table surveying is the graphical method of surveying in which field observation and plotting are done simultaneously helping the surveyor to compare the plotted details with actual features of the ground. Method of plane table surveying are,

1) Radiation

- It is the method of locating the point by drawing radial lines from the plane table station to that point.
- **In the radiation method, the maximum number of ground measurements is made.**

2) Intersection

- It is a method of locating a point by the intersection of two rays from two different stations.
- **Only one linear measurement is made in the intersection method.**
- This method is also called **Graphical triangulation.**

3) Resection

- It is the method of locating the station occupied by the plane table when the position of that station had not been previously plotted from another station.

4) Traversing

- It is that type of survey in which a **number of connected survey lines** form the framework.

6. The field observations and plotting of the plan proceed simultaneously in

(1) Chain surveying

(2) Traversing

(3) Contouring

(4) Plane table surveying

(5) None of the Options

Ans.(4)

Plane table surveying:

- Plane table surveying is a graphical method of survey in which the field observations and plotting are done simultaneously. It is simple and cheaper than Theodolite survey but it is mostly suitable for small-scale surveys.
- Plane table survey is more accurate than chain surveying.
- It is not necessary to do accurate centering of plane table for small-scale surveys, The instrument used for accurate centering in plane table survey is. Plumb bob and plumb fork

Advantages of plane table surveying are as follows:

- It is the **most used** and suitable method for surveying and preparing small-scale map but **not necessary.**
- All possible human and machine errors can be eliminated as the surveying and plotting are done simultaneously in the field.
- Plane table surveying finds its importance in places with high magnetic fluctuations where compass survey is not reliable.
- As this type of survey does not use a machine, it is less costly than most types of surveying techniques.
- It is one of the most rapid surveying techniques.
- Errors occurring due to mistakes in the field book entry are eliminated.
- Contours and other irregular objects may be accurately represented on the map since the tract is in view.
- It does not require skilled personal to plot the map.
- The errors and mistakes in plotting can be checked by drawing check lines

7. Radio progression method of plane tabling is a combination of the methods of ______ & ______

a) Interaction, resection
b) Radiation, intersection
c) Radiation, resection
d) Radiation, traversing
e) None of the above

Ans B

Plane table surveying is the graphical method of surveying in which field observation and plotting are done simultaneously helping the surveyor to compare the plotted details with actual features of the ground. Method of plane table surveying are,

- **Radiation** is the method of locating the point by drawing radial lines from the plane table station to that point.
- **The intersection** is a method of locating a point by the intersection of two rays from two different stations.
    - The intersection is one of the methods of plane table surveying which is used for plotting the positions of objects on the drawings. In this method, the plane table is shifted to a known distance in a particular direction marked on the ground and the line of sights is drawn to make an intersection of the radial lines already drawn from the first set up of the instrument.

      ∴ This method is preferred when the distance between the stations is too large or the grounds are undulating. Example: Hilly areas or Hillock without vegetation.
- **Resection** is the method of locating the station occupied by the plane table when the position of that station had not been previously plotted from other station.
- **Traversing** is that type of survey in which a number of connected survey lines form the framework.

8. Alidade is used in

(1) Tachometry

(2) Plane Tabling

(3) Chaining

(4) Compass Surveying

(5) All the Options

Ans.(2)

Plane table surveying:

- Plane table surveying is a graphical method of survey in which the field observations and plotting are done simultaneously. It is simple and cheaper than Theodolite survey but it is mostly suitable for small-scale surveys.
- Plane table survey is more accurate than chain surveying.
- It is not necessary to do accurate centering of plane table for small-scale surveys, The instrument used for accurate centering in plane table survey is. Plumb bob and plumb fork

Advantages of plane table surveying are as follows:

- It is the **most used** and suitable method for surveying and preparing small-scale map but **not necessary.**
- All possible human and machine errors can be eliminated as the surveying and plotting are done simultaneously in the field.
- Plane table surveying finds its importance in places with high magnetic fluctuations where compass survey is not reliable.
- As this type of survey does not use a machine, it is less costly than most types of surveying techniques.
- It is one of the most rapid surveying techniques.
- Errors occurring due to mistakes in the field book entry are eliminated.
- Contours and other irregular objects may be accurately represented on the map since the tract is in view.
- It does not require skilled personal to plot the map.
- The errors and mistakes in plotting can be checked by drawing check lines

Trough Compass : It is used to **orient the plane table** along the magnetic meridian.

Plumbing fork: It is used in plane table surveying is used for centering of plane table.

Level tube: It is used to check the level of the table.

Alidade: It is a straight edge ruler provided with a sighting device. It is **used for sighting the objects** and **drawing the lines** on the drawing sheet.

9. An equipment which is not required to be used in plane table surveying is :-

a) Trough compass
b) Optical square
c) An alidade
d) Spirit level
e) Plum bob

Ans B

General Plane Table Survey Equipment

Some basic surveying instruments are required for plane table surveying. Followings are the general plane table survey equipment.

1. Plane table
2. Alidade for sighting (telescopic or simple)
3. Plumb bob and plumb fork
4. Compass
5. Spirit level
6. Chain
7. Ranging rods
8. Tripod
9. Drawing sheet and drawing tools
10. Paper clips or screws

National grid

A national grid is a system of geographic coordinates that divides a country or a region into smaller units, such as squares or rectangles, for the purpose of mapping and locating places.

A map projection is a method of transforming the curved surface of the Earth onto a flat plane, such as a paper or a screen. Different map projections have different properties and distortions, such as preserving angles, areas, distances, or shapes.

Examples:

Indian Grid System (IGS)

British National Grid (BNG)

Indian Grid System (IGS)

The Indian Grid System (IGS), which covers India and some neighboring countries. The IGS uses the **Lambert Conformal Conic projection**, which preserves angles and shapes along two standard parallels, but distorts areas and distances elsewhere.

The IGS divides the region into nine zones, each with its own set of parameters. Within each zone, coordinates are given by eastings and northings, which measure the distance in meters from a false origin point. For example, the coordinates 43P 123456 234567 refer to a point within zone 43P.

British National Grid (BNG)

The British National Grid (BNG), which covers Great Britain and some adjacent islands. The BNG uses the **Transverse Mercator projection**, which preserves angles and shapes locally, but distorts areas and distances as one moves away from the central meridian.

The BNG divides the country into 100 km by 100 km squares, each identified by a two-letter code. Within each square, coordinates are given by eastings and northings, which measure the distance in meters from the southwest corner of the square. For example, the coordinates SK 53 79 refer to a 1 km by 1 km square within the SK square.

Cassini Lambert's polyconic projection

Cassini Lambert's polyconic projection is a type of map projection that was developed by Johann Heinrich Lambert in 1772 and later modified by César-François Cassini de Thury in 1786. It is also known as the Cassini-Soldner projection or the Soldner projection. It is a polyconic projection, which means that it consists of a series of conic projections that are tangent to the reference surface along different parallels. Each parallel has its own cone and scale factor, and the meridians are projected as straight lines radiating from the central meridian. The central meridian and the equator are the only lines of true scale on the map.

The Cassini Lambert's polyconic projection preserves local shapes and angles, but distorts areas and distances away from the central meridian and the equator. It is suitable for mapping regions with a greater north-south extent than east-west, such as narrow countries or continents. It was used for mapping parts of Europe, Africa, and Asia in the 18th and 19th centuries, as well as for some national grid systems, such as the British Ordnance Survey maps until 192413. However, it has been largely replaced by other projections, such as the transverse Mercator or the Lambert conformal conic, that have less distortion and better accuracy.

(Lambert’s polyconic projection)

Transformation of coordinates

The transformation of coordinates in Cassini Lambert’s polyconic projection is a process of converting the geographic coordinates (latitude and longitude) of a point on the Earth’s surface to the planar coordinates (eastings and northings) of a map based on the Cassini Lambert’s polyconic projection. This projection is a type of map projection that consists of a series of conic projections that are tangent to the reference surface along different parallels. Each parallel has its own cone and scale factor, and the meridians are projected as straight lines radiating from the central meridian.

To perform the transformation, one needs to know the parameters of the projection, such as the radius of the Earth, the central meridian, the reference latitude, and the standard parallels.

Let λ be the longitude, λ_0 be the central meridian, φ be the latitude, φ_0 be the reference latitude, R be the radius of the Earth, φ_1 and φ_2 be the standard parallels, and x and y be the eastings and northings.

First, calculate M_0, M_1, M_2, and M as:

$M_0 = R \times (1 - \sin \varphi_0)$

$M_1 = R \times (1 - \sin \varphi_1)$

$M_2 = R \times (1 - \sin \varphi_2)$

$M = R \times (1 - \sin \varphi)$

Then, calculate N_0, N_1, N_2, and N as:

$N_0 = R / \mathrm{sqrt}\,(1 + \sin \varphi_0)$

$N_1 = R / \mathrm{sqrt}\,(1 + \sin \varphi_1)$

$N_2 = R / \mathrm{sqrt}\,(1 + \sin \varphi_2)$

$N = R / \mathrm{sqrt}\,(1 + \sin \varphi)$

Next, calculate A as:

$$A = \frac{\mathrm{N0} \times \mathrm{N1} \times \log\frac{M2}{M1} - \mathrm{N1} \times \mathrm{N2} \times \log\frac{M0}{M1} + N2 \times N0 \times \log\frac{M1}{M2}}{N0 \times (N2 - N1) + N1 \times (N0 - N2) + N2 \times (N1 - N0)}$$

Finally, calculate x and y as:

$x = A \times N \times \sin(\lambda - \lambda 0)$

$y = A \times M - A \times M0 + (A \times N0 / \tan(\varphi 0)) \times (\cos(\lambda - \lambda 0) - 1)$

The inverse transformation can be done by solving for λ and φ from x and y using numerical methods.

Universal transverse Mercator

The universal transverse Mercator (UTM) projection is a way of representing the Earth's surface on a map. It is based on the transverse Mercator projection, which is a type of cylindrical projection that preserves local angles and shapes but distorts areas and distances away from the central meridian.

The UTM projection divides the Earth into 60 zones, each 6 degrees wide in longitude, and projects each zone onto a plane using a different central meridian. Each zone has its own coordinate system, with eastings and northings measured in meters from a false origin. The UTM projection is widely used for mapping large-scale features, such as topography, land use, and infrastructure, as well as for locating places using GPS devices.

Some advantages of the UTM projection are:

- It is conformal, meaning that it preserves angles and shapes locally, which is useful for navigation and surveying.

- It is metric, meaning that it uses meters as the unit of measurement, which is convenient for calculations and conversions.

- It has low distortion within each zone, meaning that it is accurate for mapping regions with a greater north-south extent than east-west.

- It is universal, meaning that it covers the whole world with a consistent system of zones and coordinates.

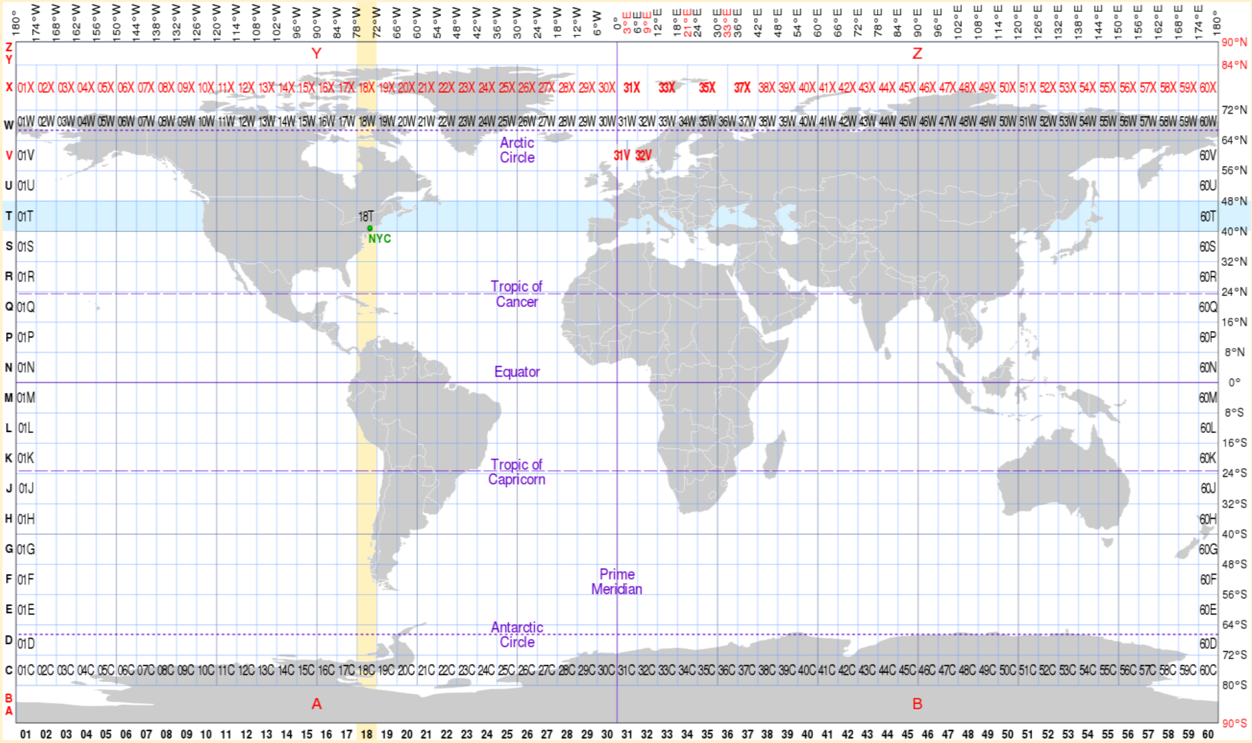
Some disadvantages of the UTM projection are:

- It is not equal-area, meaning that it distorts the size of regions, especially near the poles, where the zones become very narrow.

- It is not azimuthal, meaning that it does not preserve directions from a central point, which can cause confusion when comparing maps from different zones.

- It is not continuous, meaning that it has discontinuities at the boundaries of the zones, where the coordinates change abruptly.

- It is not unique, meaning that there are different versions of the UTM projection with different parameters, such as the radius of the Earth, the scale factor at the central meridian, and the false easting and northing values.



(UTM zones on an equirectangular world map with irregular zones in red and New York City's zone highlighted)

Transformation of coordinates

The transformation of coordinates in universal transverse Mercator projection is a process of converting the geographic coordinates (latitude and longitude) of a point on the Earth's surface to the planar coordinates (eastings and northings) of a map based on the UTM projection. This projection is a type of cylindrical projection that preserves local angles and shapes but distorts areas and distances away from the central meridian. The UTM projection divides the Earth into 60 zones, each 6 degrees wide in longitude, and projects each zone onto a plane using a different central meridian. Each zone has its own coordinate system, with eastings and northings measured in meters from a false origin[1].

To perform the transformation, one needs to know the parameters of the projection, such as the radius of the Earth, the central meridian, the scale factor at the central meridian, and the false easting and northing values. The formulas for the transformation are as follows[2]:

Let λ be the longitude, λ0 be the central meridian, φ be the latitude, R be the radius of the Earth, m be the meridional distance, ρ be the radius of curvature in the meridian plane, υ be the radius of curvature in the prime vertical plane, N be the northing, and E be the easting.

First, calculate m, ρ, and υ at the computation point (φ, λ) using:

$m = R \times (1 - n + 1.25\, n^2 - 1.40\, n^3) \times \varphi - R \times (0.5\, n - 0.625\, n^2 + 0.47\, n^3) \times \sin(2\varphi) + R \times (0.06\, n^2 - 0.09\, n^3) \times \sin(4\varphi) - R \times (0.01\, n^3) \times \sin(6\varphi)$

$\rho = R \times (1 - e^2) / (1 - e^2 \times \sin^2(\varphi))^{3/2}$

$\upsilon = R / \mathrm{sqrt}(1 - e^2 \times \sin^2(\varphi))$

where e is the eccentricity of the ellipsoid and n is a constant related to e by:

$n = (a - b) / (a + b)$

where a and b are the semi-major and semi-minor axes of the ellipsoid.

The projection northing (N) of the computation point is determined using:

$N = N_0 + k_0 \times m + k_0 \times \upsilon \times \sin(\varphi) \times \cos(\varphi) \times [0.5 + (\cos^2(\varphi) / 24) \times (5 - \tan^2(\varphi) + 9\, \eta^2 + 4\, \eta^4) + (\cos^4(\varphi) / 720) \times (61 - 58 \tan^2(\varphi) + \tan^4(\varphi))]$

where N0 is the false northing, k0 is the scale factor at the central meridian, and η is a constant related to ρ and υ by:

$\eta = \mathrm{sqrt}(\upsilon / \rho - 1)$

Finally, the projection easting (E) of the computation point is determined using:

$E = E_0 + k_0 \times \upsilon \times [\cos(\varphi) + (\cos^3(\varphi) / 6) \times (1 - \tan^2(\varphi) + \eta^2) + (\cos^5(\varphi) / 120) \times (5 - 18 \tan^2(\varphi) + \tan^4(\varphi) + 14\, \eta^2 - 58\eta^2 \times \tan^2(\varphi))]$

where E0 is the false easting.

The inverse transformation can be done by solving for φ and λ from N and E using numerical methods.

Mine Modelling

A national grid is a system of geographic coordinates that divides a country or a region into smaller units, such as squares or rectangles, for the purpose of mapping and locating places. A mine model is a representation of the geological, geotechnical, and economic aspects of a coal deposit or a coal mine. Mine models can help in planning and managing coal mines, such as estimating reserves, designing layouts, optimizing production, and reducing environmental impacts.

the Indian National Grid system uses the Everest Spheroid as a reference surface, which was originally defined by Colonel George Everest in 1830 and updated in 1956. Kalianpur (Madhya Pradesh) was chosen as the initial point of origin. The Indian National Grid system covers the region in nine zones, each using a different projection method. The projection methods are either Lambert conformal conic projection or Universal Transverse Mercator (UTM) projection, which are both types of map projections that preserve angles and shapes locally but distort areas and distances away from the central meridian. The source also provides some examples of how to convert geographic coordinates to grid coordinates and vice versa using formulas and tables.

Another source from a report by NREL, which presents the results of a grid integration study that confirmed the technical and economic viability of integrating 175 gigawatts (GW) of renewable energy into India's electricity grid by 2022. The report used advanced weather and power system modeling to explore operational impacts of meeting India's renewable energy target, which includes 100 GW of solar and 60 GW of wind. The report also identified actions that are favorable for integration, such as enhancing coal flexibility, increasing transmission capacity, and improving forecasting. The report shows a visualization of results that shows a full year of generation and transmission flows using UTM projection.

A third source, the use of geogrids for improving coal mine waste dump stability. Geogrids are geosynthetic materials that are used to reinforce soil or rock layers. The paper reviews the literature on the applications and benefits of geogrids in waste dumps, such as increasing shear strength, reducing settlement, and preventing erosion. The paper also presents a case study of using geogrids in an overburden dump at an opencast coal mine in India. The paper shows the design and layout of the geogrids using UTM coordinates.

Questions

1. What is the primary purpose of a national grid system?

   a. To divide countries into squares for farming

   b. To locate places on maps

   c. To define political boundaries

   d. To measure land area

Answer: b. To locate places on maps

2. Which map projection preserves angles and shapes but distorts areas and distances away from standard parallels?

a. Lambert Conformal Conic

b. Transverse Mercator

c. Cassini-Soldner

d. Equirectangular

Answer: a. Lambert Conformal Conic

3. How does the Indian Grid System (IGS) divide the region it covers?

a. Into squares with unique codes

b. Into nine zones, each with its own parameters

c. Into 100 km by 100 km squares

d. Into 60 zones, each 6 degrees wide

Answer: b. Into nine zones, each with its own parameters

4. What projection is used in the British National Grid (BNG), and what does it preserve locally?

a. Cassini-Soldner, areas and distances

b. Equirectangular, angles and shapes

c. Transverse Mercator, angles and shapes

d. Lambert Conformal Conic, directions and sizes

Answer: c. Transverse Mercator, angles and shapes

5. What is the primary advantage of the Cassini Lambert's polyconic projection?

a. It preserves areas and distances accurately.

b. It is conformal, preserving angles and shapes locally.

c. It is suitable for mapping regions with a greater east-west extent.

d. It is universally accepted for all types of mapping.

Answer: b. It is conformal, preserving angles and shapes locally.

6. What is the purpose of transforming coordinates in map projections?

a. To convert geographic coordinates to UTM coordinates

b. To convert map coordinates to geographic coordinates

c. To change the shape of the Earth's surface

d. To improve the accuracy of map projections

Answer: b. To convert map coordinates to geographic coordinates

7. In the Universal Transverse Mercator (UTM) projection, how many zones divide the Earth's surface?

a. 6

b. 24

c. 60

d. 100

Answer: c. 60

8. What does the UTM projection use as the unit of measurement for eastings and northings?

a. Degrees

b. Radians

c. Meters

d. Feet

Answer: c. Meters

9. What advantage does the UTM projection offer in terms of measurement?

a. It preserves areas and distances.

b. It is equal-area, reducing size distortion.

c. It is azimuthal, preserving directions from a central point.

d. It uses kilometers as the unit of measurement.

Answer: a. It preserves areas and distances.

10. How can mine models assist in coal mining operations?

a. By determining the political boundaries of mining areas

b. By optimizing production and reducing environmental impacts

c. By measuring the curvature of the Earth's surface

d. By predicting weather patterns in mining regions

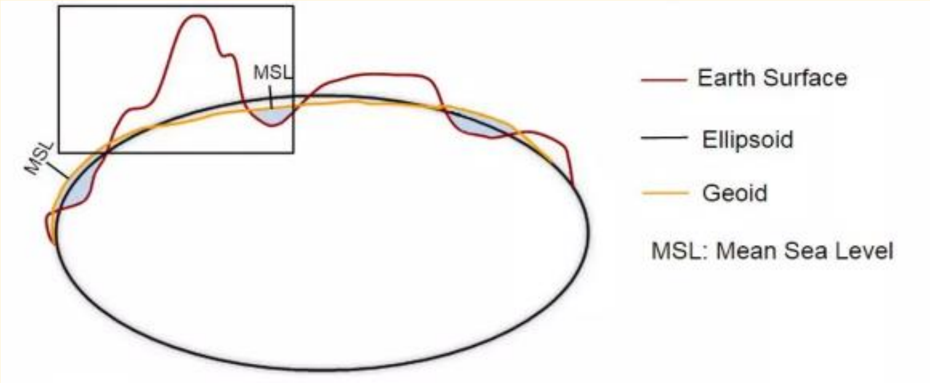
Answer: b. By optimizing production and reducing environmental impacts

Geodesy

Geodesy is the science of measuring and representing the shape, size, orientation, and gravity field of the Earth. Geodesy is important for many applications, such as mapping, navigation, surveying, geophysics, geology, and engineering. Geodesy also helps us understand the Earth's dynamics, such as plate tectonics, earthquakes, volcanoes, sea level changes, and climate change.

Geodesy involves several concepts and methods, such as:

- **Geoid**: The geoid is the hypothetical surface of the Earth that coincides with the mean sea level and extends under the continents. The geoid is irregular and bumpy due to variations in the Earth's gravity field. The geoid is used as a reference surface for measuring heights and depths.



Geoid, Ellipsoid and Topography of Earth

h = H + N

where,

h = Ellipsoidal height

H = orthometric height (perpendicular vertical distance between geoid and land surface)

N = geoidal height (undulation)

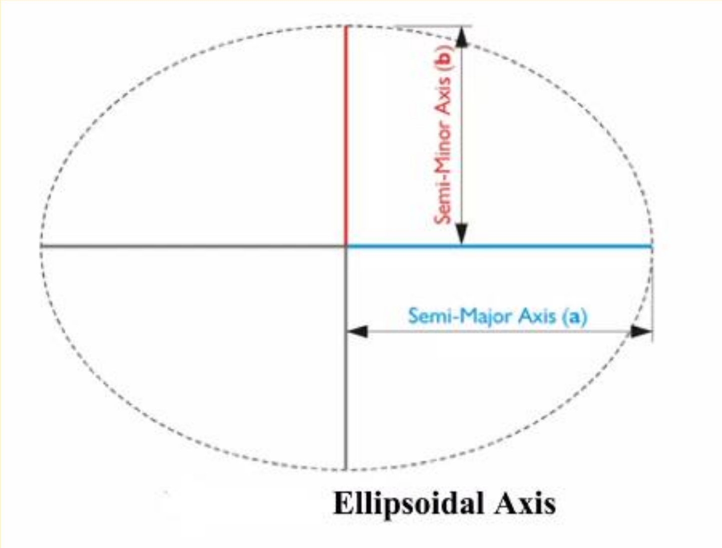
Dynamic height is a way of specifying the vertical position of a point above a vertical datum, which is a reference surface for measuring heights. Dynamic height can be computed by the following formula:

$$H = \frac{W}{\gamma_{45}}$$

where H is the dynamic height, W is the geopotential number, and $\gamma 45$ is the normal gravity at 45 degree latitude (a constant).

- **Datum**: A datum is a set of parameters that defines the origin, orientation, and scale of a coordinate system. A datum can be global or local, depending on the area it covers. A datum can also be geocentric or geodetic, depending on whether it is aligned with the center of mass or the surface of the Earth. A datum is used to transform coordinates from one system to another.

- **Ellipsoid**: An ellipsoid is a mathematical model of the shape of the Earth that approximates the geoid. An ellipsoid is defined by its semi-major axis (equatorial radius), semi-minor axis (polar radius), and flattening (ratio of the difference between the axes to the semi-major axis). An ellipsoid is used to calculate distances and angles on the Earth's surface.



Flattening = f = $\frac{a-b}{a}$

1st eccentricity = e = sqrt ($\frac{a^2-b^2}{a^2}$)

2nd eccentricity = e' = sqrt ($\frac{a^2-b^2}{b^2}$)

- **Spheroid**: A spheroid is a special case of an ellipsoid that has two equal semi-major axes. A spheroid can be oblate (flattened at the poles) or prolate (elongated at the poles). A spheroid is a simpler model of the Earth's shape than an ellipsoid, but it is less accurate. A spheroid is used to approximate the geoid or the reference surface for some datums.
- **Geocentric**: A geocentric datum is a datum that has its origin at the center of mass of the Earth. A geocentric datum is aligned with the Earth's rotation axis and equatorial plane. A geocentric datum is independent of any region or continent. A geocentric datum is used to represent global positions and movements, such as satellite orbits and plate tectonics.
- **Geodetic**: A geodetic datum is a datum that has its origin on the surface of the Earth. A geodetic datum is aligned with a local reference ellipsoid that approximates the geoid. A geodetic datum is specific to a region or continent. A geodetic datum is used to represent local positions and measurements, such as mapping and surveying.
- **Projection**: A projection is a method of transforming the curved surface of the Earth onto a flat plane, such as a paper or a screen. Different projections have different properties and distortions, such as preserving angles, areas, distances, or shapes. A projection is used to create maps and display spatial data.

Geodetic and astronomical coordinates

Geodetic and astronomical coordinates are two ways of describing the position of a point on or near the Earth's surface. Geodetic coordinates are based on a mathematical model of the Earth's shape, such as an ellipsoid or a spheroid, and a datum that defines the origin, orientation, and scale of the coordinate system. Astronomical coordinates are based on the actual direction of gravity and the celestial sphere, which is an imaginary sphere that surrounds the Earth and contains the stars and other celestial objects.

Geodetic coordinates

Geodetic coordinates consist of latitude, longitude, and height. Latitude is the angle between the equatorial plane and a line perpendicular to the reference surface. Longitude is the angle between a prime meridian and a plane passing through the point and the poles. Height is the distance from the reference surface to the point along the perpendicular line. Geodetic coordinates are used for mapping, navigation, surveying, and geodesy.

To find out geodetic coordinates of a point, one needs to know the parameters of the reference surface and the datum, such as the semi-major axis, semi-minor axis, flattening, eccentricity, central meridian, false easting, false northing, and scale factor. Depending on the type of input data available, different formulas can be used to calculate geodetic coordinates. Some examples of formulas are:

- If Cartesian coordinates (X, Y, Z) are given in a geocentric datum (such as WGS84), then geodetic coordinates (φ, λ, h) can be calculated using an iterative method:
    - First, calculate $p = \text{sqrt}(X^2 + Y^2)$ and $E^2 = a^2 - b^2$
    - Then, initialize $\varphi = \tan^{-1}(Z / (p \times (1 - E^2 / a)))$
    - Next, repeat until convergence:
        - Calculate $N = a / \text{sqrt}(1 - e^2 \times \sin^2(\varphi))$
        - Update $\varphi = \tan^{-1}((Z + e^2 \times N \times \sin(\varphi)) / p)$
    - Finally, calculate $\lambda = \tan^{-1}(Y / X)$ and $h = p / \cos(\varphi) - N$

Astronomical coordinates

Astronomical coordinates consist of geocentric latitude, geocentric longitude, and astronomical height. Geocentric latitude is the angle between the equatorial plane and a line joining the point and the center of mass of the Earth. Geocentric longitude is the angle between a prime meridian and a plane passing through the point and the center of mass of the Earth. Astronomical height is the distance from the center of mass of the Earth to the point along the line. Astronomical coordinates are used for astronomy, geophysics, and geodynamics.

To find out astronomical coordinates of a point, one needs to know the parameters of the reference ellipsoid and the datum, such as the semi-major axis, semi-minor axis, flattening, eccentricity, central meridian, false easting, false northing, and scale factor. Depending on the type of input data available, different formulas can be used to calculate astronomical coordinates. Some examples of formulas are:

- If Cartesian coordinates (X, Y, Z) are given in a geocentric datum (such as WGS84), then astronomical coordinates (φ', λ', h') can be calculated using:

   - First, calculate p = sqrt $(X^2 + Y^2)$ and $E^2 = a^2 - b^2$
   - Then, calculate φ' = $\tan^{-1}$ (Z / p)
   - Next, calculate λ' = $\tan^{-1}$ (Y / X)
   - Finally, calculate h' = sqrt $(X^2 + Y^2 + Z^2)$ - b
- If geodetic coordinates (φ, λ, h) are given in a geodetic datum (such as NAD83), then astronomical coordinates (φ', λ', h') can be calculated using:
   - First, calculate N = a / sqrt (1 - e^2 × $\sin^2$(φ))
   - Then, calculate X = (N + h) × cos(φ) × cos(λ)
   - Next, calculate Y = (N + h) × cos(φ) × sin(λ)
   - Finally, calculate Z = ((1 - e^2) × N + h) × sin(φ)
   - Then, use the same formulas as above to convert from Cartesian to astronomical coordinates.

Questions

1. What is the primary focus of geodesy as a scientific discipline?

   a. Studying the Earth's weather patterns

   b. Measuring and representing the Earth's shape, size, and gravity field

   c. Investigating the behavior of celestial objects

   d. Analyzing the composition of Earth's core

Answer: b. Measuring and representing the Earth's shape, size, and gravity field

2. What is the geoid used as a reference surface for in geodesy?

   a. Measuring horizontal distances

   b. Defining latitude and longitude

   c. Measuring heights and depths

   d. Locating celestial objects

Answer: c. Measuring heights and depths

3. What does the formula h = H + N represent in geodesy?

   a. The Earth's curvature

   b. Ellipsoidal height

   c. The speed of light

d. The shape of the geoid

Answer: b. Ellipsoidal height

4. How is dynamic height (H) calculated in geodesy?

a. $H = W \times \gamma 45$

b. $H = N - H$

c. $H = W + \gamma 45$

d. $H = N / \gamma 45$

Answer: a. $H = W \times \gamma 45$

5. What is the purpose of a datum in geodesy?

a. To define the shape of the Earth

b. To specify the celestial coordinates of stars

c. To set the scale and orientation of a coordinate system

d. To measure distances between geological features

Answer: c. To set the scale and orientation of a coordinate system

6. Which mathematical model approximates the Earth's shape and is defined by its semi-major and semi-minor axes?

a. Ellipsoid

b. Geoid

c. Spheroid

d. Datum

Answer: a. Ellipsoid

7. In geodetic coordinates, what does latitude measure?

a. The angle between the prime meridian and a line perpendicular to the reference surface

b. The distance from the equatorial plane to a point

c. The angle between the equatorial plane and a line perpendicular to the reference surface

d. The angle between a line and the Earth's surface

Answer: c. The angle between the equatorial plane and a line perpendicular to the reference surface

8. What do astronomical coordinates describe?

a. The position of celestial objects in the sky

b. The location of geographic features on Earth

c. The shape of the Earth's surface

d. The orientation of coordinate systems

Answer: a. The position of celestial objects in the sky

9. Which parameter is not typically needed to calculate geodetic coordinates (φ, λ, h) from Cartesian coordinates (X, Y, Z) in a geocentric datum?

a. Semi-major axis (a)

b. Flattening (f)

c. Normal gravity at 45 degrees latitude (γ45)

d. Eccentricity (e)

Answer: c. Normal gravity at 45 degrees latitude (γ45)

10. What is the primary difference between geocentric and geodetic datums?

a. Geocentric datums are global, while geodetic datums are local.

b. Geocentric datums are used for astronomy, while geodetic datums are for geophysics.

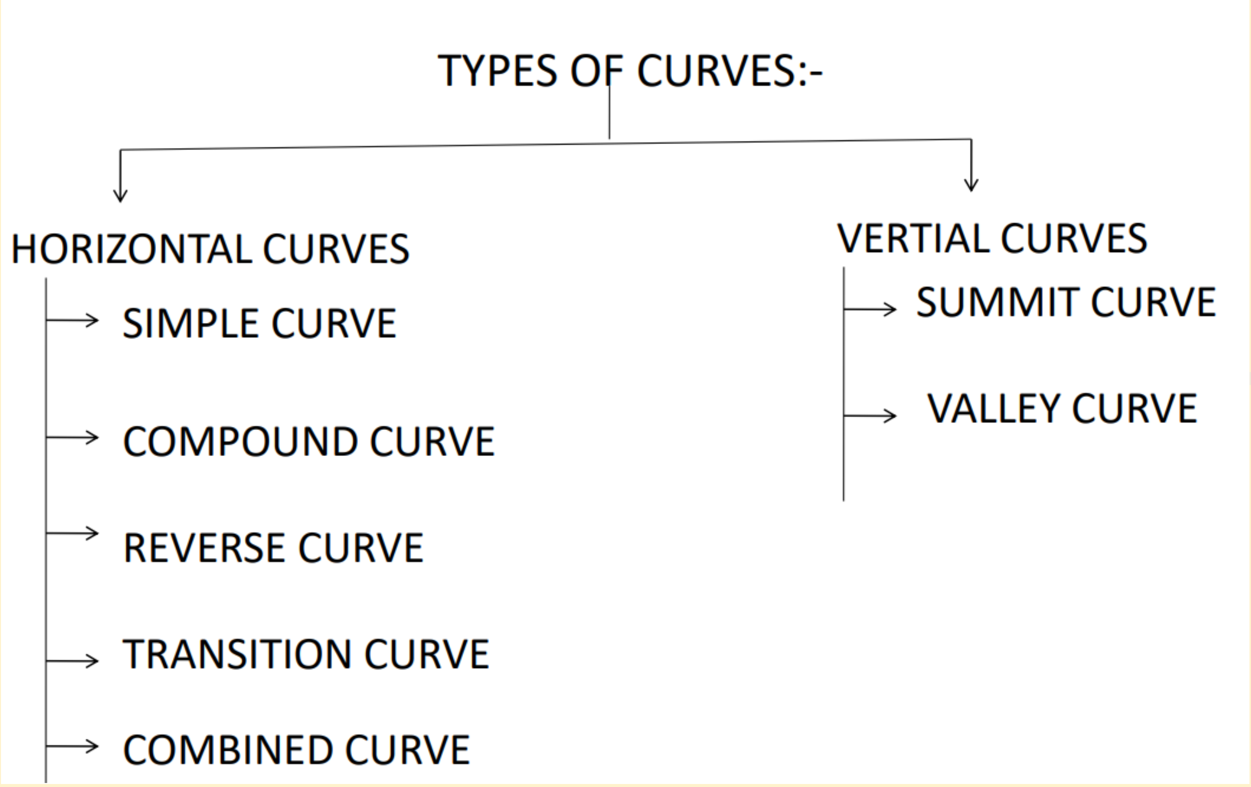
c. Geocentric datums are based on ellipsoids, while geodetic datums use spheroids.

d. Geocentric datums are centered at the Earth's surface, while geodetic datums are centered at the Earth's core.

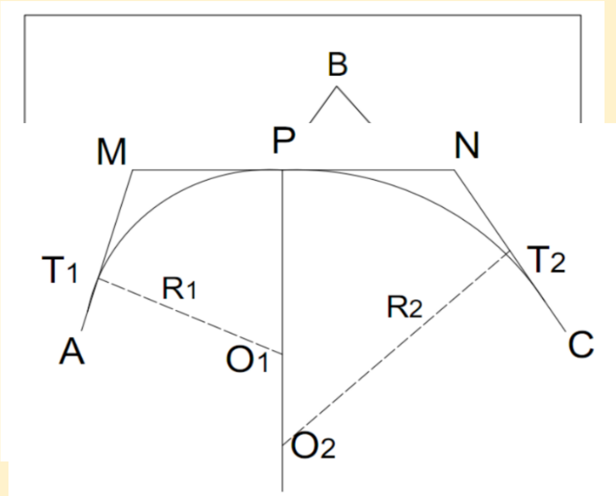
Answer: a. Geocentric datums are global, while geodetic datums are local.

CURVE RANGING

Curves are usually employed in lines of communication in order that the change of direction at the intersection of the straight line shall be gradual. The lines connected by the curves are tangential to it and are called tangents or straights.



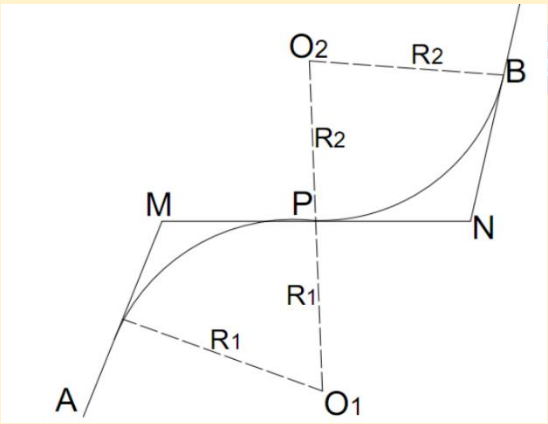
- **Simple Curve**: - A simple curve consists of a single arc connecting two straights or tangents. simple curve is normally represented by the length of its radius or by the degree of curve.



COMPOUND CURVE

- Compound curve: - A compound curve consist of two arcs of different radii curving in the same direction and lying on the same side of their common tangent , their centers being on the same side of the curve.

- Reverse Curve: - A reverse curve is composed of two arcs of equal or different radii bending or curving in opposite direction with common tangent at their junction, their centers being in opposite sides of the curve.



Notation for circular curve

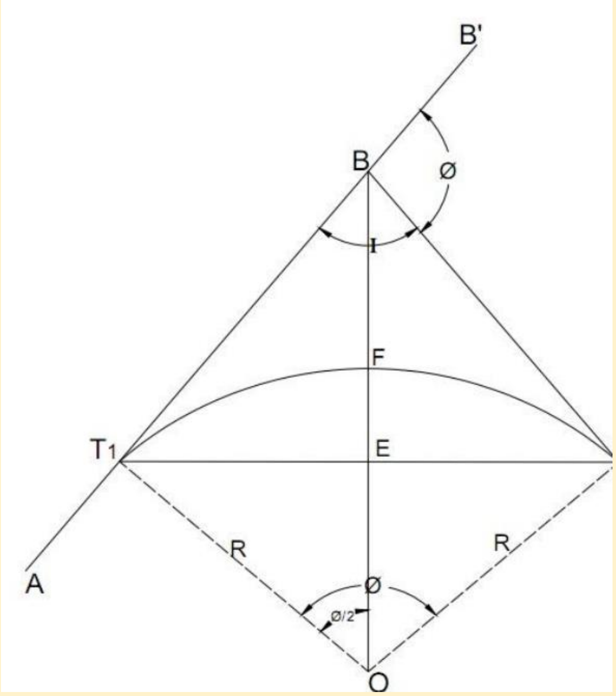
1. The straight lines AB and BC, which are connected by the curve are called the tangents or straights to the curve.

2. The point B at which the two tangent lines AB and BC intersect is known as the point of intersection (P.I.) or the vertex (V).

3. If the curve deflects to the right of direction of progress of survey (AB), it is called as right hand curve, if to the left , it is called as left hand curve.

4. The tangent line AB is called the first tangent or rear tangent (also called the back tangent)

5. The tangent line BC is called as the second tangent or forward tangent.



6. The points (T1 and T2) at which the curve touches the straights are called tangent point(T.P.). The beginning of the curve (T1) Is called the point of curve.(P.C.) or the tangent curve (T.C.). The end of the curve (T2) is known as the point of tangency(P.T.) or the curve tangent(C.T.).

7. The ∠ABC between the tangent lines AB and BC is called the angle of intersection (I). The ∠B'BC (i.e. the angle by which the forward tangent deflects from the rear tangent) is known as the deflection angle (ø) of the curve.

8. The distance from the point of intersection to the tangent point is called the tangent distance or tangent length. (BT1 and BT2).

9. The line T1T2 joining the two point (T1 and T2) is known as the long chord.(L).

10.The arc T1FT2 is called the length of the curve.(l).

11.The mid point F of the arc T1FT2 is known as the apex or the summit of the curve and lies on the bisector of the angle of the intersection.

12. The distance BF from the point of the intersection to the apex of the curve is called the apex distance of external distance.

13.The angle T1OT2 subtended at the centre of curve by the arc T1FT2 is known as the central angle, and is equal to the deflection angle.(ø)

14.The intercept EF on the line OB between the apex (F) of the curve and the midpoint (E) of the long chord is called the versed sine of the curve.

Methods of curve ranging

The methods of setting out curves may be divided in two classes according to the instrument employed.

1. Linear or chain and tape method: - Linear methods are those in which the curve is set out with chain and tape only.

2. Angular or instrumental method: - instrumental methods are those in which theodolite with or without a chain is employed to set out curve.

Transition Curve

A curve of varying radius is known as ‘transition curve’. The radius of such curve varies from infinity to certain fixed value. A transition curve is provided on both ends of the circular curve. The transition curve is also called as spiral or easement curve.

OBJECTS OF PROVIDING TRANSITION CURVES

1. To accomplish gradually the transition from the tangent to the circular curve, and from the circular curve to the tangent.

2. To obtain a gradual increase of curvature from zero at the tangent point to the specified quantity at the junction of the transition curve with the circular curve.

3. To provide the superelevation gradually from zero at the tangent point to the specified amount on the circular curve.

4. To avoid the overturning of the vehicle.

Notes: -

The types of transition curve which are in common use are

1. A Cubic parabola
2. A Clothoid or spiral
3. A lemniscate

the first being used on railways and third one on highways.

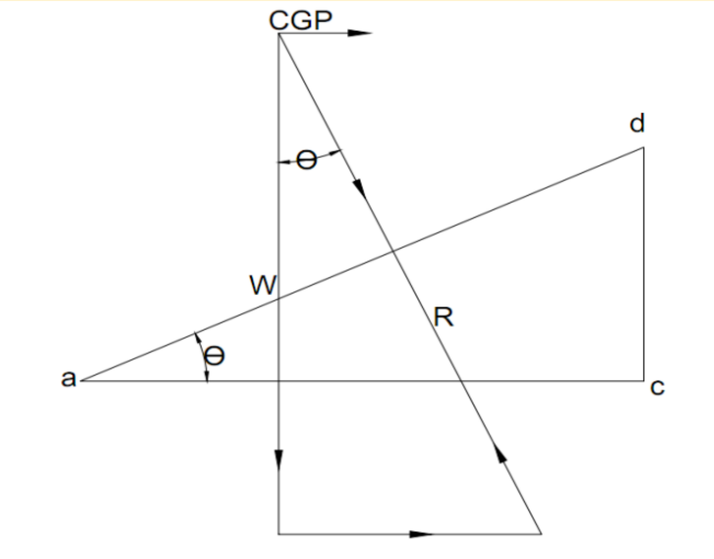
Superelevation

When a vehicle passes from a straight path to curved one, the forces acting on it are

i. The weight of the vehicle.

ii. The centrifugal force both acting through the CG of vehicle.

Since the centrifugal force is always acts in the direction perpendicular to the axis of rotation which is vertical, its direction is always horizontal. The effect of the centrifugal force is to push the vehicle off the track or rail. In order to counteract the action, the plane of rails or the road surface is made perpendicular to the resultant of centrifugal force and weight of the vehicle. In other word, the outer rail is superelevated or raised above the inner one. Similarly the road should be "banked", i.e. the outer edge of the road should be raised above the inner one, the raising of the outer rail or outer edge above the inner one, being called as superelevation or cant. The amount of cant is depend on vehicle and radius of curve.



Let, W = weight of the vehicle
P = the centrifugal force.
v = the speed of the vehicle in m/s.
g =the acceleration due to gravity = 9.81 m/s2
R = the radius of the curve in m
h = the superelevation in m
b = the width of the road in m
G = the distance between centers of the rails in m.

Then the equilibrium, the resultant of the weight and the centrifugal force must be equal and opposite to the reaction perpendicular to the road or rail surface.

$$P = \frac{Wv^2}{gR} \qquad \therefore \frac{P}{W} = \frac{v^2}{gR}$$

If Θ be the inclination of the road or rail surface, the inclination of the resultant to the vertical is also Θ, therefore we have

$$\tan\theta = \frac{dc}{ac} = \frac{P}{W} = \frac{bv^2}{gR}$$

Hence the amount of superelevation h

$$h = b\tan\theta = \frac{v^2}{gR} \quad \text{on roads}$$

$$h = \frac{Gv^2}{gR} \quad \text{on railways}$$

The amount of superelevation is limited about 1/12th of the gauge, 1/10th being permitted under special circumstances. The maximum superelevation recommended for broad gauge (1676 mm) , meter gauge (1000 mm) and narrow gauge (762 mm) are 140mm (165 mm) , 90 mm (102 mm) and 65 mm (75 mm) respectively.

Vertical Curves

When two different or contrary gradients meet, they are connected by a curve in vertical plane is called a vertical curve. It is advisable to introduce a vertical curve in road and in railway work in order to round off the angle and to obtain a gradual change in grade so that abrupt change in grade is avoided at the apex.

REQUIREMENTS

1. It gives adequate visibility and safety to the traffic.
2. It gives gradual change in grade or slope.
3. It gives adequate comfort to the passengers.

Types of Vertical Curves

1. An up grade followed by a down grade.
2. A down grade followed by an up grade.
3. An up grade followed by another up grade.
4. A down grade followed by another down grade.

Solved Previous Year Questions

1. Different grades are joined together by a:

A) Compound cur B) Transition curve
C) Reverse curve D) Vertical curve

Ans D

Different grades are joined together by a vertical curve. A vertical curve is a type of curve that is used to connect two different grades, such as a hill and a flat section of road. It is a smooth curve that gradually changes the slope of the road from one grade to another, making the transition between the two grades smoother and safer for drivers. A vertical curve can be either a crest curve or a sag curve, depending on whether the road is rising or falling. The length and shape of the vertical curve depend on the speed limit, design vehicle, and grade of the road. Therefore, option D is the correct answer.

2. The chord of curve less than peg interval is knownas:
A) Small chord B)Sub-chord
C) Normal chord D) Short chord

Ans B

A) Small chord: A chord is a straight line that connects two points on a curve. In surveying, a small chord is a chord that is less than the standard length of a full chord, which is typically equal to the length of the chain or tape used in the survey. Small chords are commonly used in engineering surveys for curve layout and design.

B) Sub-chord: A sub-chord is a chord that is shorter than the standard length of a full chord, but longer than a small chord. Sub-chords are typically used in surveying to measure curves in areas where the radius of the curve is smaller than the length of the chain or tape being used.

C) Normal chord: A normal chord is a chord that intersects the curve at a right angle. Normal chords are commonly used in engineering surveys to measure horizontal distances along a curve.

D) Short chord: A short chord is a chord that is shorter than the radius of the curve it intersects. Short chords are typically used in surveying to measure curves in areas where the radius of the curve is smaller than the length of the chain or tape being used.

3. "Super elevation" is a term used for designing
A) Benches
B) Haul Roads
C) Dumps
D) Magazine
Ans B
"Super elevation" is a term used for designing Haul Roads in open pit mining. It refers to the banked or sloped design of the road, where the outer edge of the road is higher than the inner edge. This design helps to counteract the centrifugal force of vehicles turning on the road, and reduces the risk of vehicles overturning.

4. Transition curves are introduced at either end of a circular curve, to obtain

(1) gradual increase of super elevation from zero at the tangent point to the specified amount at the junction of the transition curve with main curve

(2) gradual change of gradient from zero at the tangent point to the specified amount at the

junction of the transition curve with main curve

(3) gradually decrease of curvature from zero at the tangent point to the specified quantity at the junction of the transition curve with main curve

(4) All the Options

(5) None of the Options

Ans(1)

Transition curve:

To minimise discomfort arising out of the sudden change in curvature at the junction of a tangent and a curve, a special type of curve is provided in between for gradual change from the back tangent to the circular curve and again from the circular curve to the forward tangent. This horizontal curve having varying radius is known as the transition curve.

There are three types of transition curves which are generally provided.

1. Cubic spiral (ideal curve).

2. **Cubic parabola.**

3. Bernoulli Laminscate.

There are five objectives for providing transition curve and are given below:

1. To introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve.

2. Gradual increase of super-elevation from zero at the junction of the transition curve with the main curve to the specified amount at the point of tangency.

3. To provide a gradual introduction of extra widening.

4. A gradual change of gradient from zero at the junction of the transition curve with the main curve to the specified amount at the point of tangency.

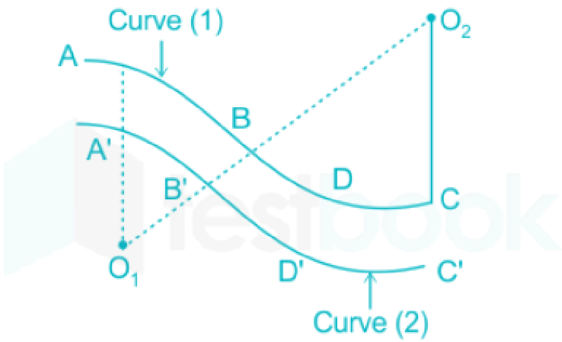
5. A gradual change of radius from some value at the junction of the transition curve with the main curve to the infinite value at the point of tangency.

5. When a curve of one radius runs into another of different radius bending at the same direction with a common tangent and their centers on the same side is called ……..

a) Sag curve
b) Compound curve
c) Transition curve
d) Serpentine curve
e) Simple curve

Ans D

- A **reverse curve** is **made** up of **two arcs having equal or different radii bending in opposite direction** with a common tangent at their junction.
- Their **centers lie on opposite sides of the curve.**
- The reverse curve is used when the straights are parallel or intersect at a very small angle.
- Reverse curves are **also called** a **serpentine curve or the S curve** because of their shape.



O_1 and O_2 are centre of curve (1) and curve (2)

Simple curve:

- A simple circular curve has the property that it **connects two straight lines** with a curve of **the constant radius at all points** on the curve and connects the two straight-line tangentially.

Compound curve:

- Many times it is not possible to provide a curve of constant radius to connect the two straight lines. In that case, we provide more than one curved of different radii to connect them.

Transition curve:

- While going through a straight road, if a curve is suddenly encountered, we feel a jerk. **In order to avoid such a sudden jerk, a Transition curve provided.**
- This is a curve of the varying radius is provided which takes off from the straight line, turns gradually, and finally meets the curve i.e. attains the same radius as that of the curve.

6. Different grades are joined together by a

a) Compound curve
b) Transition curve
c) Reverse curve
d) Vertical curve
e) None of the above

Ans D

Explanation:

Vertical Curve:

- A curve used to connect **two different** grade lines of **railways or highways** is called a **vertical curve.**
- A vertical curve may be Circular or Parabolic. the **parabolic vertical** curve is preferred more and invariably used.
- However, it is best to use a vertical curve having a **constant rate** of change of gradient i.e. a parabolic and as it turns out, **parabolic vertical** curves are easy to Calculate and used.

Transition curve:

- To minimize discomfort arising out of the sudden change in curvature at the junction of a tangent and a curve, a special type of curve is provided in between for gradual change from the back tangent to the circular curve and again from the circular curve to the forward tangent.
- This horizontal curve having varying radius is known as the transition curve.

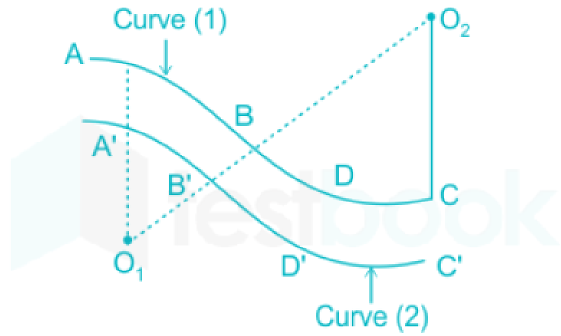
7. The curve composed of two arcs of different radii having their centers on the opposite side of the curve is known

a) A simple curve
b) A compound curve
c) A reverse curve
d) A vertical curve
e) None of the above

Ans C

Explanation:

- A **reverse curve** is **made** up of **two arcs having equal or different radii bending in opposite direction** with a common tangent at their junction.
- Their **centers lie on opposite sides of the curve.**
- The reverse curve is used when the straights are parallel or intersect at a very small angle.
- Reverse curves are **also called** a **serpentine curve or the S curve** because of their shape.



O_1 and O_2 are centre of curve (1) and curve (2)

Simple curve:

- A simple circular curve has the property that it **connects two straight lines** with a curve of **the constant radius at all points** on the curve and connects the two straight-line tangentially.

Compound curve:

- Many times it is not possible to provide a curve of constant radius to connect the two straight lines. In that case, we provide more than one curved of different radii to connect them.

Transition curve:

- While going through a straight road, if a curve is suddenly encountered, we feel a jerk. **In order to avoid such a sudden jerk, a Transition curve provided.**
- This is a curve of the varying radius is provided which takes off from the straight line, turns gradually, and finally meets the curve i.e. attains the same radius as that of the curve.

8. A vertical curve having concavity upwards is called

a) Valley curve
b) Summit curve
c) Sag curve
d) All of these
e) None of these

Ans B

Explanation:

Summit curve:

The curve which are on having a convex surface on the **upward side** is termed as the summit curve.

Valley curve:

The curve which are on having a convex surface on the **downward side** is termed as the valley curve.

Transition curve:

A curve with **variable radius** is known as Transition curve.

Compund curve:

A compound cure consists of two or more simple curve having different radii bending in the same direction and laying on the same side of common tangent.Their centre lie on the same side of curve.

9. If the degree of curve (specified length 30 m) is 3 degree, the radius of curve is approximately.

a) 573 m
b) 1910 m
c) 380 m
d) 457 m
e) None of these

Ans A

For a 30 m chain length,

Degree of curve (D) is given by

$$D = \frac{1719}{R}$$

$$\Rightarrow R = \frac{1719}{3} = 573\ \underline{m}$$

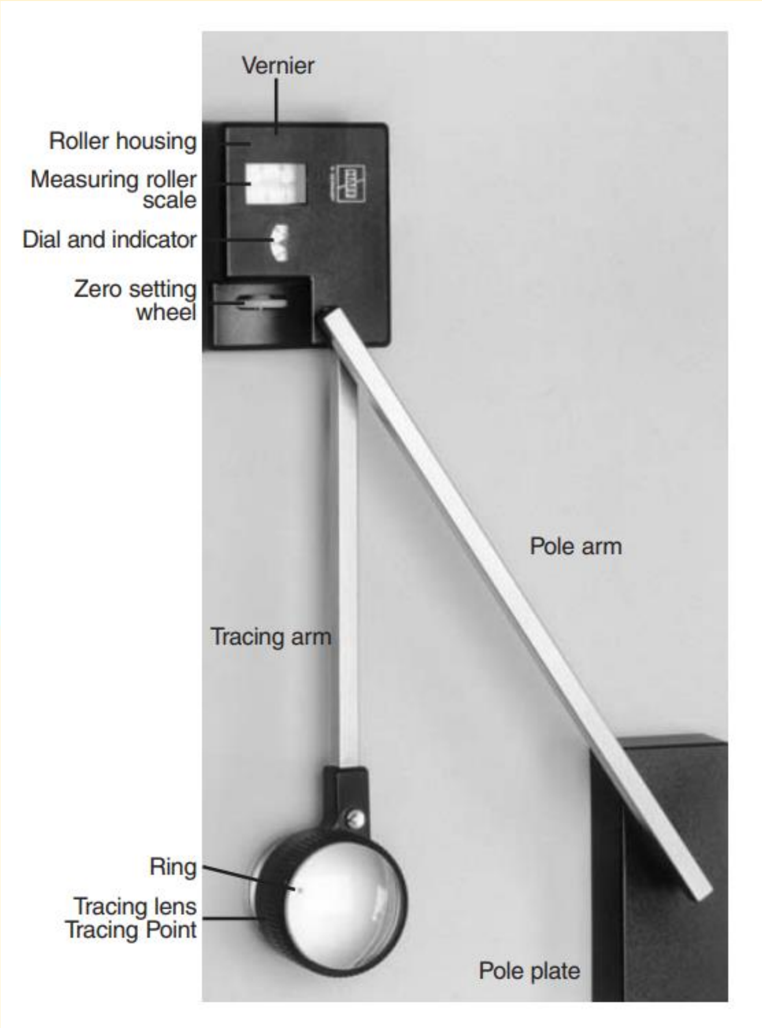
Minor Instruments

Planimeter

The planimeter is a simple instrument for the precise measurement of areas of plane figures of any shape.To measure an area it is only necessary to trace the outline of the figure in a clockwise direction with the centrepoint (within the ring) of the tracing lens and to read off the result on the scales.

The planimeter consists of 3 separate parts; the tracing arm to which is attached the roller housing the pole arm and the pole plate.The three parts are packed separately in the case.

The pole arm is a simple beam. On each end is fixed a ball, one for fitting into the roller housing, the other into the pole plate. The roller housing rests on three supports; the tracing lens, the measuring roller and a supporting ball.



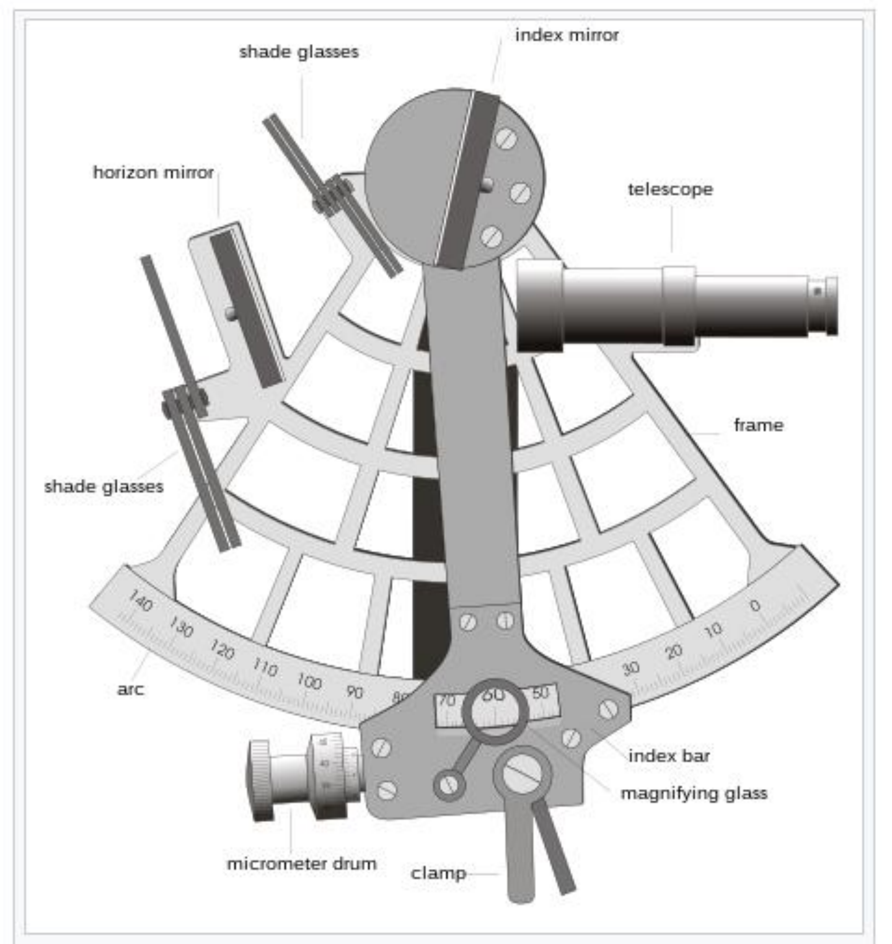
Important points: -

- Haff Planimeters are manufactured to give many years of accurate, trouble-free service but as with all precision instruments they must be handled carefully.Whenever the planimeter is not in use it should be stored safely in its case.

- The most easily damaged parts are the rim and bearings of the roller.The measuring roller is made of hardened steel and has a milled edge. Always use the setting wheel to zero the scales.
- The roller should run freely with only a little end-float. The accuracy of the planimeter can be checked at any time with the aid of the test area which is provided.

Sextant

A sextant is an instrument used for measuring the angle between two visible objects. Both horizontal and vertical angles can be measured using a sextant. It contains two mirrors which are arranged in such a way that the observer can sight both the objects at the same time. It is mainly used for navigational purposes in sea routes.



Principle of a Sextant: -

The principle of a sextant is when the ray of light is reflected from two mirrors in succession in the same plane, and then the angle between the incident and reflected ray is two times the angle between the mirrors.

Types of Sextants: -

There are three types of sextants:

1. Nautical Sextant
2. Box Sextant
3. Sounding Sextant Box

Sextant Box: -

Sextant is a small pocket instrument which looks like a sextant enclosed in a box and is 75mm in diameter. Similar to the nautical instrument, it is also used for measuring both the horizontal and vertical angles. Box sextant is a very small and handy instrument which is easy to carry. It is also used in ships for celestial navigation, and it also works well even if the ship or boat is moving.

Uses of Box Sextant: -

• Box sextant can be used as an optical square by setting vernier to 90o .

• Box sextant can be used to measure angles in chain surveying.

• It is used to check the angles measured by other surveying instruments.

• Radiation in traversing can be done using box sextant.

Abney level

Abney level is one of the various forms of clinometers used for the measurement of slopes, taking cross-sections, tracking contours, setting grades and all other rough levelling operations. It is a light, compact and hand instrument with low precision as compared to the engineer’s level.

The Abney level consists of the following: -

(1) A square sighting tube having a peephole or eye-piece at one end and a cross-wire at the other end. Near the objective end, a mirror is placed at an angle of 45 inside the tube and occupying half the width, as in the hand level.
Immediately above the mirror, an opening is provided to receive rays from the bubble tube placed above it. The line of sight is defined by the line joining the peephole and the cross-wire.

(2) A small bubble tube, placed immediately above the openings attached to a vernier arm which can be rotated by means of a milled headed screw or by rack and pinion arrangement. The image of the bubble is visible in the mirror.
When the line of sight is at any inclination, the milled-screw is operated till the bubble is bisected by the cross-wire. The vernier is thus moved from its zero position the amount of movement being equal to the inclination of the line of sight.

(3) A semicircular graduated arc is fixed in position. The zero marks of the graduations coincide with the zero of the vernier. The reading increases from 0° to 60°(or 90°) in both directions, one giving the angles of elevation and the other angles of depression.

In some instruments, the values of the slopes, corresponding to the angles, are also marked. The vernier is of the extended type having the least count of 5′ or 10′. If the instrument is to be used as a hand level, the vernier is set to read zero on the graduated arc and the level is then used as an ordinary hand level.

Uses of Abney Level

The Abney Level can be used for,

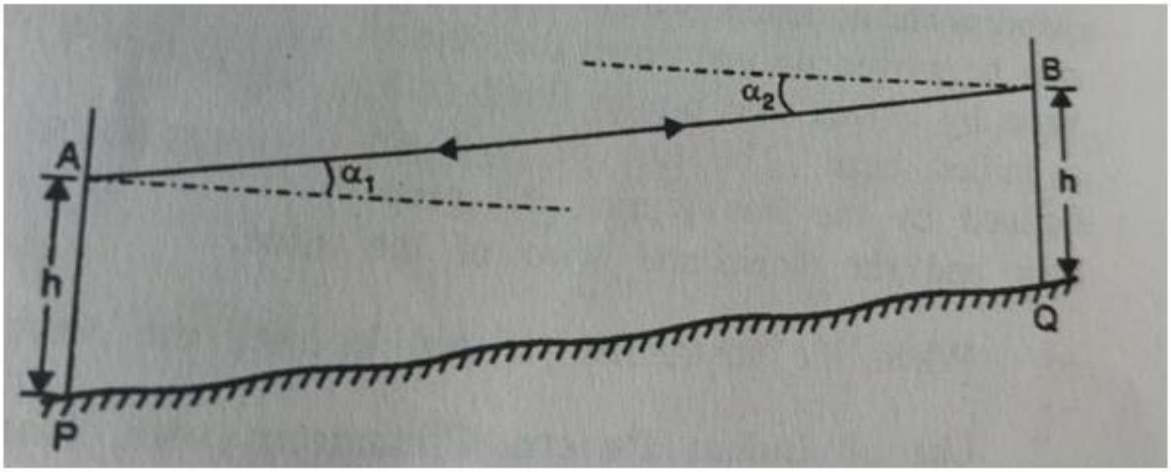
(i) Measuring Vertical angle

- Keep the instrument at eye level and direct it to the object till the line of sight passes through it.
- Since the line of sight is inclined, the bubble will go out of the centre. Bring the bubble to the centre of its run by the milled screw. When the bubble is central, the line of sight must pass through the object.
- Read the angle on the arc by means of the vernier.

(ii) Measurement of the slope of the ground

- Take a target, having cross-marks, at the observer's eye height and keep it at the other end of the line.
- Hold the instrument at one end and direct the instrument towards the target till the horizontal wire coincides with the horizontal line of the target.
- Bring the bubble in the centre of its run.
- Read the angle on the arc by means of the vernier.

Testing and adjustment of Abney Level



(i) Fix two rods, having marks at equal heights h (preferably at height of observers eye), at two points P and Q, about 20 to 50 metres apart.

(ii) Keep the Abney level at point A aginst the rod at P and measure the angle of elevation towards point B of the rod Q.

(iii) Shift the instrument to Q, bold it against B and sight A. Measure angle of depression α2.

(iv) If α1 and α2. are equal, the instrument is in adjustment i.e., the line of sight is parallel to the axis of the bubble when it is central and when vernier reads zero.

(v) If not, turn the. screw so that the vernier reads the mean reading.

(α1+ α2)/2

The bubble will no longer be central.

Bring the bubble to the centre of its run by means of its adjusting saws. Repeat the test till correct

Note: - If the adjustment is not done, the index error, equal $(\alpha 1 - \alpha 2)/2$ may be noted and the correction may be applied to all observed readings.

optical square

This instrument is used for setting out lines at right angle to main chain line. It is used where greater accuracy is required. There are two types of optical square, one using two mirrors and the other a prism.

- The mirror method is constructed based on the fact that a ray of light is reflected from a mirror at the same angle as that at which it strikes the mirror.
- The prism square method is a simplified form of optical square consisting of a single prism. It is used in the same way as the mirror square, but is rather more accurate.

Solved Previous Year Questions

1. Match the following as per the best use of instruments:

I. Digital level	a. True North
II. Gyromat	b. Elevation
III. DGPS	c. Correlation
IV. Nadir Plummet	d. Positions

(1)I-b. ll-C.III,IV-d

(2)I-b.Il-d,III-a,IV-c

(3)I-d.Il-C,III-a,IV-b

(4)I-c,Il-d,III-a,IV-b

(5) None of the Options

Ans(5)

A digital level is **an instrument that can be used to perform advanced levelling work, automatic height calculations and basic construction work**. It uses gravity as its reference point and reads bar-code scales from a bar-coded staff to capture extremely accurate readings.

The GYROMAT instrument series is **a range of precision surveying gyroscopes with band suspension**, resulting from DMT's more than 60 years of experience in the development and manufacture of gyroscopic measuring instruments.

Differential Global Positioning System (DGPS) is **an enhancement to Global Positioning System that provides improved location accuracy**, from the 15-meter nominal GPS accuracy to about 10 cm in case of the best implementations.

Optical nadir plummet is used in a total station is used for **accurate centering over a station**. It has either a bullseye or cross hair sight for positioning the instrument over a survey marker or ground control point.

2. The suspended compensation system is a component of

(1) Auto Level

(2) Tilting Level

(3) Dumpy Level

(4) Y- level

(5) None of the Options

Ans.(1)

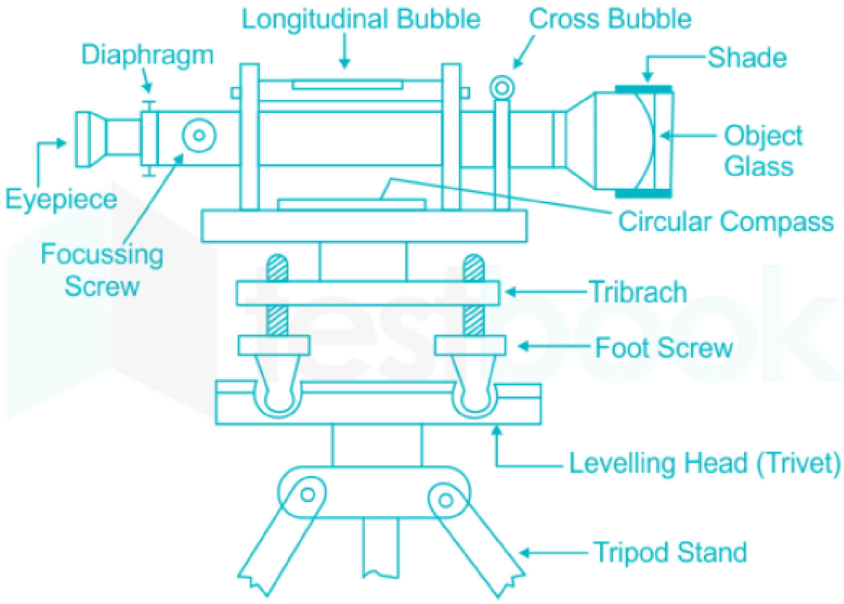
Different types of levels:

1) Reversible level:

A reversible level combines the features of both the dumpy level and the Wye level. The **telescope is supported by two rigid sockets into which the telescope can be introduced from either end** and then fixed in position by a screw. The sockets are rigidly connected to the spindle through a stage.

2). Dumpy level:

The dumpy level is an optical surveying leveling instrument consisting of a **telescope tube firmly secured in two collars fixed by adjusting screws to the stage by the vertical spindle**. The telescope of the dumpy level can rotate only in a horizontal plane.



3). Wye level:

The essential difference between the dumpy level and the Wye level is that in the **former case the telescope is fixed to the spindle while in the Wye level, the telescope is carried in two vertical Wye supports.** The Wye support consists of curved clips. The clips are raised, the telescope can be rotated in the Wyes, or removed and turned end for end.

4). Titling levels:

It consists of a **telescope attached with a level tube which can be tilted within few degrees in the vertical plane by a tilting screw**. The main peculiarity of this level is that the vertical axis need not be truly vertical, since the **line of collimation is not perpendicular to it**. The line of collimation, is, however, made horizontal for each pointing of the telescope by means of a tilting screw. It is mainly designed for precise leveling work.

3. Pick up the correct statement from the following:

(1) Gradiometer is used for setting out any required gradient

(2) Cross staff is used for setting out right angles

(3) Box sextant is used for the measurement of horizontal angles

(4) Optical square is used for setting out right angles

(5) All the Options

Ans.(5)

The gradiometer is a magnetometer which measures **the change in the magnetic field (the gradient of the field)**. Compared to a magnetometer this increases the measurement accuracy and the sensitivity to regional changes of the Earth's magnetic field.

Cross-staff is used for **setting out right angles** and French cross-staff is an advanced version of cross-staff and can set out 45-degree angles also.

Box sextant can be used as an optical square by setting vernier to 90°. Box sextant **can be used to measure angles in chain surveying**. It is used to check the angles measured by other surveying instruments. Radiation in traversing can be done using box sextant.

An optical square is **useful in turning the line of sight by 90° from its original path**. An optical square is essentially a pentagonal prism (pentaprism). Regardless of the angle at which the incident beam strikes the face of the prism, it is turned through 90° by internal reflection.

4. The device used as a substitute for plumb bob for centering a theodolite over a ground station is

(1)U –tork

(2) Alidade

(3)Optical square

(4)Optical plummet

(5) Ali of the above

Ans(4)

Optical plummet is used in a total station is used for accurate centering over a station. It has either a bullseye or cross hair sight for positioning the instrument over a survey marker or ground control point.

The older tribraches required a plumb line to allow them to be positioned vertically over a point and took longer to set up. Some modern total stations have an integral laser plummet built in.

5. Two mirrors are used for off setting in

(1) Cross-staff

(2) Optical square

(3) Miner's dial

(4) Prism compass

(5) Cross-staff and Otical square

Ans(2)

Optical square and **Prism square** are instruments used to set out a right angle to a chain line.

(i) Optical Square: It is more convenient and accurate than cross-staff for setting out right angles. Consists of **two mirrors making a 45° with each other**, one mirror totally silvered another top bottom un-silvered.

(ii) Prism Square: It works on the same principle as that of the optical square. It is more modern and precise instruments and has the merit that no adjustment is required since the angle between the reflection surface (i.e. 45°) cannot vary.

6. Use of optical square in surveying

a) Setting out right angle
b) Setting out curve
c) Centering
d) Leveling
e) None of these

Ans A

An optical square is used for setting out right angles. It consist of a small circular metal box of diameter 5 cm and depth 1.25 cm. It has a metal cover which slides round the box to cover the slits.

Principle of optical square:

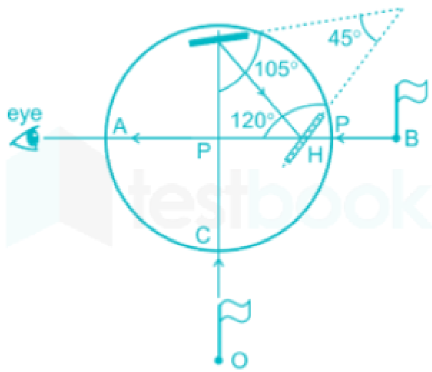
According to the principle of reflecting surfaces, the angle between the first incident ray and the last reflected ray is twice the angle between the mirrors. In this case, the angle between the mirrors is fixed at 45°. So, the angle between the horizon sight and index sight will be 90°.

Construction of Optical Square:

A horizon glass H is fixed at the bottom of the metal box. The lower half of the glass is unsilvered and the upper half is silvered.

An index glass "I" is also fixed at the bottom of the box which is completely silvered.

The angle between the index glass and horizon glass is maintained at 45°.



The horizon glass is placed at an angle of 120° with the horizon sight. The index glass is placed at an angle of 105° with the index sight.

7. The angle of intersection of the two plane mirrors of an optical square is

a) 30^0
b) 45^0
c) 60^0
d) 90^0
e) 55^0

Ans B

Concept:

Optical Square:

- An optical square is a small pocket instrument, slightly larger than a watch.
- It is used for **setting out right angles.**
- There are **two mirrors placed vertically above the base at 45 degrees to each other which are used in offsetting.**
- One mirror, known as Horizon Glass, is unsilvered at the bottom and silvered on the top.
- The other mirror, known as Index Glass, is fully painted silvered.
- The optical square is based on the principle that if a ray of light undergoes two successive reflections in a plane at right angles to each of the two. plane mirrors, the angle between the incident ray and the reflected ray is twice the angle between mirrors.

8. A Clinometers is used for

a) Measuring angle of slope
b) Correcting line of collimation
c) Setting out right angles
d) Defining natural features
e) None of these

Ans A

Explanation:

Clinometer:

- It is an instrument for measuring angles of slope, elevation or depression of an object with respect to the ground.
- **A clinometer is a special case of a spirit level.**
- **While the spirit level is restricted to relatively small angles, clinometers can be used for much larger angles.**
- These have an accuracy of one minute.
- Clinometers are used to determine straightness and flatness of surfaces.

9. Is used for centering a theodolite in mine roadways where velocity of air is high

a) Plum bob
b) Tape
c) Optical plummet
d) Peg
e) None of these

Ans C

Optical plummet: A device on some transits and theodolites used to centre the instrument over a point, in place of a plumb bob, which moves in a strong wind.
Optical Square: a small hand instrument used by surveyors for laying off a right angle by means of two mirrors set at an angle of 45 degrees.
Cross staff: The cross-staff is an instrument used to measure angles and altitudes, consisting of a trigonometrically graduated staff and one or more perpendicular vanes moving over it.

Computations

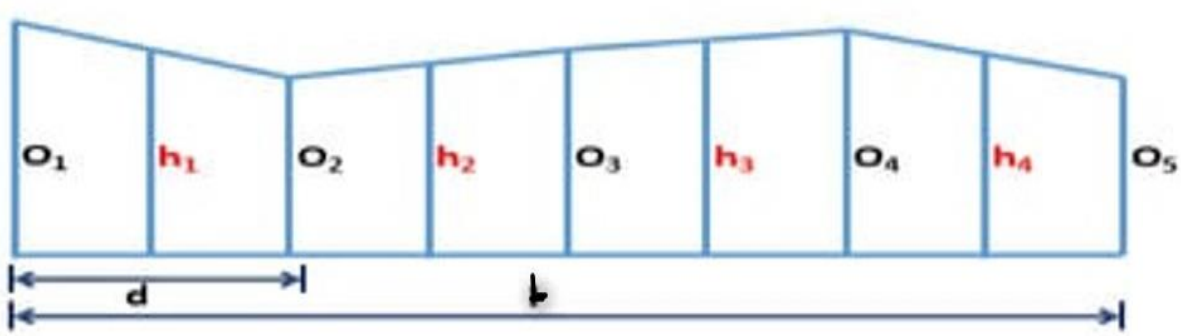
One of the main objectives of the surveying is to compute the areas and volumes. Generally, the lands will be of irregular shaped polygons. There are formulae readily available for regular polygons like, triangle, rectangle, square and other polygons. But for determining the areas of irregular polygons, different methods are used.

They are:
(1) Graphical method
(2) Co-ordinate method
(3) Planimeter

Out of these three methods, the co-ordinate method is popularly used, in land surveying for computing catchment area, drainage area, cross section of rivers, channels etc. Under this method the given area is split into two with a base line run at the centre.

Mid Ordinate Rule

The method is used with the assumption that the boundaries between the edge of the ordinates are straight lines. The base line is divided into a number of divisions.



The area is calculated from following formula,

Area = Δ = Common distance x Sum of mid ordinates

= (h, x d) + (h2 x d) + ... + (h, x d)

$= d (h + h_2 + ... + h_n)$

Where,

n = Number of divisions

d = common distance between ordinates

h_1, h2, ... h_n, Mid ordinates.

Limitation

The mid-ordinate rule is less accurate where the gradient of the function changes rapidly.

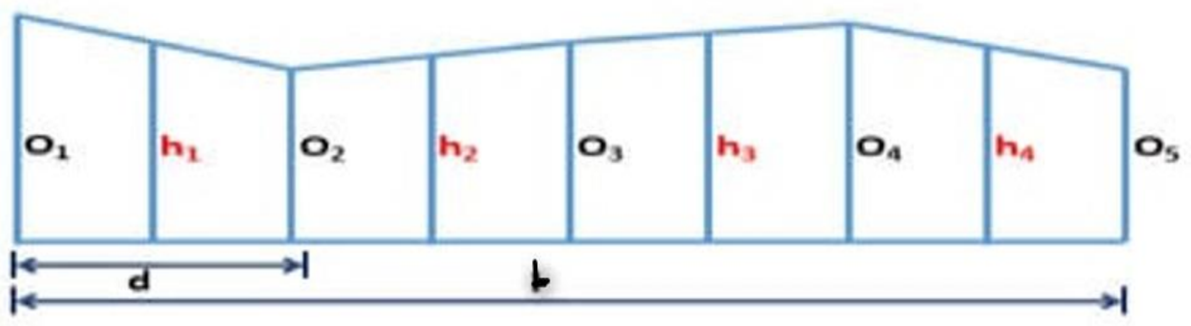
Average Ordinate Rule

This rule also assumes that the boundaries between the edges of the ordinates are straight lines. The offsets are measured to each of the points of the divisions of the base line.

The area is given by following equation,

Area = A = average ordinate x Length of the base

$=\left(\frac{O1+O2+\cdots+On}{n+1}\right) L$



Limitation

The mid-ordinate rule is less accurate where the gradient of the function changes rapidly.

Trapezoidal Rule

In this method, boundaries between the ends of ordinates are assumed to be straight. Thus, the area enclosed between these line and the irregular boundary lines are considered as trapezoids.

$$A = \frac{d}{2}[O_1 + O_n + 2(O_2 + O_3 + O_4 + \ldots + O_{n-1})]$$

A = distance between ordinate/ 2*[{first ordinate + last ordinate} + 2{sum of other ordinates)

Limitation

It uses linear approximations instead of quadratic or higher-order approximations, so it is less accurate than other methods such as Simpson’s rule or Romberg’s method.

Simpson's Rule

$$A = \frac{d}{3}\left[O_1 + O_n + 4\left(O_2 + O_4 + \ldots\right) + 2\left(O_3 + O_5 + \ldots\right)\right]$$

$$A = \frac{\text{Common distance (d)}}{3}\left[\begin{array}{l}(\text{First ordinate} + \text{Last ordinate}) + 4(\text{Sum of even ordinates}) \\ + 2(\text{Sum of odd ordinates})\end{array}\right]$$

Limitations: The rule is applicable only when the number of divisions is even or the number of ordinates are odd sometimes one or both end ordinates may be zero. However he must be taken into account while applying rules.

Earth work and Building Estimation

Earth work and building estimation are important aspects of civil engineering projects. They involve calculating the quantities of materials, labor, and equipment required for various tasks such as excavation, filling, leveling, foundation, brickwork, plastering, etc. There are different methods and techniques for estimating earth work and building work, depending on the type and complexity of the project. Some of the common methods are:

- **Long wall - short wall method:** This method is used to estimate the quantities of earth work, foundation concrete, brickwork in plinth and superstructure, etc. by dividing the building plan into strips of equal width and taking the product of the length, breadth, and height of each strip.

- **Centre line method:** This method is used to estimate the quantities of earth work, foundation concrete, brickwork in plinth and superstructure, etc. by taking the product of the centre line length, breadth, and height of each wall or column.

- **Partly centre line and partly cross wall method:** This method is a combination of the above two methods and is used when some walls are common to two rooms or when there are cross walls or partitions in the building plan.

- **Trapezoidal rule:** This method is used to estimate the area under a curve by dividing it into trapezoids and calculating their areas. This method is useful for estimating the earth work in roads, railroads, canals, etc.

- **Average ordinate rule:** This method is used to estimate the area under a curve by dividing it into strips of equal width and taking the product of the average ordinate and the width of each strip. This method is also useful for estimating the earth work in roads, railroads, canals, etc.

- **Mid-ordinate rule:** This method is used to estimate the area under a curve by dividing it into strips of equal width and taking the product of the mid-ordinate and the width of each strip. This method is also useful for estimating the earth work in roads, railroads, canals, etc.

WORKOUT PROBLEMS

1. The following offsets were taken from a chain line to an irregular boundary line at an interval of 10 m. 0, 2.50, 3.50, 5.00, 4.60, 3.20, 0 m. Compute the area between the chain line, the irregular boundary line and the end offsets by: (a) Trapezoidal Rule (b) Simpson's Rule

Solution: -

(a) Trapezoidal Rule,

Here d = 10

Area = $\frac{10}{2}\{0 + 0 + 2(2.50 + 3.50 + 5.00 + 4.60 + 3.20)\} = 5 * 37.60 = 188\ m^2$

(b) Simpson's Rule,

D = 10

Area = $\frac{10}{3}\{0 + 0 + 4(2.50 + 5.00 + 3.20)\ 2(3.50 + 4.60)\} = \frac{10}{3} * 59 = 196.66\ m^2$

2. The following offsets were taken from a survey line to a curved boundary line:

Distance (m)	0	5	10	15	20	30	40	60	80
Offset (m)	2.50	3.80	4.60	5.20	6.10	4.70	5.80	3.90	2.20

Find the area between the survey line, the curved boundary line and the first and last offsets by (a) Trapezoidal Rule and (b) Simpson's Rule.

Solution: -

Here, the intervals between the offsets are not regular throughout the length. Soothe section is divided into three compartments.

Let,

Δ1 = Area of the 1st section

Δ2 = Are of the 2nd section

Δ3 = Area of the 3rd section

Here, d_1 = 5 m

d_2 = 10 m

d_3 = 20 m

(a) By Trapezoidal Rule:

$\Delta_1 = \frac{5}{2}\{2.50 + 6.10 + 2(3.80 + 4.60 + 5.20)\} = 89.50\ m^2$

$\Delta_2 = \frac{10}{2}\{6.10 + 5.80 + 2(4.70)\} = 106\ m^2$

$\Delta_3 = \frac{10}{2}\{5.80 + 2.20 + 2(3.90)\} = 158.00\ m^2$

Total Area = 89.50 + 106.50 + 158.00 = 354.00 m^2

(b) By Simpson's Rule:

$\Delta_1 = \frac{5}{3}\{2.50 + 6.10 + 4(3.80 + 5.20 + 2(4.60)\} = 89.66\ m^2$

$\Delta_2 = \frac{10}{3}\{6.10 + 5.80 + 4.70\} = 102.33\ m^2$

$\Delta_3 = \frac{20}{3}\{5.80 + 2.20 + 4(3.90)\} = 157.33\ m^2$

Total Area = 89.66 + 102.33 + 157.33 = 349.32 m^2

Solved Previous year Questions

1. A mine boundary is plotted on a scale of 1:2000. If a Planimeter measures the plotted area as 87 cm^2, the actual mine area in m^2 is

(1) 8700

(2) 17400

(3) 34800

(4) 39000

(5) None of the Options

Ans(3)

Scale:

$$\left(\frac{1}{n}\right)^2 = \frac{\text{ground area}}{\text{Actual area}}$$

$$\Rightarrow \left(\frac{1}{2000}\right)^2 = \frac{87}{\text{Actual area}}$$

$$\Rightarrow \text{Actual area} = 87 \times 4 \times 10^6 \times 10^{-4}\ m^2$$

$$= \underline{34800}\ m^2$$

2. The perpendicular offsets taken at 10 m intervals from one end of a chain line to an irregular boundary are 3.06, 4.14, 5.6, 4.86, 6.0, 6.6, 18,63 and 7.2 m. The area enclosed between the chain line. the irregular boundary. and the first and last off sets using Simpson's rule is

(1) 503.53 sq. m

(2) 453.55 sq. m

(3) 456.55 sq. m

(4) 545.53 sq. m

(5) None of the Options

Ans.(1)

Simpson's rule

$$\text{Area} = \frac{d}{3} \times \left[(y_0 + y_n) + 2(y_2 + y_4 + \cdots) + 4(y_1 + y_3 + \cdots) \right]$$

$$= \frac{10}{3} \times \left[(3.06 + 7.2) + 2(5.6 + 6 + 7.8 + 7.2) + 4(4.14 + 4.86 + 6.6 + 63) \right]$$

$$= \frac{10}{3} \times 151.06 = 503.53 \text{ sq m}$$

3. The areas enclosed between the adjacent survey lines and the curved boundaries are determined by …………..

a) Co-ordinates
b) Average ordinates
c) Ordinates
d) Mid-ordinates
e) None of these

Ans E

Explanation

(i) For irregular boundaries or curve boundary, Simpson's rule is preferred over the trapezoidal rule to calculate the given area.

(ii) According to this rule the short length of boundaries between the two adjacent ordinates is a parabolic arch.

Important Points

Simpson's rule:

In order to apply Simpson's rule, the area must be divided in even number i.e., the **number of offsets must be odd** i.e., n term in the last offset 'O_n' should be odd.

The area is given by Simpson's rule:

$$Area = \frac{d}{3}[(O_1 + O_n) + 4(O_2 + O_4 + \ldots\ldots\ldots + O_{n-1}) + 2(O_3 + O_5 + \ldots\ldots O_{n-2})]$$

where O_1, O_2, O_3, ...O_n is the offset

Note:

(i) In case of an even number of cross-sections, the end strip is treated separately and the area of the remaining strip is calculated by Simpson's rule. The area of the last strip can be calculated by either trapezoidal or Simpson's rule.

4. An excavation is to be made for a reservoir 24 m long and 15 m wide at the bottom and 3m, deep. The sides of the excavation slope at 1½ horizontal is 1 vertical. Assume surface of the ground to be level before excavation, calculate the volume of the excavation

a) 1687.50 cum
b) 1700 cum
c) 1678.50 cum
d) 1350 cum
e) 1800 cum

Ans D

Given:

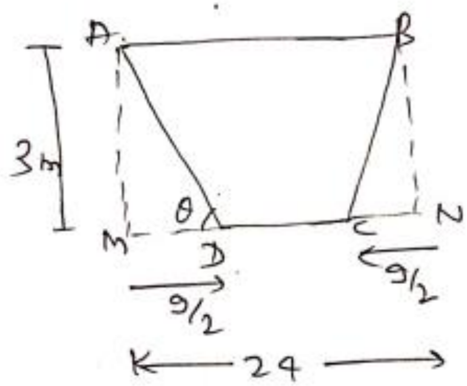
$\tan\theta = \frac{1}{3/2}$

$\frac{AM}{DM} = \frac{2}{3}$

$\Rightarrow \frac{3}{DM} = \frac{2}{3}$

$\Rightarrow DM = \frac{9}{2}$

$\therefore CN = \frac{9}{2}$



$\therefore$ Area $(A_1) = 24 \times 15 \ m^2$

$= 360 \ m^2$

$\therefore$ Area (A_2) at base $= (24-9)(15-9) = 90 \ m^2$

$\therefore$ Mean Area $(A_m) = \frac{360+90}{2} = 225 \ m^2$

$\therefore$ volume of excavation $= \frac{D}{2}[A_1 + 2A_m + A_2]$

$= \frac{3}{2}[360 + 2\times225 + 90]$

$= 1350 \ m^3$

5. A rectangle PQRS which is the plan of a part of excavation, is 36m x 24m, O being the point of intersection of its diagonals. The depths of excavation at the point P,Q,R,S and O are 2.85, 4.80, 4.50, 2.25 and 5.40 respectively. Calculate the volume of excavation within PQRS.

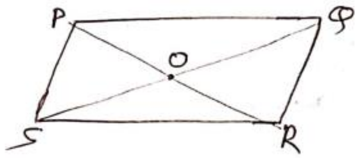
a) 3421.44 Cum
b) 3628.80 Cum
c) 3528.80 Cum
d) 3268.80 Cum
e) 3000 Cum

Ans A

Area of PQRS

$= 36 \times 24$

$= 864\ m^2$



Average height of excavation

$= \frac{1}{5}[2.85 + 4.80 + 4.50 + 2.25 + 5.40]$

$= 3.96\ m$

$\therefore$ volume of excavation within PQRS

$=$ Area $\times$ depth

$= 864 \times 3.96\ m^3$

$= 3421.44\ m^3$

6. Find the volume of frustum of cone of height 20 m, large base radius = 25 m and slant height = 29 m

a) 4613.63 cu m
b) 2692.58 cu m
c) 15525.71 cu m
d) 2900 cu m
e) None of these

Ans E

Height of Frustum = 20 m = H

large base radius = 25 m = R

Slant Height = 29m = l

let small base radius = r m

$\therefore \; l^2 = H^2 + (R-r)^2$

$\Rightarrow 29^2 = 20^2 + (25-r)^2$

$\Rightarrow \underline{r = 4}$

$\therefore$ volume of frustum of cone

$$V = \frac{\pi H}{3}\left(R^2 + Rr + r^2\right)$$

$$= \frac{\pi (20)}{3}\left(25^2 + 25 \times 4 + 4^2\right)$$

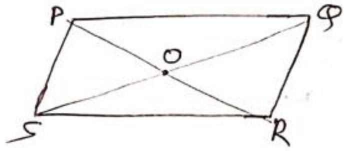
$$V = 15519.4677 \; \underline{m^3}$$

7. A rectangle PQRS which is the plan of a part of excavation, is 36m x 24m, O being the point of intersection of its diagonals. The depth of excavation within PQRS.

a) 3421.44 cum
b) 3628.80 cum
c) 3528.80 cum
d) 3268.80 cum
e) 3000 cum

Ans A

Area of PQRS



$= 36 \times 24$

$= 864\ m^2$

Average height of excavation

$= \frac{1}{5}[2.85 + 4.80 + 4.50 + 2.25 + 5.40]$

$= 3.96\ m$

$\therefore$ volume of excavation within PQRS

$=$ Area $\times$ depth

$= 864 \times 3.96\ m^3$

$= 3421.44\ \underline{m^3}$

8. Volume of earth work may be computed by

a) Mean Area
b) End area
c) Trapezoidal
d) Option a and b
e) Option a, b and c

Ans E

Volumes are computed from cross-section measurements by the **average end area method, mean area, or trapezoidal method**. These formulas are used to compute earthwork quantities because the Specifications require this calculation. All the plans and bidding for the project have been completed using this method.

9. As per Simpson rule, 'to the sum of the first and last ordinates, add ____ the sum of the remaining odd ordinates and _____ times the sum of all the even ordinates, multiply the total sum thus obtained by _______ of common distance between the ordinates and the result give the required area?

a) twice, three one-fourth
b) three time, four, one-half
c) twice, three, one-sixth
d) twice, four, one-third
e) none of the above

Ans D

Explanation:

Simpson's rule:

This rule is based on the assumption that the figures are **trapezoids.**

In order to apply Simpson's rule, the area must be divided in even number i.e., the **number of offsets must be odd** i.e., n term in the last offset 'O_n' should be odd.

The area is given by Simpson's rule:

$$Area = \frac{d}{3}[(O_1 + O_n) + 4(O_2 + O_4 + \ldots\ldots\ldots + O_{n-1}) + 2(O_3 + O_5 + \ldots\ldots O_{n-2})]$$

where O_1, O_2, O_3, ...O_n is the offset

Important Points

- In case of an even number of cross-sections, the end strip is treated separately and the area of the remaining strip is calculated by Simpson's rule. The area of the last strip can be calculated by either trapezoidal or Simpson's rule.

10. Compute the area by trapezoidal rule between the chain line, the curved boundary line and the and offsets as per the series of offsets taken at 10 m interval 0, 2.82, 3.96, 6.42, 8.61, 8.90, 5.25, 0m

a) 359.60 sq.m
b) 389.42 sq.m
c) 314.27 sq.m
d) 295.40 sq.m
e) 396.42 sq.m

Ans D

Trapezoidal formula

$$I = \frac{h}{2}\left[y_0 + 2(y_1 + y_2 + y_3 + \cdots y_{n-1}) + y_n\right]$$

where, h = interval width

y_i = readings of offsets.

$$\therefore I = \frac{10}{2}[0 + 2(2.82 + 2.96 + 8.61 + 8.90 + 5.25) + 0]$$

$$= \underline{295.40\ m^2}$$

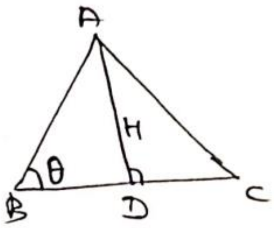
11. Area of triangle = half of the product of any two sides x ________ OR 1/2 x base x__-

a) Cos of included angle perpendicular height
b) Sine of included angle perpendicular height

c) Cos of external angle, height
d) Tan of included angle, depth
e) None of the above

Ans B

Area of triangle



$$= \frac{1}{2} \times BC \times AD$$

$$= \frac{1}{2} \times BC \times AB \times \sin\theta \quad [\because AD = AB\sin\theta]$$

12. Find the volume of a frustum of square pyramid with length of bases are 10 cm and 7 cm respectively and height is 12 cm.

a) 876 cu cm
b) 786 cu cm
c) 687 cu cm
d) 678 cu cm
e) None of these

Ans A

Area of Base $B_1 = (10)^2 = 100\ cm^2$

Area of Base $B_2 = (7)^2 = 49\ cm^2$

$\therefore$ volume of required frustum

$$= \frac{H}{3}\left[B_1 + B_2 + \sqrt{B_1 B_2}\right]$$

$$= \frac{12}{3}\left[100 + 49 + \sqrt{100 \times 49}\right]$$

$$= 876\ cm^3$$

13. Volume of earth work may be calculated by:

A) Mean areas B) End areas
C) Trapezoidal D) All of the above

Ans D

The volume of earthwork can be calculated using mean areas, end areas, or the trapezoidal method.

Mean areas method involves taking the average of the cross-sectional areas at the two ends of a section and multiplying it by the length of the section.

End areas method involves taking the areas of the cross-sections at the two ends of a section and using them to calculate the volume between them.

Trapezoidal method involves dividing a section into a number of trapezoidal areas and calculating the volume by adding up the volumes of the trapezoids.

All of these methods are commonly used to calculate the volume of earthwork for construction projects, and the choice of method depends on factors such as the complexity of the terrain and the accuracy required. Therefore, option D is the correct answer.

Theory of Errors

Theory of Error

- Measurements of angles and distances are made in different surveying processes.
- It is impossible to determine the actual values of these quantities because some type of errors always creep in every measurement.

Occurrence Of Error

1. Imperfection in Instruments

2. Environmental Condition

3. Human Limitations & Carelessness.

- **Imperfection In Instruments:** Due to faulty Instrument.

  Example: incorrect length of chain, collimation error.

- **Environmental Condition:** Due to nature error.

  Example: error due to curvature, error due to slope, error due to temperature.

- **Human Limitations & Carelessness:** Due to wrong reading/ writing.

Type Of Error

The errors can be classified into three types.

1. Gross errors or mistakes
2. Systematic or cumulative errors
3. Accidental or random errors.

1. Gross Errors Or Mistakes

- Inexperienced or careless surveyors make mistakes.
- These errors are unpredictably occurring and can be avoided by following a standard operating procedure.

2. Systematic or Cumulative Errors

- The systematic errors are of same magnitude and nature in the same conditions.
- The systematic errors can be computed and suitable corrections applied.
- For example, the error in the length of the steel tape due to change in temperature is a systematic error.

3. Accidental Or Random Errors

- Accidental errors occur due to lack of perfection in human eye.
- The accidental errors obey the law of chance.
- These error tends to compensate each other, when large in number.
- These can be understood and eliminated with the help of mathematical theory of probability.

Important Terminology

1. Precision

- Degree of perfection use at the time of measurement is called precision.
- It is adopted by using high quality instrument, skilled surveyor, and using correct manner of measurement.

2. Accuracy

- Degree of perfection obtained in measurement is called accuracy.
- If any measurement more near to the true value of quality it is considered as more accurate.

3.True Value

- Exact value of quantity is called true value.
- It is ideal value which can not be obtained.

4.True Error

- The difference between the observed value and the true value of a quantity is knows as true error.
- True error = Observed value - True value
- As the true value of a quantity is never known, the true error can also never be determined.

5.Most Probable Value (M.P.V)

- The most probable value of a quantity is a value which has more chance of being true value than any other value.
- The most probable value is very close to the true value.
- It is calculated on the basic of Principle of Least Square.
- It is equal to the the weighted average mean.

1. MPV for multiple measurement

   MPV = $\bar{x} = \frac{x_1 + x_2 \ldots . + x_n}{n}$

2. MPV for multiple measurement with weight

   MPV = $\bar{x} = \frac{x_1 w_1 + x_2 w_2 \ldots . + x_n w_n}{w_1 + w_2 \ldots + w_n}$

6. Principle of Least Square

MPV is that value of quantity for which sum of square of error is least.

- Y = sum of square of error

  $Y = (x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \ldots . . (x_n - \bar{x})^2$

7.Residual Error

- The difference between the observation value and most probable value of a quantity is called the residual error, residual or variation (v).
- Residual Error= Observed Value — Most Probable Value.

Law's of Weights

- 'Weight' is a numerical value a singed to a measurement on the basic of degree of precision & adopted which represent important of reading.
- Weight of measurement is inversely propositional to error.
- The weight of the arithmetic mean of a number of observations of unit weight is equal to the number of observations.

For example, if an angle P is measured three times and the values are obtained as below:

1	40^0 30"20"	Weight 1
2	40°30"15"	Weight 1
3	40°30"10"	Weight 1
	Sum = 121°30'45"	

Arithmetic mean = (121°30'45")/3= 40°30"15"

The arithmetic mean 40°3015" will have weight 3.

- The weight of the weighted arithmetic mean is equal to the sum of individual weights.

For example, if an angle P has the following values.

1	40 305"	weight 1
2	40°30'7"	weight 2
3	40°30"10"	weight 3

Weighted Arithmetic mean = {(40°30′5″)x1 + (40°30′7″)×2 + (40°30′10″)×3}/(1+2+3) = {243°0'22"}/6 = {40°30'3.6"}
The weighted arithmetic mean 40°30'3.6" will have weight 6.

- If measurement x, is a which taken weight w1 & measurement, x2 is a which taken weight w2 than weight of result & k is factor, for various operation are found as:

Result	Weight of Result
$x_1 + x_2$ or $x_1 - x_2$	$\frac{1}{\frac{1}{w_1}+\frac{1}{w_2}}$
$\frac{x_1}{k}$	$w1 \cdot k^2$
$x_1 \cdot k$	$\frac{w_1}{k^2}$
$x1 + k$, $x_1 - k$, $k - x_1$	w_1

Probable Error

If for a single quantity multiple measurement are taken as X_1, X_2, ... X_n with weight w_1, W_2, ...W_n. and the MVP= $\bar{x}$ then probable error can be calculated as.

1.Probable Error In Single Measurements

$$E_s = \pm 0.6745\sqrt{\frac{\Sigma w_n (x_n - \bar{x})^2}{(n-1)}}$$

2.**Probable Error In Mean (MPV)**

$$E_m = \pm 0.6745\sqrt{\frac{\Sigma w_n (x_n - \bar{x})^2}{(n-1)\Sigma w_n}}.$$

$$E_m = \frac{E_s}{\sqrt{\Sigma w_n}}.$$

3.**Probable Error Of Single Measurement Of Weight**

$$E_{sw} = \pm 0.6745\sqrt{\frac{\Sigma w_n (x_n - \bar{x})^2}{(n-1)w_o}}$$

$$E_{sw} = \frac{E_s}{\sqrt{w_o}}.$$

NOTE: For all measurement have unit weight. $\Sigma w_n = 1$

Error In Computed Result

If a quantity is expressed in digit then first and -1 digit are certain and last digit is least accurate.

Error in quantity can be assumed as x = 25.34

then Possible Error or Max error (δx) = +0.005 and

Probable error (ex)= ±0.0025 For better understanding more example are taken.

For better understanding more example are taken

1.	x = 34.55	∂x= ±0.005 ex= ±0.0025
2.	y= 56.5	∂y= ±0.05 ey= ±0.025
3.	y= 352.5	∂y= ±0.05 ey= ±0.025

Various operation are found as

Result [s]	Possible Error or Max Error [∂s]	Probable Error [es]
s = [x+y]	∂s = ± [∂x +∂y]	es = $\pm\sqrt{ex^2 + ey^2}$
s = [x-y]	∂s = ± [∂x +∂y]	es = $\pm\sqrt{ex^2 + ey^2}$
s = [x×y]	∂s = ± [x·∂y +y·∂x]	es = $\pm s\sqrt{(\frac{ex}{x})^2 + (\frac{ey}{y})^2}$
s = [x/y]	∂s = $\pm \frac{\partial x}{\partial y} + x\frac{\partial y}{\partial y^2}$	es = $\pm s\sqrt{(\frac{ex}{x})^2 + (\frac{ey}{y})^2}$

Adjustment of Triangulation Figures

The most accurate method is that of least squares but is very complicated since all the angles are simultaneously involved. However, using an approximate method, the adjustment can be achieved by adjusting angles, stations and figures separately. After adjusting the triangulation figure, the sine rule is applied for computing sides. Then the positions of the points are determined by calculating the geodetic coordinates.

ANGLE ADJUSTMENT

Many observations are made for a single angle; for example, face left and face right, vernier A and vernier B, and reading an angle on different parts of the scale. The correction to be applied is directly proportional to the weight and also to the square of the probable error. The angles can be measured with equal or unequal weights. In the former case, the most probable value is the arithmetic mean of the observations, whereas in the latter case, it is the weighted arithmetic mean of the observed angles.

STATION ADJUSTMENT

The station adjustment consists of determining the most probable values of the angles measured at a station so as to satisfy the geometric consistency. The various conditions can be:

(i) closing the horizon,

(ii) measuring the angles with equal or unequal weights, and

(iii) measuring different angles at a station individually or in combination. In the first case, the error

if any is distributed equally to all the three angles. In the second case it is distributed inversely as the respective weights. Whereas in the last case, normal equations are formed and are solved simultaneously.

FIGURE ADJUSTMENT

In any system of triangulation, determination of the most probable values of the angles so as to fulfil the geometrical conditions are called figure adjustment. There can be a number of geometrical conditions which the angles should fulfil, but since all the measured angles are affected by errors, they never will meet all the conditions perfectly.

Therefore, it is necessary to adjust the angles so as to obtain the best possible and most probable value. The best solution can be obtained by the method of least squares, also known as the rigid method, which is a little complex and therefore, the adjustments are usually done by an approximate method. The geometrical figures encountered in triangulation are a triangle, a quadrilateral or a polygon with a central station.

ADJUSTMENT OF A TRIANGLE

A triangle is the basic figure of any triangulation system. All the three angles of a triangle are adjusted. Some of the rules for applying corrections to the observed angles are as follows. Let

A, B, C = angles of the triangle

n = number of observations for an angle

w = weight of the angle

d = discrepancy (error of closure)

c = correction to observed angle.

Solved Previous Year Questions

1. Inaccurate bisection of signal, errors due to wrong bookings, errors in reading verniers are ________ errors.

f) Instrumental
g) Manipulation
h) Observational
i) Natural
j) All the above

Ans C

Observational or Personal Errors:

Inaccurate Centering:

- This is very common error and is introduced in all angles measured at a given station. Its magnitude depends upon the length of the sight. It varies inversely as the length.
- The error is much reduced by carefully centering the instrument over the station-mark.

Inaccurate Levelling:

- The effect of this error is similar to that of the error due to non-adjustment of plate levels. The error is serious when horizontal angles between points at considerably different elevations are to be measured.
- The error can be minimised by levelling the instrument carefully with reference to the altitude level.

Slip:

- The slip may occur if the instrument is not firmly screwed to the tripod-head or the shifting head is not sufficiently clamped or the lower clamp is not properly tightened. As a result, the observations will be in error. This can be prevented by proper care.

Working wrong tangent screw:

- This is a common mistake on the part of a beginner. This can be avoided by proper care and experience. Always operate the lower tangent screw for a back sight and the upper tangent screw for a foresight.

Parallax:

- This error arises due to imperfect focussing. The parallax can be eliminated by properly focussing the eye-piece and the object-glass.

Inaccurate bisection of the point sighted and non-verticality of the ranging rod:

- Care should be taken to bisect the lowest point visible on the ranging rod. In case of short sights, the point of a pencil or the blub- line may be used instead of a ranging rod. The error varies inversely with the length of sight.

Other errors such as:

  - Mistake in setting the verniers,

- Mistake in reading the scales and verniers,
- Mistake in reading wrong verniers, and
- Mistake while booking the readings can be prevented by habitual checks and precautions.

2. The standard limits of linear error of a closed traverse on surface is

a) 1:2500
b) 1:3000
c) 1:5000
d) 1:4000
e) 1:2000

Ans C

Explanation:

Limits of Errors in Chaining:

1. For measuring over **rough or hilly ground**, the permissible error in chaining is **1 in 250.**

2. In an **Ordinary Chain Survey**, the maximum permissible error is **1 in 1000.**

3. If a **steel tape or a steel band** chain is used to obtain greater accuracy in measurements, the limiting error may be **1 in 2000.**

4. When the **standardized steel or invar tape** is used and corrections for pull, temperature, sag, slope and alignment etc. are applied, the maximum error should **not exceed 1 in 5000.**

3. Which of the following is not an instrumental error

a) Error due to imperfect adjustment
b) Error due to sluggish bubble
c) Error due to movement of objective slide
d) Settlement of tripod or turning points
e) None of these

Ans D

Errors may arise from three sources:

1) Instrumental:

- The error may arise **due to imperfection or faulty adjustment of the instrument** with which measurement is being taken.
- For example, a tape may be too long or an angle measuring instrument may be out of adjustment. Such errors are known as instrumental errors.

2) Personal:

- The error may also arise **due to wanting of perfection of human sight in observing and of touch in manipulating instruments.**
- For example, an error may be there in taking the level reading or reading an angle on the circle of a theodolite. Such errors are known as personal errors.

3) Natural:

- The error may also be **due to variations in natural phenomena such as temperature, humidity, gravity, wind, refraction, and magnetic declination.** If they not properly observed while taking measurements, the results will be incorrect.
- For example, a tape maybe 20 meters at 20°C but its length will change if the field temperature is different.

SURVEY - II

Mine Plans and Sections

Mining plans and sections are important documents used in the mining industry to illustrate and representation of the geological features, mining methods, and infrastructure of a mine site, and are typically used for planning, development, and regulatory compliance purposes. Mining plans and sections are typically created by mining engineers, geologists, or other qualified professionals, and may include the following elements:

Mine Layout: The plan and section may show the overall layout of the mine site, including the locations of mining areas, access roads, haulage routes, and other infrastructure. It may also include topographical information, such as contour lines, to provide a better understanding of the terrain.

Geological Features: The plan and section may include details about the geology of the mine site, such as the location and extent of ore bodies, rock formations, faults, and other geological features that may impact mining operations.

Mining Methods: The plan and section may illustrate the mining methods being used or proposed for the mine site, such as open pit mining, underground mining, or placer mining. It may show the location of mining equipment, ventilation systems, and other mining-related infrastructure.

Mining Sequence: The plan and section may outline the sequence of mining activities, showing the order in which different areas of the mine site will be mined and the progression of mining operations over time.

Safety Measures: The plan and section may include details of safety measures and precautions, such as escape routes, emergency exits, and fire suppression systems, to ensure the safety of mine workers and compliance with regulatory requirements.

Environmental Considerations: The plan and section may address environmental considerations, such as the protection of water resources, reclamation plans, and other measures to mitigate potential impacts on the environment.

Design Details: The plan and section may include design details of mine infrastructure, such as mine workings, tunnels, slopes, and benches, as well as details of mining equipment and facilities.

Dimensions and Scale: The plan and section may provide information on the dimensions and scale of the mine site, including distances, elevations, and measurements, to provide an accurate representation of the mine site.

Mining plans and sections are typically prepared in accordance with local regulatory requirements and industry standards, and are used by mining companies, regulatory agencies, and other stakeholders to ensure safe and responsible mining operations. They are important tools for visualizing and communicating the complex details of a mining operation, and play a critical role in mine planning, development, and compliance with environmental and safety regulations.

CMR 2017, CHAPTER VI, PLANS AND SECTIONS

64. General requirements about mine plans. – (1) Every plan or section prepared or submitted in accordance with the provisions of these regulations shall-

(a) specify the name of the mine and of the owner and the purpose for which the plan is prepared;
(b) show the true north, or the magnetic meridian and the date of the later.
(c) specify a scale of the plan at least 25 centimeters long and suitably subdivided.
(d) unless otherwise provided, be on a scale having a representative factor of 2000:1 or 1000:1:

a. Provided that the Chief Inspector may, by an order in writing and subject to such conditions as he may specify therein, permit or require the plans to be prepared on any other suitable scale.

(e) be properly inked on durable paper, tracing cloth or on polyester film and be kept in good condition.

(f) have an abstract of all statutory restrictions in respect of any specified working with a reference.

(2) The conventions shown in the Schedule shall be used in preparing all plans and sections required by these regulations.

(3) The plans and sections required by these regulations shall be accurate within such limits of error as the Chief Inspector may specify by a general or special order.

(4) The plans and sections required by these regulations shall be maintained corrected up-to-date which is not earlier than three months: Provided that where any mine or seam or section is proposed to be abandoned, closed or the working thereof to be discontinued or rendered inaccessible, the plan and section shall be brought up-todate before such abandonment, closure or at the time of discontinuance, as the case may be, unless such abandonment, closure or discontinuance has been caused by circumstances beyond the control of the owner, agent or manager, in which case the fact that the plan or section is not up-to-date shall be recorded on it.

(5) All the reference stations at surface and the reference points of underground surveys shall be shown in their correct position relative to the survey of India national grid within the limits of error of survey and plotting, as specified under sub-regulation (3).

(6) Plans and sections required to be maintained under these regulations shall be kept available for inspection in the office at the mine and shall not be removed therefrom except by or with the approval in writing of the Regional Inspector, unless a true copy thereof has been kept therein.

(7) The Chief Inspector may, subject to the conditions as he may specify in the order, permit preparation of plans or sections in variance with the provisions of this regulation.

NOTIFICATION Dhanbad, the 1st October 2018

SPECIFICATIONS OF LIMITS OF ERROR

1.0 Plans

1.1 Accuracy of Correlation with Survey of India National Grid

The positions of the surface reference stations and the centers of all mine shafts at the surface and reference points of underground surveys and also the boundaries of the mine and all surface features required to be shown shall be shown upon the key and Master plans in their correct positions relative to the Survey of India National Grid within the limits of error of survey and plotting as specified hereinafter.

1.2 Plotting Errors

All surface and underground surveys made and carried out in accordance with this Code shall be plotted on the plan of the mine so that, in the case of a plan on the scale of 1/2000, all points in the survey are correct by scale to their calculated co-ordinate position within a limit not exceeding 50 centimetres. In case of a plan prepared on the scale of 1/1000, the corresponding limit of error shall not exceed 25centimetres.

65. Type of plans. – (1) The owner, agent or manager of every mine shall keep the following plans and sections:

(a) a surface plan showing every surface feature within the boundaries, such as telephone, telegraph or power transmission line, watermain, tramline, railway, road, river, watercourse, reservoir, tank, bore-hole, shaft and incline opening, opencast working, subsidence and building on the surface;

(b) an underground plan showing-

i. the position of the workings of the mine belowground.
ii. every borehole and shaft with depth, incline opening, cross-measure drift, goaf, fire-stopping or seal, water-dam (with dimensions and other particulars of construction), pumping station and haulage roadway;
iii. every important surface feature within the boundaries, such as railway, road, river, stream, water-course, tank, reservoir, opencast working and building which is within 200 meters of any part of the workings measured on the horizontal plane;
iv. the general direction and rate of dip of the strata;
v. such sections of the seam as may be necessary to show any substantial variation in the thickness or character thereof and showing the working section, and such section of the strata sunk or driven through in the mine or proved by boring as may be available;
vi. the position of every roll, washout, dyke and every fault with the amount and direction of its throw and hade;
vii. an abstract of all statutory restrictions in respect of any specified working with reference to the order imposing the same, and,

whenever this plan is brought up-to-date, the then position of the workings shall be shown by dotted line drawn through the ends of the working and such dotted line shall be marked with the date of the last survey;

(c) where a seam has an average inclination of more than thirty degrees from the horizontal, one or more vertical mine section or sections, as may be required by Regional Inspector, showing a vertical projection of the mine working: Provided that in case of a mine having opencast workings, vertical mine sections showing vertical projections of mine workings at suitable intervals not exceeding 100 m, in both, longitudinal as well as transverse directions, shall be prepared and maintained irrespective of the inclination of coal seam;

(d) a ventilation plan, and section where necessary, showing the system of ventilation in the mine, and in particular –

i. the general direction of air-current;
ii. every point where the quantity of air is measured;
iii. every air-crossing, ventilation door, stopping and every other principal device for the regulation and distribution of air;

iv. every fire-stopping and its serial number;
v. every room used for storing inflammable material;
vi. the position of fire-fighting equipment;
vii. every water-dam with dimensions and other particulars of construction;
viii. every pumping, telephone and ambulance station;
ix. every haulage and travelling roadway;
x. every auxiliary or booster fan;
xi. every stone dust barrier;

(e) a joint survey plan showing the details required under clause (b) of this sub-regulation and sub-regulations (6) and (7), signed by the surveyor and the manager of the mine and also of adjoining mines having working within 60 meters of the common boundary or where the boundary is in dispute, within 60 meters of the boundary claimed by the owner of the mine concerned signifying the correctness of the common boundary, or the disputed boundaries, as the case may be, and of the position of the working in relation to one another;

(f) a geological plan of the area of leasehold, on a suitable scale; and

(g) a water-danger plan and section showing-

i. nullah, river, lake, water pond, water coarse, drainage or any other water bodies on surface or belowground existing upto 200 meters of the boundary of the mine;
ii. the position of the working belowground and every borehole and shaft (with depth), drive, cross-cut, staple pit, excavation and air passage connected therewith;
iii. the position of every dyke, fault and other geological disturbance with the amount and direction of its throw as well as hade;
iv. levels taken in workings belowground at easily identifiable points sufficient in number to allow the construction of sections along all drives, main headings and haulage roadways;
v. every source of water such as river, stream, water-course, reservoir, water-logged opencast working on the surface, and also the outline of all water-logged workings belowground lying within 60 meters of any part of the workings measured in any direction;
vi. every reservoir, dam or other structure, either above or belowground, constructed to withstand a pressure of water or to control inrush of water, along with reference to its design and other details of construction; and
vii. the highest flood level of the area.

69. Preparation of plans by surveyors.– (1) Every plan and section, and tracing thereof, prepared under these regulations shall be prepared by or under the personal supervision of the surveyor.

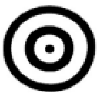
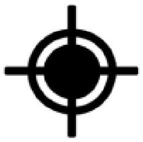
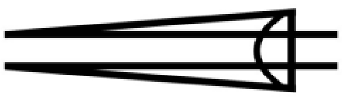
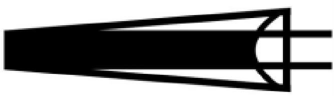
(2) Every plan or section, or any part thereof, prepared by or under the supervision of a surveyor shall carry thereon a certificate by him to the effect that the plan or section or part thereof is correct; and shall be signed and dated by the surveyor and countersigned and dated by the manager on every occasion that the plan or section is brought up-to-date.

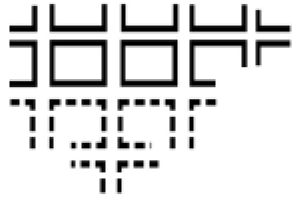
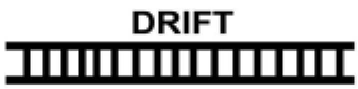
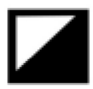
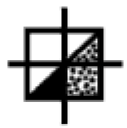
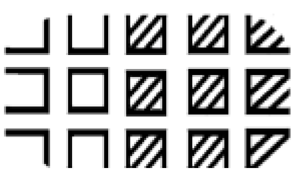
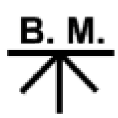
(3) Every tracing of a plan or section or of any part thereof shall bear a reference to the original plan or section from which it was copied and shall be certified thereon by the surveyor with date to be a true copy of the original plan or section.

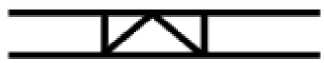
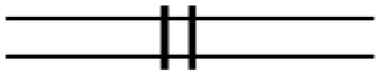
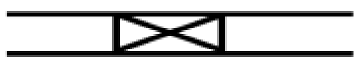
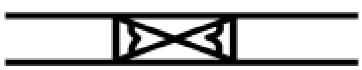
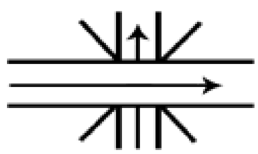
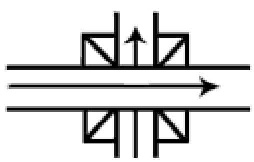
(4) If the surveyor fails or omits to show any part of the workings or allows the plans or sections to be inaccurate, he shall be guilty of a breach of these regulations:

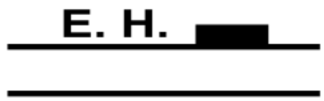
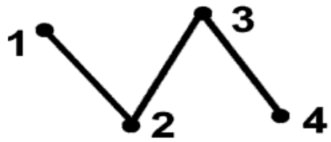
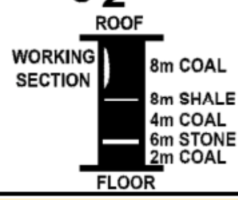
Provided that nothing in this sub-regulation shall, exempt the owner, agent or manager of their responsibility to ensure that every plan or section prepared, kept or submitted under these regulations or by any order made thereunder is correct and maintained up-to-date as required thereunder.

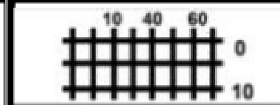
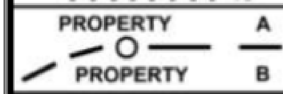
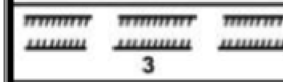
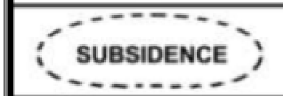
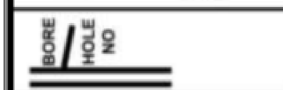
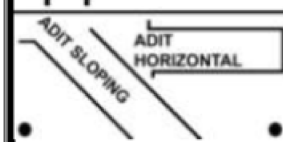
CONVENTIONS FOR PREPARING PLANS AND SECTIONS-CMR-2017

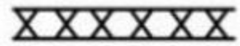
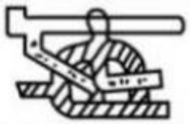
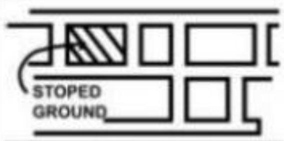
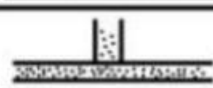
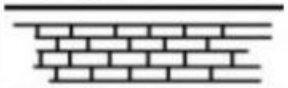
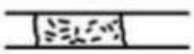
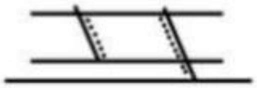
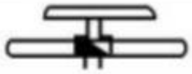
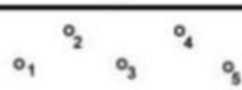
NAME	SYMBOL	REMARK
BOUNDARY OF LEASE HOLD		In Red
UNDERGROUND COAL BARRIER		In Green
SHAFT		
ABANDONED SHAFT		
INCLINE		
ABANDONED INCLINE		

NAME	SYMBOL	REMARK
PILLARS AND GALLERIES		Workings shown by dotted lines are not surveyed and their extent is not correctly known
DRIFT		In Burnt Sienna showing gradient in Black
QUARTERLY SURVEY LINE		
STAPLE SHAFT		In Red should state distance up and down to all insets
ABANDONED STAPLE SHAFT		In Red
FAULT		In Red showing the amount and direction of throw
DYKE OR OTHER INTRUSION		In Green
GOAF		
SUBSIDENCE		In Red
BENCH MARK		

NAME	SYMBOL	REMARK
SURFACE CONTOUR		In Burnt Sienna
UNDERGROUND SPOT LEVEL	+ 104.94	In Blue
WATER DAM		In Red
DIRECTION OF AIR CURRENT		Intake in Blue Return Red
DOORS		In Red
BRICK/STONE OR CONCRETE VENTILATION STOPPING		In Red
FIRE DAM, SEAL OR STOPPING		In Red
EXPLOSION PROOF STOPPING		In Red
AIR CROSSING		
EXPLOSION PROOF AIR CROSSING		
REGULATOR		In Red
AUXILIARY FAN		In Red
TELEPHONE		In Red

NAME	SYMBOL	REMARK
UNDERGOUND FIRST-AID STATION		Thick cross in Red
ENGINE HOUSE OR ROOM		
BORE HOLE		Should show serial number & diameter
SURVEY LINES & STATIONS		In Red
SECTION OF SEAM		

	Symbols	Remarks
Co-ordinate Lines		In Black
Boundary of the Mine		In Red
Outcrop of Dyke		In Brown
Subsidence of Surface		In Red
Prohibited Mining Area		In Red
(a) Borehole (Vertical) from Surface		In Red
(b) Boreholes (Inclined) From Surface		In Red
(c) Boreholes (Underground)		In Red
(a) Shafts		In Black
(b) Abandoned Shafts		In Black
Winze		According to Shape
Adit		

	Symbols	Remarks
Cross-Cuts		
Levels		
Vertical Projection of Under Ground Workings		In Black
(a) Packs and Sand Filling		In Black
(b) Waste Rock Filling		In Black
(c) Granite Pack Walls		In Black
(a) Fault Planes		In Green
(b) Pegmatite Intrusions		In Blue
Dyke		In Brown
Date of Last Survey		In Black
(a) Survey Station		In Black

	Symbols	Remarks
Bench Mark	B.M	In Black
(a) Brick, Stone or Concret Ventilation Stoppings		In Black
(b) Horizontal Seals		In Black
Brattice		In Red
(a) Fire Dams or Seals, Open		In Red
(b) Fire Dams or Seals Closed		In Red
Water Dams		In Blue
(a) Doors Open		In Black
(b) Doors Closed		In Black
Regulators	B	In Red
Air Crossings		
(a) Direction of Air Current Intake		In Blue
(b) Return		In Red

Duties and responsibilities of surveyors

CMR – 2017, reg no: 53

Duties and responsibilities of surveyor. –

(1) The surveyor shall –

(a) make such accurate surveys and leveling, and prepare such plans and sections and tracings thereof, as the manager may direct or as may be required by the Act or by the regulations or orders made thereunder, and shall sign the plans, sections and tracings and date his signature.

(b) be responsible for the accuracy of any plan and section, or tracings thereof that has been prepared and signed by him.

(2) The surveyor shall record in a bound paged book kept for the purpose –

(a) the full facts when working of the mine have approached to about 120 meters from the mine boundary, or from disused or waterlogged workings.

(b) any doubts which may arise or exist concerning the accuracy of the plans and sections prepared under these regulations.

(c) any other matter relating to the preparation of the plans and sections that he may like to bring to the notice of the manager, and every entry in the book shall be signed and dated by the surveyor and countersigned and dated by the manager: Provided that where in any mine two or more surveyors are employed, each of the surveyors shall make the entries aforesaid in respect of the workings in his jurisdiction or of the plans and sections in his charge.

(3) Nothing in sub-regulation (2) shall absolve the owner, agent, or manager of his responsibility under the provisions of the Act and under these regulations or orders made thereunder.

MMR-1961, reg no: 52

Duties and responsibilities of surveyors –

(1) Every surveyor shall –

(a) make such accurate surveys and levellings, and prepare such plans and sections and tracings thereof, as the manager may direct or as may be required by the Act or by the regulations or orders made thereunder, and shall sign the plans, sections and tracings and date his signature; and

(b) be responsible for the accuracy of any plan and section, or tracings thereof that has been prepared and signed by him.

(2) The surveyor shall record in a bound-paged book kept for the purpose –

(a) the full facts when workings of the mine have approached to about 75 metres from the mine boundary, or from disused or waterlogged workings.

(b) any doubts which may exists concerning the accuracy of the plans and sections prepared under these regulations; and

(c) any other matter relating to the preparation of the plans and sections that he may like to bring to the notice of the manager. Every entry in the book shall be signed and dated by the surveyor and countersigned and dated by the manager: Provided that where in any mine two or more surveyors are employed, each of the surveyors shall make the entries aforesaid in respect of the workings in his jurisdiction or of the plans and sections in his charge.

(3) Nothing in sub-regulation (2) shall absolve the owner, agent or manager of his responsibility under the Act and under these regulations or orders made thereunder.

Appointment of surveyors

CMR – 2017, reg no: 34

Appointment of surveyors.–

(1) At every mine, one or more persons holding a Surveyor's Certificate shall be appointed to be the surveyor for carrying out the surveys and levellings and for preparing the plans and sections required under the Act or the regulations, or orders made thereunder.

Provided that in case of mines having opencast workings only, nothing in this sub-regulation shall prohibit the appoint of one or more persons holding a Surveyor's Certificate restricted to opencast mines only for carrying out the surveys and levellings and for preparing the plans and sections required under the Act or the regulations, or orders made thereunder.

(2) No person shall be appointed as a surveyor of more than one mine or in any other capacity in the same mine, without the previous permission in writing of the Chief Inspector and subject to such conditions as may be specified therein.

(3) The number of surveyors required to be appointed shall be on the scale as may be specified by the Board: Provided that in specific cases, the Chief Inspector may relax the requirement of the appointment of surveyors.

(4) If a mine has more than one surveyor, each shall carry the duties and the responsibilities of the surveyor for the part or section of the mine to be assigned in writing by the owner, agent or manager:

Provided that the owner, agent or manager shall appoint one of the surveyors to be responsible for the preparation and maintenance of the plans required to be prepared and maintained under these regulations who shall also be responsible for co-ordination and overall supervision of survey work in the mine.

MMR-1961, reg no: 38

Appointment of surveyors –

(1) At every mine having workings belowground and at such other mines or classes of mines as may be notified from time to time by the Central Government a person not less than 23 years of age and holding a Surveyor's Certificate shall be appointed to be the Surveyor for carrying out the surveys and levellings and for preparing the plans and sections required under the Act or the regulations, or orders made thereunder. Provided that nothing in this sub-regulation shall be deemed to prohibit the employment of two or more surveyors at one mine so long as the jurisdiction and sphere of responsibility of each of the surveyors is defined by the manger in his letter of appointment.

(2) A notice of every such appointment giving the name and full particulars of the qualifications of the person so appointed, shall be sent to the Regional Inspector within seven days of such appointment.

(3) No person shall be appointed as a surveyor of more than one mine or in any other capacity in the same mine, without the previous permission in writing of the Regional Inspector and subject to such conditions as may be specified therein. The Regional Inspector may, by an order in writing, revoke such permission if the circumstances under which it was granted have altered or the Regional Inspector finds that the surveyor has not been able to carry out satisfactorily the work allotted to him.

Questions

1. What is the purpose of mining plans and sections?

a) To communicate the layout and design of a mining operation

b) To provide a visual representation of geological features

c) To assist in planning and development of a mine site

d) All of the above

Answer: d) All of the above

2. Which of the following is NOT a type of mining method that may be illustrated in a mining plan and section?

a) Open pit mining

b) Underground mining

c) Placer mining

d) Refining mining

Answer: d) Refining mining

3. What information may be included in the geological features section of a mining plan and section?

a) Location and extent of ore bodies

b) Rock formations and faults

c) Topographical information

d) All of the above

Answer: d) All of the above

4. Who is responsible for preparing and maintaining mining plans and sections?

a) Surveyors

b) Mine owners

c) Regulatory agencies

d) All of the above

Answer: a) Surveyors

5. Which regulation requires mining plans and sections to be accurate and up-to-date?

a) Regulation 65

b) Regulation 69

c) Regulation 5

d) Regulation 69(3)

Answer: b) Regulation 69

6. What is the responsibility of the surveyor in relation to mining plans and sections?

a) Ensure accuracy and sign the plans and sections

b) Maintain up-to-date records

c) Communicate any issues to the manager

d) All of the above

Answer: d) All of the above

7. What is the purpose of conventions for preparing plans and sections?

a) To ensure consistency and standardization

b) To facilitate communication and understanding

c) To comply with regulatory requirements

d) All of the above

Answer: d) All of the above

8. Who is ultimately responsible for the accuracy of mining plans and sections?

a) Surveyors

b) Mine owners

c) Regulatory agencies

d) All of the above

Answer: b) Mine owners

9. What is the purpose of the book maintained by the surveyor?

a) Record entries related to the preparation of plans and sections

b) Document any inaccuracies or discrepancies

c) Communicate with the manager

d) All of the above

Answer: d) All of the above

10. Which regulation emphasizes the responsibility of the owner, agent, or manager in ensuring the accuracy and maintenance of mining plans and sections?

a) Regulation 65

b) Regulation 69

c) Regulation 5

d) Regulation 69(3)

Answer: d) Regulation 69(3)

Underground Traversing

Underground traversing refers to the process of moving through roadways and drifts in underground environments, such as mines, caves, tunnels, or other subterranean structures. It involves navigating through narrow passages, often with limited visibility and confined spaces, while taking into consideration the potential hazards associated with underground environments, such as uneven terrain, unstable ground conditions, and the presence of gases or other substances.

Underground traversing typically requires specialized training, equipment, and safety precautions to ensure the well-being of individuals involved. Some common techniques and considerations for underground traversing include:

Proper lighting: Underground environments are often dark or poorly lit, so it's important to have adequate lighting equipment, such as headlamps, flashlights, or other illumination devices, to improve visibility and navigate safely.

Navigation tools: Underground traversing may involve the use of compasses, maps, or other navigation tools to help individuals maintain their bearings and stay on course.

Personal protective equipment (PPE): PPE, such as hard hats, safety boots, gloves, and respiratory protection, may be required to protect against potential hazards, such as falling debris, slippery surfaces, or airborne contaminants.

Communication: Communication is essential in underground traversing, as it allows team members to stay connected and coordinate their movements. This may involve the use of two-way radios, hand signals, or other means of communication.

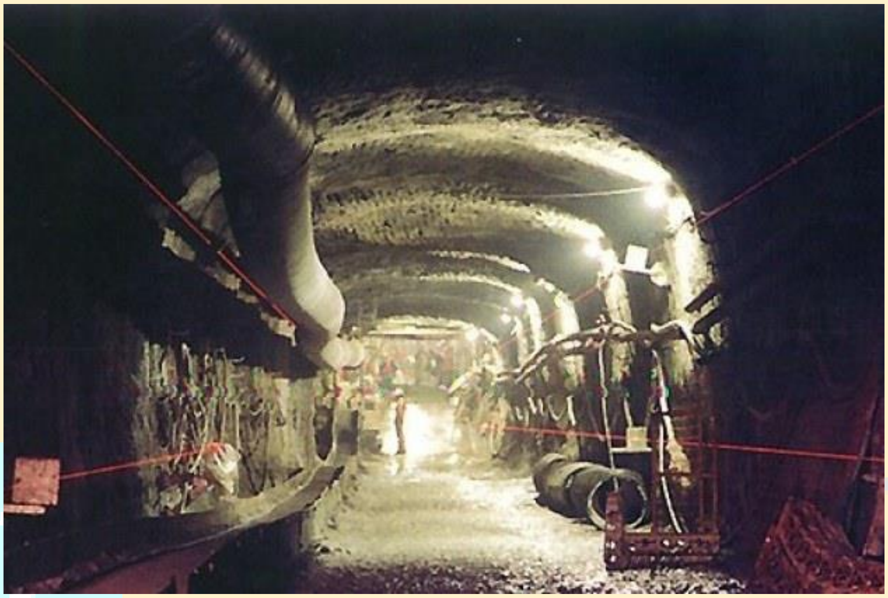
Hazard assessment: Underground environments can present various hazards, such as unstable ground conditions, flooding, or the presence of harmful gases. Proper hazard assessment and risk management techniques should be used to identify and mitigate potential dangers.

Rope work: In some cases, rope work techniques, such as rappelling or ascending, may be required to navigate vertical or steep sections of underground passages.

Emergency preparedness: Underground traversing requires proper emergency preparedness, including having a plan for evacuation, rescue, and first aid. This may involve carrying emergency supplies, such as food, water, and first aid kits, and knowing the location of emergency exits or communication devices.

Training and experience: Proper training and experience in underground traversing techniques, including knowledge of equipment, safety procedures, and emergency protocols, are crucial for safe and effective navigation in underground environments.

Overall, underground traversing can be challenging and requires specialized knowledge, skills, and equipment. It is essential to prioritize safety and follow proper procedures to ensure the well-being of all individuals involved in underground traversing activities.



Traversing through roadways and drifts

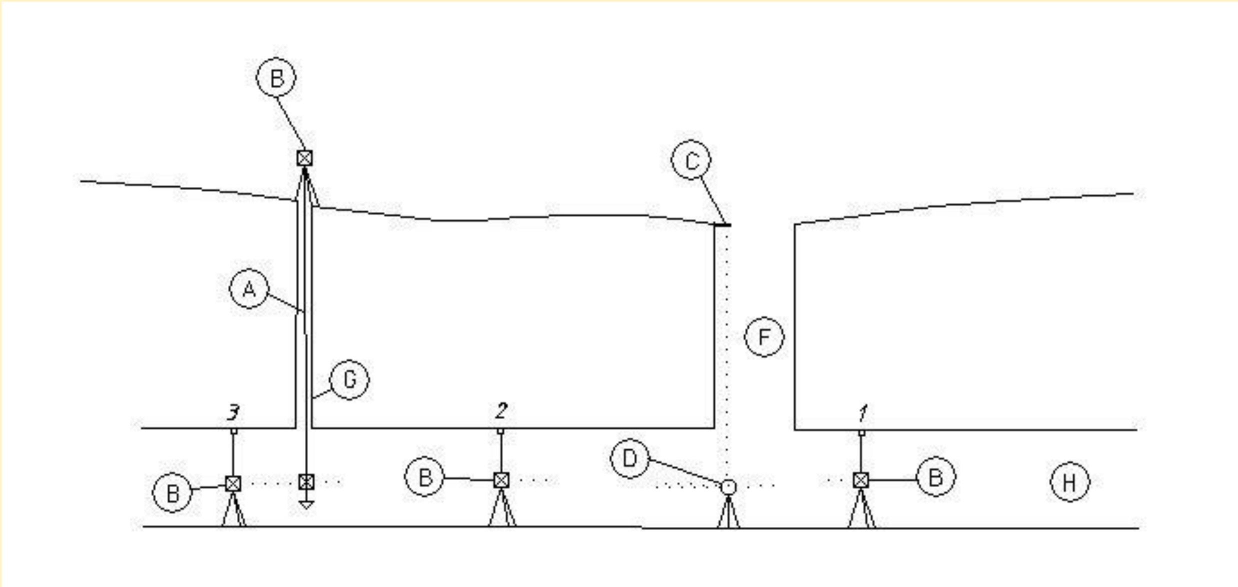
Underground traversing through roadways and drifts, from a surveying perspective, involves using specialized surveying techniques and equipment to accurately measure and map underground passages or drifts, as well as determine the position and orientation of the traversing route. Here's a general overview of how it can be done:

Establish control points: Establish control points on the surface or in the underground environment using surveying techniques such as total stations, GPS, or other relevant surveying equipment. Control points serve as reference points with known coordinates or elevations that are used as a basis for measurements.

Conduct underground surveys: Use appropriate surveying methods and equipment to measure and map the underground roadways or drifts. This may include using total stations, laser scanners, or other surveying instruments to measure distances, angles, and elevations of points along the traversing route. These measurements can be used to create accurate maps or drawings of the underground passages or drifts.

Determine traversing route: Based on the survey data, determine the traversing route through the underground roadways or drifts, taking into account factors such as the desired path, clearance requirements, and any other specific requirements or constraints.

Mark traversing points: Mark points along the traversing route in the underground environment using appropriate surveying techniques, such as placing markers or setting stakes. These markers serve as reference points for navigation during the traversing process.



Conduct traversing: Follow the marked traversing points along the determined route, using navigation tools such as compasses, maps, or GPS devices to ensure accurate positioning. Measure distances, angles, and elevations as needed to confirm the location and orientation of the traversing route.

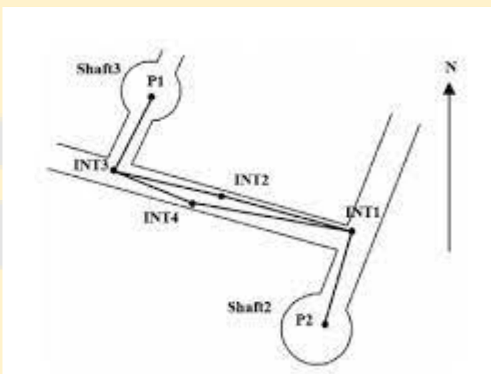


Figure 4—Underground traverse connecting plumb P2 and plumb P1

Adjust and record measurements: Continuously adjust and record measurements during the traversing process to ensure accuracy. This may involve measuring additional points or making corrections as needed to maintain accurate positioning.

Monitor and document: Monitor the underground environment for any changes or hazards during the traversing process, and document any relevant findings or observations. This may include noting changes in ground conditions, water levels, or other environmental factors that may affect the traversing activity.

Verify and report results: Once the traversing is complete, verify the results by comparing them with the initial survey data and other relevant references. Prepare a report or documentation of the traversing activity, including maps, drawings, measurements, and any other relevant information.

It's important to note that underground traversing through roadways and drifts may require specialized surveying techniques, equipment, and expertise, and it should be conducted by trained and experienced surveyors who are familiar with the specific requirements and safety protocols associated with underground environments. Proper safety precautions and guidelines should always be followed to ensure the safety and accuracy of the traversing activity.

Questions

1. What is the purpose of underground traversing?

a) To explore underground environments for scientific research

b) To navigate through narrow passages in underground structures

c) To measure and map underground roadways and drifts

d) To search for valuable minerals or resources underground

Answer: b) To navigate through narrow passages in underground structures

2. Which of the following is NOT a common technique used in underground traversing?

a) Proper lighting

b) Rope work techniques

c) Communication devices

d) Surface mapping

Answer: d) Surface mapping

3. What is the importance of personal protective equipment (PPE) in underground traversing?

a) To enhance visibility in dark environments

b) To communicate with team members

c) To protect against potential hazards

d) To measure distances accurately

Answer: c) To protect against potential hazards

4. What is the purpose of hazard assessment in underground traversing?

a) To identify potential dangers and mitigate risks

b) To measure distances and angles accurately

c) To communicate with team members

d) To navigate vertical or steep sections

Answer: a) To identify potential dangers and mitigate risks

5. Which of the following is NOT a navigation tool used in underground traversing?

a) Compass

b) Map

c) GPS device

d) Laser scanner

Answer: d) Laser scanner

6. What is the importance of emergency preparedness in underground traversing?

a) To ensure accurate measurements

b) To navigate through narrow passages

c) To protect against potential hazards

d) To plan for evacuation and rescue

Answer: d) To plan for evacuation and rescue

7. What is the role of surveying methods and equipment in underground traversing?

a) To enhance visibility in dark environments

b) To measure distances, angles, and elevations

c) To communicate with team members

d) To protect against potential hazards

Answer: b) To measure distances, angles, and elevations

8. What is the purpose of marking traversing points in underground traversing?

a) To enhance visibility in dark environments

b) To communicate with team members

c) To measure distances accurately

d) To serve as reference points for navigation

Answer: d) To serve as reference points for navigation

9. What should be done to ensure accuracy during the traversing process?

a) Continuously adjust and record measurements

b) Use proper lighting equipment

c) Communicate with team members

d) Conduct hazard assessment

Answer: a) Continuously adjust and record measurements

10. Who should conduct underground traversing through roadways and drifts?

a) Anyone with basic navigation skills

b) Trained and experienced surveyors

c) Miners or cave explorers

d) Construction workers

Answer: b) Trained and experienced surveyors

Surface and Underground Correlation

Difference between Surface & Underground Survey

- The lighting in underground passageways is generally poor and artificial illumination must be provided 10 view instrument crosshairs. to read verniers, to sight targets, and to permit normal movements of survey presonnel in executing their duties.
- The working space of passageway is often cramped.
- In certain types of operations. Survey lines must be carried through locks in pressure chambers.
- In many instances the underground workings arc wet, with considerable water dripping from the roofs of passage ways and running along the floors.
- Instrument stations and benchmarks for levelling must often be set into the roof of a passageway to minimize disturbance from the operations being carried on in the workings.
- Instrument stations are set with some difficulty since plugs must be driven into drill holes in rock.
- Lines of sight are frequently very short either because (If crooked passage or because alignment must often be brought down from the surface through small shafts). Care must therefore be taken in all surveying operations involving the alignment of tunnels or the running of underground traverses.
- The sights taken in shafts and sloping passageways are often sharply.

Correlation Survey: The Correlation Surveys are carried out in underground mines in order to establish the spatial relationship between the surface features and underground workings. It is needed to know the positions of vital surface features and mine lease boundary with respect to the underground workings from safety point of view. The correlation surveys are also essential for underground expansion work, correct location of underground workings with respect to the structures on the surface, combined workings of adjacent areas and adjacent seams and for the connections of underground workings.

Correlation surveys are essential for

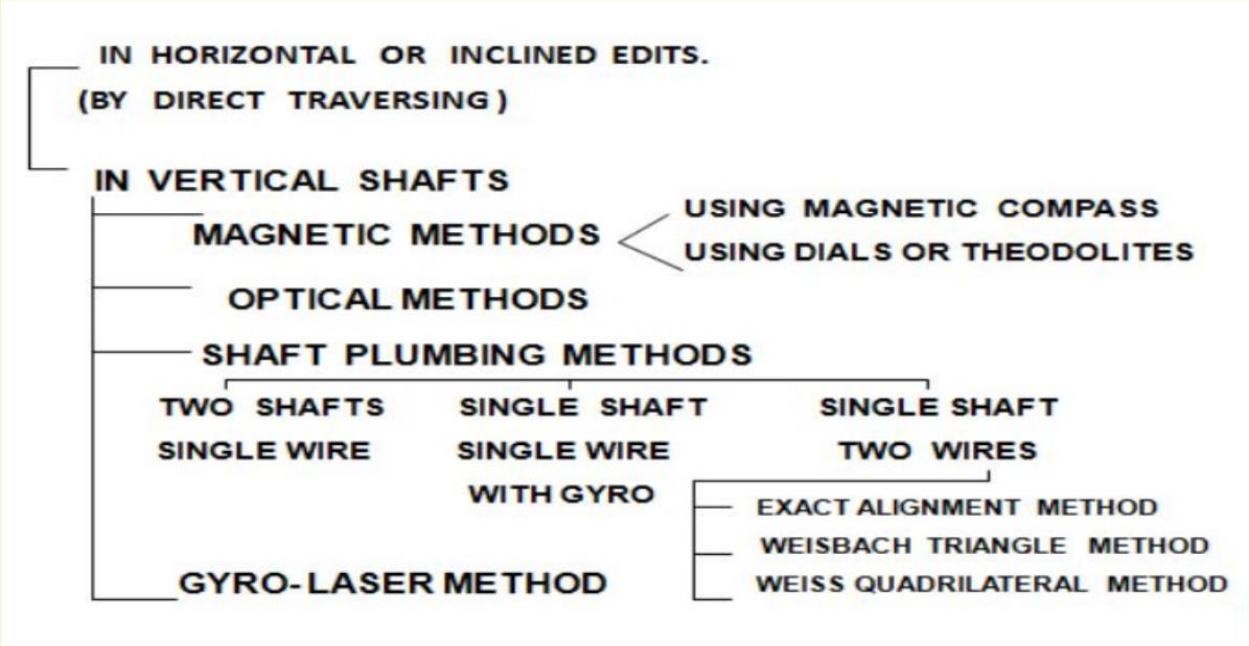
- Correct location of underground workings with respect to the surface features.
- Combined workings of adjacent areas and adjacent seams.
- Connection of underground workings.
- Mine expansion works.

The method of correlation survey will depend upon the approach system of the underground structures.(incine ,adit , shaft)

The correlation survey involves:

- Determination or transfer of coordinates
- Determination or transfer of bearing or azimuth
- Determination or transfer of height or reduced level (R.L.)

Correlation Survey Classification



1. Direct traversing through
   i. Level adits
   ii. Inclined adits
2. By plumbing wires in shafts
   i. One wire in each of the two shafts
   ii. Two or more wires in one shaft, which provides a number of methods to accomplish the work. They are ;
      a. Co-planning or alignment method,
      b. Weisbach triangle method with clamped or swinging wires
      c. Weiss quadrilateral method
3. Optical shaft plumbing
   a. Using a transit instrument
   b. Using laser beam or Nadir plummet
4. Gyro – Laser combination method.

Direct traversing

If a deposit is opened by a horizontal entry (adit) or an inclined entry (incline), the underground survey can be oriented by running a polygonometric traverse from the surface into the mine. If only one adit or incline is available, the traverse is run from an approach station on the surface, say, B, to the first side of the underground survey net. A back traverse line is run usually through other, temporarily established points. The polygonometric traverse run to a side CD in the figure makes it possible to calculate the direction angle aCD of the side and the coordinates of a point C:

$$\alpha_{CD} = \alpha_{AB} + \beta_1 + \beta_2 + \ldots + \beta_n \pm 180^\circ \cdot n$$

$$x_C = x_B + l_1 \cos \alpha_{B1} + l_2 \cos \alpha_{12} + \ldots + l_n \cos \alpha_{nC}$$

$$y_C = y_B + l_1 \sin \alpha_{B1} + l_2 \sin \alpha_{12} + \ldots + l_n \sin \alpha_{nC}$$

where $\beta_1, \beta_2, \ldots, \beta_n$ are the measured angles; n is the number of measured angles; $\alpha_{B1}, \ldots, \alpha_{nC}$ are the direction angles of sides; and $l_1, l_2, \ldots, l_n$ are the measured lengths of sides.

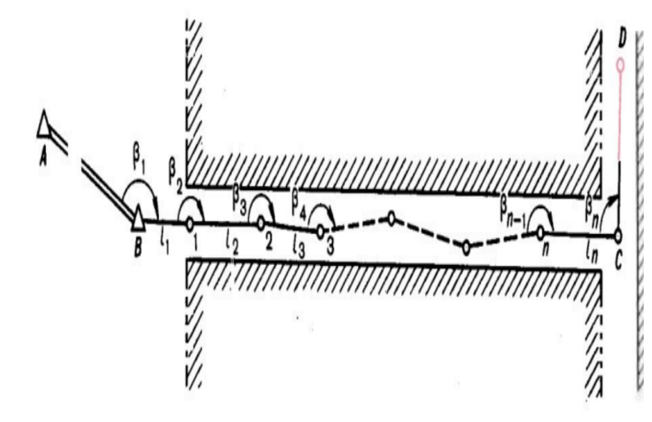


Fig. 4.2 Orientation via adit

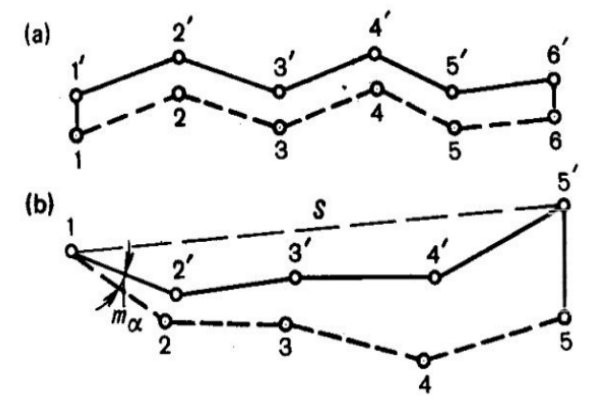


Fig. 4.1 Effect of centring error (*a*) and orientation error (*b*) on positions of points of underground theodolite traverse

Figure 3-2 Wall Station Prism placed into Sleeve

Figure 3-3 Check Survey traversing up the Incline

Correlation by plumbing wires in the vertical shafts (geometric methods)

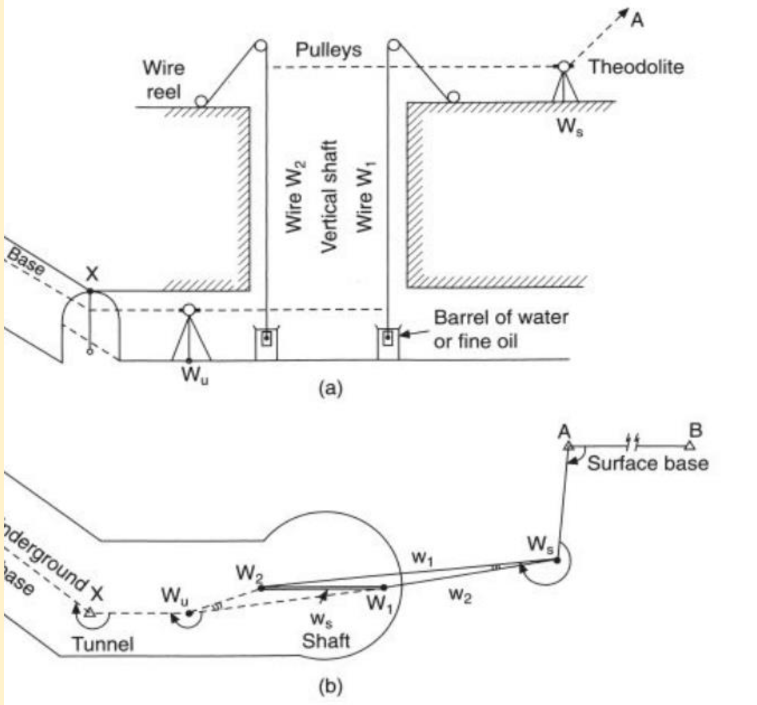
- The weight suspended from should be about L/3 kg.
- The weight should be limited to about half the breaking strain of the wire.
- Single strand 304 stainless steel spring wire has a tensile strength of about 1900MPa (1mm-1.5mm diameter). Music (piano) wire has a higher tensile strength: (2200Mpa for 1.3mm). MPa =Pa/mm2 =9.8N/mm2 .
- In general, thin wires have a tensile strength of 200kg/mm2 . (2000MPa)
- Minimum cross-sectional area of the wire = maximum load (plumb weight)/tensile strenth. For accurate sighting the diameter of the wire should be about 40″ wide in the telescope of the TS. 0.6mm from 3m distance. Aiming at the centre of the wire is difficult.
- Putting some figures to the plumbing problem: L = 60m 5 Plumb mass =60/3 = 20kg . Breaking strain = 40kg Cross-section area = 40/200 = 0.2mm2

Piano wire is often used for shaft standard. Other type of wire galvanized steel, wire, 1/8" dia, having breaking strength of 1 ton and a weight of 18 lb per 100yds.

breaking strength of a wire - Plm

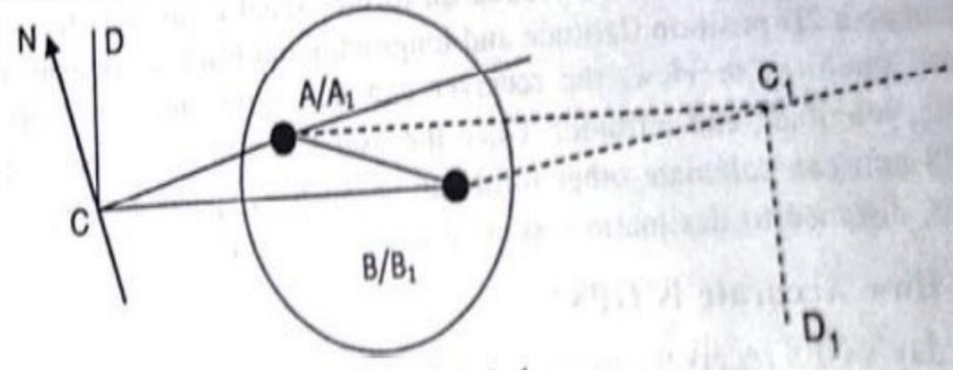
Diameter - V

- TENSILE STRENGTH > OR = 200 kg / sq mm
- Lead plumb bob,
- Heavy and non-magnetic Thumb rule,
- Wt. OF PLUMB – BOB (in kg) =
    - DEPTH / 3 (in m)
- Diam. of wire not less than ½ wt. of bob
- DEFLECTION OF WIRE
    - α SQUARE OF DEPTH
    - α 1 / (diameter of wire



13.2 *(a) Section, and (b) plan*

5.10.2 Weisbach Triangle Method



CD = Surface base line whose bearing is known

C_1D_1 = Underground base line whose bearing has to be determined with respect to CD

ABC and $A_1B_1C_1$, known as weissbach triangle

Theodolite is set at the point C and the angles <DCA & <ACB has determined

Assuming, $< DCA = \alpha$ and $< ACB = \beta$

In triangle ABC,

AB/ Sin C = AC/ Sin B

$\Rightarrow$ Sin B = b*Sin C/ c

Since angles B and C are very small, Sin B = <B and Sin C = <C

Therefore, <B = (b* angle C)/ c = γ (Assume)

azimuth of AB = azimuth of CD + <DCA + <XAB

= azimuth of CD + <DCA + <ACB + <ABC

Now the theodolite is fixed in underground station C1 and the angles $B_1C_1D_1$ and $A_1C_1B_1$ has been measured

Again from sine rule, we can get

Angle $A_1 = (B_1C_1/A_1B_1)$ * angle $C_1 = a_1$ *angle C_1/c_1

Azimuth of line B_1C_1 = azimuth of AB + angle A_1 + angle C_1

Azimuth of line C_1D_1 = azimuth of line B_1C_1 + angle $(180 - \angle B_1C_1D_1)$

Example 1. In a weisbach triangle, the azimuth of a plumb-plane marked by two wires A and B is 115°23'49", and C is a theodolite station on the south side of the eastern prolongation of AB. Given the following data, calculate the azimuth of the line CD. Illustrate your answer by a sketch.

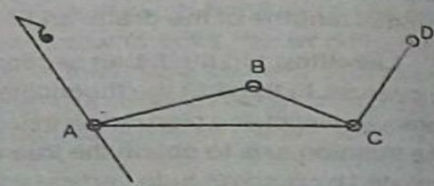
AB = 3.481 m

BC = 2.674 m

CA = 6.155 m

Angle ACD = 179°14'33"

Angle BCD = 179010'17"



Answer : In triangle ABC :

Angle ACB = 179°14'33" – 179°10'17"

= 4'16"

As the sides of very small angles are proportional to the angles themselve, hence –

$$\text{Angle BAC} = \frac{\text{BC x Angle ACB}}{\text{AB}} = \frac{2.674 \times 4'16''}{3.481} = 3'17''$$

Azimuth AC = 115°23'49" + 0°3'17" = 115°27'06"

Azimuth CA = 115°27'06" + 180°00'00" = 295°27'06"

Azimuth CD = Azimuth of CA + Angle ACD

= 295°27'06" + 179°14'33"

= 474°41'39" – 360° = **114°41'39"**

JOINT SURVEYING

Let the workings of two adjoining collieries have reached within 30 m of a common boundary necessitating a joint survey to be made. The workings of one colliery are accessible through inclines and those of other through shafts. In such a case the survey work consists of three parts-

1. Surface survey.
2. Correlation through incline and shafts.
3. Underground traverse and location of barrier galleries.

The relative position of shaft, incline, boundary pillars, etc. should be accurately detrmined and for the purpose two points are fixed near the entry of two collieries from a nearby trijunction post and triangulation survey comprising of well-conditioned triangles in the area is carried out. A suitable base line and a check base are carefully measured by a steel tape and necessary corrections for temperature, standardisation, sag, slope, tension, etc. are applied to determine their accurate lengths. Angles of each triangle are very carefully measured with a pre-adjusted Theodolite. The two meridian may also be determined by observation of circumpolar star at equal altitudes. The co-ordinates of triangulation stations are then calculated

Surface traverses are run from triangulation stations to locate boundary pillars, incline, shaft, etc. which may be closed either on trangulation stations or on themselves. In case of the mine which is accessible through inclines, the correlation of underground workings consist of carrying over a surface traverse to underground workings through inclines directly and closing the same on nearby triangulation stations previously fixed by the shortest available route.

The correlation of underground and surfacae surveys in case of the other mine worked through shafts is a tedious job and consists of suspending two plumb bobs one in each of the shafts and the line joining the wires forms a common base for surface and underground survey. By carrying oul surface traverses from previously fixed triangulation stations, co-ordinates of underground survey stations are calculated. Two or more plumb wires in each shaft may be taken to ensure accuracy in work.

Underground traverses in both the mines with a theodolite are then carried out from the points fixed by correlation survey, to the common boundary by the shortest route and as far as practicable close to the galleries near the boundary and closed polygonally. Subsidiary surveys are then accurately carried out from the main traverse to locate the exact ends of drivages.

Co-ordinates of underground traverse and subsidiary survey stations are calculated and the positions of the traverse both surface and underground in the two collieries are plotted on the same mounted paper with the same origin. The galleries, the boundary pillars, etc. are accurately plotted on the plan. In this manner the surface features, boundary pillars and underground workings of both mines towards the common barrier and shafts, inclines, etc. are marked on one plan.

The joint survey should be performed with utmost precision and precautions by the two surveyors of the two mines. Bookings should be made in two note books which should be signed by the two surveyours. All calulations for co-ordinates should be made separately by them and checked jointly.

Magnetic and gyroscopic orientation are techniques used in mining surveying to determine the orientation and direction of geological features, such as ore bodies or rock formations, within a mine site. These techniques are important for planning and designing mining operations, as well as for safety considerations.

Magnetic Orientation: Magnetic orientation relies on the natural magnetic properties of rocks and minerals to determine their orientation. Many rocks and minerals have small amounts of magnetic minerals, such as magnetite, which can create a magnetic field. Magnetic surveys involve the use of magnetometers, which are devices that measure the strength and direction of the Earth's magnetic field. By measuring the magnetic field at various points on the surface or underground, surveyors can create maps that show the magnetic anomalies caused by the presence of magnetic minerals. These maps can then be used to determine the orientation and extent of geological features, such as mineralized zones or faults, which can be important for identifying potential mining targets.

Gyroscopic Orientation: Gyroscopic orientation, also known as gyro surveying or gyro surveying, uses gyroscopes to measure the orientation of boreholes or drill holes. Gyroscopes are devices that use the principles of angular momentum to maintain a stable orientation regardless of changes in external forces or movements. In mining surveying, gyroscopes can be used to measure the azimuth (horizontal angle) and dip (vertical angle) of a borehole or drill hole, which helps in determining the orientation and direction of geological features, such as mineralized zones or faults. Gyroscopic orientation is particularly useful in underground mining, where access to the surface may be limited and magnetic disturbances may be present.

Both magnetic and gyroscopic orientation techniques have their advantages and limitations. Magnetic orientation can be relatively simple and cost-effective, but it may be affected by external magnetic interference or the presence of non-magnetic rocks or minerals. Gyroscopic orientation is more precise and less affected by external factors, but it can be more complex and expensive to implement. In many cases, a combination of both techniques may be used to obtain the most accurate and reliable results in mining surveying.

Azimuth by gyro attachment

Determination of bearing and transforming it to the underground.

Gyro-theodolite /Gyromat is a surveying instrument used to orientate an underground survey base line relative to true north.

Magnetic bearings measured with compass are liable to gross errors and are open to objections because of low accuracy of measurement, variation in magnetic declination and erratic behavior of compass near known or unknown magnetic fields.

The gyro attachment consists of a gyro motor suspended vertically, like a plumb bob on a thin metal tape. Its spin axis is therefore held horizontal through gravity. The gyro motor powered by the accompanying battery unit spins at 22000 revolutions per minute about this horizontal axis and tries to maintain, in space, its initial random spinning plane created by its moment of inertia. The gyro, together with the theodolite and tripod is earthbound and is pulled out of its original spinning plane by the earth’s rotation. The gravity influenced gyro reacts to this interference and its spin axis oscillates about the plumb line until the spin axis is oriented in the meridian plane and the rotation of gyro corresponds to the rotation of the earth from west to east. As a result there is no interference, but the gyro does not stabilize immediately in north-south direction and oscillates about the meridian plane because of its mass inertia.

Questions

1. What is the purpose of gyroscopic orientation in mining surveying?

a) To measure the depth of boreholes or drill holes

b) To determine the orientation and extent of geological features

c) To calculate the volume of mineralized zones

d) To identify potential mining targets

Answer: b) To determine the orientation and extent of geological features

2. What is the main principle behind gyroscopes?

a) Angular momentum

b) Magnetic interference

c) Gravity

d) External forces

Answer: a) Angular momentum

3. Which technique is more precise and less affected by external factors in mining surveying?

a) Gyroscopic orientation

b) Magnetic orientation

c) Combination of both techniques

d) None of the above

Answer: a) Gyroscopic orientation

4. What is the purpose of the gyro-theodolite in underground surveying?

a) To measure the azimuth and dip of boreholes

b) To determine the depth of underground structures

c) To calculate the volume of mineral deposits

d) To identify potential mining targets

Answer: a) To measure the azimuth and dip of boreholes

5. How does the gyro-theodolite react to the interference caused by the Earth's rotation?

a) It stabilizes immediately in the north-south direction

b) It oscillates about the meridian plane

c) It aligns with the Earth's magnetic field

d) It remains unaffected by the Earth's rotation

Answer: b) It oscillates about the meridian plane

6. Which factor influences the oscillation of the gyro-theodolite in the meridian plane?

a) External magnetic interference

b) Mass inertia of the gyro

c) Gravity

d) Earth's rotation

Answer: b) Mass inertia of the gyro

7. What is the spin rate of the gyro motor in the gyro-theodolite?

a) 2200 revolutions per minute

b) 22000 revolutions per minute

c) 220 revolutions per minute

d) 220000 revolutions per minute

Answer: b) 22000 revolutions per minute

8. Which technique is relatively simple and cost-effective in mining surveying?

a) Gyroscopic orientation

b) Magnetic orientation

c) Combination of both techniques

d) None of the above

Answer: b) Magnetic orientation

9. What can affect the accuracy of magnetic orientation in mining surveying?

a) External magnetic interference

b) Presence of non-magnetic rocks or minerals

c) Both a) and b)

d) None of the above

Answer: c) Both a) and b)

10. Which technique is used to obtain the most accurate and reliable results in mining surveying?

a) Gyroscopic orientation

b) Magnetic orientation

c) Combination of both techniques

d) None of the above

Answer: c) Combination of both techniques

Stope Surveying

Stoping is the process of extracting the desired ore or other mineral from an underground mine.

The technique of determining the the amount of ground removed during given period and the position of stope faces relative to each other is known as stope surveying.

Stope surveying is a critical component of underground mining operations, involving the measurement and mapping of excavated stopes or underground openings. Accurate stope surveying is important for planning and design of mining activities, monitoring of mining progress, and ensuring safety and compliance with mining regulations.

Purpose of Stope Surveying

- To determine the amount of ground removed during given period
- To determine the position of stope faces relative to each other
- To determine the position of stope faces relative from shaft, pillars and boundaries Economic Aspect
- contract miner payments/ Stopers
- Accuracy of Drilling
- Bonus
- geological and planning purposes
- keeping mine plans up to date.

Selection of Stope Survey depends on

- Size, shape and dip of the ore body
- Method of working
- The degree of accuracy required and the time available.

Methods of Stope Surveying

There are several methods of stope surveying commonly used in underground mining operations, including:

Traditional Surveying Techniques: Traditional surveying techniques involve the use of various surveying instruments, such as total stations, theodolites, and leveling equipment, to measure angles, distances, and elevations. Surveyors may set up reference points, known as control points, at established locations within the mine, and use them as a base for measuring and mapping the stopes. These measurements are typically taken manually by surveyors, and the data is processed and analyzed to create accurate stope plans and maps.

Terrestrial Laser Scanning (TLS): TLS, also known as LIDAR (Light Detection and Ranging), is a modern surveying technique that uses laser scanners to capture three-dimensional (3D) data of the stope surfaces. TLS can quickly and accurately measure millions of points on the stope surfaces, capturing the shape, size, and position of the stopes with high precision. The collected data can be processed to generate detailed 3D models, maps, and cross-sectional profiles of the stopes, which can be used for stope planning, monitoring, and analysis.

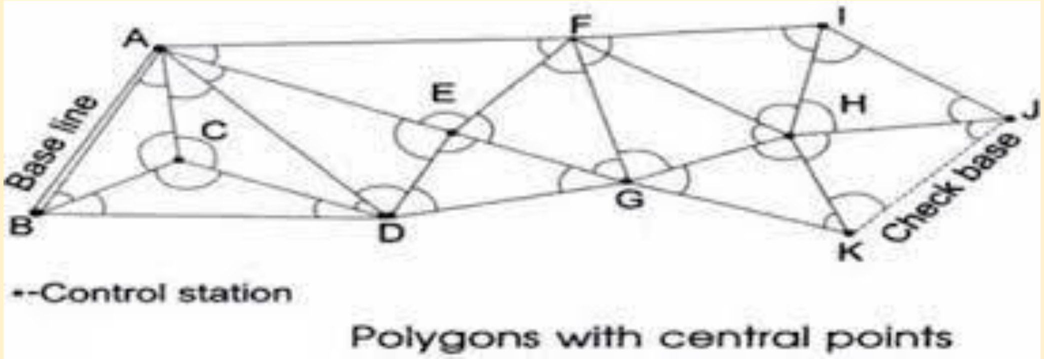
Global Navigation Satellite Systems (GNSS): GNSS, such as GPS (Global Positioning System), is a satellite-based positioning and navigation system that can be used for stope surveying in underground mines. GNSS receivers can be used to determine the precise positions of survey points on the stope surfaces, allowing for accurate mapping and measurement of the stopes. However, GNSS signals can be affected by underground conditions, such as poor signal reception due to the presence of tunnels or other obstructions, which may require additional techniques or equipment for accurate surveying.

Remote Sensing Techniques: Remote sensing techniques, such as drones or unmanned aerial vehicles (UAVs), can be used for stope surveying in underground mines. Drones equipped with high-resolution cameras or LIDAR sensors can capture aerial imagery or 3D data of the stopes from above, providing detailed information on the stope surfaces and surrounding areas. The collected data can be processed and analyzed to generate stope plans, maps, and 3D models.

Mine Surveying Software: There are specialized mine surveying software packages available that provide tools for stope surveying, data processing, and analysis. These software packages may include features such as stope modeling, point cloud processing, geodetic calculations, and data integration, which can streamline the surveying process and facilitate the creation of accurate stope maps and plans.

It's important to note that the selection of stope surveying methods may depend on various factors, including the mine site conditions, equipment availability, accuracy requirements, and project budget. Qualified surveyors with expertise in underground mining operations and surveying techniques should be consulted to determine the most appropriate method for a specific mining operation.

Tape triangulation: A method of measuring mine roadway area in which a tape is stretched diagonally across the roadway. Offsets to the roof, floor, and sides are taken at right angles to the tape and on both sides of it. Alternatively, the floor of the cross section is divided into equal increments and vertical offsets to the roof are made at each division. Horizontal offsets to the sidewalls are made from the nearest adjacent vertical offsets. The measurements so obtained are plotted to scale, and the area of the resulting diagram is determined from the plot.



Radiation in stope Surveying

Radiation is sometimes used in stope surveying as a method for measuring distances or determining the location of points within underground mines. One common technique that involves the use of radiation is called "radiolocation" or "radiometric surveying". This method uses radioactive sources, typically gamma-emitting isotopes, which are placed at known points in the mine, and detectors that measure the intensity of the radiation at various locations.

The detectors, which are typically portable and handheld devices, are used to measure the intensity of the gamma radiation emitted by the radioactive sources. The measured intensity can be used to determine the distance between the detector and the radioactive source, as the intensity of gamma radiation decreases with distance according to the inverse square law. By taking measurements at multiple locations, and knowing the positions of the radioactive sources, the surveyor can triangulate or otherwise calculate the location of points within the mine.

Radiometric surveying can be used for various purposes in stope surveying, such as determining the position of stopes, measuring the distances between survey points, and locating underground features or infrastructure. It can be particularly useful in mines where other surveying methods, such as traditional surveying or GPS, may be challenging due to limited visibility, lack of reference points, or other factors.

Auxiliary telescope: An auxiliary telescope, also known as a solar attachment or a solar telescope, is a specialized instrument used in mine surveying to measure horizontal angles with high accuracy. It is typically used in conjunction with a theodolite, which is a precision instrument used for measuring horizontal and vertical angles in surveying.

The auxiliary telescope is designed to work with the theodolite and is mounted on top of the theodolite's telescope. It has its own reticle or crosshair, which is used to precisely measure the angle between the vertical line of the theodolite's telescope and the direction of the sun's rays. This allows the surveyor to determine the solar azimuth or solar altitude, which can be used to determine the time of day or establish reference points for horizontal angle measurements.

In mine surveying, the auxiliary telescope is typically used in underground mines where access to the surface for measuring angles directly with theodolite is not possible. By measuring the solar azimuth or altitude with the auxiliary telescope, the surveyor can establish reference points for horizontal angle measurements within the mine workings. This allows for accurate mapping and surveying of underground tunnels, stopes, and other mine features.

It's worth noting that the use of an auxiliary telescope in mine surveying requires specialized training and expertise. The instrument must be properly calibrated and used according to established procedures and guidelines to ensure accurate and reliable measurements. Additionally, factors such as atmospheric conditions, time of day, and the location of the mine can affect the accuracy of the measurements, and proper corrections and adjustments may need to be applied. Qualified and experienced mine surveyors should be consulted for the correct use of auxiliary telescopes in mine surveying operations.

Hanging compass

The mine surveyor's hanging compass has a needle with sharp edges to ensure accurate and comfortable reading. A small piece of copper which is used to adjust for inclination is placed on the south end of the needle. The magnetized needle is mounted on a thoroughly centered and polished bearing pin. This allows for almost frictionless movement. The compass needle can be locked using the lateral knurled knob, for instance when the compass is not in use.

The hanging element is the part that houses the mine surveying compass itself. The two bearing screws positioned opposite to each other allow for free movement of the compass inside the hanging element's metal ring. That element as well as the compass are made of light weight, corrosion-resistant materials without magnetic influence. There are two bows attached to the metal ring of the hanging element with prismatic-shaped hooks at each end. The connecting line of those two hooks runs exactly through the middle of the compass.

The protractor tool has the shape of a semicircular arch. The graduation markings start with 0 degree in the middle and then go to 90 degree on each side. A pendulum is attached to a small hole in the center. The pendulum string indicates the inclination angle on the graduated arc. The protractor tool is put onto a string using two lateral hooks.

There are two metal clips in the carrying case that can be used to avoid any slipping of the hanging element or the protractor tool.

The mine surveying compass and the protractor tool are safely stored and transported in a foam-padded plastic case.

In combination with the mine surveyor's hanging compass, the baseplate is used to draw a chart of the magnetic directions that have been measured.

Questions

1. What is the purpose of using an auxiliary telescope in mine surveying?

a) To establish reference points for vertical angle measurements

b) To determine the orientation and direction of geological features

c) To accurately map and survey underground mine workings

d) To measure the magnetic declination in the mine

Answer: c) To accurately map and survey underground mine workings

2. What is the advantage of using an auxiliary telescope in mine surveying?

a) It allows for accurate horizontal angle measurements

b) It eliminates the need for compass measurements

c) It provides a direct view of underground tunnels

d) It reduces the need for specialized training

Answer: a) It allows for accurate horizontal angle measurements

3. What type of training and expertise is required for using an auxiliary telescope in mine surveying?

a) Basic knowledge of compass measurements

b) Familiarity with underground mine workings

c) Specialized training in gyroscopic orientation

d) Expertise in using telescopes and mapping instruments

Answer: d) Expertise in using telescopes and mapping instruments

4. How does the use of an auxiliary telescope contribute to accurate mapping in mine surveying?

a) It provides precise measurements of magnetic declination

b) It allows for accurate determination of geological features

c) It establishes reference points for vertical angle measurements

d) It enables accurate mapping of underground tunnels and mine features

Answer: d) It enables accurate mapping of underground tunnels and mine features

5. What are some challenges or limitations of using an auxiliary telescope in mine surveying?

a) Limited visibility in underground mine workings

b) Difficulty in establishing reference points

c) High cost of the instrument

d) Inaccuracy in horizontal angle measurements

Answer: a) Limited visibility in underground mine workings

Photogrammetry

- It is the science of making measurements from photographs.
- Output of photogrammetry is typically a map,diagram measurement, or a 3D model of some real-world object or scene.
- Photogrammetric surveying or photogrammetry is the branch of surveying in which maps are prepared from photo-graphs taken from ground or air stations.
- With an advancement of the photogrammetric techniques, photographs are also being used for the interpretation of geology, classification of soils and crops,etc.
- Is the science of making measurements from photographs, especially for recovering the exact positions of surface points.
- Used to recover the motion pathways of designated reference points located on any moving object, on its components and in the immediately adjacent environment.
- Photogrammetry may employ high-speed imaging and remote sensing in order to detect, measure and record complex 2-D and 3-D motion fields.

Now a days devices– drone camera, aircraft, photo theodolite, digital camera etc.

- Photogrammetry is traditionally used to create topographic maps from aerial and spatial imagery. Close range photogrammetry is also used at the School of Surveying to obtain accurate measurements of animals in wildlife research or to create virtual models of historical buildings.
- The fundamental principle used by photogrammetry is triangulation. By taking photographs from at least two different locations, so-called "lines of sight" can be developed from each camera to points on the object.
- Photogrammetry is used in fields such as topographic mapping, architecture, engineering, manufacturing, quality control, police investigation, cultural heritage, and geology.

Broadly Photogrammetry Requires:

- Planning & taking the photographs
- Processing the photographs
- Measuring the photographs & Reducing
- the measurement to produce end results.

Principle of photogrammetric survey

Principle of photogrammetric survey in its simplest form is very similar to that of the plane table survey.

- Only difference is that the most of the work which in plane table survey is executed in the field, but here is done in office.
- The principal point of each photograph is used as a fixed station and rays are drawn to get points of intersections very similar to those used in plane table.
- Is suitable for topographical or engineering surveys and also for those projects demanding higher accuracy.

- It is unsuitable for dense forest & others due to the difficulty of identifying points upon the pair of photographs.

Types of Photogrammetry

The photographs used in photogrammetry may be broadly classified into two types depending upon the camera position at the time of photography. The types are-

- Terrestrial Photographs
- Aerial Photographs

Terrestrial Photographs

• Photographs taken from camera station at a fixed position on or near the ground is known as Terrestrial Photographs.

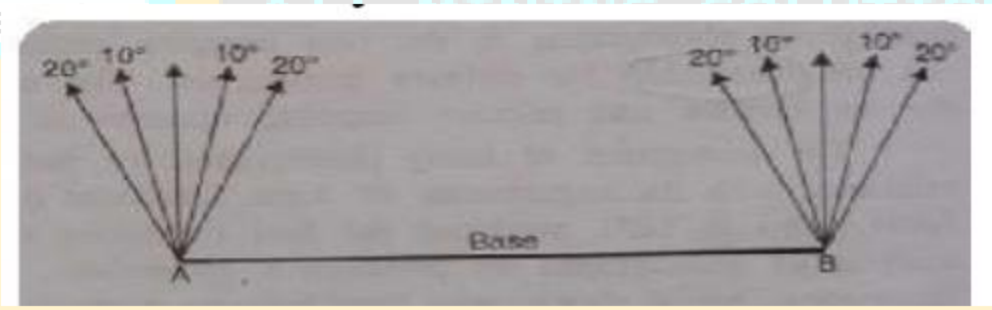
• The photographs are taken by means of a photo theodolite which is combination of a camera and a theodolite.

• Based on the principle that "if the directions of same objects photographed from two extremities of measured base are known, their position can be located by the intersection of two rays to the same object.

Difference between this and plane tabling is that more details are at once obtained from the photographs and their subsequent plotting etc. is done by the office while in plane tabling all the detailing is done in the field itself.

- Fig A and B are the two stations at the ends of base AB.

• Arrows indicate the directions of horizontal pointing (in plan) of the camera.



• For each pair of pictures taken from the two ends, the camera axis is kept parallel to each other. • From economy and speed point of view, minimum number of photographs should be used to cover the whole area and to achieve this, it is essential to select the best positions of the camera stations.

• Study of the area should be done from the existing maps, and a ground reconnaissance should be made. Selection of actual stations depends upon the size and ruggedness of the area. These photographs provides the front view of elevation & are generally used for the survey of structure & Architectural Monuments.

Aerial photographs

- Photographs taken from a Aerial camera mounted on a aerial vehicle

- Used for various purpose, mainly information extraction on the ground surface
- Aerial photographs are obtained from the aerial cameras mounted on aerial vehicle(aeroplane for the purpose of photography)
- Used for various purpose, mainly information extraction on the ground surface
- Photographs are taken from camera station in the air with the axis of camera vertical or nearly vertical.
- Is the branch of photogrammetry where the photographs are taken from air station.
- This is the best mapping procedure yet developed for large objects and are useful for military intelligence.
- For this, aerial camera is used which are fixed on flying aircraft.

According to the direction of the camera axis at the time of exposure aerial photographs may be classified into:

- Vertical photographs
- Oblique photographs

Vertical photographs

- These photographs are taken from the air with the axis of the Camera vertical or nearly vertical.
- A truly vertical Photograph closely resembles a map.
- These are utilized for the compilation of topographic and engineering surveys on various scales.

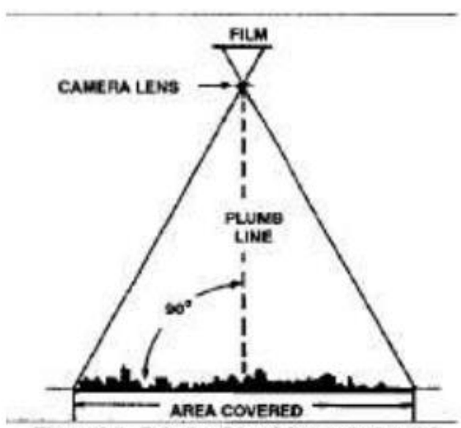
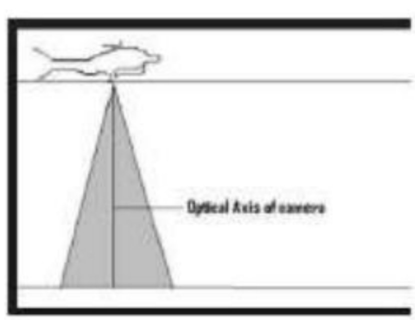


Figure 8-1. Relationship of the vertical aerial photograph with the ground.



Scale of Vertical Photograph

The scale of a vertical photograph in photogrammetry is the ratio of a distance on the photo to the corresponding distance on the ground. However, this ratio is not constant for a vertical photograph, because it varies with the elevation of the terrain. Therefore, the scale of a vertical photograph depends on the focal length of the camera, the flying height above the ground, and the elevation of the point of interest.

to express the scale of a vertical photograph is by using this formula:

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

where:

- S is the photographic scale at a point
- f is the camera focal length
- H is the flying height above datum
- h is the elevation above datum of the point

Oblique photographs

Photographs are taken from air with the axis of the camera intentionally tilted from the vertical.

• An oblique photograph covers larger area of the ground but clarity of details diminishes towards the far end of the photograph.

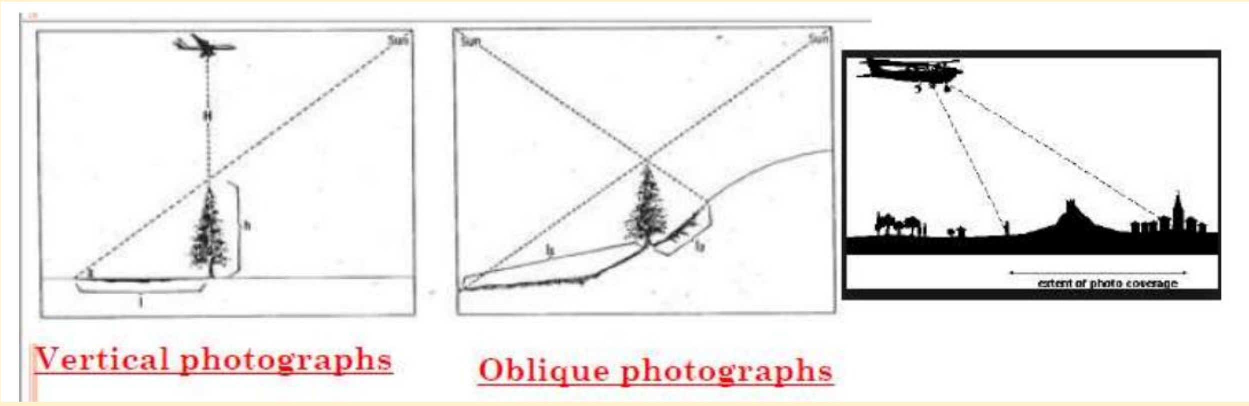
• Depending upon the angle of obliquity, oblique photographs may he further divided into two categories.

• Low oblique photographs:

- An oblique photograph which does not show the horizon, is known as low oblique photograph.
- Such photographs are generally used to compile reconnaissance maps of inaccessible areas.

• High oblique photograph:

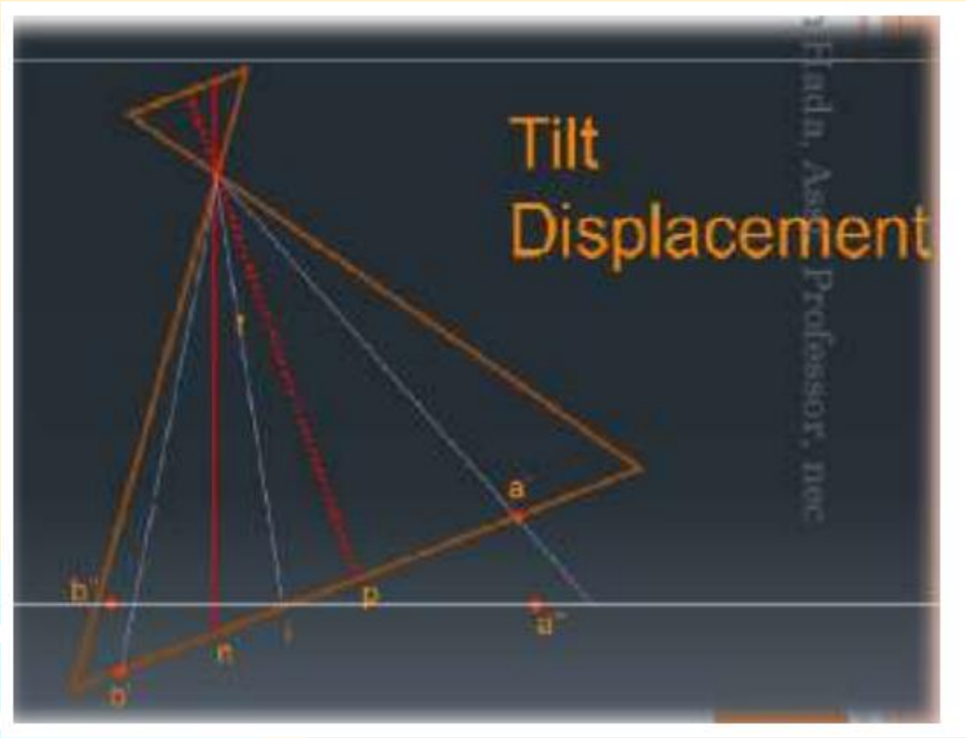
- An oblique photograph which is sufficiently tilted to show the horizon, is known as high oblique, photograph.
- Such photographs were previously used for the extension of planimetric and height control in areas having scanty ground control.



Tilt Displacement

- Defined as the difference between the distance of the image of a point on the tilted photograph from the isocenter and the distance of the image of the same point on the photograph from the isocenter if there had been no tilt.

- An error in the position of a point on the photograph due to indeliberate tilting of the aircraft:
  - Due to instability of aircraft.
  - May be due to tilting of the aircraft along the flight.
  - line and/or perpendicular to the flight line.
  - Increases radially from the isocenter.



Flight planning

- A flight planning consists of a flight (navigation) map which shows where the aerial photographs are to be taken and parameters (specifications) which outlines the specific requirements such as aerial camera and film requirements, scale, flying height, end lap, side lap, tilt and swing round (yaw) tolerances, etc.
- The flight planning is the first step in photogrammetric project. The main goal of planning is finding out the best fit flight lines and camera exposure stations. In order to cover the project area with minimum number of models, flight lines and camera exposure stations must be planed carefully.

Application of Photogrammetry in Mining

- Used to conduct topographical survey or engineering surveys.
- Suitable for mountainous and hilly terrain with little vegetation.
- Used for geological mapping which includes identification of land forms, rock type & rock structures.
- Used for projects demanding higher accuracy, since it provides
- accurate measurements.
- Used in urban and regional planning applications.
- Used mostly in Planning/designing in transport planning, bridge,
- pipeline, hydropower, urban planning, security and strategic
- planning, disaster management, natural resources management, city

- models, conservation of archaeological sites etc.

Photograph Vs Map

Photograph	Map
Raw data captured by a camera	Processed products derived from photographs
Perspective geometry with distortions	Orthographic geometry without distortions
Three-dimensional measurements	Two-dimensional measurements
More detail and visual information	More abstract and symbolic information
Require camera parameters	Require terrain models

Questions:

1. What is the fundamental principle used in photogrammetry?

a) Triangulation

b) Trilateration

c) Intersection

d) Resection

Answer: a) Triangulation

2. Which type of photographs are taken from a fixed position on or near the ground?

a) Terrestrial photographs

b) Aerial photographs

c) Oblique photographs

d) Vertical photographs

Answer: a) Terrestrial photographs

3. What is the main purpose of flight planning in photogrammetry?

a) Determining camera parameters

b) Selecting camera exposure stations

c) Planning flight lines for aerial photography

d) All of the above

Answer: d) All of the above

4. Which type of photograph covers a larger area of the ground but has diminished clarity of details?

a) Terrestrial photograph

b) Vertical photograph

c) Oblique photograph

d) High oblique photograph

Answer: c) Oblique photograph

5. What is the formula to express the scale of a vertical photograph in photogrammetry?

a) S = f/(H-h)

b) S = (H-h)/f

c) S = f*(H-h)

d) S = (H-h)/f^2

Answer: a) S = f/(H-h)

6. Which type of photograph is commonly used for surveying structures and architectural monuments?

a) Terrestrial photograph

b) Vertical photograph

c) Oblique photograph

d) High oblique photograph

Answer: b) Vertical photograph

7. What is the main difference between a photograph and a map in photogrammetry?

a) Raw data captured by a camera vs. processed products derived from photographs

b) Perspective geometry with distortions vs. orthographic geometry without distortions

c) Three-dimensional measurements vs. two-dimensional measurements

d) More detail and visual information vs. more abstract and symbolic information

Answer: a) Raw data captured by a camera vs. processed products derived from photographs

8. Which type of photograph is obtained from an aerial camera mounted on an aerial vehicle?

a) Terrestrial photograph

b) Vertical photograph

c) Oblique photograph

d) Aerial photograph

Answer: d) Aerial photograph

9. What is the main purpose of using oblique photographs in photogrammetry?

a) To cover a larger area of the ground

b) To capture detailed information with clarity

c) To create three-dimensional models

d) To extract information on the ground surface

Answer: a) To cover a larger area of the ground

10. What is the first step in a photogrammetric project?

a) Determining camera parameters

b) Conducting ground reconnaissance

c) Flight planning

d) Capturing aerial photographs

Answer: c) Flight planning

Global Positioning System

The Global Positioning System (GPS) is a satellite-based navigation and surveying system for determination of precise position and time, using radio signals from the satellites, in realtime or in post-processing mode. GPS is being used all over the world for numerous navigational and positioning applications, including navigation on land, in air and on sea, determining the precise coordinates of important geographical features as an essential input to mapping and Geographical Information System (GIS), along with its use for precise cadastral surveys, vehicle guidance in cities and on highways using GPS-GIS integrated systems, earthquake and landslide monitoring, etc. In India also, GPS is being used for numerous applications in diverse fields like aircraft and ship navigation, surveying, geodetic control networks, crustal deformation studies, cadastral surveys, creation of GIS databases, time service, etc., by various organisations.

GPS Segments

The Global Positioning System basically consists of three segments: the Space Segment, The Control Segment and the User Segment.

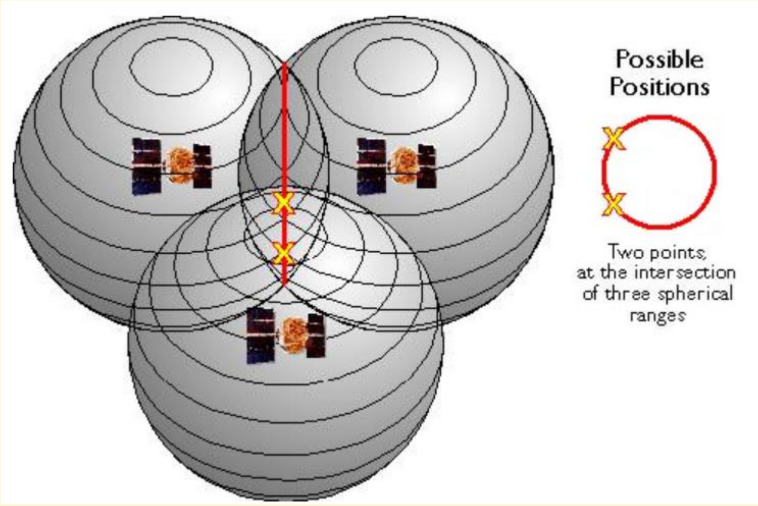
Space Segment: The Space Segment contains 24 satellites, in 12-hour near-circular orbits at altitude of about 20000 km, with inclination of orbit 55°. The constellation ensures at least 4 satellites in view from any point on the earth at any time for 3-D positioning and navigation on world-wide basis. The three axes controlled, earth-pointing satellites continuously transmit navigation and system data comprising predicted satellite ephemeris, clock error etc., on dual frequency L1 and L2 bands.

Control Segment: This has a Master Control Station (MCS), few Monitor Stations (MSs) and an Up Load Station (ULS). The MSs are transportable shelters with receivers and computers; all located in U.S.A., 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 and clock drift relative to system time. The data thus processed generates refined information of gravity field influencing the satellite motion, solar pressure parameters, position, clock bias and electronic delay characteristics of ground stations and other observable system influences. Future navigation messages are generated from this and loaded into satellite memory once a day via ULS which has a parabolic antenna, a transmitter and a computer.

Thus, role of Control Segment is: -

- To estimate satellite [space vehicle (SV)] ephemerides and atomic clock behaviour.
- To predict SV positions and clock drifts.
- To upload this data to SVs.

User Segment: The user equipment consists of an antenna, a receiver, a data-processor with software and a control/display unit. The GPS receiver measures the pseudo range, phase and other data using navigation signals from minimum 4 satellites and computes the 3-D position, velocity and system time. The position is in geocentric coordinates in the basic reference coordinate system: World Geodetic reference System 1984 (WGS 84), which are converted and displayed as geographic, UTM, grid, or any other type of coordinates. Corrections like delay due to ionospheric and tropospheric refraction, clock errors, etc. are also computed and applied by the user equipment / processing software..



Features of GPS Satellites

Some of the important features of the GPS satellites are as follows : -

- Design Life: 5 years (with expendables stored for 7 years)
- On orbit weight: 430 kg
- End-of-life power: 400 W
- Power Source: 5m2 solar arrays tracking the sun and 3 Ni-cd batteries for eclipse
- 3 axis stablished, earth pointing satellites
- Navigation Pay Load: Pseudo Random Noise (PRN) signal assembly, atomic frequency standard
- Cesium beam atomic Clocks accurate to 10-14 sec, processor and L band antenna
- Codes:

(a) Precision (P) Code: Generated at GPS clock frequency of 10.23 MHz (equivalent to 30 m in range) interpolated to sub-meter level. Repeats itself after 267 days, resolution = 100 nanoseconds.

(b) Coarse Acquisition (C/A) Code: Code sequence frequency of 1.023 MHz (range 300 m) interpolated to few m. Repeats itself every 1 millisecond, resolution = 1 micro second

- PRN navigation signals on two frequencies:

(a) 1575.42 Mhz - L1 Band - Wave length 19 cm.

(b) 1227.6 MHz - L2 Band - Wave length 24 cm.

Principle of Operation

Each GPS satellite carries an atomic clock with stability better than 1 in 10^{14}, which is used to generate dual frequency PRN spread spectrum L band navigation signals. These massages, continuously transmitted by satellite on P code and C/A code modulated on L1 carrier frequency, contain information of satellite ephemarides and satellite clock error. Remote MSs located in U.S.A. receive these massages and transfer to MCS which computes future information to be uploaded and stored in satellite memory for further broadcast. The purpose of code is to identify each satellite uniquely, to enable measurement of signal travel time and to facilitate selective denial of use to unauthorised users. The user equipment receives navigation massages from at least 4 satellites available above the horizon at any place at any time. Correlation of received code with corresponding code synthesised by receiver allows ground observer to measure transit time of signal from the satellite to the receiver, from which range to satellite can be computed. Simultaneous reception of 4 navigation signals from 4 satellites, containing information of time of transmission of code to 10 nanosecond accuracy and satellite position on basis of broadcast ephemeris enable the observer to form 4 pseudo range (actual range + offset due to user's clock bias) equations which can be solved to get the 3 parameters of the observer's position in 3 dimensions i.e. X, Y and Z in Earth-centered Cartesian coordinates, or equivalently the longitude, latitude and height above ellipsoid, and the receiver clock error.

APPLICATIONS OF GPS

Due to the high accuracy, versatility, ease and economy of operation, and all-weather operation offered by GPS, it has found numerous applications in many fields, ranging from the mm-level high precision geodesy to the several-metre level navigational positioning. Some of these applications are:

- Establishment of high precision zero order Geodetic National Survey Control Network of GPS stations.
- Strengthening, densification and readjustment of existing Primary Control Networks using GPS stations.
- Connecting remote islands to mainland Geodetic Control Networks.
- Determination of a precise geoid using GPS data.
- Earth rotation and Polar Motion Studies from GPS data.
- Estimating gravity anomalies using GPS.
- Marine Geodesy: positioning of oceanic stations, buoys etc.
- Earthquake monitoring: Crustal movements of the order of few cm/years can be monitored using GPS method, thus making GPS most suitable for monitoring continental drifts, neotectonics / seismotectonic movement, etc.
- Vertical Control Network: High accuracy of few mm in heights achievable with GPS at much less cost and time compared to levelling to make GPS method most suitable for establishing lower accuracy vertical control networks.
- Geophysical positioning, mineral exploration and mining.
- Survey control for topographical and cadastral surveys. - Ground control for photogrammetric control surveys and mapping.
- Offshore positioning: Shipping, offshore platforms, fishing boats etc.
- Instantaneous time transfer over trans-continental distances with accuracies of few nano seconds.
- Space craft tracking: Vector separation between GPS satellites and any other satellites can be monitored by GPS, e.g., pinpointing the location of LANDSAT etc.
- General aircraft navigation, approach to runways, navigation/positioning in remote areas like deserts, dense jungles, shaded areas of microwave, precise sea navigation, approach to harbors etc. It is expected that in 1990s most civilian aircrafts, ships, boats will be

fitted with GPS equipments and even hikers, boat and car owners, truck drivers will be using it extensively.,

- Military; Improved weapon delivery accuracies i.e. for missiles etc., for ranging in artillery, navigation for Army, Navy, Airforce - thus affecting ultimate saving of upto 1 billion dollars annually on navigation in U.S.A.
- Scientific applications, like studies related to the ionosphere and troposphere, glaciology, etc.

Questions:

1. What is the purpose of the Control Segment in GPS?

a) To estimate satellite ephemerides and atomic clock behavior

b) To measure the pseudo range, phase, and other data

c) To provide user equipment with navigation messages

d) To track satellites and accumulate ranging data

Answer: a) To estimate satellite ephemerides and atomic clock behavior

2. Which code is generated at the GPS clock frequency of 10.23 MHz?

a) Precision (P) Code

b) Coarse Acquisition (C/A) Code

c) Navigation signals

d) PRN navigation signals

Answer: a) Precision (P) Code

3. What is the resolution of the Precision (P) Code?

a) 100 nanoseconds

b) 1 microsecond

c) 30 meters

d) 300 meters

Answer: a) 100 nanoseconds

4. What is the purpose of the PRN navigation signals?

a) To identify each satellite uniquely

b) To measure signal travel time

c) To facilitate selective denial of use to unauthorized users

d) All of the above

Answer: d) All of the above

5. How many satellites are required for user equipment to receive navigation messages?

a) 2

b) 3

c) 4

d) 5

Answer: c) 4

6. What is the basic reference coordinate system used in GPS?

a) World Geodetic reference System 1984 (WGS 84)

b) Universal Transverse Mercator (UTM)

c) Geographic coordinates

d) Grid coordinates

Answer: a) World Geodetic reference System 1984 (WGS 84)

Subsidence Surveying

Subsidence Surveying

Subsidence surveying is the process of measuring the deformation of the Earth's surface caused by the sinking or settling of the ground. This type of surveying is commonly used in mining, where subsidence can occur as a result of underground mining activities. The purpose of subsidence surveying is to monitor the level of subsidence over time, so that any potential hazards can be identified and managed.

Subsidence can be caused by several factors, including natural phenomena such as sinkholes and geological processes, as well as human activities such as mining, oil and gas extraction, and groundwater pumping. In mining, subsidence can occur due to the collapse of underground cavities or pillars that support the weight of the overlying rock.

Construction and Layout of Subsidence Monitoring Stations

Subsidence monitoring stations are typically set up around mining areas to monitor the level of subsidence over time. The stations consist of a series of markers or prisms, which are placed on the ground at fixed intervals. The markers are typically made of concrete or steel, and are designed to withstand the weight of heavy equipment and the effects of weather and erosion.

The layout of the monitoring stations is critical to ensuring accurate and reliable subsidence measurements. The markers must be placed in a grid pattern, with a sufficient number of markers to capture the full extent of the subsidence zone. The distance between the markers should be no more than 30 meters, and the location of each marker should be accurately recorded using GPS or other surveying techniques.

The choice of markers and their placement depends on the specific mining activity and the expected level of subsidence. For example, if the subsidence is expected to be minimal, simple surface markers may be sufficient. However, if significant subsidence is expected, more robust and stable markers may be required, such as buried anchors or borehole tiltmeters.

Subsidence Measurements

Subsidence measurements are typically taken using a range of surveying techniques, including leveling, GPS, and satellite imagery. The choice of measurement technique will depend on a range of factors, including the accuracy required, the size of the subsidence zone, and the availability of equipment.

Leveling:

Leveling is a traditional surveying technique that involves measuring the height of markers at different points around the subsidence zone. The height of each marker is measured using a leveling instrument, and the data is used to create a contour map of the subsidence zone. This technique is accurate but time-consuming, and requires a skilled operator.

GPS:

GPS is a satellite-based positioning system that is commonly used for subsidence monitoring. GPS receivers are placed on the markers around the subsidence zone, and the data is used to calculate the position and height of each marker. This data can then be used to create a 3D model of the subsidence zone. GPS is fast, accurate, and can be automated, making it an ideal technique for large-scale subsidence monitoring.

Satellite Imagery:

Satellite imagery is a remote sensing technique that is used to monitor subsidence over large areas. Satellites are used to capture high-resolution images of the subsidence zone, which are then analyzed to identify any changes in the height or position of the markers over time. This technique is useful for monitoring subsidence in remote or inaccessible areas, but is less accurate than GPS or leveling.

Other Techniques:

Other subsidence monitoring techniques include tiltmeters, which measure the inclination of the ground, and InSAR (Interferometric Synthetic Aperture Radar), which uses radar to measure changes in the height of the ground. These techniques are typically used in conjunction with other surveying techniques to provide additional data on subsidence.

Data Analysis:

Once subsidence measurements have been taken, the data must be analyzed to identify any changes in the subsidence over time. This involves comparing the current measurements to previous measurements to identify any trends or patterns. The data can also be used to create subsidence maps, which provide a visual representation of the subsidence zone and the level of subsidence at each marker.

The analysis of subsidence data is critical to ensuring the safety of mining operations and the surrounding communities. Any significant changes in the subsidence must be identified and managed to prevent damage to infrastructure and potential hazards to human life.

Management of Subsidence

The management of subsidence involves a range of strategies to mitigate the risks associated with subsidence. These strategies may include:

- Modifying mining practices to reduce the extent of subsidence
- Using support structures to stabilize the ground
- Relocating infrastructure to avoid subsidence zones
- Monitoring subsidence and implementing early warning systems
- Compensating affected parties for any damage caused by subsidence

Conclusion

- Subsidence surveying, the construction and layout of subsidence monitoring stations, and subsidence measurements are critical aspects of mining operations. The accurate monitoring of subsidence is essential to ensuring the safety of mining operations and the surrounding communities.

- The construction and layout of subsidence monitoring stations must be carefully planned to ensure accurate and reliable measurements. The choice of markers and measurement techniques must be appropriate for the specific mining activity and the expected level of subsidence.

- Once subsidence measurements have been taken, the data must be analyzed to identify any changes in the subsidence over time. The data can then be used to create subsidence maps and to implement strategies to manage the risks associated with subsidence.
- In conclusion, subsidence monitoring is an essential part of mining operations, and must be carried out with the utmost care and attention to ensure the safety of all parties involved.

Questions

1. What is the purpose of placing markers in a grid pattern during subsidence surveying?

a) To create a visual representation of the subsidence zone

b) To measure the depth of underground mines

c) To ensure accurate and reliable measurements

d) To prevent damage to infrastructure

Answer: c) To ensure accurate and reliable measurements

2. What is the recommended maximum distance between subsidence markers?

a) 10 meters

b) 20 meters

c) 30 meters

d) 40 meters

Answer: c) 30 meters

3. How should the location of each subsidence marker be recorded?

a) Using GPS or other surveying techniques

b) Using satellite imagery

c) Using laser scanning technology

d) Using manual measurements

Answer: a) Using GPS or other surveying techniques

4. The choice of markers and their placement depends on:

a) The expected level of subsidence

b) The depth of underground mines

c) The availability of satellite imagery

d) The type of minerals being extracted

Answer: a) The expected level of subsidence

5. What is the purpose of analyzing subsidence data in mining operations?

a) To create 3D models of subsidence zones

b) To ensure the safety of mining operations and surrounding communities

c) To measure the depth of underground mines

d) To identify potential mineral deposits

Answer: b) To ensure the safety of mining operations and surrounding communities

6. What should be done if significant changes in subsidence are identified?

a) Implement early warning systems

b) Compensate affected parties for damage caused by subsidence

c) Avoid subsidence zones

d) All of the above

Answer: d) All of the above

7. What is the main objective of subsidence surveying in mining operations?

a) To measure the depth of underground mines

b) To create 3D models of subsidence zones

c) To ensure the safety of mining operations and surrounding communities

d) To analyze the stability of mine shafts

Answer: c) To ensure the safety of mining operations and surrounding communities

8. Why must the construction and layout of subsidence monitoring stations be carefully planned?

a) To prevent damage to infrastructure

b) To ensure accurate and reliable measurements

c) To avoid subsidence zones

d) To create visual representations of subsidence

Answer: b) To ensure accurate and reliable measurements

9. What is the recommended number of markers to capture the full extent of a subsidence zone?

a) As few as possible

b) At least 10 markers

c) At least 20 markers

d) A sufficient number of markers

Answer: d) A sufficient number of markers

10. What is the ultimate goal of subsidence surveying in mining operations?

a) To measure the depth of underground mines

b) To create 3D models of subsidence zones

c) To ensure the safety of mining operations and surrounding communities

d) To analyze the stability of mine shafts

Answer: c) To ensure the safety of mining operations and surrounding communities

Borehole Surveying

Introduction:

Borehole surveying is a critical technique used in the mining industry to determine the location, direction, and inclination of boreholes. The information obtained from borehole surveying is important for creating accurate maps of the surrounding geology and for planning mining operations. In this detailed note, we will discuss borehole surveying in-depth, including the different types of surveying methods, the accuracy of each method, the limitations of borehole surveying, and how to interpret the data obtained from borehole surveying.

Types of Borehole Surveying Methods

There are several methods of borehole surveying, including magnetic, gravity, and gyroscopic methods.

Magnetic Surveying: Magnetic surveying is one of the most common methods used in borehole surveying. It involves the use of a magnetic compass to determine the direction and inclination of the borehole. A magnetic tool is lowered down the borehole, and the direction of the magnetic field is measured at regular intervals. The data is then used to calculate the direction and inclination of the borehole.

Gravity Surveying: Gravity surveying involves measuring the gravitational pull on the borehole to determine its orientation. A gravity tool is lowered down the borehole, and the changes in gravity are measured at regular intervals. The data is then used to calculate the orientation of the borehole.

Gyroscopic Surveying: Gyroscopic surveying is the most accurate method of borehole surveying. It involves the use of a spinning gyroscopic tool to measure the orientation of the borehole. The tool is lowered down the borehole, and the changes in orientation are measured at regular intervals. The data is then used to calculate the orientation of the borehole with an accuracy of up to 0.1 degrees.

Accuracy of Borehole Surveying

The accuracy of borehole surveying depends on several factors, including the type of surveying method used, the depth of the borehole, and the quality of the equipment used.

Magnetic Surveying: Magnetic surveying is generally accurate to within 1-2 degrees.

Gravity Surveying: Gravity surveying is generally accurate to within 0.1 degrees.

Gyroscopic Surveying: Gyroscopic surveying is the most accurate method, with an accuracy of up to 0.1 degrees.

Limitations of Borehole Surveying

While borehole surveying is a critical technique for understanding the geology of the surrounding area and for planning mining operations, it has some limitations.

Depth: Borehole surveying becomes more difficult and less accurate at greater depths due to the effects of pressure and temperature.

Surrounding Geology: Borehole surveying can only provide information about the orientation of the borehole, not the geology of the surrounding area.

Cost: Borehole surveying can be expensive and time-consuming, especially for deep boreholes.

Interpretation of Borehole Surveying Data

Once the data from borehole surveying has been collected, it must be analyzed and interpreted by a geologist or mining engineer.

Data Analysis: The data collected from borehole surveying is analyzed to create accurate maps of the surrounding geology.

Interpretation: The data is then interpreted by a geologist or mining engineer to plan mining operations. This involves determining the direction of mining operations and ensuring that the borehole is properly aligned.

Conclusion

Borehole surveying is a critical technique used in the mining industry to determine the location, direction, and inclination of boreholes. The accuracy of borehole surveying depends on the type of surveying method used, the depth of the borehole, and the quality of the equipment used. While borehole surveying has some limitations, it is an important technique for understanding the geology of the surrounding area and for planning mining operations. The data obtained from borehole surveying is analyzed and interpreted by geologists and mining engineers to create accurate maps of the surrounding geology and to plan mining operations.

It is important to note that borehole surveying is just one aspect of mining exploration and planning. It is often used in conjunction with other techniques such as drilling, sampling, and geological mapping to get a more complete picture of the geology of the area. The information obtained from borehole surveying is also used to identify potential mineral deposits and to determine the viability of mining operations in the area.

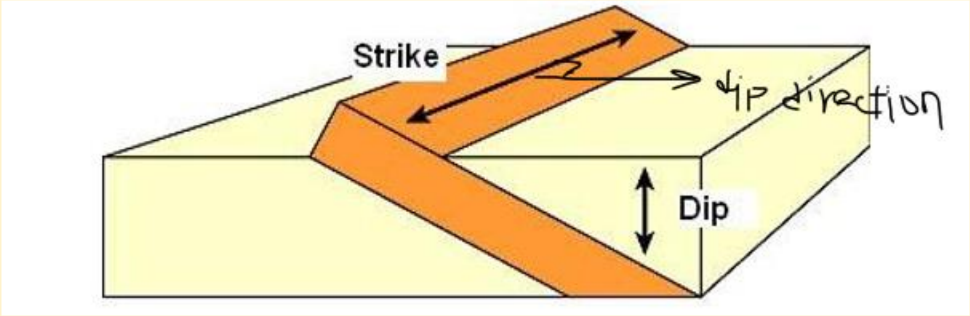
In summary, borehole surveying is a critical technique in the mining industry that provides important information for understanding the geology of the surrounding area and for planning mining operations. The accuracy of borehole surveying depends on several factors, including the type of surveying method used, the depth of the borehole, and the quality of the equipment used. While borehole surveying has some limitations, it is an important tool for mining exploration and planning, and its data is analyzed and interpreted by geologists and mining engineers to create accurate maps of the surrounding geology and to plan mining operations.

Dip, Strike, Outcrop and Fault

Dip is the angle that a rock surface makes with a horizontal plane. It is measured in degrees from 0° (horizontal) to 90° (vertical). Dip indicates the direction and steepness of the slope of the rock layer.

Strike is the direction of the line formed by the intersection of a rock surface with a horizontal plane. It is usually expressed as a compass bearing, such as N-S or NE-SW. Strike indicates the orientation of the rock layer.

The **dip direction** is always perpendicular to the strike.



Altitude: it defines the location of the failure plan.

It can be represented as in WCB and QB:

In WCB:

Altitude (WCB) = strike (WCB) / dip (degree)

In QB:

Altitude (WCB) = strike (QB) / dip direction (QB) / dip (degree)

Outcrop is a large mass of rock that stands above the surface of the ground. It is where the rock layer is exposed and visible. Outcrop patterns show the shape and extent of the rock layer on a map.

Fault is a fracture or zone of fractures in the rock where there has been displacement or movement along the fracture. Faults can have different types and sizes, depending on the direction and amount of movement. Faults can affect the dip and strike of the rock layers.

Problem Solving

1. Which method of borehole surveying is the most accurate?

a) Magnetic surveying

b) Gravity surveying

c) Gyroscopic surveying

d) All methods have the same accuracy

Solution: c) Gyroscopic surveying

2. What is the typical accuracy of magnetic surveying?

a) 0.1 degrees

b) 1-2 degrees

c) 0.01 degrees

d) 0.5 degrees

Solution: b) 1-2 degrees

3. What are the limitations of borehole surveying?

a) It provides information about the geology of the surrounding area.

b) It becomes less accurate at greater depths.

c) It is a cost-effective method.

d) It can be used independently without other exploration techniques.

Solution: b) It becomes less accurate at greater depths.

4. Who interprets the data obtained from borehole surveying?

a) Geologists and mining engineers

b) Surveyors and technicians

c) Miners and drillers

d) Environmentalists and conservationists

Solution: a) Geologists and mining engineers

5. What is the purpose of borehole surveying in the mining industry?

a) To determine the location of mineral deposits

b) To create accurate maps of the surrounding geology

c) To plan mining operations

d) All of the above

Solution: d) All of the above

6.if strike is N 50^0 W and dip = 45^0 then what is altitude?

a) 320^0 / 50^0

b) 450^0 / 60^0

c) 310^0 / 45^0

d) 210^0 / 30^0

ans: c

altitude = strike (in WCB) / dip (in degree)

=>strike in WCB = $360^0 – 50^0 = 310^0$

So, altitude = 310^0/ 45^0

Laser

Introduction:

Lasers are powerful and versatile tools that have revolutionized the mining industry in recent years. They have become increasingly popular due to their high precision, accuracy, and speed, making them ideal for a range of mining applications. In this detailed note, we will discuss the different types of lasers, their characteristics, and their mining applications.

Types of Lasers

There are several types of lasers, including solid-state lasers, gas lasers, fiber lasers, and diode lasers.

Solid-State Lasers: Solid-state lasers use a solid-state material, such as a crystal or glass, as the laser medium. They are known for their high energy efficiency, long lifetimes, and high beam quality. Solid-state lasers are often used in mining applications such as drilling, cutting, and welding.

Gas Lasers: Gas lasers use a gas, such as helium-neon or carbon dioxide, as the laser medium. They are known for their high output power and high beam quality. Gas lasers are often used in mining applications such as laser-induced breakdown spectroscopy (LIBS) and laser ablation.

Fiber Lasers: Fiber lasers use a fiber-optic cable as the laser medium. They are known for their high energy efficiency, long lifetimes, and high beam quality. Fiber lasers are often used in mining applications such as laser cutting, welding, and marking.

Diode Lasers: Diode lasers use a semiconductor material as the laser medium. They are known for their small size, high energy efficiency, and low cost. Diode lasers are often used in mining applications such as laser scanning and mapping.

Characteristics of Lasers

Lasers have several characteristics that make them ideal for a range of mining applications.

High Precision and Accuracy: Lasers are known for their high precision and accuracy, making them ideal for applications that require precise measurements, such as surveying and mapping.

High Speed: Lasers can operate at high speeds, making them ideal for applications that require fast processing times, such as drilling and cutting.

Non-Contact: Lasers operate without physical contact, making them ideal for applications that require non-destructive testing and inspection.

Mining Applications of Lasers: Lasers have a wide range of mining applications, including drilling, cutting, welding, surveying, and mapping.

Drilling: Lasers are used in drilling applications to create precise and accurate holes in rock and other materials. This is especially useful in the mining industry, where drilling is a critical process for extracting minerals.

Cutting: Lasers are used in cutting applications to create precise and accurate cuts in rock and other materials. This is useful for creating custom shapes and sizes for mining equipment and structures.

Welding: Lasers are used in welding applications to join pieces of metal or other materials together. This is useful for creating strong and durable mining equipment and structures.

Surveying: Lasers are used in surveying applications to create accurate and detailed maps of mining sites. This information is used to plan mining operations and to ensure the safety of workers.

Mapping: Lasers are used in mapping applications to create 3D models of mining sites. This information is used to identify potential mineral deposits and to plan mining operations.

Lasers have become an essential tool in the mining industry due to their high precision, accuracy, and speed. They have a wide range of applications, including drilling, cutting, welding, surveying, and mapping. The different types of lasers, including solid-state lasers, gas lasers, fiber lasers, and diode lasers, each have their own unique characteristics that make them suitable for specific mining applications. As the mining industry continues to evolve, lasers will continue to play an increasingly important role in improving efficiency, accuracy, and safety.

Advantages of Using Lasers in Mining

There are several advantages of using lasers in mining operations, including:

1. **Increased Efficiency**: Lasers are incredibly fast and precise, which can significantly increase the efficiency of mining operations. For example, lasers can quickly and accurately cut and drill through rock, reducing the time and effort required for manual drilling or cutting.
2. **Improved Safety:** Lasers can be used for remote and automated mining operations, reducing the risk of injury to workers. For example, lasers can be used to remotely control drilling equipment, reducing the need for workers to be present in dangerous areas.
3. **Increased Accuracy:** Lasers are incredibly precise, which can lead to increased accuracy in mining operations. For example, lasers can be used to create accurate 3D models of mining sites, which can be used to plan and optimize mining operations.
4. **Reduced Environmental Impact:** Lasers can be used for non-destructive testing and inspection, reducing the environmental impact of mining operations. For example, lasers can be used to inspect pipelines and equipment for leaks without damaging the surrounding environment.
5. **Improved Mineral Extraction:** Lasers can be used to extract minerals more efficiently and with less waste. For example, lasers can be used to selectively extract minerals from ore, reducing the amount of waste produced during the extraction process.

Mining Applications of Different Types of Lasers

Different types of lasers are used for different mining applications, depending on the specific requirements of the operation. Here are some examples of the mining applications of different types of lasers:

1. **Solid-State Lasers:** Solid-state lasers are commonly used for drilling, cutting, and welding in mining operations. For example, solid-state lasers can be used to drill holes in rock for blasting, or to cut and weld metal parts for mining equipment.
2. **Gas Lasers:** Gas lasers are commonly used for spectroscopy and laser ablation in mining operations. For example, gas lasers can be used to analyze the chemical composition of rock samples, or to remove material from a surface for analysis.
3. **Fiber Lasers:** Fiber lasers are commonly used for cutting, welding, and marking in mining operations. For example, fiber lasers can be used to cut and weld metal parts for mining equipment, or to mark and label mining products.
4. **Diode Lasers:** Diode lasers are commonly used for scanning and mapping in mining operations. For example, diode lasers can be used to create 3D models of mining sites, or to scan and map the interior of tunnels and shafts.

Challenges and Limitations of Using Lasers in Mining

While lasers offer many advantages for mining operations, there are also some challenges and limitations to their use. Here are some of the challenges and limitations of using lasers in mining:

1. **High Cost:** Lasers can be expensive to purchase and maintain, which can be a barrier for smaller mining operations.
2. **Limited Range:** The range of lasers is limited, which can make them less useful for large-scale mining operations. For example, lasers may not be able to penetrate deep underground or through thick layers of rock.
3. **Hazardous Materials:** Some lasers require hazardous materials, such as toxic gases, to operate, which can pose a risk to workers and the environment.
4. **Maintenance Requirements:** Lasers require regular maintenance to ensure that they operate correctly and safely, which can be time-consuming and expensive.

Conclusion

Lasers have become an important tool for mining operations due to their high precision, accuracy, and speed. Different types of lasers are used for different mining applications, depending on the specific requirements of the operation. Lasers offer several advantages for mining operations, including increased efficiency, improved safety, increased accuracy, reduced environmental impact, and improved mineral extraction. However, there are also some challenges and limitations to using lasers in mining , including high cost, limited range, hazardous materials, and maintenance requirements. Despite these challenges, the benefits of using lasers in mining operations make them a valuable tool for the industry.

In recent years, advances in laser technology have continued to improve the capabilities and applications of lasers in mining. For example, developments in fiber laser technology have led to increased power and efficiency, making them more useful for heavy-duty mining applications. Additionally, advances in lidar technology (which uses lasers for remote sensing and mapping) have enabled more detailed and accurate mapping of mining sites.

As the mining industry continues to evolve, lasers are likely to play an increasingly important role in mining operations. While the initial costs and maintenance requirements of using lasers may be a barrier for some operations, the benefits of increased efficiency, improved safety, and reduced environmental impact make them a worthwhile investment in the long term. Additionally, as technology continues to improve, the cost and accessibility of laser technology are likely to continue to decrease, making them more accessible to smaller operations.

In conclusion, lasers are a valuable tool for the mining industry, offering several advantages over traditional mining methods. Different types of lasers are used for different mining applications, and advances in laser technology are likely to continue to improve their capabilities and applications in the industry. While there are some challenges and limitations to using lasers in mining, the benefits they offer make them a worthwhile investment for many mining operations.

Problem solving:

1. What is one advantage of using lasers in mining operations?

a) Increased efficiency

b) Increased cost

c) Increased environmental impact

d) Increased manual labor

Answer: a) Increased efficiency

2. Which type of laser is commonly used for drilling and cutting in mining operations?

a) Solid-state lasers

b) Gas lasers

c) Fiber lasers

d) Diode lasers

Answer: a) Solid-state lasers

3. What is one limitation of using lasers in mining operations?

a) Low precision and accuracy

b) High cost

c) Limited range

d) Increased environmental impact

Answer: c) Limited range

4. Which type of laser is commonly used for spectroscopy and laser ablation in mining operations?

a) Solid-state lasers

b) Gas lasers

c) Fiber lasers

d) Diode lasers

Answer: b) Gas lasers

5. What is one advantage of using lasers in mining operations related to safety?

a) Increased risk of injury to workers

b) Remote and automated operations

c) Increased manual labor

d) Reduced accuracy

Answer: b) Remote and automated operations

6. Which type of laser is commonly used for cutting, welding, and marking in mining operations?

a) Solid-state lasers

b) Gas lasers

c) Fiber lasers

d) Diode lasers

Answer: c) Fiber lasers

7. What is one challenge of using lasers in mining operations?

a) Low cost

b) Limited maintenance requirements

c) Hazardous materials

d) Increased range

Answer: c) Hazardous materials

8. Which type of laser is commonly used for scanning and mapping in mining operations?

a) Solid-state lasers

b) Gas lasers

c) Fiber lasers

d) Diode lasers

Answer: d) Diode lasers

9. What is one advantage of using lasers in mining operations related to accuracy?

a) Increased waste production

b) Reduced accuracy

c) Increased precision and accuracy

d) Increased environmental impact

Answer: c) Increased precision and accuracy

10. What is one benefit of using lasers in mining operations related to environmental impact?

a) Increased waste production

b) Reduced accuracy

c) Increased precision and accuracy

d) Reduced environmental impact

Answer: d) Reduced environmental impact

Geological map reading

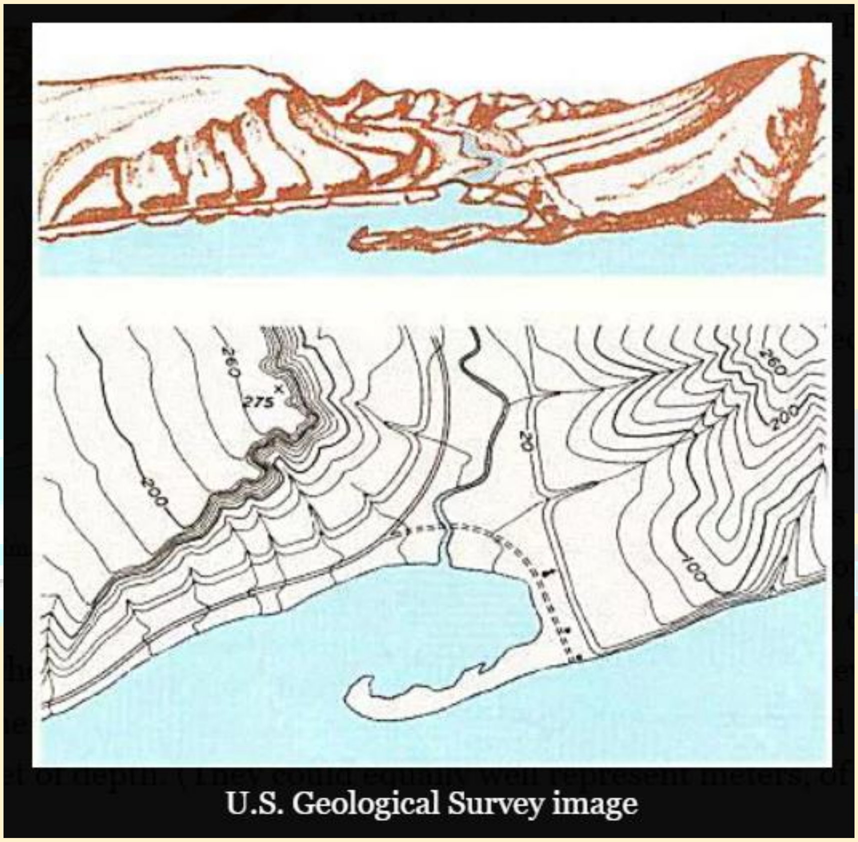
Geologic maps are a mix of truth and beauty, and they may be the most condensed form of knowledge ever recorded on paper.

There isn't much on the map in the glove box of your automobile but roads, cities, coastlines, and borders. However, if you look closely, you can see how difficult it is to fit all that information on paper in a way that makes it helpful. Imagine that you also wish to convey essential details about the local geology.

1- Topography on Maps

One aspect of geology is the contour of the land—where the hills and valleys are, the location of the streams, the slope angles, etc. You need a topographic or contour map, such as those released by the government, for that level of specific information on the area.

The U.S. Geological Survey (USGS) has provided the graphic above that demonstrates how a landscape (top) transforms to a contour map. Fine contour lines—lines of equal elevation—show the forms of the hills and dales on the map. Those lines indicate where the shoreline would be after every 20 feet of depth if the sea were to rise. (Of course, they could also stand in for metres.)

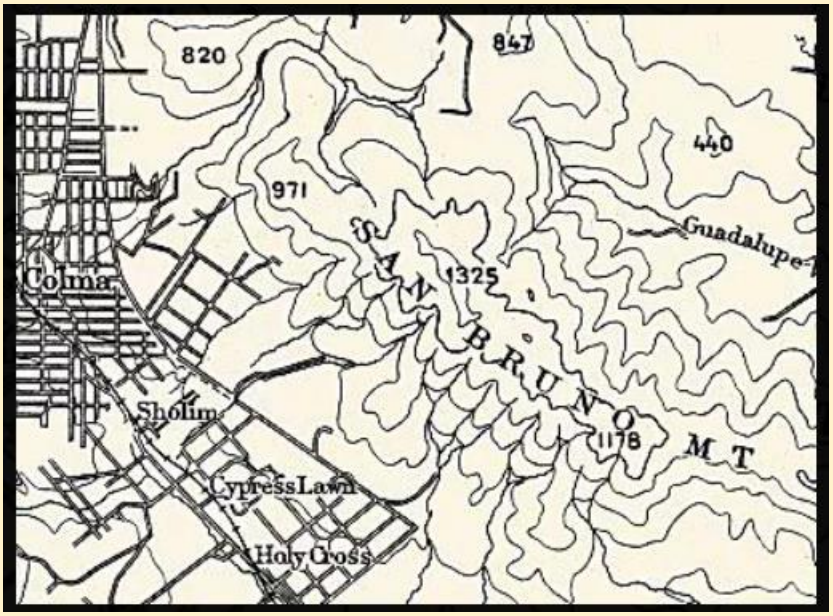


U.S. Geological Survey image

2- Contour Maps

You can see the roads, waterways, railroads, place names, and other components of any good map on this 1930 contour map from the U.S. Department of Commerce. 200-foot contours show the shape of San Bruno Mountain, while a thicker contour indicates the 1,000-foot level. Hills' heights are indicated on their summits. You may develop a solid mental image of what's happening in the landscape with some practise.

Observe how the information packed in the image allows you to get precise figures for hill slopes and gradients despite the fact that the map is a flat sheet. The vertical distance is in the contours, and the horizontal distance can be measured directly off the paper. That is easy math that computers can handle. In order to recreate the shape of the terrain, the USGS took all of its maps and produced a 3D digital map for the lower 48 states. Another calculation is used to shade the map in order to simulate how the sun would illuminate it.



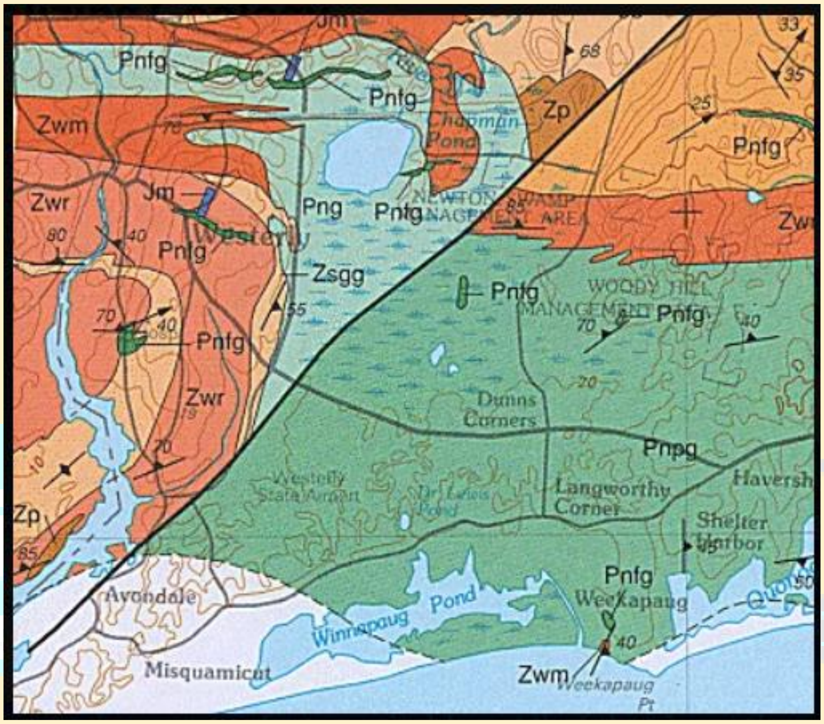
3- Topographic Map Symbols

More than just contours can be found on topographic maps. Symbols are used to denote the type of roads, notable buildings, power lines, and other characteristics on this example of a 1947 map from the USGS. An irregular stream, which is represented by the blue dashed and dotted line, is one that is dry for a portion of the year. The homes-covered land is depicted on the red screen. The USGS's topographic maps contain hundreds of distinct symbols.

4- Symbolizing Geology

A geologic map's contours and topography are only the beginning. Through colours, patterns, and symbols, the map also depicts different rock kinds, geologic structures, and more on the printed page.

An example of a true geology map can be seen here. The essential elements—shorelines, roads, towns, structures, and borders—that were previously mentioned can be seen as grey areas. In addition to the blue symbols for various water features, the contours are also shown in brown. The base of the map contains all of stuff. The black lines, symbols, labels, and coloured sections make up the geologic portion. Geologists have accumulated a significant deal of information over many years of fieldwork, which is summarised in the lines and symbols.



5- Contacts, Faults, Strikes, and Dips

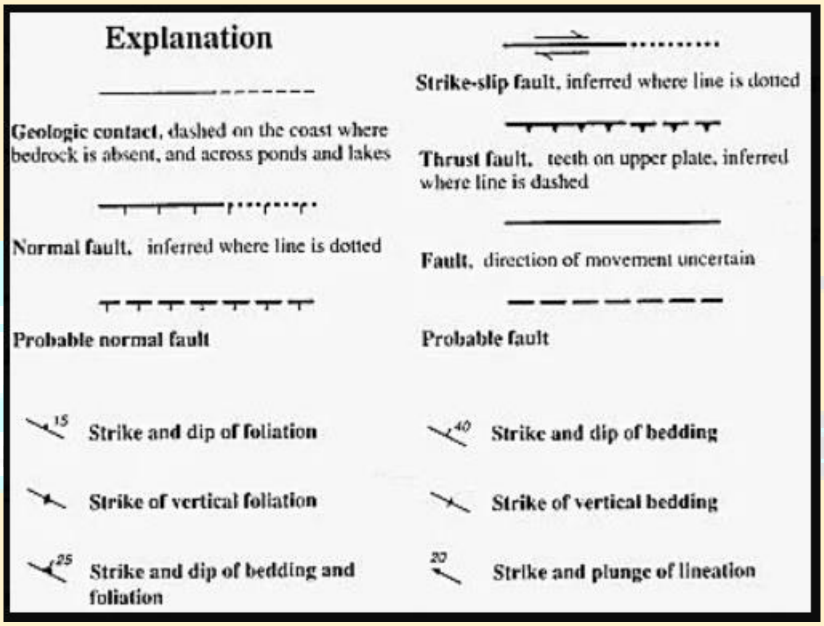
Different rock formations are shown on the map by lines. According to geologists, the lines represent the intersections between several rock units. Unless the contact is confirmed to be a fault, a severe discontinuity that makes it obvious that something has moved there, it is depicted as a fine line.

The little numerals next to the short lines are strike-and-dip symbols. The third dimension of the rock layers—the direction in which they protrude into the ground—is shown by these. Geologists use a compass and transit to determine the orientation of rocks wherever they can find an appropriate outcrop. They search for the sedimentary layers known as bedding planes in sedimentary rocks. The direction of foliation, or the direction of mineral layers, is measured in place of bedding because it may be impossible to detect bedding in some rocks.

The orientation is noted as a strike and a dip in either situation. The direction of a level line drawn across a rock's surface—the direction you would walk if there were no uphill or downhill gradient—is the direction of the rock's bedding or foliation. The dip is the downward slope of the bed or foliation. The painted centre line on the road represents the dip direction and a painted crosswalk represents the strike if you were to imagine a route descending straight down a slope. You only need only two figures to describe the direction of the rock. Each symbol on a map often represents the average of numerous measurements.

These symbols could possibly have an additional arrow to indicate the direction of lineation. Lineation may take the form of folds, a slickenside, mineral grains that have been stretched out, or another similar feature. Lineation is the printing on a sheet of paper that is randomly lying on the street; the arrow points in the direction it is printed. The number indicates the angle of the dive or dip in that direction.

The Federal Geographic Data Committee specifies the complete documentation of geologic map symbols.



6- Geologic Age and Formation Symbols

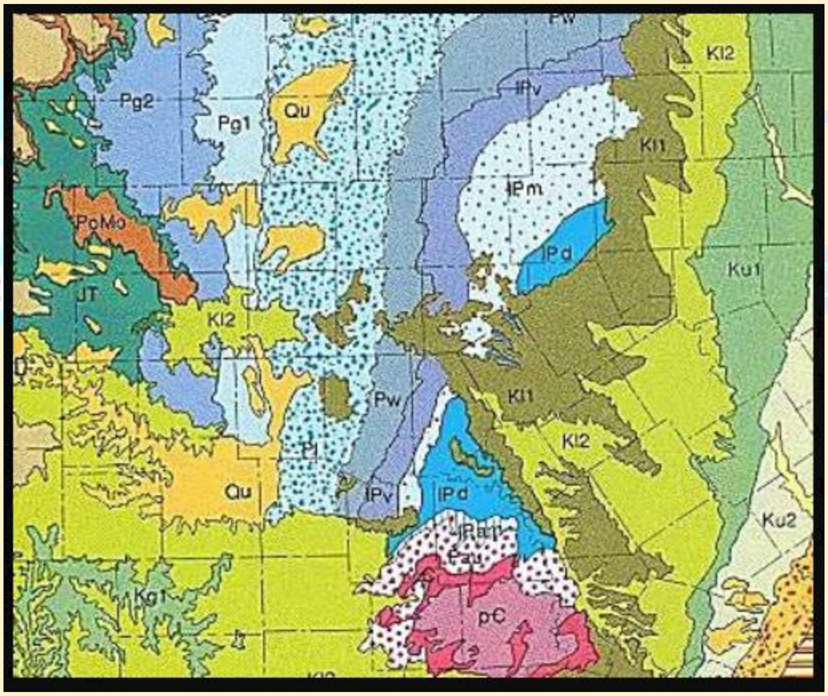
Cenozoic	Cz	Carboniferous	C
Quaternary	Q	Pennsylvanian	IP
Tertiary	T	Mississippian	M
Neogene	N	Devonian	D
Paleogene	Pe	Silurian	S
Mesozoic	Mz	Ordovician	O
Cretaceous	K	Cambrian	Є
Jurassic	J	Precambrian	pЄ
Triassic	TR	Proterozoic	P
Paleozoic	Pz	Archean	A
Permian	P		

The names and ages of the rock units in a region are denoted by the letter symbols. As was said before, the first letter denotes the geologic era. The other letters stand for either the name of the rock formation or its type. A nice illustration of the employment of the symbols is found on the geologic map of Rhode Island.

Some of the age symbols are peculiar; for example, so many age words start with P that unique symbols are required to keep them distinct. The Cretaceous Period is represented by the letter K, which is derived from the German phrase Kreidezeit, which is also true for the letter C. The meteor strike that signals the end of the Cretaceous and the start of the Tertiary is therefore referred to as the "K-T event."

In a formation symbol, the additional letters typically designate the kind of rock. A unit that is made up of Cretaceous shale might have the symbol "Ksh." The Rutabaga Formation might be denoted by the initials "Kr," since it contains a variety of rock types. In the Cenozoic, the second letter may also serve as an age designation, in which case a unit of Oligocene sandstone would be designated as "Tos."

7- Geologic Map Colors



All of the data on the geologic map, including the strike and dip, trend and plunge, relative age, and rock unit, were gathered through the diligent work and skilled observation of field geologists. However, the colours of geology maps are what really make them beautiful, not just the data they show.

A geologic map could be created utilising only lines and letter symbols in black and white instead of colours. However, it would be difficult to use, similar to a paint-by-numbers design without the paint. What hues should be used to represent the various rock ages? The mellow American standard and the more arbitrary International standard are two traditions that emerged in the late 1800s. Knowing the distinction between the two enables one to quickly determine the location of a geologic

These requirements are only the beginning. They only apply to sedimentary rocks with marine origin, which are the most prevalent types of rocks. Terrestrial sedimentary rocks add patterns to the same colour scheme. Red colours are common in igneous rocks, while lighter tones and haphazard polygonal patterns are found in plutonic rocks. Age darkens them both. Rich secondary colours and directed, linear patterns are used in the formation of metamorphic rocks. Because of all of this complexity, creating geologic maps is a skilled craft.

Every geologic map has a justification for deviating from the norm. Perhaps there aren't any rocks from specific eras so that other units' colour variations can be made without creating confusion, or perhaps the colours clash horribly, or maybe printing costs are too high. Geologic maps are fascinating for this and another reason: each one is made specifically to meet a certain set of requirements. Every time, one among those requirements is that the map look attractive. Geologic maps, particularly the paper-based varieties, represent a conversation between beauty and truth.

Problem solving

1. What is the purpose of a topographic or contour map?

a) To show the shape of the land and its features

b) To display the geologic structures and rock types

c) To indicate the age of rock units in an area

d) To represent the colors and patterns of different rock formations

Answer: a) To show the shape of the land and its features

2. What do contour lines on a topographic map represent?

a) Lines of equal elevation

b) Lines of equal rock age

c) Lines of equal rock type

d) Lines of equal geologic structure

Answer: a) Lines of equal elevation

3. What do symbols on a topographic map represent?

a) Type of roads, buildings, and power lines

b) Rock formations and geologic structures

c) Contour lines and elevation levels

d) Intermittent streams and land covered with homes

Answer: a) Type of roads, buildings, and power lines

4. What do black lines, symbols, labels, and areas of color represent on a geologic map?

a) Contour lines and elevation levels

b) Rock formations and geologic structures

c) Type of roads, buildings, and power lines

d) Intermittent streams and land covered with homes

Answer: b) Rock formations and geologic structures

5. What do strike-and-dip symbols represent on a geologic map?

a) The direction and steepness of rock layers

b) The age and type of rock units

c) The elevation and contour lines

d) The presence of faults and discontinuities

Answer: a) The direction and steepness of rock layers

6. What do the letter symbols on a geologic map signify?

a) The name and age of rock units

b) The direction and steepness of rock layers

c) The type of roads, buildings, and power lines

d) The presence of faults and discontinuities

Answer: a) The name and age of rock units

7. What do the colors on a geologic map represent?

a) The age of rocks

b) The type of rock formations

c) The elevation levels

d) The presence of faults and discontinuities

Answer: b) The type of rock formations

8. Which tradition arose in the late 1800s and determines the colors used on geologic maps?

a) Harmonious American standard

b) Arbitrary International standard

c) Sedimentary rock standard

d) Terrestrial rock standard

Answer: a) Harmonious American standard

9. What makes geologic map design a specialized art?

a) The use of colors and patterns to represent different rock formations

b) The inclusion of contour lines and elevation levels

c) The representation of geologic structures and rock types

d) The customization of maps to meet specific needs

Answer: a) The use of colors and patterns to represent different rock formations

10. What is the relationship between geologic maps and truth and beauty?

a) Geologic maps represent a combination of truth and beauty

b) Geologic maps prioritize truth over beauty

c) Geologic maps prioritize beauty over truth

d) Geologic maps have no relationship with truth and beauty

Answer: a) Geologic maps represent a combination of truth and beauty

Profiling of benches, highwall, dumps

Profiling of benches, highwall and dumps is a process of designing and evaluating the stability and capacity of the waste rock material that is removed from the mining area to expose the ore or coal seams. It involves considering various factors, such as the geotechnical properties of the material, the geometry and configuration of the slope and highwall, and the external loading conditions. Profiling of benches, highwall and dumps is important for the safety and efficiency of mining operations, as well as for the environmental and social impacts of waste disposal.

It can help to optimize the mine planning and design, as well as to reduce the environmental and social impacts of waste disposal. For example, by profiling the OB dump slope and highwall, the mine operator can determine the optimal slope angle, height, width, and number of benches that can maximize the dump capacity and stability, while minimizing the land use, water consumption, dust generation, and visual impact.

It can also help to monitor the performance and behavior of the OB dump slope and highwall over time, as well as to detect any signs of instability or failure. For example, by profiling the OB dump slope and highwall using geoelectrical methods, the mine operator can identify any changes in the resistivity or shear wave velocity of the OB material that may indicate the presence of cracks, voids, water seepage, or weak zones.

Profiling

Some of the steps involved in profiling of benches, highwall and dumps in mines are:

-Collecting samples of the overburden (OB) material from the mining site and conducting laboratory tests to determine the density, strength, friction, cohesion, and other properties of the material:

This step involves taking representative samples of the OB material from different locations and depths of the mining site and sending them to a laboratory for testing. The laboratory tests can include direct shear test, triaxial test, unconfined compression test, consolidation test, etc. to measure the physical and mechanical properties of the OB material, such as density, strength, friction angle, cohesion, permeability, compressibility, etc. These properties are important for understanding the behavior and response of the OB material under different loading and environmental conditions.

- Performing in situ tests, such as multichannel analysis of surface waves, to characterize the OB layers and their heterogeneity:

This step involves conducting field tests on the OB dump site to obtain information about the subsurface structure and variation of the OB layers. One of the common methods used for this purpose is multichannel analysis of surface waves (MASW), which is a non-destructive technique that uses seismic waves to estimate the shear wave velocity profile of the OB layers. The shear wave velocity is related to the stiffness and density of the OB material and can indicate the presence of weak zones or discontinuities in the OB dump.

-Using numerical models and software, such as Optum G2, to optimize the geometric parameters of the OB dump slope and highwall, such as bench slope angle, overall slope angle, bench height, total dump height, bench width, number of benches, floor inclination, etc:

This step involves using computer-based tools and software to simulate and analyze the stability and capacity of the OB dump slope and highwall under different scenarios. One of the software that can be used for this purpose is Optum G2, which is a finite element program that can model complex geotechnical problems with nonlinear material behavior and large deformations. Optum G2 can be used to optimize the geometric parameters of the OB dump slope and highwall by performing parametric studies and sensitivity analyses to find the optimal values that maximize the stability and capacity of the OB dump while minimizing the cost and environmental impact.

- Evaluating the factor of safety (FOS) and other output parameters, such as displacement, stress, strain, etc., to assess the state of stability of the OB dump slope and highwall under static and dynamic loading conditions:

This step involves interpreting and evaluating the results obtained from the numerical models and software to assess the state of stability of the OB dump slope and highwall. One of the key indicators of stability is:

the factor of safety (FOS), which is defined as the ratio of resisting forces to driving forces acting on a potential failure surface. A FOS greater than one indicates that the slope is stable, while a FOS less than one indicates that the slope is unstable. Other output parameters that can be used to assess the state of stability are displacement, stress, strain, pore pressure, etc., which can show how much deformation or movement occurs in the OB dump slope and highwall under static or dynamic loading conditions. Static loading conditions include gravity, self-weight, water pressure, etc., while dynamic loading conditions include seismic activity, blasting vibrations, etc.

-Implementing appropriate measures to reduce the risk of slope failure, such as benching, decking, catch benches, drainage systems, reinforcement, etc:

This step involves applying suitable measures to improve or maintain the stability and capacity of the OB dump slope and highwall based on the results obtained from the previous steps. Some of these measures are:

- **Benching**: This is a method of dividing a large slope into smaller segments or benches by creating horizontal cuts or terraces along the slope. Benching can reduce the overall slope angle and increase the stability of each bench by providing a flat surface for equipment operation and worker access.

- **Decking:** This is a method of placing a layer or deck of inert material on top of each bench to reduce or eliminate air blast effects from blasting operations. Decking can also reduce dust emissions and noise levels from blasting operations.

- **Catch benches**: These are horizontal spaces set in from the highwall to retain rock spillage or debris from falling onto lower benches or into active mining areas. Catch benches can prevent or minimize damage to equipment and workers from rockfall hazards.

- **Drainage systems**: These are structures or devices that are designed to collect and divert water from rainfall or groundwater seepage away from the OB dump slope and highwall. Drainage systems can reduce the pore pressure and the weight of the OB material and increase its strength and stability.

- **Reinforcement:** These are materials or elements that are inserted or applied to the OB dump slope and highwall to enhance its strength and stability. Reinforcement can include rock bolts, cables, anchors, nails, meshes, geotextiles, etc.

Instrument used

The instruments that are used for profiling of benches, highwall and dumps in mines are:

- For collecting samples of the OB material from the mining site and conducting laboratory tests, some of the instruments that are used are: drill rigs, core barrels, sample bags, sieves, scales, ovens, direct shear apparatus, triaxial apparatus, unconfined compression apparatus, consolidation apparatus, etc.

- For performing in situ tests on the OB dump site to characterize the OB layers and their heterogeneity, some of the instruments that are used are: multichannel analysis of surface waves (MASW) equipment, which consists of a seismic source (such as a hammer or a vibrator), a receiver array (such as geophones or accelerometers), a data acquisition system (such as a seismograph or a laptop), and a data processing software (such as SurfSeis or Geogiga).

- For using numerical models and software to optimize the geometric parameters of the OB dump slope and highwall, some of the instruments that are used are: computers with adequate hardware and software specifications, such as Optum G2, which is a finite element program that can model complex geotechnical problems with nonlinear material behavior and large deformations.

- For evaluating the factor of safety and other output parameters to assess the state of stability of the OB dump slope and highwall under static and dynamic loading conditions, some of the instruments that are used are: computers with adequate hardware and software specifications, such as Optum G2 or other slope stability analysis software (such as Slide or Slope/W), which can calculate the factor of safety and other output parameters based on the input data and assumptions.

- For implementing appropriate measures to reduce the risk of slope failure, such as benching, decking, catch benches, drainage systems, reinforcement, etc., some of the instruments that are used are: excavators, bulldozers, loaders, trucks, cranes, shovels, drills, blasting equipment, rock bolts, cables, anchors, nails, meshes, geotextiles, pipes, pumps, etc.

Problem solving:

1. What is the purpose of profiling benches, highwall, and dumps in mining operations?

a) To maximize the dump capacity and stability

b) To minimize the environmental impact of waste disposal

c) To optimize mine planning and design

d) All of the above

Answer: d) All of the above

2. Which method is commonly used to characterize the subsurface structure and variation of the overburden (OB) layers?

a) Direct shear test

b) Triaxial test

c) Multichannel analysis of surface waves (MASW)

d) Unconfined compression test

Answer: c) Multichannel analysis of surface waves (MASW)

3. Which software can be used to optimize the geometric parameters of the OB dump slope and highwall?

a) Optum G2

b) Slide

c) Slope/W

d) SurfSeis

Answer: a) Optum G2

4. What does the factor of safety (FOS) indicate in slope stability analysis?

a) The stability of the slope

b) The presence of cracks or voids in the slope

c) The density of the OB material

d) The shear wave velocity of the OB material

Answer: a) The stability of the slope

5. Which measure is used to divide a large slope into smaller segments or benches?

a) Benching

b) Decking

c) Catch benches

d) Drainage systems

Answer: a) Benching

6. What is the purpose of catch benches in mining operations?

a) To reduce dust emissions

b) To prevent rockfall hazards

c) To optimize the slope angle

d) To enhance the strength of the slope

Answer: b) To prevent rockfall hazards

7. Which instrument is commonly used to collect samples of the OB material from the mining site?

a) Multichannel analysis of surface waves (MASW) equipment

b) Drill rigs

c) Core barrels

d) Geophones

Answer: b) Drill rigs

8. Which software can be used to calculate the factor of safety and other output parameters in slope stability analysis?

a) Optum G2

b) Slide

c) Slope/W

d) SurfSeis

Answer: b) Slide

9. Which instrument is commonly used to reinforce the OB dump slope and highwall?

a) Excavators

b) Rock bolts

c) Bulldozers

d) Geotextiles

Answer: b) Rock bolts

10. Which instrument is commonly used to measure the shear wave velocity profile of the OB layers?

a) Drill rigs

b) Core barrels

c) Multichannel analysis of surface waves (MASW) equipment

d) Geophones

Answer: c) Multichannel analysis of surface waves (MASW) equipment

Dump / Highwall stability monitoring using different instruments.

Dump / highwall monitoring is the process of assessing the stability and safety of the slopes that are formed by the excavation or dumping of overburden material in open cast mines. Dump / highwall monitoring is important to prevent slope failures that can cause damage, injury, or loss of life. Dump / highwall monitoring can also help optimize the mining operations and reduce the environmental impact.

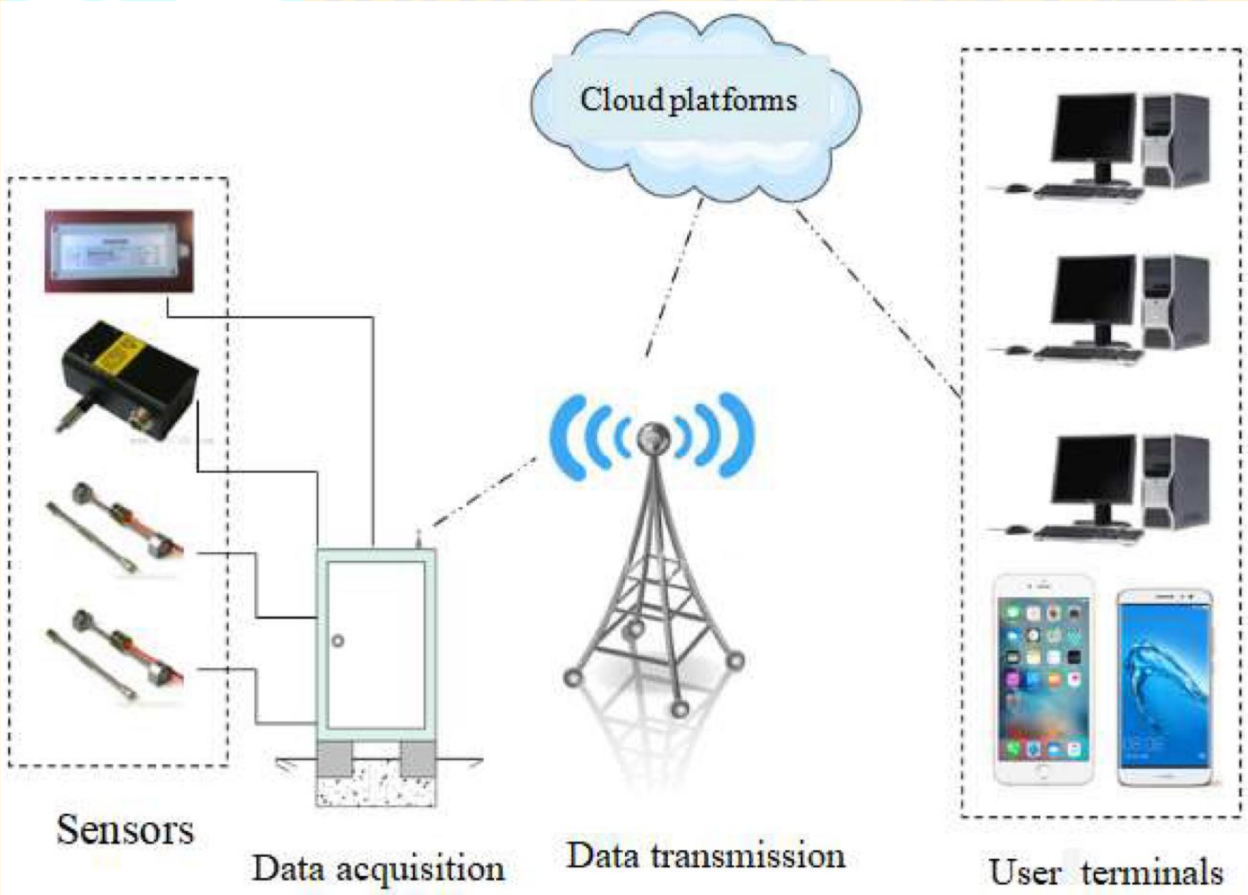
There are various instruments and techniques that can be used for dump / highwall monitoring, such as:

-Laser scanner

This is a device that uses a laser beam to scan the surface of the slope and create a 3D model of it. The 3D model can then be compared with the previous scans to detect any changes or movements that may indicate a risk of slope failure. A laser scanner can also provide a high-resolution and accurate representation of the shape and geometry of the dump / highwall, which can be used for analysis and planning. A laser scanner can scan a large area in a short time, but it may not be able to scan continuously or in real time, and it may be affected by the environmental conditions in the mining site.

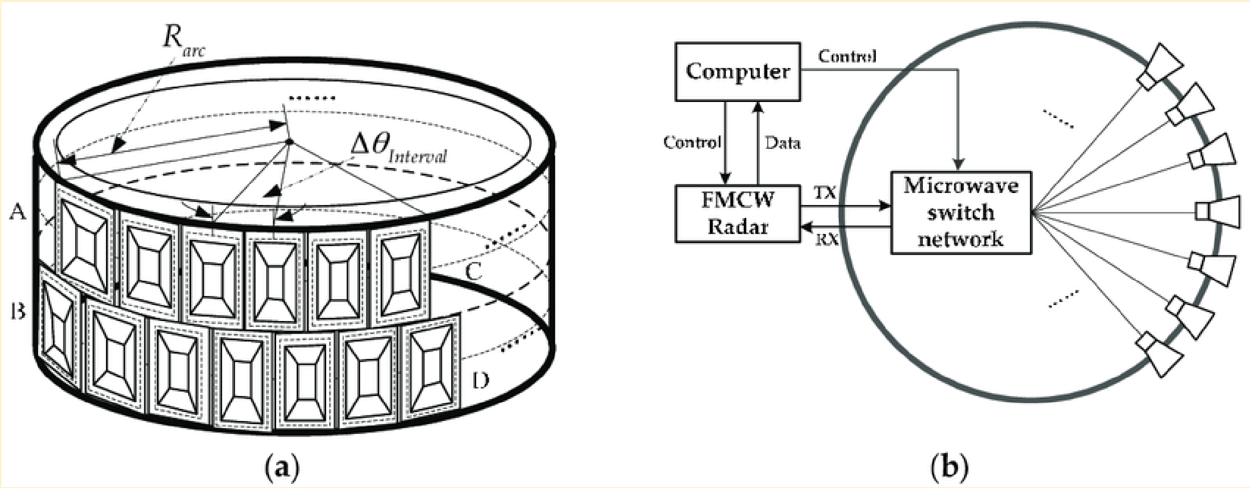
-Continuous real time monitor

This is a device that uses sensors or cameras to detect the changes in the dump / highwall surface over time. A continuous real time monitor can provide near real-time feedback and alert the operators of any potential instability. However, a continuous real time monitor may require more installation and maintenance costs than a laser scanner.



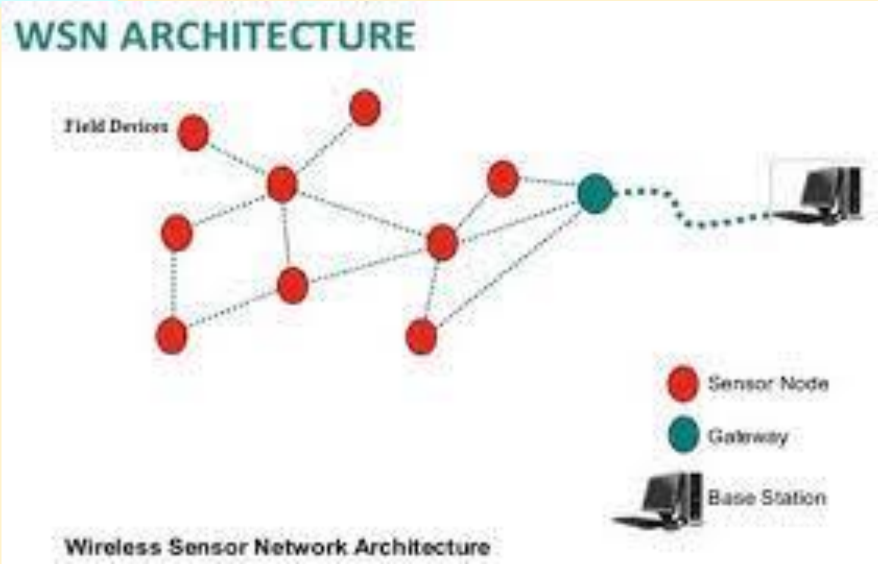
-Ground-based synthetic aperture radar (GBSAR)

This is a device that uses radar waves to measure the surface deformation of the dump / highwall. GBSAR can scan the slope continuously and in real time and provide high-precision and high-resolution data. GBSAR can also operate under all weather conditions and over long distances. However, GBSAR may be expensive and complex to install and operate.



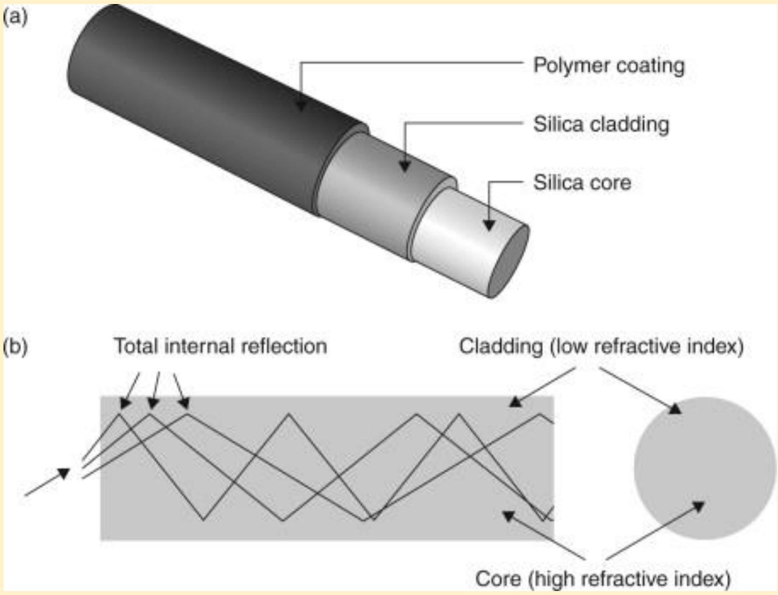
-Wireless sensor network (WSN)

This is a system that consists of multiple sensors that communicate wirelessly with each other and a central node. WSN can monitor various parameters of the dump / highwall, such as displacement, tilt, temperature, humidity, etc. WSN can provide low-cost and flexible monitoring solutions, but it may face challenges such as power consumption, data transmission, and security.



-Optical fiber sensor (OFS)

This is a device that uses optical fibers to measure the strain and temperature of the dump / highwall. OFS can provide long-term and distributed monitoring, and it is immune to electromagnetic interference. However, OFS may be affected by mechanical damage or environmental factors, and it may require special installation and calibration.

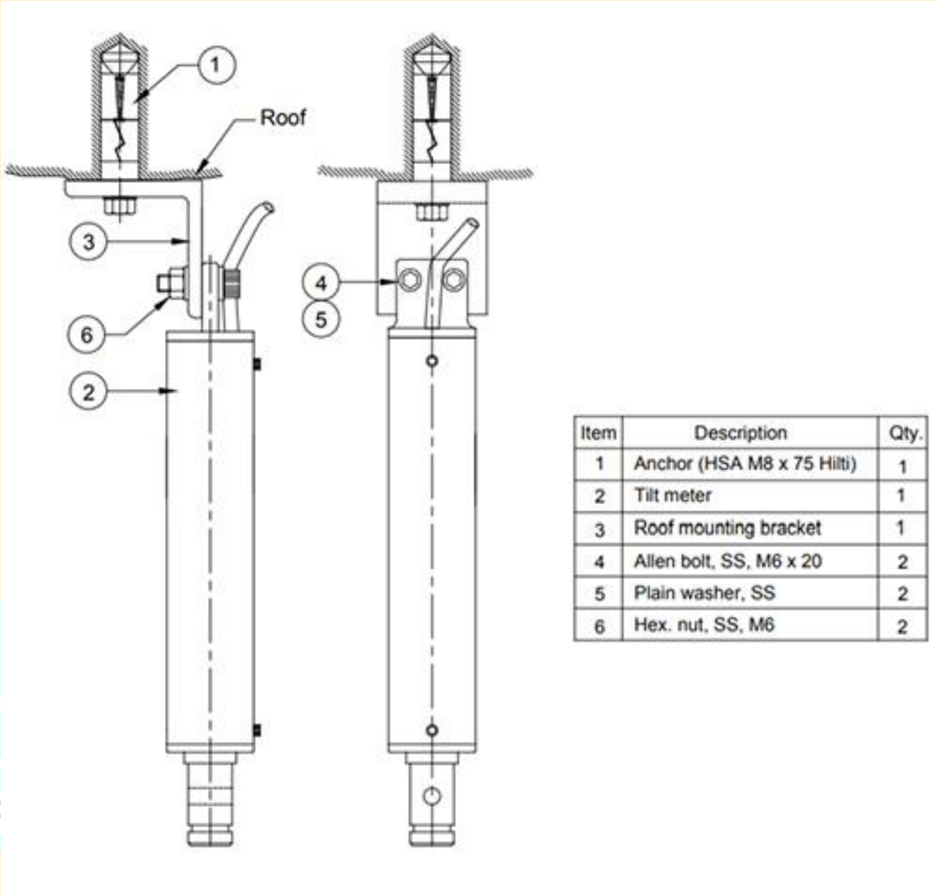


-Drone or unmanned aerial vehicle (UAV)

This is a device that flies over the dump / highwall and captures images or videos of the surface. Drone or UAV can provide a fast and flexible way to monitor the dump / highwall from different angles and heights. Drone or UAV can also be equipped with various sensors, such as thermal, multispectral, or lidar, to collect more information about the surface condition. However, drone or UAV may have limited battery life and flight range, and it may be affected by weather or interference.

-Inclinometer or tiltmeter

This is a device that measures the angle or tilt of the dump / highwall. Inclinometer or tiltmeter can be installed on the surface or inside the boreholes of the dump / highwall to monitor the deformation and displacement of the slope. Inclinometer or tiltmeter can provide a simple and direct way to detect any instability of the dump / highwall. However, inclinometer or tiltmeter may not be able to measure the movement in all directions, and it may require frequent calibration.



Item	Description	Qty.
1	Anchor (HSA M8 x 75 Hilti)	1
2	Tilt meter	1
3	Roof mounting bracket	1
4	Allen bolt, SS, M6 x 20	2
5	Plain washer, SS	2
6	Hex. nut, SS, M6	2

Figure 3: Tiltmeter on roof

-Extensometer

This is a device that measures the change in length or distance between two points on the dump / highwall. Extensometers can be used to monitor the strain and stress of the slope material. Extensometers can be installed on the surface or inside the boreholes of the dump / highwall to measure the horizontal or vertical movement. Extensometers can provide a precise and sensitive way to monitor the dump / highwall stability. However, extensometers may be affected by temperature or moisture, and it may require regular maintenance.

Problem solving:

1. Which instrument uses a laser beam to create a 3D model of the dump/highwall surface?

a) Continuous real-time monitor

b) Ground-based synthetic aperture radar (GBSAR)

c) Laser scanner

d) Inclinometer

Solution: c) Laser scanner

2. Which instrument provides near real-time feedback and alerts for potential instability?

a) Continuous real-time monitor

b) Optical fiber sensor (OFS)

c) Drone or unmanned aerial vehicle (UAV)

d) Extensometer

Solution: a) Continuous real-time monitor

3. Which instrument uses radar waves to measure surface deformation?

a) Laser scanner

b) Wireless sensor network (WSN)

c) Ground-based synthetic aperture radar (GBSAR)

d) Inclinometer

Solution: c) Ground-based synthetic aperture radar (GBSAR)

4. Which instrument uses sensors or cameras to detect changes in the dump/highwall surface over time?

a) Laser scanner

b) Continuous real-time monitor

c) Drone or unmanned aerial vehicle (UAV)

d) Extensometer

Solution: b) Continuous real-time monitor

5. Which instrument can monitor various parameters such as displacement, tilt, temperature, and humidity?

a) Wireless sensor network (WSN)

b) Optical fiber sensor (OFS)

c) Inclinometer

d) Extensometer

Solution: a) Wireless sensor network (WSN)

6. Which instrument provides a fast and flexible way to monitor the dump/highwall from different angles and heights?

a) Laser scanner

b) Ground-based synthetic aperture radar (GBSAR)

c) Drone or unmanned aerial vehicle (UAV)

d) Inclinometer

Solution: c) Drone or unmanned aerial vehicle (UAV)

7. Which instrument measures the angle or tilt of the dump/highwall?

a) Continuous real-time monitor

b) Inclinometer

c) Laser scanner

d) Extensometer

Solution: b) Inclinometer

8. Which instrument measures the change in length or distance between two points on the dump/highwall?

a) Optical fiber sensor (OFS)

b) Extensometer

c) Ground-based synthetic aperture radar (GBSAR)

d) Wireless sensor network (WSN)

Solution: b) Extensometer

9. Which instrument provides long-term and distributed monitoring using optical fibers?

a) Inclinometer

b) Extensometer

c) Optical fiber sensor (OFS)

d) Continuous real-time monitor

Solution: c) Optical fiber sensor (OFS)

10. Which instrument can be installed on the surface or inside boreholes to monitor dump/highwall stability?

a) Laser scanner

b) Continuous real-time monitor

c) Inclinometer

d) Wireless sensor network (WSN)

Solution: c) Inclinometer

Application of computers in mine surveying and preparation of mine plan, 3D laser profiling of surfaces and bench / slopes.

Computers have become an essential tool for mine surveying, as they can help with various aspects of the process, such as data collection, analysis, display, and interpretation. Some of the applications of computers in mine surveying are:

Application of computers in mine surveying

-Data collection: Computers can be used to collect and store data from various sources, such as field measurements, aerial photographs, satellite images, and geological maps. Computers can also interface with surveying instruments, such as theodolites, total stations, GPS receivers, and laser scanners, to automate the data acquisition and reduce errors.

-Data analysis: Computers can perform various statistical and mathematical operations on the data, such as interpolation, extrapolation, regression, correlation, geostatistics, and optimization. Computers can also apply different models and methods to the data, such as porphyry copper models[2], multivariate analysis[2], operations research methods[2], and trace element analysis. These techniques can help to estimate the parameters of ore deposits, such as grade, tonnage, cutoff value, and profitability.

-Data display: Computers can generate various types of graphical representations of the data, such as maps, charts, diagrams, histograms, scatter plots, and contour plots. Computers can also use different colors, symbols, scales, and projections to enhance the visual appeal and clarity of the data. Computers can also create three-dimensional models and animations of the ore deposits and the mine layout.

-**Data interpretation**: Computers can assist in the interpretation of the data by applying various algorithms and rules to the data, such as pattern recognition, clustering, classification, and decision trees. Computers can also use artificial intelligence and machine learning techniques to learn from the data and make predictions and recommendations.

software applications

There are many different software applications that can be used for mine surveying and planning, depending on the needs and preferences of the mine surveyors. Some of the popular software for mine surveying are:

-Maptek: Maptek is a suite of tools for mine planning and geology surveying and modelling. It includes Vulcan, which is a software for 3D geological modelling, mine design and production planning; DomainMCF, which is a software for resource modelling using cloud processing and machine learning; Laser Scanners, which are hardware devices for capturing point cloud data from industrial survey projects; and PointStudio, which is a software for point cloud processing and modelling.

-GEOVIA Surpac: GEOVIA Surpac is software for integrated geology, resource modelling, mine planning and production. It supports open pit and underground operations and exploration projects in more than 120 countries. It has features such as drillhole data management, geostatistics, block modelling, mine design, resource estimation, and more. It also has multilingual capabilities and can interface with other GEOVIA products, such as MineSched.

-Datamine: Datamine is a software for mining operations that covers various aspects of the mining value chain. It includes Amine, which is a software for underground mine design and surveying; Studio Survey, which is a software exclusively designed for the needs of mine surveyors; Studio UG, which is a software for underground drill and blast design; Studio OP, which is a software for open pit planning and scheduling; and more.

-Carlson: Carlson is a software for land development and mining professionals. It includes Carlson Mining, which is a software for mine design, scheduling, and mapping; Carlson Survey, which is a software for survey data collection and processing; Carlson Civil, which is a software for civil engineering design and documentation; and more.

-Micromine: Micromine is software for exploration and mining operations. It includes Micromine Core, which is a software for geological modelling and resource estimation; Micromine Pit Optimizer, which is a software for open pit optimisation and design; Micromine Scheduler, which is a software for mine scheduling and production control; and more.

-Minex: Minex is software for geological modelling and mine planning for coal and other stratified deposits. It has features such as borehole data management, seam modelling, resource calculation, pit design, dump design, reserve scheduling, reclamation planning, and more.

Computers have revolutionized the field of mine surveying by making it more efficient, accurate, and reliable. Computers have also enabled the integration of different types of data and methods to provide a comprehensive and holistic view of the ore deposits and the mining operations.

3D laser profiling of surfaces and bench / slopes

3D laser profiling is a technique that uses a laser beam to scan the surface of an object and measure its shape, height, and texture. It is often used for machine vision applications, such as inspection, quality control, and metrology. 3D laser profiling can also be used for mine surveying, as it can help to capture the geometry and features of the mine surfaces and benches/slopes.

Some of the benefits of 3D laser profiling for mine surveying are:

- It is a non-contact method, which means it does not damage or disturb the surface being measured.
- It can measure large areas and complex shapes with high accuracy and resolution.
- It can handle different surface materials and colors if they are not too reflective or light-absorbing.
- It can provide real-time feedback and visualization of the data.

Some of the challenges of 3D laser profiling for mine surveying are:

- It requires a stable and calibrated setup of the laser source, the camera, and the angle between them.
- It may be affected by environmental factors, such as dust, smoke, humidity, and temperature.
- It may have difficulty measuring steep slopes or vertical walls, as the laser beam may not reach or reflect from them properly.

Some of the software that can be used for 3D laser profiling for mine surveying are:

- Maptek: Maptek is a suite of tools for mine planning and geology surveying and modelling. It includes Laser Scanners, which are hardware devices for capturing point cloud data from industrial survey projects; and PointStudio, which is a software for point cloud processing and modelling.

-Bruker: Bruker is a provider of 3D optical profilers based on white light interferometry (WLI) technology. It offers various models of benchtop and floor-standing profilers that can measure surface roughness, texture, shape, and dimensions of various samples.

-Clearview Imaging: Clearview Imaging is a supplier of machine vision components and solutions. It offers various types of 3D laser profiling sensors and cameras that can be integrated with software platforms such as Halcon or Sherlock to perform 3D measurement and analysis.

3D laser profiling is a technique that uses a laser beam to scan the surface of an object and measure its shape, height, and texture. It is often used for machine vision applications, such as inspection, quality control, and metrology.

To perform 3D laser profiling, you need a laser source, a camera, and an angle between them. The laser source projects a fixed laser line onto the object's surface, and the camera captures the image of the laser line from a known offset angle. The camera can be mounted on a fixed position or on a moving platform, such as a robot arm or a conveyor belt. The object can also be moved relative to the laser line to scan the entire surface.

The image of the laser line is then processed by software that can calculate the distance between the camera and the object's surface at each point along the line. This is done by using the principle of triangulation, which is based on the geometry of similar triangles. By knowing the angle between the laser source and the camera, and the position of the laser line on the image sensor, the software can determine the height of each point on the object's surface.

By repeating this process for thousands of profiles per second, the software can generate a 3D point cloud of the object's surface, which can be used for various measurements and analysis. For example, you can measure the volume, height, cross section, and planarity of the object. You can also inspect the surface for defects, such as scratches, dents, or holes.

Problem Solving:

1. Which of the following is NOT an application of computers in mine surveying?

a) Data collection

b) Data analysis

c) Data interpretation

d) Data excavation

Solution: d) Data excavation

2. Which software is NOT commonly used for mine surveying and planning?

a) Maptek

b) GEOVIA Surpac

c) AutoCAD

d) Datamine

Solution: c) AutoCAD

3. What is the main advantage of 3D laser profiling for mine surveying?

a) It is a contact method, ensuring accurate measurements.

b) It can measure small areas with high accuracy.

c) It can handle all surface materials and colors.

d) It provides real-time feedback and visualization.

Solution: d) It provides real-time feedback and visualization.

4. Which factor can affect the accuracy of 3D laser profiling?

a) Dust

b) Humidity

c) Temperature

d) All of the above

Solution: d) All of the above

5. Which software is commonly used for point cloud processing and modeling in mine surveying?

a) Maptek

b) Carlson

c) Micromine

d) Bruker

Solution: a) Maptek

6. What is the main principle behind 3D laser profiling?

a) Triangulation

b) Reflection

c) Refraction

d) Diffraction

Solution: a) Triangulation

7. Which component is NOT required for 3D laser profiling?

a) Laser source

b) Camera

c) Angle measurement device

d) Reflective surface

Solution: d) Reflective surface

8. Which software is commonly used for geological modeling and resource estimation in mine planning?

a) GEOVIA Surpac

b) Carlson

c) Minex

d) Clearview Imaging

Solution: a) GEOVIA Surpac

9. What is the main advantage of using computers in mine surveying?

a) Reduced errors in data collection

b) Real-time data interpretation

c) Contactless measurement of surfaces

d) Improved accuracy of laser profiling

Solution: a) Reduced errors in data collection

10. Which technique is NOT commonly used for data analysis in mine surveying?

a) Interpolation

b) Extrapolation

c) Regression

d) Spectroscopy

Solution: d) Spectroscopy

DGMS CIRCULARS IN RESPECT TO PLANS & SECTIONS FROM YEAR 1935-2017

PLANS AND SECTIONS

CMR 58/MMR 60

1. All geological disturbances to be shown on plans accompanying applications—The plans with applications for permission under various Regulations of the Coal Mines Regulations 1957/Metalliferous Mines Regulations, 1961 for making workings beneath houses, roads, railways, rivers, tanks, waterlogged workings etc. sometimes do not show all known geological disturbances. It may be appreciated that in the absence of such details on plans, it is not possible to properly examine the cases. It is therefore requested that henceforth all plans enclosed with applications made under various Regulations should show all geological disturbances. All such plans should bear a clear certificate under Reg.64 of the CMR 1957/Reg. 66 of the MMR 1961 mentioning presence and/or absence of geological disturbances.

(Cir. 44/1971)

2. Standards of accuracy of mine plans and sections : Specifications of Limits of Error— In pursuance of Reg. 58(3) of CMR 1957 and Reg. 60(3) of the MMR 1961, it is hereby required that all plans and sections prepared or submitted in accordance with the provisions of the regulations shall be accurate within the limits of error as specified in the Appendix below.

APPENDIX

SPECIFICATION OF LIMITS OF ERROR

Plans

3.1 *Accuracy of Correlation with Survey of India National Grid*—The positions of the surface reference stations and the centres of all mine shafts at the surface and reference points of underground surveys and also the boundaries of the mine and all surface features required to be shown shall be shown upon the key and Master Plans in their correct positions relative to the Survey of India National Grid within the limits of error of survey and plotting required by this Code (See para 2.3)

3.2 *Plotting Errors*—All surface and underground surveys made and carried out in accordance with this Code shall be plotted on the plan of the mine so that, in the case of a plan on the scale of 1/2,000, all points in the survey are correct by scale to their calculated co-ordinate position within a limit not exceeding 50cm. In case of a plan prepared on the scale of 1/1,000, the corresponding limit of error shall not exceed 25cm.

Surface Surveys

3.3 *Triangulation Station Points*— The position of every station point of triangulation with reference to the point of origin of the survey, calculated from an initial base line (or the Survey of India topo triangulation stations) shall agree with the position of that station point, calculated from a verification base line, within a limit of error not exceeding l/5,000th of the linear horizontal distance of the station point from the point of origin.

3.4 *Traverses*—Every traverse made between station points of a triangulation and/or for the determination of the boundaries of the mine or for the determination of other important surface details, shall be closed Polygonally and shall be made within limits of error as follows :

(i) The total angular error of the traverse shall not exceed 30/n seconds when 'n' is the number of observing stations (including the initial and closing stations).

(ii) The error of closure (calculated by co-ordinates) after distribution of the total angular error shall not exceed 1/3,000th of the sum of the horizontal lengths of thedrafts of the traverse.

Underground Surveys

3.5 *Instruments for Main Road Traverses*—Every traverse made to determine or check the position of an underground survey station or to check the position of the main roadways of a mine shall be made with a theodolite the smallest reading of which does not exceed 20 seconds of arc, and all measurements shall be made with a steel band or steel tape not less than 30 metres in length.

3.6 *Angular Error of Closed Traverses*— The total angular error of any underground traverse or check survey which has been closed polygonally shall not exceed (20+x)/n second in which expression the value of 'n' is 10 seconds or the smallest reading in seconds of sub-division of the circle of the instrument employed (whichever is greater) and 'n' is the number of observing stations.

3.7 *Co-ordinate Error of Closed Traverses*— The error of closure of any underground traverse of check survey which has been closed polygonally (calculated by co-ordinates after distribution of the total angular error) shall not exceed l/2,500th of the sum of the horizontal lengths of the drafts of the traverse.

3.8 *Co-ordinate Error of Open Traverses*—Where an underground traverse has commenced from and closed upon surface reference points upon survey stations of which the co-ordinates have previously been determined, but has not been closed polygonally, the error of closure (calculated by co-ordinates) shall not exceed l/l,500th of the sum of the horizontal lengths of the drafts of the traverse.

3.9 *Subsidiary Surveys*— Subsidiary surveys, to determine the position of any line of face or goaf and the positions or road junctions made between any two stations of check survey, shall have a permissible limit of error of closure by plotting not exceeding l/500th of the sum of the horizontal lengths of the drafts of the survey.

3.10 *Checking Subsidiary Surveys*—Where it is impracticable to maintain underground check survey stations, and/or where subsidiary surveys cannot be closed upon check survey stations, the difference in location of any point on the line of face or goaf as determined by any two or more such surveys shall not exceed 3 metres.

3.11 *Errors of Correlation by Wires*—The correlations of the surface and the underground workings carried out by :

(i) Single wire in each of/two or more shafts,

Or

(ii) two or more wires in a single shaft shall be deemed to be within the required limit of error when the difference in value of the azimuth of any reference line of the underground survey relative to the surface reference base line, as determined by two or more independent series of observations between wires, does not exceed two minutes of arc.

3.12 *Errors of Magnetic Correlation*—The correlation of the surface and underground workings by precise magnetic observations (carried out by magnetic observations on thesurface reference base line and by magnetic observations on not less than two underground observation lines, each tested independently for magnetic attraction, and connected by traverse survey carried within the limit of error required by para 3.7 above) shall be deemed to bewithin the required limit of error when (after distribution of the permissible angular error in thetraverse connecting the underground observation base lines) the difference of azimuth between those base lines so determined agrees with the difference of bearing between the base lines as determined by magnetic observation relative to the surface reference base line, within a limit oferror not exceeding two minutes of arc.

3.13 *Errors of Correlation by Direct Connection*—For the correlation of -the surface and underground workings by direct connections through adits and inclines the traverse connection from, or between the points of reference to the surface shall be carried out within a limit of error required by para 3.7 of the Code, and the correlation shall be deemed to be within the required limit of error when (after distribution of the permissible angular error in the traverse) the values of the azimuth of any underground reference line, relative to the surface reference base line, as determined by any two or more such independent surveys, agree within a limit of errors not exceeding one minute of arc.

Levels

3.14 *Errors of Surface Levels*—The leveling to determine mine surface bench marks shall commence from a railway bench mark and close upon a second railway bench mark within a limit of error not exceeding 2 cm. per km. After Survey of India bench marks are available, the railway bench marks and Survey of India bench marks shall be linked by a leveling within a limit of error not exceeding 2 cm. per km. and thereafter a note shall be made on the plangiving the correction relating to the surface bench mark value with the Survey of India levelingand National Datum lines.

3.15 *Errors for Underground Bench Marks*—The levels of shaft inset bench marks shall be determined by shaft measurements and shall be deemed to be within the required limit of error when any two or more measurements from the surface bench mark to the mine inset bench mark agree within a limit of error not exceeding l/5,000th.

3.16 *Error of Underground Leveling*—All underground leveling made to determine or check the levels of underground bench marks shall close within a limit of error not exceeding l/2,500th of the inclined length of the route of the leveling.

3.17 *Subsidiary Levels*—*In* the case of subsidiary levellings made to determine the level of any point on a line of face or goaf or of any other part of the workings and which are not closed between underground bench marks, the difference in the levels of any such point as determined by any two or more such leveling shall not exceed 50 cm.

SUMMARY OF LIMITS OF ERROR

Plans

Plans on the 1/2,000 scale	50 centimetres
Plans on the 1/1,000 scale	25 centimetres
(i) Triangulation	
Position of stations of the triangulation as determined from initial and verification bases	l/5,000th of the lines horizontal distance of local point of origin.
(ii) Traverses	
Total angular error	30/n seconds
Error of closure	l/3,000th of the horizontal length of the traverse

Underground Surveys

(i) Traverse closed polygonally	
Total angular error	(20+X)/n seconds
Error of closure	l/2,500th the horizontal length of the traverse
(ii) Traverse not closed polygonally but closed upon reference points	
Error of closure	1/1,500th of horizontal length of the traverse
(iii) Subsidiary Surveys	
Error of closure by plotting	l/500th of horizontal length of the traverse
Difference of two or more determinations of any subsidiary points	3 metres

Correlations

By shaft wires	2 minutes of arc
By magnetic observations	2 minutes of arc
By direct connection	11 minutes of arc

Levels

Surface mine bench marks	2 cms. per km.
Inset bench marks	Two or more shaft measurements of established inset bench mark should agree within 1/5,000.
Inbye bench marks	l/2,500th of the inclined length of the leveling.
Subsidiary points	50 centimetres.

(Cir. 20/1966 & Cir. 42/1967)

3. Important Surveys—To comply with the standards of accuracy in preparation of mine plans, it is necessary that all important surface and underground surveys and leveling are done by experienced qualified surveyors themselves.

Examples of important surveys and leveling that should be personally carried out by qualified surveyors :

(a) *Surface Surveys*— Establishment of triangulation base lines.

(b) Underground Surveys—

(1) Main Road Traverses.

(2) Main Road Check Surveys—These should be made when any point of the workings of the mine has advanced at a distance of 500 metres from the previous check survey.

(3) Check surveys for Reference Points.

(4) Check surveys for barriers against waterlogged workings; before abandonment; and on change of ownership or on re-opening etc. as per regulation 65 of the Coal Mines Regulations, 1957.

(5) Correlation of underground and surface surveys.

(6) Joint Surveys.

(c) leveling—

(1) Establishment of surface and underground bench marks.

(2) Levels of workings about to be abandoned.

(3) Subsidence leveling.

(Cir. 28/1966)

4. Use of polyester film for original mine plans—The original mine plans are required to be prepared on mounted paper and tracings on tracing cloth are prepared from the original plans for various statutory purposes.

However, the non-availability of good quality drawing paper mounted on cloth, in the Indian market, through indigenous sources, has been causing concern to the mining industry ingeneral.

The problem was discussed with Director, Survey of India, Eastern Circle, Calcutta, who opined that presently the best medium for preparation and maintenance of plans is the polyestertracing film (which is now being manufactured by some Indian firms), which has betterdimensional stability than best of the mounted paper.

Use should, therefore, be made of polyester tracing film of 125 micro gauge for preparation of original mine plans and of lesser gauge for tracings of various statutory/other plans.

(Cir. Gem.2/1980)

CMR59/MMR61

1. Plans of Old Workings— In some mines the main underground plan does not show the old workings in the seam. This is a serious contravention of the provisions of Reg. 59(1) (b) (ii) of CMR 1957.

The plan maintained under this clause should show the position of all the workings of the seam or section. Failure to do so may result in the advancing galleries holing inadvertently into old workings, causing an inrush of gases or water.

Special attention should therefore be paid to this matter. A remark on the condition of the old workings (viz., date of abandonment or discontinuance, whether full of water or gases, and the reduced levels of the edges of workings, if available) should also be noted on the plan.

(Cir. 6/1955)

2. Joint Survey Plan—The plan kept under Clause (d) of Reg. 59(1) of CMR 1957 shall also on every occasion that the details required under Clause (a) of Reg. 59(4) are brought up-to- date in compliance with the provision of Reg. 58(3), be signed by the surveyor and the manager of the adjoining mine(s) having workings within 60 metres of the common boundary (or where the boundary is in dispute, within 60 metres of the boundary claimed by the owner of the mine concerned) signifying the correctness of the common boundary, or the disputed boundaries, as the case may be, and of the position of the workings in relation to one another.

(Cir. 12/1958)

3. Water Courses to be Re-surveyed— As in several cases the course of jores, nallas and other water courses has shifted to a considerable extent over the past few years from the courseshown on the mine plans, it is necessary that every water course is re-surveyed and correlated with the workings belowground. Wherever any large discrepancy is noticed from the known data, it should be intimated to the J.D.M.S. The report should be accompanied by necessary plans explaining the change. If the re-survey indicates that any new danger has arisen, this should also be clearly indicated in the intimation aforesaid.

(Cir. 44/1959)

1. **Particulars of dams to be shown on plans**— The depth to which the dams are cut into the roof, floor and sides are important dimensions. Similarly, the materials used in the construction of a dam are also important details. These should be shown/indicated on the plan.

(D.G.M.S. Instruction dated 12.8.59)

2. Water Danger Plan— The surface contour lines and underground spot levels etc. and the permanent benchmark required to be shown under Reg. 59(3) of CMR 1957 should be shown on a separate tracing of the underground workings of the mine, which should be kept up-to-date as required under Reg. 58(3)

The plan, which may be called 'Water Danger Plan', shall also show surface drainage system of the mine.

(Cir. 13/1958 & 30/1969)

3. Water Danger Plan: Measures to give warning of danger of inundation—Attention is invited to Circular No. 30 of 1969 regarding maintenance of a separate Water Danger Plan at the mine. This is to amplify that the plan to be so maintained should show the following features to serve the desired purpose of guarding against danger of surface and underground inundation—

(i) the position of the workings below ground; and every borehole and shaft (with depth), including opening, cross-measure drift, goaf, pumping station.

(ii) the general direction and rate of dip of the strata.

(iii) such sections of the seam as may be necessary to show any substantial variation in the thickness or character thereof and show the working section.

(iv) the position of every dyke, fault and other geological disturbance with the amount and direction of throw.

(v) the position and reduced level of permanent benchmark.

(vi) spot levels taken in workings belowground at easily identifiable points e.g.,

(a) along haulage roadways, at every roadway junction except in roadways where tramming is done by manual means in which case spot levels may be shown at points not more than 150 metres apart.

(b) in the case of the headings which have been discontinued either temporarily or permanently also at the end of such headings.

(vii) every source of water such as river, stream, watercourse, reservoir, water-logged opencast workings on the surface, and the outline of all water-logged workings on the belowground lying within 60 metres of any part of the workings measured in any direction.

(viii) every reservoir, dam or other structure, either above or belowground, constructed to withstand a pressure of water or to control an inrush of water, along with reference to its design and other details of construction.

(ix) surface contour lines drawn at vertical intervals not exceeding five metres (or ten metres in the case of a mine where there are no workings belowground or in case of mines situated in hilly terrain, such other larger interval as the J.D.M.S. may permit by an order in writing and subject to such conditions as he may specify) over the whole area lying within 200 metres of any part of the workings.

(x) surface drainage system of the mine.

(xi) the highest flood level of the area.

(xii) warning lines to draw visual attention to dangers of inundation arising out of (a) surface water (b) unconsolidated strata, (c) water bearing strata and (d) underground water.

Note—The distance at which these warning lines may be drawn from the source of danger would vary depending upon the rate of progress of workings in a mine and cannot, therefore,be specifically indicated. This distance should, however, be such as to enable the management to take note of danger well in advance so that necessary permission for working within a statutorily restricted area could be obtained well in time.

2.0 In this context. Article 4 of Code of Coal Mines Surveying Practice recommended by the Technical Committee on Mining Standards in respect of Standards of Accuracy of Mine Plans, appointed by the Government of India, is reproduced in the Appendix, for ready reference and necessary action in respect of additional measures to be taken to give timely warning of danger of inundation.

APPENDIX

Extract from the Code of Coal Mines Surveying Practice
ARTICLE 4: Measures to give Warning of Danger of Inundation

4.1 Responsibility—It is one of the important statutory duties and responsibilities of surveyors to record in a bound paged book 'the full facts when workings of the mine have approached to about 75 metres from the mine boundary or from disused or waterlogged working'. Besides this requirement it is recommended that warning lines should be drawn on plans to draw visual attention to dangers of inundation arising out of—

(i) Surface water
(ii) Unconsolidated strata
(iii) Water-bearing strata, and
(iv) Underground water.

4.1.2 The distance at which these warning lines may be drawn from the source of danger would vary depending upon the rate of progress of workings in a mine, and cannot therefore be specifically laid down, but this distance should be such as to enable the management to take note of the danger well in advance so that necessary permission for working within a statutorily restricted area could be obtained.

4.1.3 The following code of practice requiring measures to be taken for giving warning of danger of inundation are in addition to and not in substitution for any relevant provisions of theCoal Mines Regulations, 1957 or any amendments thereof.

4.2 Workings in the Proximity of Bodies of Water on the Surface or Underground

4.2.1 Location of Bodies of Water—Every effort shall be made to locate and to mark on the underground plan, Manager's plan, Overman's plan and on Water Danger plan, the limits of any surface or underground body of water which may constitute a danger within the boundary of a mine or within 60 metres outside the boundary.

4.2.2 Water in Old Workings—Where old workings exist which may constitute a danger, it shall be assumed, for the purpose of marking the above-mentioned plans, that they contain water until the contrary is proved.

4.2.3 Position of Old Workings—All possible steps shall be taken to ensure that the outline of all old workings, in the same seam or in any other seam within 60 metres (being the shortest distance measured on any direction whether horizontal, vertical, or inclined) thereof are shown correctly on the underground plan, Manager's plan. Overman's plan and Water Danger plan. Such an outline shall be endorsed with the name of seam, reduced level of the water and the date on which such water level was recorded.

All old plans shall be regarded with suspicion until their accuracy has been verified, and every effort shall be made to obtain all existing information about old workings; if there is doubt about the position of old workings, this fact shall be mentioned on the plans.

4.2.4 Warning Line—In addition to showing the outline of any body of water which may constitute a danger, the above plans shall be marked with a green line verged yellow to indicate that any advance beyond that line will bring the workings within a distance of 120 metres of the body of water or such greater distance as may be fixed by the management.

4.2.5 Large Cautionary Zones—If the size of the cautionary zone is such that it covers the whole area of the plan, and no warning line can be shown, the words 'SURFACE WATER' or 'UNDERGROUND WATER' whichever are applicable shall be printed in green large type lettering across the plan, together with a note of the depth and reduced level of the water and its pressure if known.

4.2.6 Statutory Restriction Line—The underground plan, manager's, overman's and water danger plans shall also be marked with a green line verged green at a distance of 60 metres (being the shortest distance measured in any direction whether horizontal, vertical or inclined) from the edge of any body of water to indicate that any advance beyond that line can only be made with the permission of Chief Inspector of Mines.

4.2.7 Check Surveys—When approaching a body of water likely to constitute a danger, check surveys and leveling of the workings shall be carried out when a point has been reached 120 metres, or such greater distance as may be fixed by the management, from the body of water. Wherever possible, there shall be an independent check by a surveyor other than the one normally conducting surveys at the colliery.

4.2.5 *Undersea Workings and Water Bearing Strata*—The foregoing provisions shall not apply to undersea workings ad water-bearing strata which may constitute a danger. These shall receive special consideration by the management.

4.2.9 *Informing the Management*—The surveyor shall inform the manager in writing, of all known facts when approach is being made towards a water cautionary zone. All reservations and doubts which may exist concerning the accuracy of the plans shall be fully explained.

4.3 Workings in the Proximity of Unconsolidated Surface Deposits

4.3.1 Definition of Unconsolidated Surface Deposits—For the purpose of this code the term 'Unconsolidated surface deposits' includes moss, peat, quicksand, and in addition, abandoned opencast workings, sand, gravel, silt, mud and any other fluid matter, other than water, lying above the rock head, and likely to constitute a danger.

4.3.2 Making the Plans—When the geological maps of the area or any investigation or local knowledge indicates the existence of unconsolidated surface deposits within the boundary of a mine or within 60 metres outside it, the limits and nature of such deposits shall be marked on the geological plan, underground plan, manager's plan, overman's plan & water danger plan. The limits so marked shall be endorsed in green large type lettering with the words 'UNCONSOLIDATED DEPOSITS' together with a note of their thickness.

4.3.3 Warning Line— In addition to showing the outline of any body of unconsolidated surface deposit as above, a warning line consisting of a green line verged yellow, drawn in such a position as to indicate that any advance beyond that line will bring the workings within a distance of 120 metres, or ten times the thickness of the seam worked (whichever is the greater) of the unconsolidated surface deposits.

4.3.4 Large Cautionary Zone— If the whole area of the plan is overlaid by unconsolidated deposits and no warning line can be shown, the words 'UNCONSOLIDATED DEPOSITS' shall be printed in green large type lettering across the plan and the thickness of the deposit shall be shown.

4.3.5 Statutory Restriction Line—The underground, manager's overman's, and water danger plans shall also be marked with the green line verged green at a distance of 60 metres (being the shortest distance in any direction whether horizontal, vertical or inclined) from the edge of unconsolidated surface deposits to indicate that any advance beyond that line can only be made with the permission of Chief Inspector of Mines.

4.3.6 Informing the Management—The Surveyor shall inform the manager in writing of the full facts when approach is being made towards a cautionary zone for unconsolidated deposits, and all reservations and doubts which may exist concerning the accuracy of the plans shall be fully explained.

(Cir. Tech. 1/1976)

4. Maintenance of off-set plans of workings beneath surface features—Permissions under 105 and 126 of Coal Mines Regulations, 1957 have been granted for development of workings under different surface features stipulating inter-alias the dimensions of the galleries which may be driven.

The frequency and type of inspections to be made beneath such surface features have been stipulated in DGMS Circular No. 1 of 1960. It is observed (that with the passage of time and spalling from the pillar sides and sometime due to robbing, the dimensions of the galleries increase beyond the permitted limits and the supporting pillars become less in size.

In view of the above managements are requested to prepare and maintain off-set plans on a scale having a representative factor of 500: 1 in respect of all existing workings beneath the surface features and within a distance of 45 metres thereof in case of permissions granted underReg. 105 and within a distance of 15 metres thereof in case of permissions granted under Reg. 126.

The job of completion of the off-set plans, referred to above, shall be completed within one year and the completion report shall be sent to the concerned Director of Mines Safety of the Region and the D.G.M.S.

(Cir. Tech. 11/1982)

5. Scale of mine plans—In exercise of powers under Rg. 55(1) (d) of the Coal Mines Regulations 1957, the D.G.M.S. has required (vide the Directorate's Notification No. 1632 dated 8th Dec., 1980 published in the Gazette of India, Part-11, Section 3(i), G.S.R. 76 dated 17th Jan.. 1981) the owners/agents/managers of all coal mines to prepare and maintain all the new and reconstructed mine plans on a standard metric scale, having representative factor of 2000:1 or 1000:1

(Cir. Legis. 2/1981)

6. Geological Plan—A scale of 16" to a mile (1"-330 ft or a R.F. of 1:3960) is considered suitable for the purpose.

The plans may be made out from the relevant sheets of GSI maps. In case, however, GSI maps on this scale are not available, the smaller-scale GSI maps may be enlarged to this scale. Fuller details of geological features and disturbances etc. should then be filled in, the information being obtained from the field and collected from the locality. All known information should be shown on the plan.

(Cir. 3/1958)

7. Scale of Geological Plan—The Mine Geological Plan may be maintained at a scale having a representative factor of 5000:1 or on any other scale on which the statutory plan showing the workings of the mine is prepared.

(Cir. 65/1964)

CMR 61 / MMR 63

1. Plans of abandoned or discontinued workings— It is very essential to have the up-to-date and complete plans of the abandoned or discontinued workings at a mine in the interest of safety of persons employed in the neighboring mine as well as of the public. Their non- submission constitutes a serious violation and also a continuing offence so long as it is not remedied and complied with. Therefore, correct and up-to-date plans of the discontinued or abandoned workings as required under Reg. 63 of the MMR 1961 shall be submitted.

(Cir. 7/1967)

2. Checklist for Abandoned mine plans under Regulation 61 of CMR 1957— When any mine or seam or section thereof is abandoned or the working thereof has been discontinuedover a period exceeding 60 days, the owner of the mine is required to submit, within 30 days of abandonment or 90 days of discontinuance, to the D.G.M.S. two copies of Abandoned Mine Plans and Sections. These are, in fact, true copies of the up-to-date plan and section of the workings of the mine or part, maintained under Regulation 59(i) (b) and (c) with additional information regarding location of the mine etc.

To cut down procedural delay in processing and recording the AMPS, it is hereby advised that these A.M. Plans be submitted to the Dy. Director-General of Mines Safety of the concerned Zone.

From experience it can be said that at times the plans and sections submitted lack vital details which also raise doubts about their accuracy. Consequently, considerable time andenergy must be spent to get the desired information. To guard against such eventualities in future management is advised to ensure that the plans being submitted are verified for detailsas per the check list given in the appendix.

APPENDIX

Check list for submission a/abandoned mine Plans under Reg. 61 of CMR 1957

1.1 From DGMS/AMP/I

(i) Two copies of the (printed) forms obtainable from the Dy. Director-General of the concerned Zone shall be submitted, duly filled in along with the plans.

(ii) Factual information about all the items in the forms shall be furnished correctly and fully.

1.2 Plans and Sections :

(1) Two copies of the plans/sections shall be submitted on tracing cloth/ polyester tracing film only.

(2) The plans/sections shall be true copies of the original plans/sections, which are being maintained at the mine under Reg. 59(1) (b) and (c) and a certificate to this shall be incorporated on both the sets of tracings. The plans shall, however, show as given below :

2.1 *Reg. 58(1) :*

(a) (i) Name of owner :
(ii) Name of mine :
(iii) Purpose for which the plan/section is prepared.

(b) True north or magnetic meridian with date of the latter :

(c) A scale, at least 25 cms. long and suitably sub-divided.

2.2 Conventions as per second schedule

2.3 Plans to be brought up-to-date before abandonment or at the time of I discontinuance.

3.0 *Reg. 59(1) (b):*

(i) Position of workings, belowground.

(ii) Position of boreholes and shafts (with depth), incline openings, cross-measure drifts,goaves, fire stoppings or seals.

(iii) Every important surface feature within the boundaries such as RIy., road, river, stream, water course, tank, reservoir, opencast working and building which is within 200 mtrs of any parts of the working measured horizontally and H.F.L. of river(s) and stream(s).

(iv) General direction and rate of dip of strata. (v) Sections of the seam(s).

(vi) The position of every fault, dyke, and other geological disturbances with amount of throw and direction.

(vii) (I) an abstract of all statutory restrictions in respect of the working, if any, withreference to the order imposing the same.

(II) end of the workings marked with dotted lines and last date of survey.

4.0 Reg. 56 (1) (c) : Vertical mine sections, where average inclination exceeds 30 degrees from the horizontal.

Reg. 59 (2) : Multi-section workings lying within 9 mtrs. to be shown in different colour on a combined plan separately.

Reg. 59 (3) (a) : Surface contour lines at vertical intervals, not exceeding 5 mtrs.

Reg. 59 (3) (b): Spot levels along all important drivage and at the ends of the headings.

Reg. 59 (3) (c) : Benchmark on the surface in relation to M.S.L.

Reg. 59 (4) (a) (i) Settled and/or claimed boundary of the mine.

(ii) Up-to-date working of all the mines situated within 60 mtrs from the boundary.

5.0 Reg. 61 (1) : Distance and bearing of at least one shaft or opening, in relation. to T.J.P. (Tri-junction-pillar) or any permanent surface features.

Underground spot levels at the end of all workings.

Position of water dam(s) with dimensions and particulars of construction.

6.0 Reg. 64 (2) : A certificate of correctness of the plan (as printed in the original plan).

Reg. 64 (3) : The tracing should bear index No. of the original plan, from which it is traced and should be certified to be a true copy of the original plan by the surveyor and countersigned by the Manager.

7.0 If certain particulars as given above are not shown in the plan due to its nonexistence or non-applicability, certificates to this effect shall also be clearly given on the body of the plan.

(Cir. Legis. 1/1987)

3. Submission of Abandoned Mine Plans under Regulation 63 of MMR 1961— When any mine or in case of a mine to which Reg. 142 applies, any part thereof, is abandoned or the workings thereof have been discontinued for a period exceeding four months, the owner of the mine must submit, within 30 days of abandonment/five months of discontinuance, to the D.G.M.S. two copies of Abandoned Mine Plans and sections. These are in fact, true copies of up-to-date plan and section of the workings of the mine or part, maintained under clauses (b), (c) & (d) of Reg. 61(1), with additional information regarding the location of the mine.

To cut down procedural delays in processing and recording the AMPs, managements are hereby advised to submit these A.M. Plans to the Dy. Director-General of Mines Safety of the concerned Zone.

From past experience it can be said that at times the plans and sections submitted lack vital details which also raise doubts about their accuracy.

Consequently, considerable time and energy has to be spent to get the desired information. To guard against such eventualities in future you are advised to ensure that the plans beingsubmitted are verified for details as per the check list given in the appendix.

Appendix

1.1 From DGMS/AMP/L

(i) Two copies of the (printed) forms obtainable from the Dy. Director General of the concerned Zone/Director General, Dhanbad shall be submitted, duly filled in, along with plans;

ii) Factual information about all the items in the form shall be furnished correctly and fully.

(iii) The owner/agent/manager shall sign the form with name and his designation.

1.2 Plans & Sections :

(1) Two copies of the plans/sections shall be submitted on tracing cloth/ polyester tracing film only.

(2) The plans/sections shall be true copies of the original plans/sections, which are being maintained at the mine under Regulation 61(1) (b) (c) & (d) and certificate to this effect shall be incorporated on both the sets of tracings. The plans shall, however, show as given below :

2.1 Reg. 60 (1)

(a) (i) Name of owner:
(ii) Name of Mine
(iii) Purpose for which the plan/section is prepared.

(b) True north or magnetic meridian with date of the latter:

(c) A scale, at least 25 cms long and suitably sub-divided.

3.0 The plans to be brought up to date before abandonment or at the time of discontinuance.

4.0 Reg. 61 (1) (b):

(i) Position of workings, belowground.

(ii) Position of boreholes and shafts (with depth), drive, cross- cut, winze, rise, excavation (Sloped ground) and every tunnel and air passage connected therewith.

(iii) Pillars or blocks of minerals are left to support of surface features. (iv) Every importantsurface feature within the boundaries such as Rly., road, river, stream, water course, tank;

reservoir, opencast workings and building within 200 mtrs of any part of the workingsmeasured horizontally.

(v) General strike of vein and mineral bed.

(vi) The position of every fault, dyke, and other geological disturbance with amount of throw and direction.
(vii)

(viii) (I) an abstract of all statutory restrictions in respect of the workings, if any withreference to the order for imposing the same,

(II) end of the workings marked with dotted lines and last date of survey.

5.0 Reg. 61 (1)	(c) :	Transverse sections as per requirement.
	(d) :	Vertical sections as per requirement.
	(f) (vi):	Surface contour lines at vertical interval not exceeding 5 mtrs.
	(vii) (I):	the highest flood levels.
	(II) :	benchmark on the surface in relation to M.S.L.
(2)	:	Multi-section workings lying within 10 mtrs. to be shown in different colour on a combined plan.
(3)	(a) (i):	Settled and/or claimed boundary of the mines.
	(ii) :	Up-to-date workings of all the mines situated within 60 mtrs.from the mine boundary
6.0 Reg. 63 (1)	(i) :	Distance and bearing of at least one shaft or opening, in relation to T.J.P. or any other permanent surfacefeature.
	(ii) :	Underground spot levels at the end of all workings.
	(iii) :	Position of water dam(s) with dimensions and particulars ofconstruction.
7.0 Reg. 66 (2)	:	A certificate of correctness of the Plan (as printed in the original plan).
Reg. 66 (3)	:	Every tracing should bear the index No. of the original plan from which it is traced and should be certified to be true copy of the original plan by the surveyor and countersigned by the Manager.

8.0 If certain particulars as given above are not shown on the plan due to its nonexistence or non-applicability, certificates to this effect shall also be clearly given on the body of the plan.

(Cir.Legis. 2/1987)

4. Submission of Abandonment Mine Plan (A.M.P.)— Provisions of Reg. 61 of the Coal Mines Regulations 1957 require submission of plans and sections to the D.G.M.S. within 30 days of abandonment or 90 days of discontinuance of a mine or seam or section thereof. Apart from the statutory requirement, these A.M.Ps. serve useful purpose both for the mine operators and the community.

Unfortunately, the submission of A.M.Ps. has fallen down sharply in the recent past.

NOTIFICATION

Dhanbad, the 1st October, 2018

G.S.R. 973(E).—In exercise of the powers conferred on me as Chief Inspector of Mines, under sub- regulation (3) of Regulation 64 of the Coal Mines Regulations 2017, I, Prasanta Kumar Sarkar, ChiefInspector of Mines, also designated as the Director General of Mines Safety, hereby, specify that all plans and sections prepared or submitted in accordance with the provisions of Coal Mines Regulations, 2017 shall be accurate within the limits of error as specified below:

SPECIFICATIONS OF LIMITS OF ERROR

1.0 Plans

1.1 Accuracy of Correlation with Survey of India National Grid

The positions of the surface reference stations and the centres of all mine shafts at the surface and reference points of underground surveys and also the boundaries of the mine and all surface features required to be shown shall be shown upon the key and Master plans in their correct positions relative to the Survey of India National Grid within the limits of error of survey and plotting as specified hereinafter.

1.2 Plotting Errors

All surface and underground surveys made and carried out in accordance with this Code shall be plotted on the plan of the mine so that, in the case of a plan on the scale of 1/2000, allpoints in the survey are correct by scale to their calculated co-ordinate position within a limit not exceeding 50 centimetres. In case of a plan prepared on the scale of 1/1000, the corresponding limit of error shall not exceed 25centimetres.

2.0 Surface surveys

2.1 Triangulation Station points

The position of every station point of triangulation with reference to the point of origin of the survey, calculated from an initial base line (or the Survey of India topo triangulation stations) shall agree with theposition of that station point, calculated from a verification base line, within a limit of error not exceeding1/5,000th of the linear horizontal distance of the station point from the point of origin.

2.2 Traverses

Every traverse made between station points of a triangulation and / or for the determination of the boundaries of the mine or for the determination of other important surface details, shall be closed polygonally and shall be made within limits of error as follows:

(i) The total angular error of the traverse shall not exceed 30√n seconds where ‘n’ is the number ofobserving stations (including the initial and closing stations).

(ii) The error of closure (calculated by co-ordinates) after distribution of the total angular error shallnot exceed 1/3,000th of the sum of the horizontal lengths of the drafts of the traverse.

3.0 Underground Surveys

3.1 Instrument for Main Road Traverses:

Every traverse made to determine or check the position of an underground survey station or the check theposition of the main roadways of a mine shall be made with a theodolite the smallest reading of which does not exceed 20 seconds of arc and all measurements shall be made with a steel band or steel tape not less than 30 metres in length.

3.2 Angular Error of Closed Traverses

The total angular error of any underground traverse or check survey which has been closed polygonally shall not exceed (20 + x)√n seconds, in which expression the value of ‘x’ is 10 seconds or the smallest reading in seconds of sub-division of the circle of the instrument employed (whichever is greater) and ‘n’ is the number of observing stations.

3.3 Co-ordinate Error of Closed Traverses

The error of closure of any underground traverse of check survey which has been closed polygonally (calculated by co-ordinates after distribution of the total angular error) shall not exceed 1/2500th of the sum of the horizontal lengths of the drafts of the traverse.

3.4 Co-ordinate Error of Open Traverses

Where an underground traverse has commenced from and closed upon surface reference points or upon survey stations of which the co-ordinates have previously been determined, but has not been closed polygonally, the error of closure (calculated by co-ordinates) shall not exceed 1/1,500th of sum of the horizontal lengths of the drafts of the traverse.

3.5 Subsidiary Surveys

Subsidiary surveys, to determine the position of any line of face or goaf and the positions of road junctions made between any two stations of check survey, shall have a permissible limit of error of closure by plotting not exceeding 1/500th of sum of the horizontal lengths of the drafts of the survey.

3.6 Checking Subsidiary Surveys

Where it is impracticable to maintain underground check survey stations, and/or where subsidiary surveys cannot be closed upon check survey stations, the difference in location of any point on the line offace or goaf as determined by any two or more such surveys shall not exceed 3 metres.

3.7 Errors of Correlation by wires

The correlations of surface and underground workings carried out by:

(i) Single wire in each of two or more shafts.

or

(ii) Two or more wires in a single shaft

Shall be deemed to be within the required limit of error when the difference in value of azimuth of any reference line of the underground survey relative to the surface reference base line, as determined by two or more independent series of observations between wires, does not exceed two minutes of arc.

3.8 Errors of Magnetic Correlation

The Correlation of the surface and underground workings by precise magnetic observation (carried out bymagnetic observations on the surface reference base line and by magnetic observations on not less than two underground observation lines, each tested independently for magnetic attraction and connected by a traverse survey carried out within the limit of error required by para 3.3 above) shall be deemed to be within the required limit of error when (after distribution of the permissible angular error in the traverse connecting the underground observation base lines) the difference of azimuth between those base lines so determined agrees with the difference of bearing between the base lines as determined by magnetic observation relative to the surface reference base line, within a limit of error not exceeding two minutesof arc.

3.9 Errors of correlation by Direct Connection

For the correlation of the surface and underground workings by direct connections through adits and inclines the traverse connection from, or between the points of reference to the surface shall be carried out within a limit of error required by para 3.3 of this Code, and the correlation shall be deemed to be within the required limit of error when (after distribution of the permissible angular error in the traverse) the values of the azimuth of any underground reference line relative to the surface reference base line, as determined by any two or more such independent surveys, agree within a limit of error not exceeding oneminute of arc.

4.0 Levels

4.1 Errors of Surface Levels

The levelling to determine mine surface benchmarks shall commence from a railway bench mark and close upon a second railway bench mark or shall commence from a Survey of India bench mark and closeupon a second Survey of India bench mark, within a limit of error not exceeding 2 centimetres per kilometer. After Survey of India benchmarks are available, the railway bench marks and Survey of India benchmarks shall be linked by a levelling within a limit of error not exceeding 2 cm per km, and thereafter a note shall be made on the plan giving the correction relating to the surface bench mark value with the Survey of India levelling and National Datum lines.

4.2 Errors for Underground Benchmarks

The Levels of shaft inset benchmarks shall be determined by shaft measurements and shall be deemed to be within the required limit of error when any two or more measurements from the surface benchmark tothe mine inset benchmark agree within a limit of error not exceeding 1/5,000th.

4.3 Errors of Underground Levelling

All such underground leveling made to determine or check the levels of underground benchmarks shall close within a limit of error not exceeding 1/2500th of the inclined length of the route of the levelling.

4.4 Subsidiary Levels

In the case of subsidiary leveling made to determine the level of any point on a line of face or goaf or of any other part of the workings and which are not closed between underground benchmarks, the difference in levels of any such point as determined by any two or more such leveling shall not exceed

50 cm.

SUMMARY OF LIMITS OF ERROR

1.0 Plans

<u>Plotting errors</u>

Plans on 1/2000 scale	50 cm.
Plans on 1/1,000 scale	25 cm.

2.0 Surface Surveys

(i) <u>Triangulation</u>

Position of stations of the triangulation As determined from initial and origin. Verification bases	1/5,000th of the linear horizontal distance from the local point or

(ii) Traverses

Total angular error	30√ n seconds
Error of closure	1/3,000th of horizontal length of thetraverse.

3.0 Underground Surveys

(i) <u>Traverse closed polygonally</u>

Total angular error	(20+x)√n seconds
Error of closure	1/2,500th of the horizontal length ofthe traverse

(ii) <u>Traverse not closed polygonally but closed upon reference point</u>

Error of closure	1/1,500th of horizontal length ofthe traverse

(iii) <u>Subsidiary Surveys</u>

Error of closure by plotting	1/500th of horizontal length of thetraverse
Difference of two or more determinations metresof any subsidiary points	3

4.0 Correlations

By shaft wires	2 minutes of arc
By magnetic observations	2 minutes of arc

By direct connection	1 minute of arc

5.0 Levels

Surface mine bench marks	2 cms per km
Inset bench marks	Two or more shaft measurementsto established inset bench mark

should agree within 1/5,000.

Inbye bench marks	1/2500th of the inclined length ofthe levelling
Subsidiary points	50 cm.

Managements are requested to ensure submission of A.M.Ps. to the D.G.M.S. within the time frame stipulated in the regulations. In respect of the abandoned mines/seams for which A.M.P. had not been submitted, the same may be done as early as possible.

(Cir. Legis. 3/1992)

CMR 62 / MMR 64

1. Survey instruments and materials—According to Reg. 62 of the Coal mines Regulations, 1957 and the corresponding Reg. 64 of the Metalliferous Mines Regulations, 1961, it is the responsibility of the owner or agent of the mine to "provide accurate and reliable survey instruments and materials for the proper carrying out of all survey and leveling work and for the preparation of the plans and sections required under these regulations; and no other instruments shall be used in connection with any such survey or leveling work". It is noticed that some of the mines have not provided such instruments with the result that the mine surveyors find it difficult to prepare plans accurately. Managements are therefore requested to take necessary corrective actions.

(Cir. 75/1965)

2. Mine Surveyor : Facilities and workload—At several mines inadequate facilities are provided to surveyors to carry out their work. Therefore, the surveyors working at such mines find it extremely difficult to comply with the recommended standards of accuracy.

In addition to their statutory functions, surveyors look after numerous other jobs such as civil engineering works, preparation of bills etc. All these additional jobs leave surveyors with insufficient time to do justice to the important functions for which they are statutorily responsible and liable for penal action.

Now that high quality precision survey instruments are available in the country through indigenous sources, there is no reason why the same cannot be provided.

Further a surveyor shall be provided with due assistance of chainmen in the field and draftsman etc. in the drawing office. Therefore, before fixing the workload of a surveyor in the mine, the facilities, both in respect of instruments and personnel, provided to a surveyor shall be taken into account.

(Cir. 18/1972)

CMR 63

Numbering of plans—The plans submitted along with any application for depillaring, and also those required to be submitted along with other applications made under CMRs should be suitably numbered for future reference.

(Cir. 19/1960)

CMR 66

Winding Arrangements at Second Outlet—In exercise of powers under the proviso to Reg. 66(2) of CMR 1957 it is clarified that the mechanical equipment for winding cannot be considered to be "so installed and maintained as to be constantly available for use" unless—

(a) in case of a steam engine, the steam is available all the time; and

(b) in all cases, a winding engine-man and a banksman are posted at the pit top all thetime, whenever any person is present belowground.

(Cir. 22/1960)

MMR 75

Ladders and platforms—During the past few years number of fatal accidents by falling from the ladderways has been persistently high. In most of the cases, persons fell down from ladders between two platforms 10 to 15 m. vertically apart and fixed to the sides of the shaft by iron spikes, while ascending or descending.

Though the Regulation 75(i) of the Metalliferous Mines Regulations, 1961, stipulates provision of platforms at not more than 15 m intervals where the inclination is more than 30°, and 10m intervals where inclination is more than 60°, it is highly desirable that this vertical interval should be reduced further and platforms may be provided at closer intervals of 3 m.

(Cir. Tech. 6/1978)

Bibliography

1. R, S. (2021, February 15). *Electronic Distance Measurement (EDM)*.
2. *chain surveying*. (n.d.).
3. Khurmi, R. S., & Gupta, J. K. (2007, January 1). *Civil Engineering (Conventional & Objective Type)*.
4. *Survey Stations | Main Stations | Subsidiary or Tie Station*. Civil Engineering Terms (2010, August 31).
5. *Raymond Banerjee (Dead) Through Lrs And Others v. C.J Victor (Dead) And Others, Allahabad High Court, Judgment, Law, casemine.com*. (n.d.).
6. *Modern EDM instruments work on the principle of measuri*. (2023, May 25). Testbook.
7. *What is EDM in survey?* (n.d.). EngineerSupply.
8. *PRINCIPLE OF ELECTRONIC DISTANCE MEASUREMENT & ITS TYPES*. (2022, January 10). VALUER WORLD.
9. *Constants and Conversions*. (n.d.).
10. Deloney, M. L. (2023, August 18). *Difference Between Whole Circle Bearing and Quadrantal Bearing | What Is WCB | What Is QB*. CivilJungle.
11. *Total station - GIS Wiki | The GIS Encyclopedia*. (n.d.).
12. (2023, May 29). *Total Station: Operation, Uses, and Advantages*. Sunder Surveying.
13. *Total station*. (2023, June 16). Wikipedia. https://en.wikipedia.org/wiki/Total_station
14. A., & A. (2023, April 18). *Total Station in Surveying: Types, Uses and Applications*. ConstructionPlacements.
15. *project report on bridge construction*. (n.d.). Scribd.
16. Schmidt, M. O., & Wong, K. W. (1985, January 1). *Fundamentals of Surveying*. Cengage Learning.
17. *The subtense tacheometry method is adopted when the ground i*. (2023, March 30). Testbook.
18. *Tacheometric Surveying- Methods, Detail Procedures*. (n.d.). Civil Engineering.
19. *What is Theodolite? Uses of theodolite in surveying*. (n.d.). Civil Engineering. https://civiltoday.com/surveying/290-what-is-theodolite-uses-of-theodolite-in-surveying
20. *Important Parts of a Theodolite with Functions*. (n.d.). Civil Engineering.
21. Bennett, G. G., & Freislich, J. G. (1979, January 1). *Field Astronomy for Surveyors*.
22. *What is longitude?* (n.d.).
23. *Astronomical Surveying*. (n.d.). BrainKart.
24. *LESSON 14. Computation of area and volume*. (n.d.).
25. Huffman, R. L., Fangmeier, D. D., Elliot, W. J., & Workman, S. R. (2013, January 1). *Soil and Water Conservation Engineering*.
26. *Area and volume_Surveying, Civil Engineering*. (n.d.). PPT.
27. Maurya, P. (2021, October 23). *Theory Of Errors (Type Of Error, Law's Of Weights, Probable Error, Error In Computed Result) | ESE NOTES*. ESE NOTES.
28. CMR- 2017 reg nos:- 53- 64.

29. Walker, J., & Awange, J. (2020, June 6). *Surveying for Civil and Mine Engineers*. Springer Nature.
30. *Correlation survey and depth measurement in underground metal mines*. (n.d.).
31. Anupoju, S. (2017, November 10). *Underground Surveying Methods and Applications*. The Constructor.
32. *Photogrammetry- Surveying*. (n.d.). PPT.
33. *PHOTOGRAMMETIC SURVEYING*. (n.d.). PPT.
34. Kulkarni, K.N. (2020). THE GLOBAL POSITIONING SYSTEM AND ITS APPLICATIONS.
35. *EMERGENCY RESPONDER RADIO COVERAGE (ERRC) | General Survey Of Radio Frequency Bands | PDF4PRO*. (2023, September 4). PDF4PRO.
36. *The direction of a dip in reference of strike is always at w*. (2021, September 29). Testbook.
37. *NCL Mining Sirdar, Surveyor Syllabus* (2022, December 13)*; Exam Pattern PDF*. FreshersNow.Com. https://www.freshersnow.com/ncl-mining-sirdar-syllabus/

Reference

1. R, S. (2021, February 15). *Electronic Distance Measurement (EDM)*. https://civiliansthecreators.blogspot.com/2020/05/edm-surveying.html
2. *chain surveying*. (n.d.). https://amiestudycircle.com/free-samples/amie/chapters/chain%20surveying%20mine%20surveying.pdf/.
3. Khurmi, R. S., & Gupta, J. K. (2007, January 1). *Civil Engineering (Conventional & Objective Type)*.
4. *Survey Stations | Main Stations | Subsidiary or Tie Station*. Civil Engineering Terms (2010, August 31). https://www.civilengineeringterms.com/surveying-levelling/90/
5. *Raymond Banerjee (Dead) Through Lrs And Others v. C.J Victor (Dead) And Others, Allahabad High Court, Judgment, Law, casemine.com*. (n.d.). https://www.casemine.com. https://www.casemine.com/judgement/in/5767b106e691cb22da6d1079
6. *Modern EDM instruments work on the principle of measuri*. (2023, May 25). Testbook. https://testbook.com/question-answer/modern-edm-instruments-work-on-the-principle--61c323e7a7a024a032675fc9#:~:text=Electronic%20distance%20measurement%20(EDM)%20is,of%20up%20to%20100%20kilometers.
7. *What is EDM in survey?* (n.d.). EngineerSupply. https://www.engineersupply.com/EDM.aspx
8. *PRINCIPLE OF ELECTRONIC DISTANCE MEASUREMENT & ITS TYPES*. (2022, January 10). VALUER WORLD. https://www.valuerworld.com/2022/01/10/principle-of-electronic-distance-measurement-its-types/
9. *Constants and Conversions*. (n.d.). https://otadtv.com/tech/constants.html
10. Deloney, M. L. (2023, August 18). *Difference Between Whole Circle Bearing and Quadrantal Bearing | What Is WCB | What Is QB*. CivilJungle. https://civiljungle.com/wcb-vs-qb/
11. *Total station - GIS Wiki | The GIS Encyclopedia*. (n.d.). http://wiki.gis.com/wiki/index.php/Total_station.
12. (2023, May 29). *Total Station: Operation, Uses, and Advantages*. Sunder Surveying. https://www.sundersurveying.com/total-station/
13. *Total station*. (2023, June 16). Wikipedia. https://en.wikipedia.org/wiki/Total_station
14. A., & A. (2023, April 18). *Total Station in Surveying: Types, Uses and Applications*. ConstructionPlacements. https://www.constructionplacements.com/total-station-in-surveying-types-uses-and-applications/#:~:text=A%20total%20station%20is%20an,angles%20to%20%C2%B13%20seconds.
15. *project report on bridge construction*. (n.d.). Scribd. https://www.scribd.com/document/435005866/project-report-on-bridge-construction
16. Schmidt, M. O., & Wong, K. W. (1985, January 1). *Fundamentals of Surveying*. Cengage Learning.

17. *The subtense tacheometry method is adopted when the ground i*. (2023, March 30). Testbook. https://testbook.com/question-answer/the-subtense-tacheometry-method-is-adopted-when-th--5fe0c134394f509a496e5529
18. *Tacheometric Surveying- Methods, Detail Procedures*. (n.d.). Civil Engineering. https://civiltoday.com/surveying/184-tacheometric-surveying
19. *What is Theodolite? Uses of theodolite in surveying*. (n.d.). Civil Engineering. https://civiltoday.com/surveying/290-what-is-theodolite-uses-of-theodolite-in-surveying
20. *Important Parts of a Theodolite with Functions*. (n.d.). Civil Engineering. https://civiltoday.com/surveying/291-parts-of-theodolite
21. Bennett, G. G., & Freislich, J. G. (1979, January 1). *Field Astronomy for Surveyors*.
22. *What is longitude?* (n.d.). https://oceanservice.noaa.gov/facts/longitude.html/
23. *Astronomical Surveying*. (n.d.). BrainKart. https://www.brainkart.com/article/Astronomical-Surveying_4675/
24. *S&L: LESSON 14. Computation of area and volume*. (n.d.). http://ecoursesonline.iasri.res.in/mod/page/view.php?id=1298
25. Huffman, R. L., Fangmeier, D. D., Elliot, W. J., & Workman, S. R. (2013, January 1). *Soil and Water Conservation Engineering*.
26. *Area and volume_Surveying, Civil Engineering*. (n.d.). PPT. https://www.slideshare.net/AshishMakwana1/area-and-volumesurveying-civil-engineering
27. Maurya, P. (2021, October 23). *Theory Of Errors (Type Of Error, Law's Of Weights, Probable Error, Error In Computed Result) | ESE NOTES*. ESE NOTES. https://esenotes.com/theory-of-errors-type-of-error-laws-of-weights-probable-error-error-in-computed-result/
28. CMR- 2017 reg nos:- 53- 64.
29. Walker, J., & Awange, J. (2020, June 6). *Surveying for Civil and Mine Engineers*. Springer Nature.
30. *Correlation survey and depth measurement in underground metal mines*. (n.d.). https://www.slideshare.net/safdar5647/correlation-survey-and-depth-measurement-in-underground-metal-mines
31. *Photogrammetry- Surveying*. (n.d.). PPT. https://www.slideshare.net/gokulsaud/photogrammetry-nec-for-students
32. *PHOTOGRAMMETIC SURVEYING*. (n.d.). PPT. https://www.slideshare.net/kiranshinde1010/photogrammetic-surveying
33. Kulkarni, K.N. (2020). THE GLOBAL POSITIONING SYSTEM AND ITS APPLICATIONS.
34. *The direction of a dip in reference of strike is always at w*. (2021, September 29). Testbook. https://testbook.com/question-answer/the-direction-of-a-dip-in-reference-of-strike-is-a--6017cd31b0ff7cf96f535507#:~:text=DIP%20is%20the%20acute%20angle,each%20other%20on%20a%20map
35. *NCL Mining Sirdar, Surveyor Syllabus* (2022, December 13)*; Exam Pattern PDF*. FreshersNow.Com. https://www.freshersnow.com/ncl-mining-sirdar-syllabus/

FOR ANY CORRECTION/ EDITION/ADDITION WHATSAPP US ON 8804777500

-----THANK YOU—BEST OF LUCK--