

THEORY & OBJECTIVE

SURVEY

*By
Team of
Engineers Academy*

- State Engineering Services Examinations.
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SURVEYING PRINCIPLE'S

THEORY

1.1 DEFINITION OF SURVEYING

Surveying is the science or art of making the measurements necessary to determine or establish the relative positions of points. The points may be on, above or below the surface of the earth. Surveying is done to ascertain and delineate on map or plan the shape and extent of any portion of the earth's surface:

1.2 TYPES OF SURVEYING

Primarily Surveying can be divide into two classes

- (1) Plane Surveying
- (2) Geodetic surveying

(1) Plane Surveying : In plane surveying the curvature of the earth' surface is neglected. The earth's surface is considered plane. The line connecting any two points on the surface of the earth is considered straight line and the angles of polygons as plane angles. This type of survey is adopted when surveys extend over small area.

(2) Geodetic Surveying : This method of survey is adopted when large distances and areas are to be covered. In this survey curvature of the earth is considered in all the measurement taken on the surface of the earth. All the lines in the surface of the earth are curved lines and all the polygons formed on the surface are spherical polygons. This survey is also called trigonometrical survey.

The main characteristics of Geodetic survey

- (a) very large distances and areas.
- (b) use of very precise instruments.
- (c) use of refined method of observation.
- (d) high degree of precision.

1.3 CLASSIFICATION OF SURVEYS

1. Based upon the nature of field of survey

- (i) **Land survey :** This survey work is done on the land only. It can be divided into following types.
 - (a) Topographical surveys
 - (b) City surveys
 - (c) Cadastral surveys : They are also conducted for fixing the position of pathways, properties; transfer of land from one owner to another, boundries of districts, States, Municipalities and even countries are fixed by this survey.
- (ii) Astronomical Survey
- (iii) Marine or Navigational Surveys

2. Based on the Object of Surveying

- (i) Engineering surveys
- (ii) Military surveys
- (iii) Geological surveys
- (iv) Archaeological surveys

3. Based upon the Instruments used

- (i) Chain survey
- (ii) Compass survey
- (iii) Theodolite survey
- (iv) Tacheometric survey
- (v) Photographic survey
- (vi) Aerial survey
- (vii) Levelling

4. Based upon the method employed in survey

- (i) Triangulation survey
- (ii) Traverse survey

1.4 PRINCIPLES OF SURVEYING

(1) In order to fix the location of any point measurements from two reference points whose position are known have to be taken : According to this fundamental, for the location of the relative position, of any point at least two measurements are required from reference points the positions of reference points being already fixed. The two measurements from reference points may be

- (i) linear measurements
- (ii) angular measurements
- (iii) linear and angular measurements.

(2) To work from whole to part : According to this principle of surveying first of all a system of control points is fixed covering whole of area to be surveyed with very high degree of precision.

The object of this system of working is to prevent the accumulation of error and to control and localize the minor errors.

1.5 SCALE

- (1) Engineer's scale :** In this method of representation of scale 1 cm on the plane represents some whole number of meters on the ground.
- (2) Representative Fraction (RF) method :** According to this type of scale one unit length on the plane represents so many units of length on the ground. The ratio of plane distance to the corresponding ground distance is independent of units and is called representative fraction can be very easily found for any given Engineers scale.
- (3) Graphical scale :** The scale may be represented on the plane graphically. It should be represented near the title of the map so that it is clearly visible.

1.5.1 Types of Scales

The scales may be classified under following five heads

(1) Plain Scale : A plain scale consist of a line divided into suitable number of equal parts or unit. The first part is undivided into smaller part. Plain scales represent either two units or a unit and it sub-division such as meters and decimeters miles and furlongs, units and tenths etc.

(2) Diagonal Scale : Diagonal scale is used to read three dimensions such as meters, decimeters and centimeters.

The principle of construction of a diagonal scale is based on the fact that similar triangles have their like sides proportional.

(3) Comparative Scales : Scales having same representative fraction but graduated to read different units are called comparative series. Comparative scales may be plain scales or diagonal scales.

(4) Vernier Scale : Vernier scales are used to read very small units with great accuracy. Vernier scale consists of two parts—a primary scale and a vernier. The primary scale is nothing but plain scale fully divided into minor divisions.

Types of Verniers

Vernier may be divided into two classes

- (a) Direct vernier :** In direct vernier the smallest division on the vernier is shorter than the smallest division on the main scale. In it n divisions of vernier are equal in length to $(n - 1)$ divisions of the primary or main scale.

Since n divisions of vernier are equal to $(n - 1)$ divisions of the main scale

$$nv = (n - 1) s$$

$$v = \left(\frac{n-1}{n} \right) s = \left(1 - \frac{1}{n} \right) s$$

$$\text{Least count (LC)} = s - v = s - \left(\frac{n-1}{n} \right) s = \frac{s}{n}$$

s = value of smallest divisions of main scale.

v = value of smallest divisions on the vernier

n = number of divisions on vernier.

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

- (b) Retrograde vernier :** In retrograde vernier the length of smallest division on the vernier is longer than the smallest division on the main scale. In it n divisions of the vernier are equal in length to $n + 1$ divisions of the main scale.

In this case also $nv = (n + 1)s$

$$v = \left(\frac{n+1}{n} \right) s$$

$$\text{LC} = v - s = \left(\frac{n+1}{n} \right) s - s = \frac{s}{n}$$

(5) Shrunk Scale : If a graphical scale is not constructed on an old map and map has shrunk, it becomes necessary to refine the shrunk scale of the plane so that plane could be correctly interpreted. Representative fraction of the original scale is known. The distance between two points on the map is measured and then compared with the corresponding distance on the map as calculated from the given scale or representative fraction. The ratio of the shrunk length to the true length is known as the shrinkage factors which is obviously less than unity. The shrunk scale is then obtained as follows

$$\text{Shrunk scale} = \text{shrinkage factor} \times \text{original scale of the map}$$

If representative fraction of the original scale is $\frac{1}{1000}$ and shrinkage factor is $\frac{10}{11}$. The representative

fraction of shrunk scale shall be $\frac{10}{11} \times \frac{1}{1000} = \frac{1}{1100}$ i.e. 1 cm = 11 m.

1.6 MEASUREMENT WITH WRONG SCALE

If any measurement on the map has been taken with a wrong scale the distance so measured will be wrong. The true distance and areas can be found by using following relations.

$$\begin{aligned}\text{True length} &= \left(\frac{\text{Wrong scale}}{\text{Correct scale}} \right) \times \text{Measured length} \\ &= \left(\frac{\text{R.F. wrong scale}}{\text{R.F. of correct scale}} \right) \times \text{Measured length}\end{aligned}$$

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

1.7 SOME IMPORTANT DEFINITIONS

(1) **Accuracy** : The degree of perfection obtained in observations, instruments used, and the methods employed, is known as the accuracy. Accuracy depends on the :

- (a) Precision of the instruments used
- (b) Precision of the methods used
- (c) Perfectness of the planning
- (d) Perfectness of the observations

(2) **Error** : The difference between the true value and the measured value of anything is known as the error.

(3) **Discrepancy** : It is the difference between the two measured value of the same quantity. It is not an error. A discrepancy may be small, yet the error may be large. Discrepancy does not reveal the magnitude of systematic errors.

(4) **Precision** : It denotes relative or apparent nearness to the truth and is based upon the refinement of the measurements and the size of the discrepancies.

1.8 SOURCES OF ERRORS

- 1. Natural errors.
- 2. Instrumental errors.
- 3. Personal errors.

1.9 PROBABILITY

Most probable value : It is that value of a quantity which has more chances of being correct than any other quantity. The most probable error is that quantity which when added to and subtracted from the most probable value fixed the limits within which the true value of measured quantity must lie.

Theory of Errors : The probable error of a single measurement is obtained from the equation.

$$PE = \pm 0.6745 \sqrt{\frac{\sum d^2}{n-1}}$$

The probable error of the mean of a number of observations of the same quantity is calculated from the equation.

$$PE_m = \pm 0.6745 \sqrt{\frac{\sum d^2}{n(n-1)}}$$

Principle of least squares : The principle of least squares which is developed from the law of probability, requires adjusting the observed values so as to produce a minimum sum of the squares of the errors (residuals).

Example 1 : A Philadelphia rod has the main scale graduations in centimeters. Design a suitable retrograde vernier to read upto 1 mm.

Solution :

$$\text{Least Count} = \frac{s}{n}$$

Here, $1 = \frac{10}{n} \text{ or } n = 10$

Ten divisions of the vernier should be equal to 11 divisions of the main scale.

Example 2 : A surveyor measured the distance between two points marked on the plan drawn to a scale of 1 cm = 1m (RF = 1 : 100) and found it to be 50m. Later he detected that he used a wrong scale of 1 cm = 50 cm (RF = 1 : 50) for the measurement.

(a) Determine the correct length.

(b) What would be the correct area if the measured area is 60 m² ?

Solution :

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

$$= \frac{1/50}{1/100} \times 50 = 100\text{m}$$

$$\text{correct area} = \left(\frac{1/50}{1/100} \right)^2 \times 60 = 240 \text{ m}^2$$

Example 3 : Design a direct vernier for a theodolite circle having main scale graduations upto 20 minutes (20') if the least count required is 20 seconds (20").

Solution :

$$\text{Least Count} = \frac{s}{n}$$

Here, $20'' = \frac{20 \times 60}{n}, n = 60$

As in the case of a direct vernier, n divisions of the vernier are equal to (n – 1) divisions of the main scale, 60 divisions of the vernier scale should be equal to 59 divisions of the main scale. A length of 59 divisions of the main scale should be taken and divided into 60 divisions to form the vernier scale.

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OBJECTIVE QUESTIONS

1. The required slope correction for a length of 60 m, along a gradient of 1 in 20 is:
(a) 7.50 cm (b) 0.750 cm
(c) 75.0 cm (d) 5.50 cm
2. It is required to produce a small-scale map of an area in magnetic zone by directly plotting and checking the work in the field itself. Which one of the following surveys will be most appropriate for purpose?
(a) Chain (b) Theodolite
(c) Plane table (d) Compass
3. Which of the following scales is the largest one
(a) 1 cm = 50 m
(b) 1 : 42 000
(c) RF = 1/300 000
(d) 1 cm = 50 km
4. The shrinkage factor of an old map is $\frac{24}{25}$ and the RF of original map is $\frac{1}{2400}$, then the corrected scale for the map is
(a) $\frac{1}{2400}$ (b) $\frac{1}{2500}$
(c) $\frac{1}{600}$ (d) $\frac{1}{60000}$
5. The RF of scale 1 cm = 1 km is
(a) $\frac{1}{100000}$ (b) $\frac{1}{10000}$
(c) $\frac{1}{100}$ (d) $\frac{1}{10}$
6. The smallest length that can be drawn on a map is
(a) 0.25 mm (b) 0.5 mm
(c) 10 mm (d) 15 mm
7. The main plate of a transit is divided into 1080 equal divisions. 60 divisions of the vernier coincide exactly with 59 divisions of the main plate. The least count (in seconds) of the transit is
(a) 5 (b) 10
(c) 15 (d) 20
8. The difference in the length of an arc and its subtended chord on earth's surface for a distance of 18.5 km is about
(a) 0.1 cm (b) 1.52 cm
(c) 10 cm (d) 100 cm
9. Surveys which are carried out to provide a national grid of control for preparation of accurate maps of large areas are known as
(a) Plane surveys
(b) Geodetic surveys
(c) Geographical surveys
(d) Topographical surveys
10. Surveys which are carried out to depict mountains, water bodies, hills and other details are known as
(a) Cadastral surveys
(b) City surveys
(c) Topographical surveys
(d) Hydrographic surveys
11. Match the following :
Section-I
(I) Topographical survey
(II) Cadastral surveys
(III) City survey
(IV) Engineering surveys
Section-II
(A) To determine the natural features of a country such as hills, valley, rivers, lakes, etc.
(B) To survey for the features such as roads, railways, canals, buildings, towns, villages, etc.
(C) To locate the boundaries of fields, houses, etc.
(D) To determine quantities and for collection of data for road, railways, reservoirs, sewerage, water supply scheme, etc.
(E) For laying out plots and construction streets, water supply systems and sewers.

- (a) I-A and B, II-C, III-E, IV-D
- (b) I-C, II-A and B, III-C, IV-E
- (c) I-D, II-A and B, III-C, IV-E
- (d) I-B, II-C, III-A, IV-D and E

12. A point R can be located by the two control points P and Q by

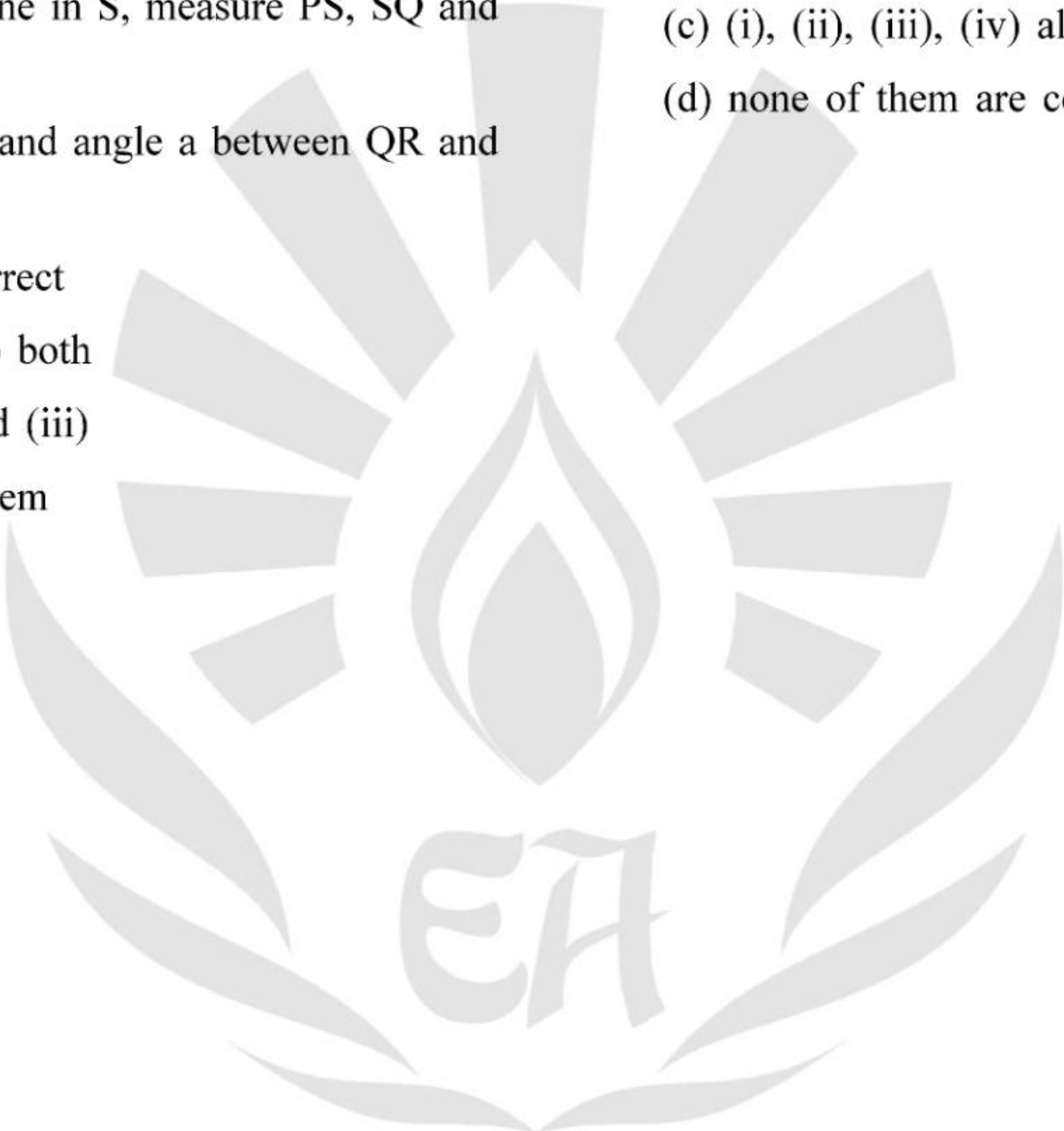
- (i) measuring PR and QR from P and Q, measure distance of R and plot
- (ii) dropping a perpendicular from R on PQ, meeting the line in S, measure PS, SQ and plot
- (iii) distance QR and angle α between QR and QP

- (a) only (i) is correct
- (b) by (i) and (ii) both
- (c) by (i), (ii) and (iii)
- (d) by none of them

13. The objective of a survey is to

- (i) prepare a plan or map
 - (ii) determine the relative position of points
 - (iii) determine position of points in a horizontal plane
 - (iv) determine position of points in a vertical plane
- (a) only (i) is correct
 - (b) only (i) and (ii) are correct
 - (c) (i), (ii), (iii), (iv) all are correct
 - (d) none of them are correct

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ANSWERS EXPLANATIONS1. *Ans. (a)*

Angle of sloping ground is

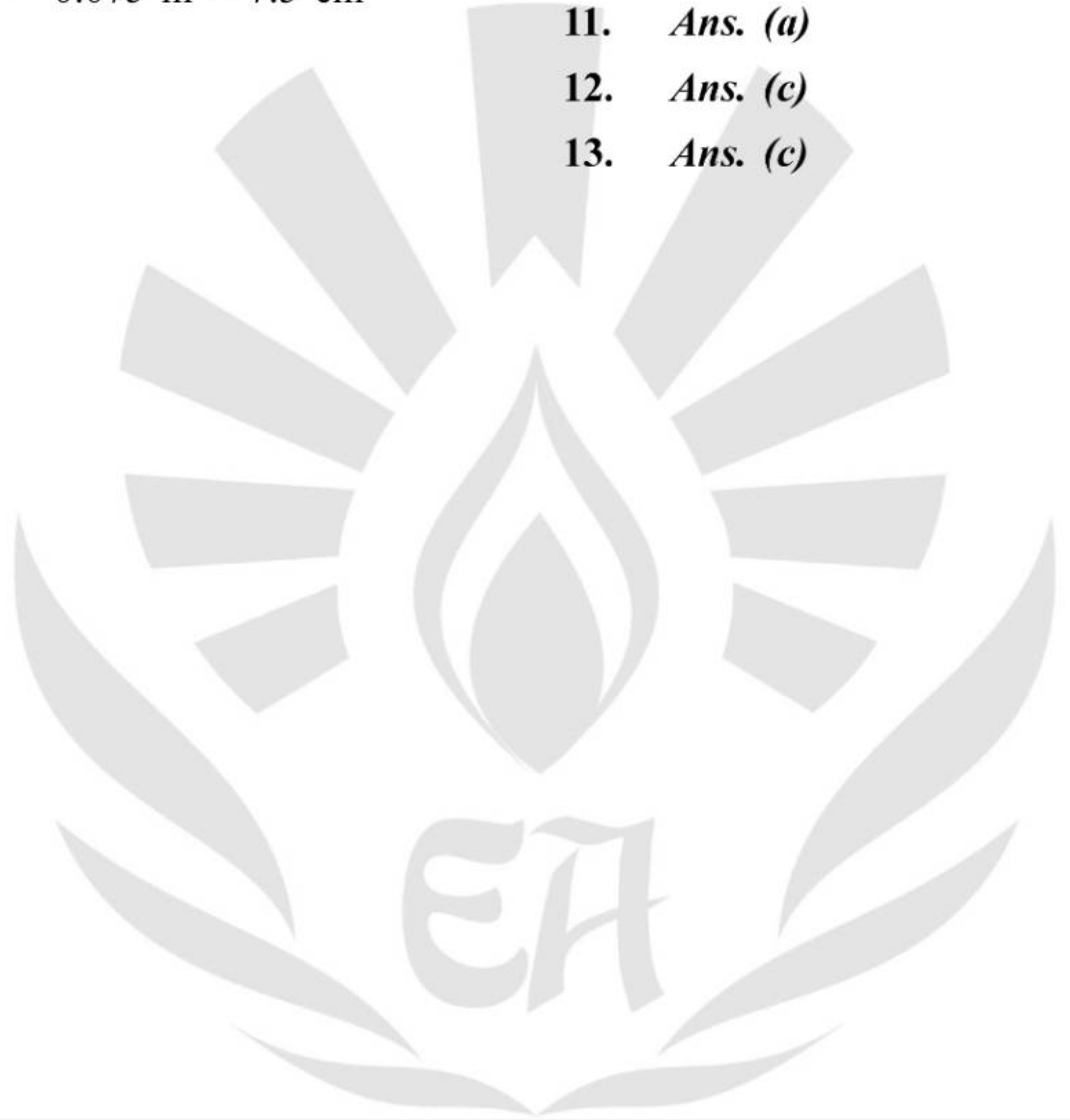
$$= \tan^{-1} \left(\frac{1}{20} \right) = 2.86^\circ$$

Horizontal distance = $60 \times \cos 2.86^\circ$ slope correction is = $60 - (60 \times \cos 2.86^\circ)$

$$= 0.075 \text{ m} = 7.5 \text{ cm}$$

2. *Ans. (c)*3. *Ans. (a)*4. *Ans. (b)*5. *Ans. (a)*6. *Ans. (a)*7. *Ans. (d)*8. *Ans. (b)*9. *Ans. (d)*10. *Ans. (c)*11. *Ans. (a)*12. *Ans. (c)*13. *Ans. (c)*

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DISTANCE MEASURING INSTRUMENTS

THEORY

2.1 MEASUREMENT OF DISTANCE

The various methods of measuring the distances are listed as following

1. Passometer
2. Pedometer
3. Odometer
4. Speedometer
5. Perambulator
6. Chaining.

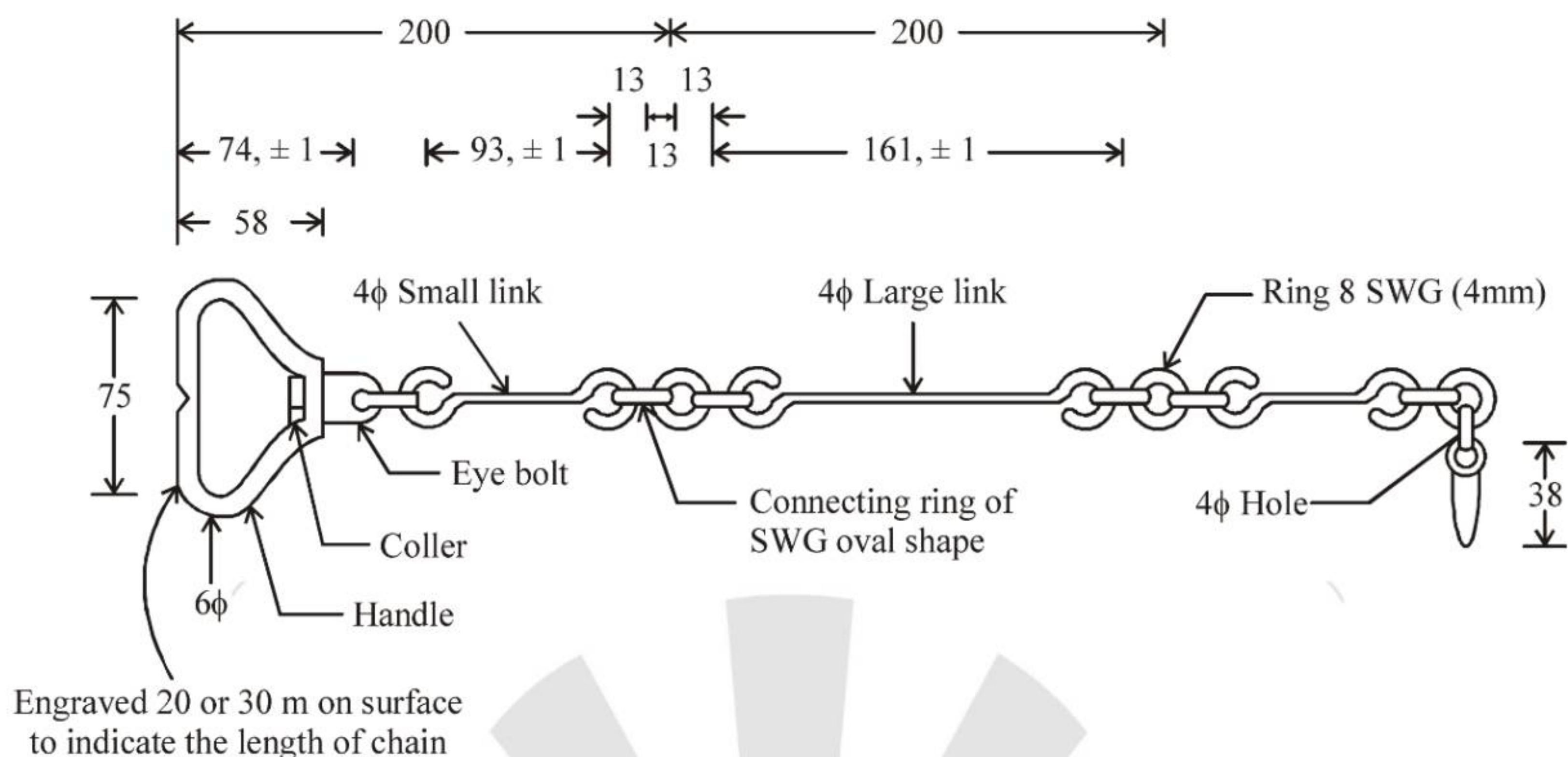
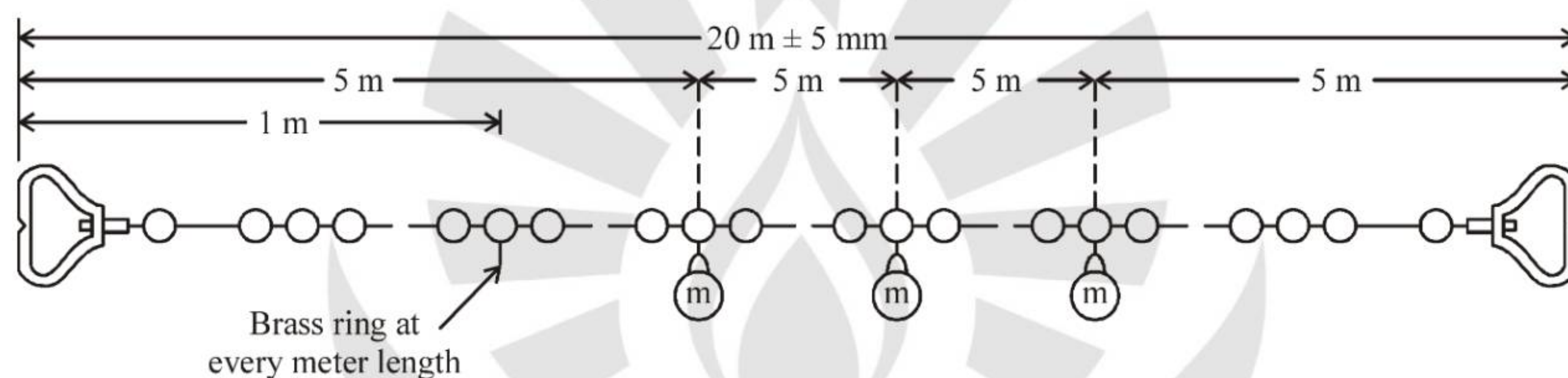
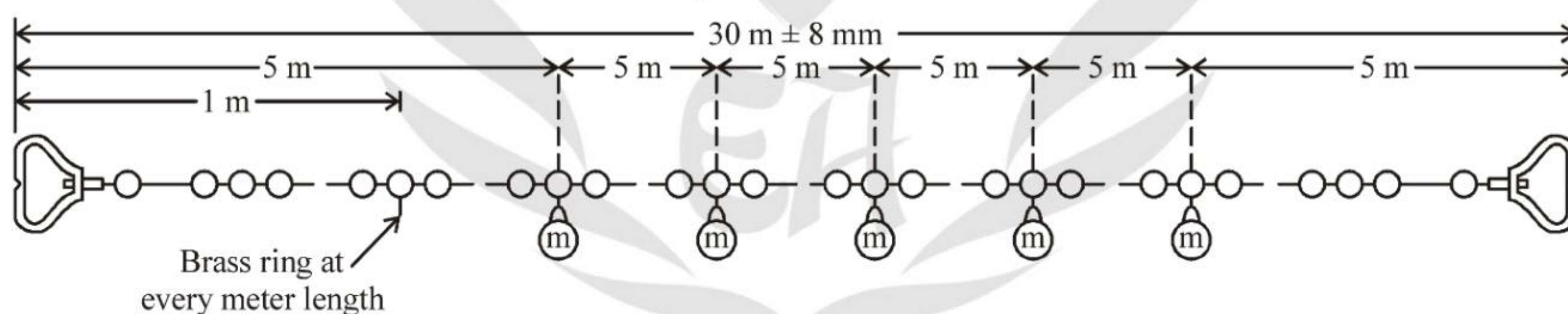
2.1.1 Measuring Distance

Following are the instruments used for measuring the distances :

- (1) Chains
- (2) Tape
- (3) Arrows
- (4) Pegs
- (5) Ranging rods
- (6) Offset rods
- (7) Plasterer's laths and whites
- (8) Plumb bob

(1) Chain : It is made of galvanized mild steel wire having 4 mm diameter. It consists of links. The ends of the links are bent into loops. The links are connected together by means of three oval or circular rings. The rings afford flexibility to the chain and make it less liable to become kinked.

- (a) **Engineer's Chain :** This chain is 100 feet long and has 100 links each one foot in length it is used mostly for Engineer survey and thus named. Engineer's chain. Brass tags are attached at every 10 links. Reckoning from one end of the chain, tags with one notch is attached at 10 links, with two notches at 20 links, with three notches at 30 links with four notches at 40 links.
- (b) **Gunter's chain :** It is also sometimes referred as surveyor's chain. It is 66 ft. long and is divided into 100 links each link being 0.66 ft. It is very convenient for measuring the distances in miles and furlongs. It is equally convenient where area to be measured is in acres. System of tags is similar to that explained for engineer's chain.
- (c) **Revenue chain :** This chain is 33 feet long and has 16 links. It is used for measuring fields in cadastral survey.
- (d) **Metric chain :** Metric chains are used for survey work in India. The metric chains are available in lengths of 5, 10, 20 and 30 meters.

**Fig. : Details of a metric chain****Fig. : 20 m chain.****Fig. : 30 m chain**

(2) Tapes : Tapes are used for the same purpose as the chains. But they are more accurate and easy to handle. The tape is a graduated strip and enclosed in a case of leather or metal. The tapes are classified according to the material they are made of

- Cloth or linen tape :** This tape is not used for engineering surveys. However, it may be used for taking subsidiary measurements like offsets. It consists of 12 to 15 mm wide strip of closely woven cloth, varnished to make it stiff and moisture resistant. It is available in 10 m, 20 m, 25 m and 30 m lengths.
- Metallic tape :** Like linen tape, this tape is also made from varnished strip of water proof cloth. But in this case in order to strengthen the tape, thin brass, copper or bronze wires are interwoven in the strip.
- Steel tapes :** Steel tapes are available in lengths of 1, 2, 10, 20, 30 and 50 m. The tapes of 10, 20, 30 and 50 m lengths are provided with a brass ring at the free end with the help of a metal strip of the same width as the tape. The length of the tape includes the length of the ring also.

(d) **Invar Tape** : This tape is used when survey work has to be conducted with a very high degree of precision as in measurement of base lines in triangulation. Invar is an alloy of steel and nickel and has very low coefficient of thermal expansion (0.0000005 per F) Because of low coefficient of the thermal expansion, effect of temperature change on the length of the tape is almost negligible.

(3) **Arrows** : A bundle of 10 arrows is always issued along with the chain, whenever survey is to be conducted with the help of chain. They are also, sometimes, referred as marking pins or chaining pins.

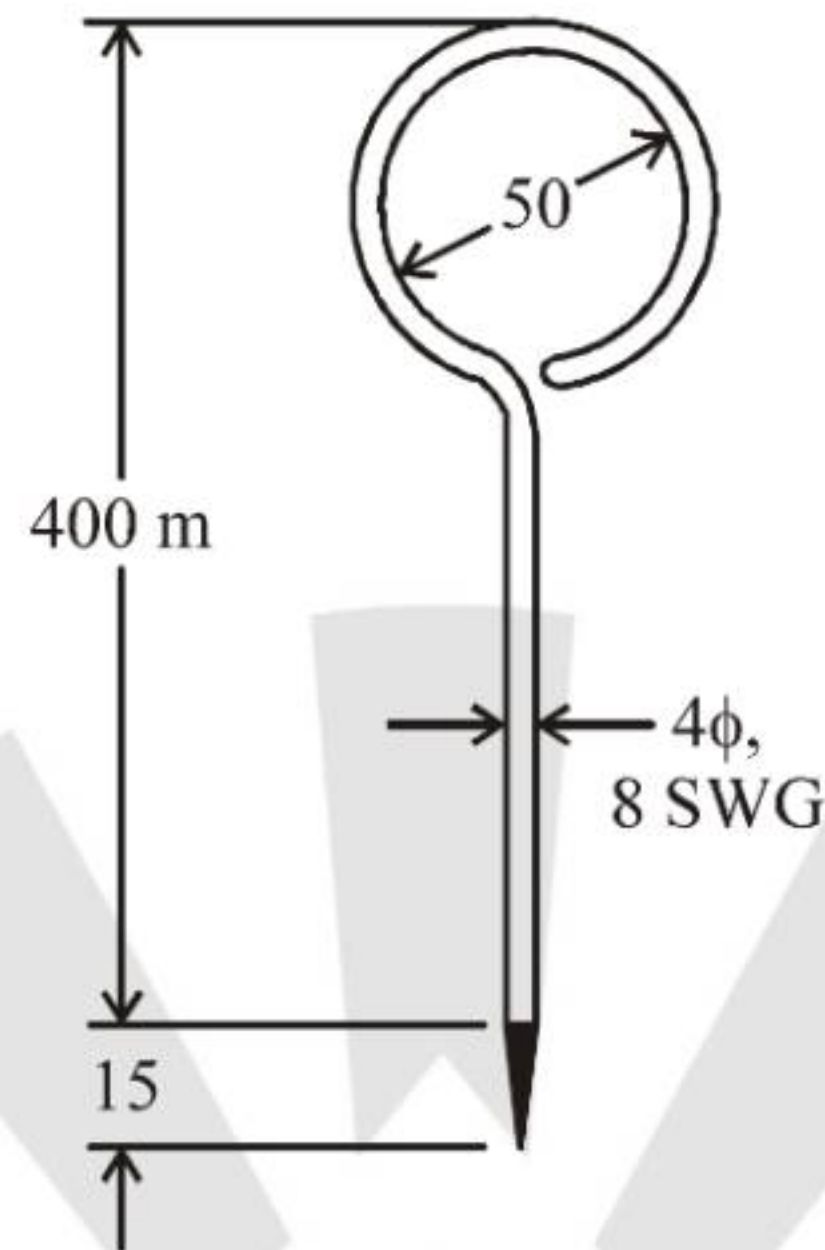


Fig. : Arrows

They are used to mark the end of each chains during the process of chaining.

(4) **Pegs** : Pegs are generally made of timber but they can be made from angle irons also, if situation demands. Pegs are used to mark the positions of survey stations. Wooden pegs are usually 25 cm square 15 cm long for soft ground.

(5) **Ranging Rods** : Ranging rods are used for marking the positions of intermediate points while ranging a survey line. They are circular or octagonal in cross-section and have 3 cm nominal diameter. They are made of well seasoned straight grained timber of Teak, Deodar and Sisham.

(6) **Plasterer's Laths and White** : They are useful for ranging long lines on very undulating ground and also when forward ranging rod is not visible due to obstructions. Crossing of a depression may also require use of laths.

(7) **Plumb Bob** : Plumb bob is made of brass or copper. It is used for transferring points vertically from space to the ground or from ground to space. It is used by suspending in space by means of a thread. It is used for centering most of the survey instruments like, theodolite, plane table, compass etc. It is also used for making ranging poles vertical and transferring points to ground vertically while measuring distances on slopes. It works on the fundamental that any thing suspended freely, in space represents a plumb line or vertical line at that place.

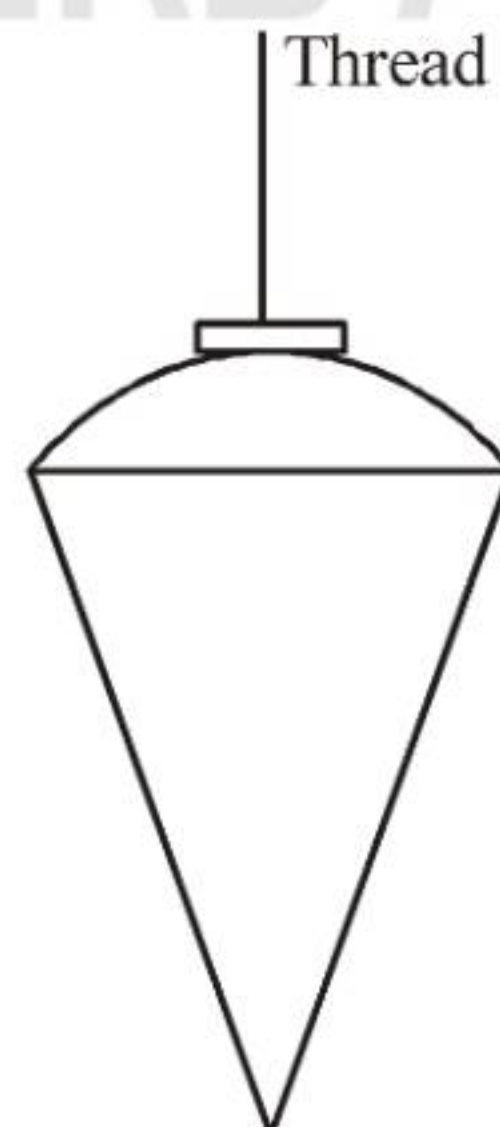


Fig. : Plumb-bob

2.2 CORRECTION TO LENGTH, AREA AND VOLUME

(i) **Correction to measured length :** If the chain is too short, the distance measured by it will be more than the true distance. Similarly if the chain is too long, the distance measured by it will be less than the true distance.

The measured length with the help of wrong chain can be corrected by using formula.

$$\text{True or actual length} = \frac{L'}{L} \times \text{measured wrong length of the line.}$$

or

$$l = \frac{L'}{L} \times l'$$

where L = True or standard length of the chain
 L' = Actual length of the chain of the tape
 l' = Measured length of the line with wrong chain
 l = True length of the line

(ii) **Correction to the measured area :** If some area is measured by an incorrect chain, it can be corrected as follows

$$A = \left(\frac{L'}{L} \right)^2 A'$$

where A = True area
 A' = Measured area.

L and L' carry same meaning as before.

(iii) **Correction to the measured volume :** If erroneous chain has been used to measure volume; it can be corrected as follows,

$$\text{True volume} = \left(\frac{L'}{L} \right)^3 \times \text{Measured volume}$$

L and L' carry same meaning as before.

2.3 TYPE OF ERRORS

- (i) **Cumulative errors :** Time mistakes are also classified as third category of errors. The cumulative errors are those which occur in the same direction and tend to add up.
- (ii) **Compensating errors :** The compensating errors those which are liable to occur in either and hence tend to compensate.

Cumulative errors are serious as they make the apparent measurements too long or too short. Compensating errors do not affect the measurements that much.

The causes of errors may be the following

1. Wrong length of the chain or tape
2. Defective ranging.
3. Careless holding and marking.
4. Not straightening the chain.
5. Undulating and sloping ground.
6. Sag in the chain or Tape.
7. Variation in pull.
8. Personal mistakes.