SURVEYING

CIVIL ENGINEERING

3rd Semester, SBTE BIHAR

(As Per New Syllabus Effective from 2016-2019 Batch)

1st Chapter and 2nd Chapter

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CHAPTER 1

01_TYPES OF SURVEY

1.1 DEFINITION

Surveying is the science and art of determining the relative positions of various points above, on or below the surface of the earth. The relative positions are determined by measuring horizontal distances, vertical distances (elevations), horizontal angles and vertical angles accurately using various surveying instruments. After taking the measurements in the field, computations are done and the plans and maps are prepared in the office. These plans and maps are used for planning of engineering works, marking of boundaries, computations of areas and volumes, and various other purposes.

1.2 OBJECTIVES OF SURVEYING

The basic objective of surveying in engineering are:

1. To determine areas, volume and other related quantities.
2. To prepare plan or map so that it may represent the area on a horizontal plane.
3. To find out vertical distances by means of vertical sections drawn separately or by contour lines, and some other methods.
4. To establish points by predetermined angular and linear measurements.

1.3 PRINCIPLES OF SURVEYING

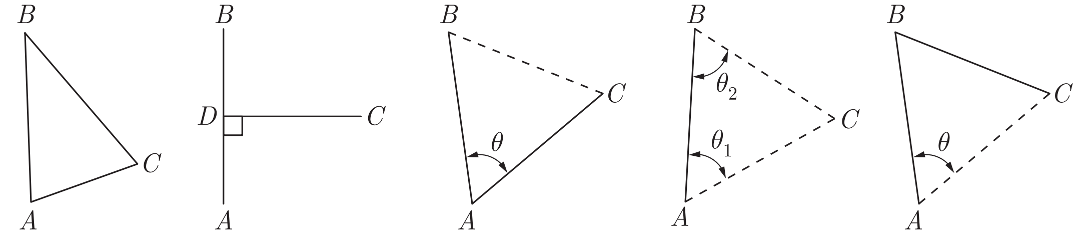
The various methods of surveying are based on following fundamental principal :

1. Fixing a point in relation to points already fixed, and
2. Working from the whole to the part.

1.3.1 Fixing a point in relation to points already fixed

In Fig.1.1, the positions of two points A and B are already fixed. The third point C can be located in relation to A and B, by the following direct approaches:

(a) Measure the distances AC and BC, and locate C as the intersection point of the arcs with centres at A and B.



(a) (b) (c) (d) (e)

Fig. 1.1: Fixing a point in relation to points already fixed

(b) Measure the perpendicular distance CD of C from AB and the distance AD or BD, to locate C.

(c) Measure the distance AC and angle BAC, to locate C.

(d) Measure the angles BAC and ABC, to locate C.

(e) Measure the angle BAC and the distance BC, to locate C.

The plotting of points on drawing sheet is done by scaling the measured distances. The above methods, specially (b), (c), and (d) could also be employed for measuring the relative altitudes.

For a given survey work, depending on the purpose of the survey, the degree of accuracy required, the nature and the extent of the area, and the time available, a surveyor may adopt different combinations of the above approaches and various types of available instruments for fixing horizontal and vertical locations of points.

1.3.2 Working From The Whole To The Part

This is very important principle in surveying. The surveyor should first establish a sufficient number of points with high degree of precision in and around the area to be surveyed. Such points are known as primary control points. The gaps are then filled with a system of secondary control points at closer intervals with slightly less precision. Further gaps are then filled by tertiary control points at even closer intervals and with even less precision. For the surveys which are of ordinary nature, the tertiary control points are used to fix details on the ground. As a rule, the errors in survey details should be too small to plot, while the accuracy of the control points used for plotting the detail must be as high as possible.

The purpose of working from the whole to the part is mainly to localise the errors, i.e., not to magnify, and to control the accumulation of errors.

1.4 USES OF SURVEY

Following are the uses of the surveying :

1. To prepare a topographical map this shows the hills, valley, rivers, villages, town etc. of a country.
2. To prepare a cadastral map showing the boundaries of fields houses, and other properties.
3. To prepare an engineering map to show details like roads, railways, canals etc.
4. To prepare military map showing roads and railways, communication with different parts of country.
5. To prepare contour map and to determine capacity of a reservoirs and ton find the best possible route for roads, railways etc.
6. To prepare archaeological map including places where ancient relics exist.
7. To prepare a geological map showing areas including underground resources.

1.5 CLASSIFICATION OF SURVEYING

Primarily, surveying can be divided into two classes:

(1) Plane Surveying
(2) Geodetic Surveying

Plane Surveying

In this type of surveying the mean surface of the earth is considered as a plane and the spheroidal shape is neglected. All triangles formed by survey lines are considered as plane triangles. The level line is considered as straight and all plumb lines are considered parallel.

Geodetic surveying

In this type of surveying the shape of the earth is taken into account. All lines lying in the surface are curved lines and the triangles are spherical triangles. It, therefore, involves spherical trigonometry. All geodetic surveys include work of larger magnitude and high degree of precision.

Surveys may be classified under following headings which define the purpose of the resulting maps.

1.5.1 Classification Based Upon The Nature Of The Field Survey

Land Surveying

1. **Topographical Surveys :** This consists of horizontal and vertical location of certain points by linear and angular measurements and is made to determine the natural features of a country such as rivers, streams, lakes, woods, hills, etc., and such artificial features as roads, railways, canals, towns and villages.
2. **Cadastral Surveys :** Cadastral surveys are made incident to the fixing of property lines, the calculation of land area, or the transfer of land property from one owner to another. They are also made to fix the boundaries of municipalities and of State and Federal jurisdictions.
3. **City Surveying :** They are made in connection with the construction of streets, water supply systems, sewers and other works.

Marine or Hydrographic Survey :

Marine or hydrographic survey deals with bodies of water for purpose of navigation, water supply, harbour works or for the determination of mean sea level. The work consists in measurement of discharge of streams, making topographic survey of shores and banks, taking and locating soundings to determine the depth of water and observing the fluctuations of the ocean tide.

Astronomical Survey :

The astronomical survey offers the surveyor means of determining the absolute location of any point or the absolute location and direction of any line on the surface of the earth. This consists in observations to the heavenly bodies such as the sun or any fixed star.

1.5.2 Classification Based On The Object Of Survey

1. **Engineering Survey:** This is undertaken for the determination of quantities or to afford sufficient data for the designing of engineering works such as roads and reservoirs, or those connected with sewage disposal or water supply.
2. **Military Survey :** This is used for determining points of strategic importance.
3. **Mine Survey :** This is used for the exploring mineral wealth.
4. **Geological Survey :** This is used for determining different strata in the earth's crust.
5. **Archaeological Survey :** This is used for unearthing relics of antiquity.

1.5.3 Classification Based On Instruments Used

An alternative classification may be based upon the instruments or methods employed the chief types being:

1. Chain survey
2. Theodolite survey
3. Traverse survey
4. Triangulation survey
5. Tacheometric survey
6. Plane table survey
7. Photogrammetric survey and
8. Aerial survey

1.5.4 Classification Based on the Methods Employed

Based on the methods employed, surveying may be classified as triangulation and traversing.

1. **Triangulation:** In this method control points are established through a network of triangles.
2. **Traversing:** In this scheme of establishing control points consist of a series of connected points established through linear and angular measurements. If last line meets the starting point it is called as closed traverse. If it does not meet, it is known as open traverse.

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REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS

1.1 The object of surveying is to procedure a

(a) Drawing (b) Cross- section

(c) Sketch (d) Map

Ans. (d) Map

1.2 In surveying the measurement are taken in-

(a) Vertical plane

(b) Inclined plane

(c) Horizontal plane

(d) Vertical and Horizontal plane

Ans. (c) Horizontal plane

1.3 The main principle of surveying is work from-

(a) Part to whole (b) Whole to part

(c) Lower to higher level (d) Higher to lower level

Ans. (b) Whole to part

1.4 The relative elevation of points is determined by :

(a) Plane table survey

(b) Geodetic surveying

(c) Levelling

(d) Compass surveying

Ans. (c) Levelling

1.5 The curvature of the earth is not considered in

(a) Plane surveying

(b) Geodetic surveying

(c) Hydrographic surveying

(d) Ariel surveying

Ans. (a) Plane surveying

1.6 Curvature of earth is considered in :

(a) Plane surveying

(b) Geodetic surveying

(c) Compass surveying

(d) Survey in small area

Ans. (b) Geodetic surveying

1.7 Strata of earth crust is determined by :

(a) Mine survey

(b) Military survey

(c) Archaeological survey
(d) Geological survey

Ans. (d) Geological survey

1.8 Surveys which are carried out to depict mountains, valleys, rivers, forest and other details of a country are known as
(a) Cadastral surveys
(b) Engineering surveys
(c) Mine surveys
(d) Topographical surveys

Ans. (d) Topographical surveys

1.9 The curvature of the earth is taken into account when the extent of the area is more than
(a) $50\,km^2$ (b) $100\,km^2$
(c) $250\,km^2$ (d) $750\,km^2$

Ans. (c) $250\,km^2$

1.10 Hydrographic survey deals with mapping of-
(a) Canal system
(b) Mountainous region
(c) Large water bodies
(d) Movements of clouds

Ans. (c) Large water bodies

1.11 The method of plane surveying can be used when the extent of area is less than
(a) $250\,km^2$ (b) $500\,km^2$
(c) $2500\,km^2$ (d) $5000\,km^2$

Ans. (a) $250\,km^2$

1.12 Plan is a graphical representation of the features on large scale as projected on
(a) Horizontal plane
(b) Vertical plane
(c) In any plane
(d) None of the above

Ans. (a) Horizontal plane

SHORT QUESTIONS

LONG QUESTIONS

NUMERICAL QUESTIONS

CHAPTER 2

02_CHAIN AND CROSS STAFF SURVEY

2.1 PRINCIPLE OF CHAIN SURVEY

Chain surveying is the simplest method of surveying. Because in this method only linear measurements are-made and no angular measurements are taken. The area to be surveyed is divided into a number of triangles, and the sides of the triangles are directly measured in the field as shown in Fig. 2.1. Since a triangle is a simple plane geometrical figure, it can be plotted from the measured lengths of its sides alone. In chain surveying, a network of triangles is preferred.

Preferably, all the sides of a triangle should be nearly equal having each angle nearly 60° to ensure minimum distortion due to errors in measurement of sides and plotting. Generally, such an ideal condition is practically not possible always due to configuration of the terrain and, therefore, attempt should be made to have well-conditioned triangles in which no angle is smaller than 30° and no angle is greater than 120°. The arrangement of triangles to be adopted in the field, depends on the shape, topography, and the natural or artificial obstacles met with.

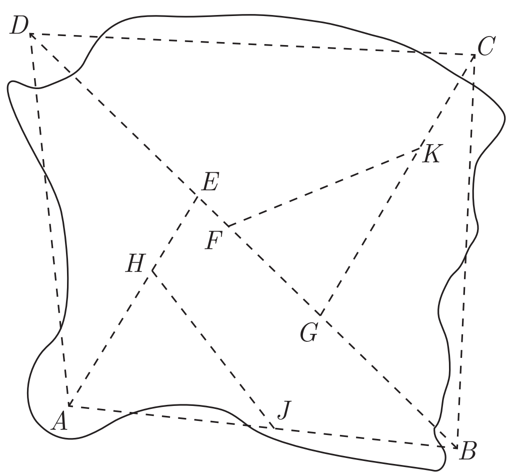


Figure 2.1:

Chain surveying equipment may be classified as those for linear measurements, those for measuring right angles, and miscellaneous items.

2.1.1 Chain

This is made of 100 to 150 pieces called links. Link is made of galvanised, mild steel wire, 8 SWG (4 mm diameter) to 12 SWG. The ends of each link are bent into loops and connected together by three oval or circular rings which make the chain flexible. The ends of the chain have brass handles with swivel joints and the total length is measured from one handle end to the other. The length of a link is the distance between the centres of two consecutive middle rings; the end links include the handles. Metallic tally markers indicate distinctive points along the chain, say every 5 m, to facilitate quick reading of fractional parts. The survey chain is robust, easily read, and easily repaired in the field.

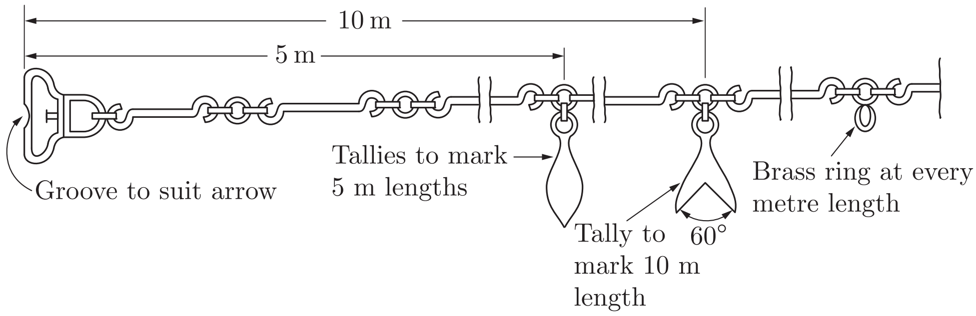


Figure 2.2: 20-metre chain (100 links)

2.1.2 Tapes

Tapes may be made of following material :

1. **Linen :** The linen tape is a painted and varnished strip of woven linen about 15 mm wide. It is attached to a spindle in a leather case into which it is wound when not in use. The linen tape is subject to serious variations in length, and is fragile, hence it is not used for precise measurements.
2. **Metallic :** The metallic tape is actually a linen tape into which copper or brass wires are woven to increase strength and enhance consistency in length. This is only partially successful.
3. **Invar Alloy :** For high precision work, a tape made of the alloy invar is used. This is an alloy of steel with 36% nickel.

2.1.3 Ranging Rods

Ranging rods mark the positions of stations which are clearly visible. They are also used to set out ranging lines. They are generally made of well-seasoned wood of circular cross-section, about 30 mm wide and 2 m to 3 m long. A pointed steel shoe at the bottom facilitates fixing the rod into the ground.

They are painted with characteristic red and white bands for visibility. A tripod is used to support the rods on hard or paved ground. When the rods are located far away, flags fastened at the top increase their visibility.

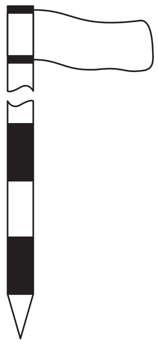


Figure 2.3: Ranging rod

2.1.4 Pegs

Pegs are used to mark definite points on the ground either temporarily or semi-permanently. Wood pieces, tapered at one end, are commonly used. They are driven into the ground to mark stations. They are about 2.5 cm square and 15 cm long. Pegs are usually made of hard, well seasoned treated (creosoted) wood; alternatively iron pegs or long wire nails can be used.

2.1.5 Arrows

To mark the ends of chain lengths and to record the number of times a chain is laid in measuring a line, a set of marking pins or arrows is used. The set commonly consists of ten arrows made of iron or steel wire, preferably of heavier section than the chain and about 30–45 cm long. The section is pointed at one end to facilitate thrusting into the ground; the other end is bent to form a ring for convenient carrying.

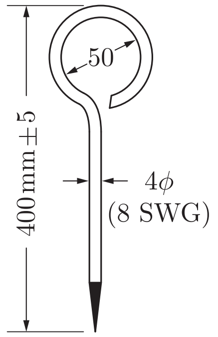


Figure 2.4: Arrow

2.1.6 Offset rods

An offset rod is similar to a ranging rod. It is used to measure short offsets. It is 3 m long and subdivided into bands of 0.2 m. It has an iron shoe at one end and a notch or hook at the other. The hook facilitates pulling the chain through hedges or other obstructions. The rod is also provided with two narrow slots passing through the centre of the section at eye level, set at right angles to each other, to align the line of offset.

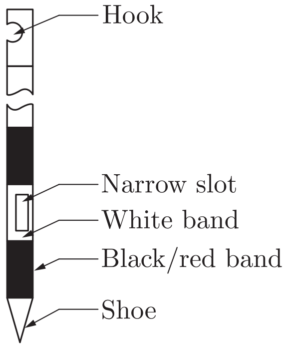


Figure 2.5: Offset rod

2.1.7 Line Rangers

The line ranger establishes intermediate points on a straight line joining two distant points without having to sight from one of them. It consists of two reflecting surfaces (plane mirrors or square prisms) arranged one above the other, with their reflecting surfaces normal to each other.

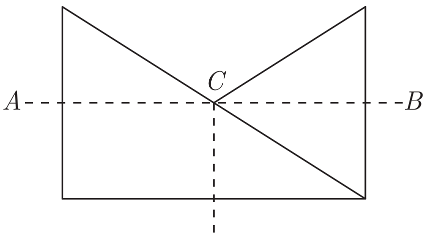
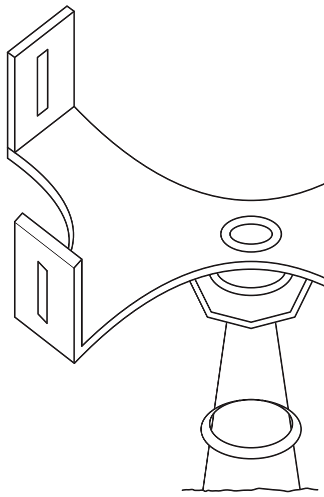


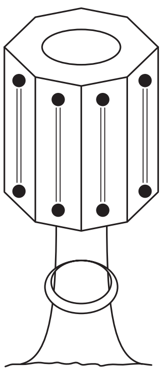
Figure 2.6: Line ranger

2.1.8 Cross-staff

Cross staff is a simple device to set out right angles. If consists of a piece of wood or other material shaped like a cross. It is mounted on a pole with a pointed metallic shoe to fix it in the ground. Two pairs of vertical slits yielding two lines of sight are arranged at right angles on it. One line of sight is arranged to be along a known line, and the perpendicular line of sight is determined by the other pair of vanes, facilitating the fixing of a ranging rod at a reasonable distance. Another form of cross-staff consists of a hollow octagonal box with pairs of slits on opposite faces. It is possible to set both 45° and 90° angles with it. The two types are shown in Figures. 2.7 (a) and 2.7 (b).



(a) Vane form



(b) Prism form

Figure 2.7: Two forms of cross-staff

2.1.9 Optical Square

It is a compact, hand-held instrument to set out right angles more accurately than with the cross-staff. A ray of light reflected successively from two surfaces undergoes a deviation of twice the angle between the reflecting surfaces. Two mirrors at 45° to each other are mounted in a circular box or open frame, as shown in Figure 2.8.

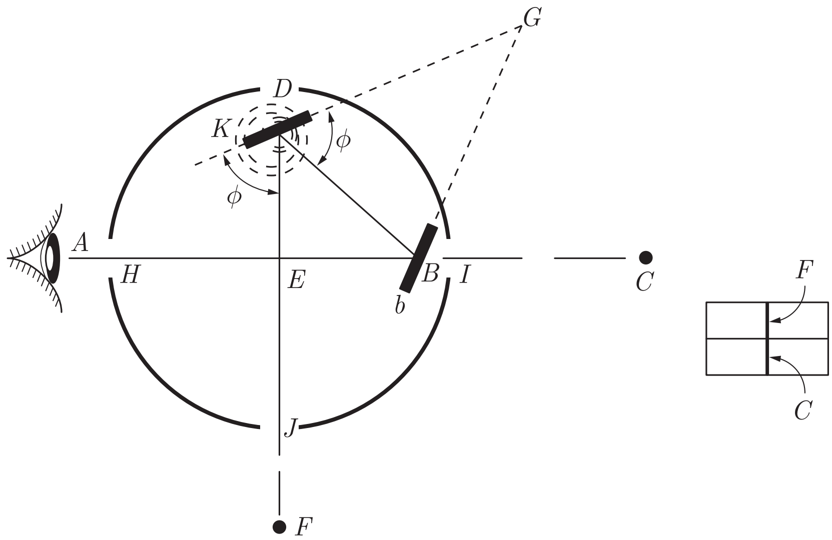


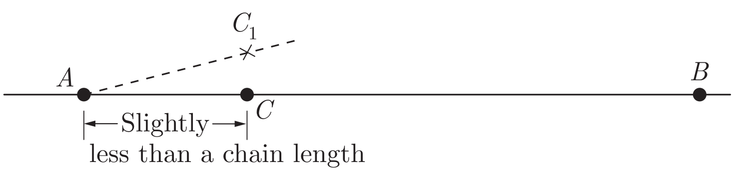
Figure 2.8: Schematic of an optical square

2.2 RANGING

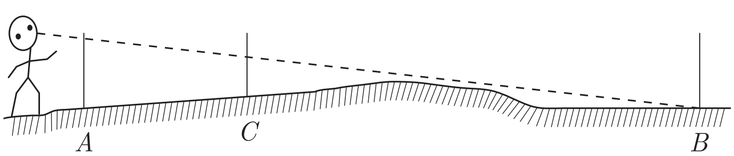
When survey line is longer than a chain length, it is necessary to align intermediate points on survey line. The process of locating intermediate points on survey line is known as ranging. The methods of ranging are classified as direct ranging and indirect ranging.

2.2.1 Direct Ranging

This is possible, if the first and last points on the survey line are intervisible. Fig. 2.9 shows the end points A, B in a survey line which are intervisible. Now it is necessary to locate point C on line AB, which is slightly less than a chain length from A. It needs two persons. At points A and B ranging rods are erected. The assistant of survey positions himself as close to line AB as possible at a distance slightly less than a chain length and holds a ranging rod. The surveyor positions himself approximately 2 m behind A and sights ranging rods at A and B. He directs the assistant to move to the left or right of line AB till he finds the ranging rods at A, B and C in a line. The surveyor should always observe at lower portion of the ranging rods. The signals used in instructing the assistant at C while ranging are shown in Table 2.1



(a) Plan view



(b) Sectional view

Figure 2.9: Direct ranging

Table 2.1 : Signals used in instructing assistant in ranging

S.No.	Signals by Surveyor	Instruction to Assistant
1.	Rapid sweep with right hand	Move considerably to right
2.	Slow sweep with right hand	Move slowly to the right
3.	Right arm extended	Continue to move to right
4.	Right arm up and moved to the right	Plumb the rod to right
5.	Rapid sweep with left hand	Move considerably to left
6.	Slow sweep with left hand	Move slowly to the left
7.	Left arm extended	Continue to move to left
8.	Left arm up and moved to the left	Plumb the rod to the left
9.	Both hands above head and then brought down	Correct

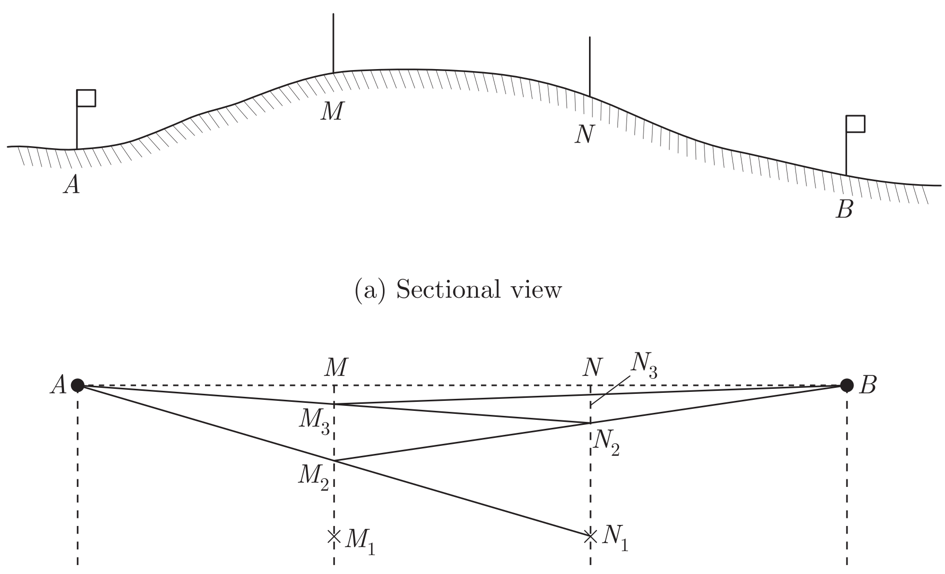
10.	Both arms extended forward horizontally and hands depressed briskly	Fix the rod

NOTE :
1. Arms should be fully extended clear of the body.
2. Coloured handkerchief may be held in hand if distances are more.

2.2.2 Indirect Ranging

If the two end points of the line to be measured are not intervisible, the surveyor has to go for indirect ranging. This is also called reciprocal ranging. The invisibility of points may be due to unevenness of the ground or due to long distance. Fig. 2.10 (a) shows cross-section of the ground which is a typical case of invisibility of point B of the line from point A. Fig 2.10 (b) shows the plan. M and N are the two points to be fixed or AB such that both points are visible from A as well as B. It needs four people to fix points M and N one person near each point A , B, M and N.

The persons at M and N position themselves near M and N say at M_1 and N_1. First person at A directs the person at M to come to M_2 so that AM_2N_1 are in a line. Then person at B directs the person at N_1 to move to N_2 so that BN_1M_2 are in a line. In the next cycle again person at A directs the person to M to move to M_3 such that AM_3N_2 are in a line which is followed by directing person at N_2 to move to N_3 by person at B. The process continues till AM NB are in a line.



(a) Sectional view

(b) Plan view

Figure 2.10: Indirect/Reciprocal Ranging

2.3 CHAINING ON PLAIN GROUND

Let us suppose that it is necessary to measure the distance AB by chain surveying. The number of persons normally required would be four, namely, leader, follower and two assistants. The leader is holding the front handle of the chain while the follower is holding the back handle of the chain. The duties of leader include pulling the chain in forward direction, inserting arrows at the end of every chain, etc. The duties of follower include picking of arrows, instructing the leader, etc. The process of chaining on plain ground will be carried out as follows:

1. The stations A and B are fixed and ranging rods are erected at intermediate stations P and Q by ranging, as shown in Fig. 2.11.
2. The follower throws the chain roughly along the line AP.
3. The leader, with 10 arrows and handle of chain in his hands, moves along the chain and during walking, he observes the chain for bent links, open joints or knots.
4. After reaching near the end of the chain, the leader gets instructions from the follower and he stands in line with AP.
5. The leader makes the chain straight with slow jerks and at this time, the follower should make suitable arrangements on his side such that his end does not move.
6. The leader fixes the arrow at the end of chain.
7. The leader then taking the chain starts walking further and the follower starts moving in the direction AP.
8. On reaching near the arrow, the follower shouts **chain** so that the leader stops moving further.
9. The procedure is repeated until point B is reached.

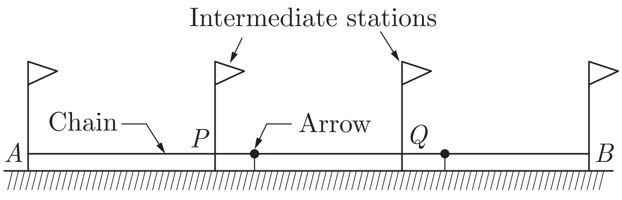


Figure 2.11: Chaining on plain ground

Points to be Observed During Chaining on Plain Ground

Following points should be carefully observed during the process of chaining on plain ground:

1. **Folding and unfolding of chain:** The chain should be carefully folded and unfolded. Generally, two handles are kept in right hand and the chain is thrown by the follower. Then, the leader takes one of the handle and starts moving.
2. **Number of arrows:** The leader inserts the arrow at the end of measured chain length and the follower collects the arrow thus inserted by leader. Hence, the sum total of arrows held by follower and leader should always be equal to the arrows taken in the beginning by leader which is usually ten. Thus, the arrows possessed by leader and follower provide a useful check during chaining.
4. **Reading the chain:** The fractions of chain should be read very carefully as there are identical tags for 1 m and 9 m; 2 m and 8 m; 3 m and 7 m; 4 m and 6 m. Hence, it should be seen whether the tag is in front or on the

back of the central tag.

5. **Testing and adjusting chain:** The chain should be tested and adjusted for correct length before starting the chaining. If it is found afterwards that the length was measured by a wrong chain, the corrections should be applied in the following manner:

$$\text{True length of line} = \frac{L_1}{L} \times \text{measured length of line}$$

$$\text{True area} = \left(\frac{L_1}{L}\right)^2 \times \text{measured area}$$

$$\text{True volume} = \left(\frac{L_1}{L}\right)^3 \times \text{measured volume}$$

where L = True length of chain

e = Elongation or shortening of chain

L_1 = Incorrect length of chain

$= L + e$, if chain is long

$= L - e$, if chain is short

2.4 CHAINING ON SLOPING GROUND

If the ground has a slope upto about 3°, it is treated as a flat or a level ground. But if the slope of ground exceeds 3° or say 1 in 20, it becomes essential to work out the corresponding horizontal distances of sloping ground because the distances required for plotting are the horizontal distances.

Following are the two commonly used methods :

1. Direct method of chaining
2. Indirect method of chaining

2.4.1 Direct Method of Chaining

This is method horizontal distances are measured directly by stepping. Thus this method is also known as stepping. Let us suppose that the distance PQ, as shown in Fig. 2.12, is to be measured by this method. The procedure will be as follows:

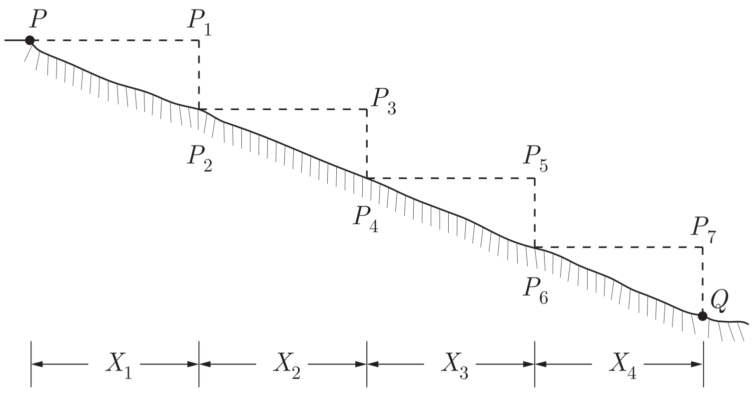


Figure 2.12: Direct method of chaining on sloping ground

(1) A suitable length of chain or tape is stretched out.
(2) The follower holds the zero end of the chain and the leader holds the other end of the chain by means of an offset rod or other suitable equipment.
(3) The follower ranges the leader in line with Q.
(4) The leader then transfers the point P_1 to the point P_2 on the ground by means of a plumb bob and puts up an arrow at point P_2. If plumb bob is not available, the transfer of point P_1 to P_2 can be carried out less accurately by dropping a pebble or an arrow.
(5) The follower then comes to the point P_2 and the process is repeated till point Q is reached.
(6) The horizontal distance $PQ = X_1 + X_2 + X_3 + X_4$.

Points to be Observed During Direct Method of Chaining

Following points should be observed while using this method:

(1) **Direction of work:** It is more convenient to step down the hill rather than to step up the hill. In the second case, the follower has to perform two actions simultaneously, namely, (i) to hold the zero end of chain or tape exactly vertically above the point on the ground and (ii) to range the leader and resist his pull. Hence, while chaining uphill, it is desirable to have sufficient poles in the line so that the leader can align himself.
(2) **Error due to sag:** It is found that error due to sag varies directly as the square of the weight of chain and inversely as the square of the pull applied to the chain. Hence, to bring down the error due to sag to a minimum, light steel tape is preferred to chain and it should be sufficiently stretched during the process.
(3) **Horizontality of chain:** The chain or tape should be stretched in such a way that it is more or less horizontal. For this purpose, an independent person standing on one side of the line should guide the leader.
(4) **Length of step:** The length of each step need not be uniform. It should vary inversely with the steepness of the slope i.e. it should be less for steep slope and more for gentle slope.
(5) **Record of steps:** Great care is necessary to keep a correct record of the steps. It is desirable to have the same length in a series of the steps like 20, 30 or 40 links. It is advisable to avoid the use of arrows to mark the ends of short steps. It is better to insert arrow only at the ends of chain lengths and to use nails or twig splits at the intermediate points.

2.4.2 Indirect Method of Chaining

In this method, the distance is measured on the sloping ground and then, by geometrical considerations, it is converted into equivalent horizontal distance. The methods adopted are as follows:

(1) Hypotenusal allowance
(2) Measuring angle of inclination
(3) Measuring difference in level.

(1) **Hypotenusal allowance:** In Fig 2.13, L represents the length of chain and θ represents the angle of slope of the ground.

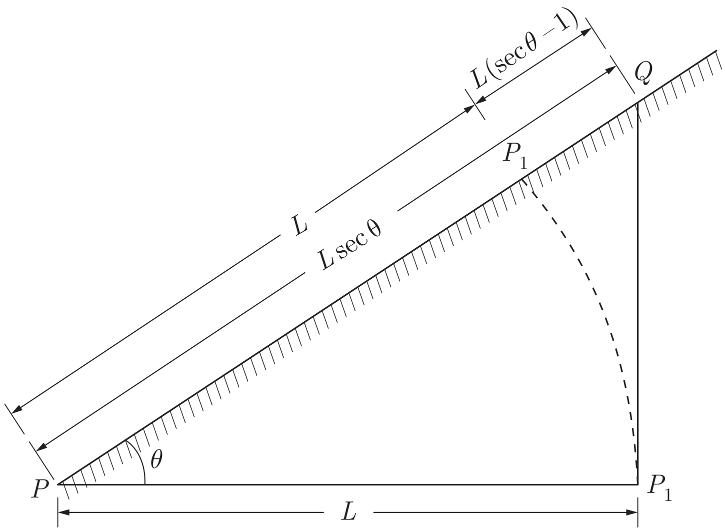


Figure 2.13: Hypotenusal Allowance

As seen from Fig. 2.13, it is quite evident that to measure horizontal distance L, the equivalent distance on slope is $L\sec\theta$. Hence, in this method, PP_1 is measured by the chain and then, it is prolonged or extended to point Q by a distance equal to $P_1Q = L(\sec\theta - 1)$. The care should however be taken to see that the point prolonged is in line PQ. As the distance P_1Q is measured along hypotenuse, the amount $L(\sec\theta - 1)$ is known as hypotenusal allowance.

Then, required distance = number of chains measured.

(2) **Measuring angle of inclination:** In this method, the angles of inclination of ground are measured by clinometer or by some such instrument. Let us suppose that in Fig. 2.14, horizontal equivalent of distance PQ is to be measured. Then, the distances PP_1, P_1P_2, P_2P_3 and P_3Q are measured along the slope and the corresponding angles of inclination θ_1, θ_2, θ_3 and θ_4 are also measured. The horizontal distance PQ is then worked out by the following relation :

Horizontal distance

$$PQ = X_1\cos\theta_1 + X_2\cos\theta_2 + X_3\cos\theta_3 + X_4\cos\theta_4$$

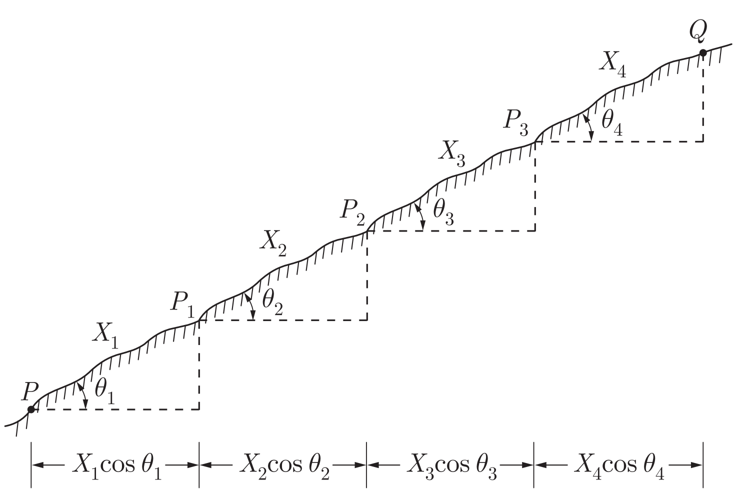


Figure 2.14: Indirect method – Measuring Angle of Inclination

In its simplest form, a clinometer essentially consists of the following three parts, as shown in Fig. 2.15 :

1. Graduated semicircle resembling a protractor;
2. Light plumb bob suspended from a long thread; and
3. Line of sight in the form of a line joining two points.

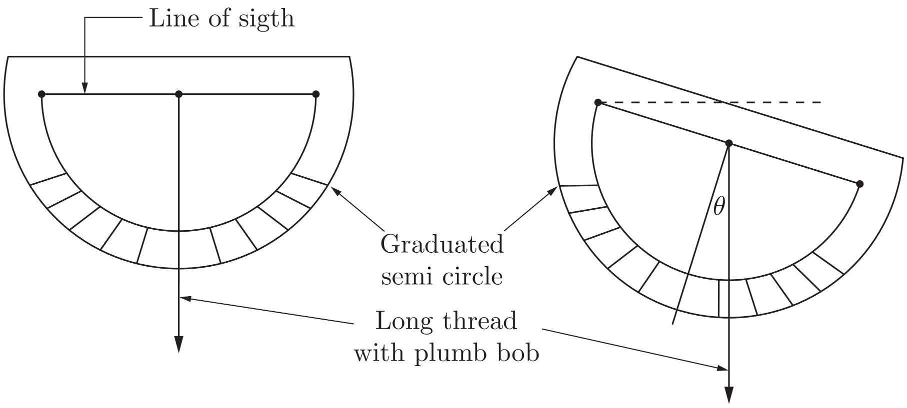


Figure 2.15: Clinometer

The thread touches the zero mark of the graduated are when the instrument is horizontal. For measuring the angle of inclination, a mark is made on the ranging rod at the eye level of the observer. The instrument is then tilted so that the line of sight passes through the mark on the ranging rod. The thread will still remain vertical and the plumb bob will be on the station. The reading against the thread will give the slope of ground.

(3) **Measuring difference in level:** In this method, the difference in elevation between two points P and Q is determined by a levelling instrument. See Fig. 2.16.

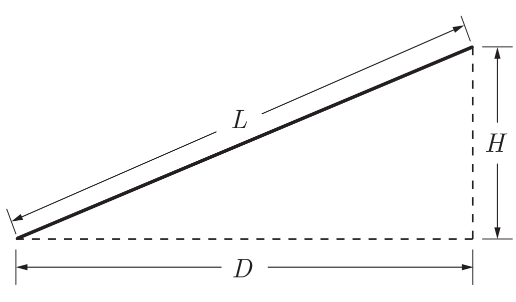


Figure 2.16: Indirect method – Measuring Difference in Level

Let D = Horizontal distance of PQ

H = Difference in level of P and Q

L = Measured length along slope.

Then, $D = \sqrt{L^2 - H^2}$

The relative merits of the direct and indirect methods can be summarized as follows:

(1) The method of stepping is quicker on short slopes of varying degree and it is generally used more in ordinary work.

(2) The method of stepping proves to be useless on very flat slopes because the sag error may exceed the provision made by assuming the inclined and horizontal lengths equal.

(3) The results obtained by the measurement on ground are better than stepping. But the methods prove to be tedious except on ground characterized by long gentle slopes.

2.5 CHAIN TRIANGULATION

Chain surveying is the simplest method of surveying in which only linear measurements are made in the field. This type of surveying is suitable for surveys of small extent on open ground to secure data for exact description of the boundaries of a piece of land or to take simple details.

The principle of chain survey or Chain Triangulation, as is sometimes called, is to provide a skeleton or framework consisting of a number of connected triangles, as triangle is the only simple figure that can be plotted from the lengths of its sides measured in the field. To get good results in plotting, the framework should consist of triangles which are as nearly equilateral as possible.

2.6 SURVEY STATIONS

A survey station is a major point on the chain line and can be either at the beginning of the chain line or at the end. Such station is known as main station. However, subsidiary or tie station can also be selected anywhere on the chain line and subsidiary or tie lines may be run through them.

A survey station may be marked on the ground by driving pegs if the ground is soft. However, on roads and streets etc., the survey station can be marked or located by making two or preferably three tie measurements with respect to some permanent reference objects near the station.

2.6.1 Technical Terms and their Definitions

The important technical terms related to chain surveying are as follows :

1. **Main survey station:** The point where two sides of a main triangle meet is called, a main survey station. Main survey station is a point at either end of a chain line.
2. **Subsidiary survey station (or tie station):** The stations which are selected on the main survey lines for running auxiliary lines, are called subsidiary stations.
3. **Main survey lines:** The chain line joining the two main survey stations, is known as the main survey line.
4. **Auxiliary, subsidiary, or tie lines:** The chain line joining two subsidiary survey stations, is known as auxiliary, subsidiary or more commonly as tie line. Auxiliary lines are provided to locate the interior details which are

far away from the main lines.

5. **Base line:** The longest of the main survey lines, is called a base line. Various survey stations are plotted with reference to the base line.
6. **Check line:** The line which is run in the field to check the accuracy of the field work, is called the check line. If the measured length of a check line agrees with the length scaled off the plan, the survey is accurate.

2.6.2 Selection of Stations

The following points should be kept in mind while selecting survey stations:

1. Main survey stations at the ends of chain lines, should be intervisible.
2. Survey lines should be minimum possible.
3. Survey stations should form well conditioned triangles.
4. Every triangle should be provided with a check line.
5. Tie lines should be provided to avoid too long offsets.
6. Obstacles to ranging and chaining, if any, should be avoided.
7. The larger side of the triangle should be placed parallel to boundaries, roads, buildings, etc. to have short offsets.
8. To avoid tresspassing, main survey lines should remain within the boundaries of the property to be surveyed.
9. Chain lines should lie preferably over level ground.
10. Lines should be laid on one side of the road to avoid interruption to chaining by moving traffic.
11. The main principle of surveying viz., working from the whole to the part and not from the part to the whole, should be strictly observed.

2.7 OFFSETS

An offset is defined as the lateral measurement i.e. distance measured from the chain line, which is taken to locate the position of a point with respect to the chain line.

2.7.1 Types of Offsets

Depending upon the length, the offsets are classified as short offsets and long offsets. The offsets having their length less than 15 m are called short offsets. and the offsets having their length more than 15 m, are called long offsets.

Depending upon the angle made by the offset with the chain line, the offsets are divided into the following two types:

1. **Perpendicular Offsets:** When the lateral measurements for fixing detail points, are made perpendicular to a chain line, the offsets are known as perpendicular or right angled offsets. EN is a perpendicular offset on the right side of the chain line AB. (Fig. 2.17a)

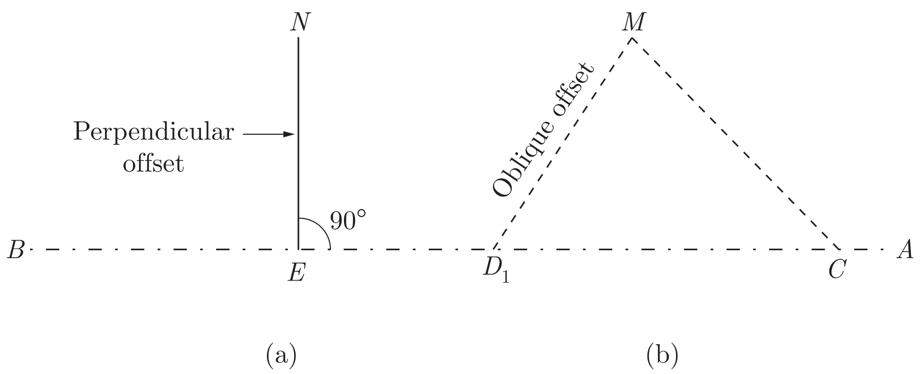


Figure 2.17: Perpendicular and oblique offsets.

2. **Oblique Offsets:** When the lateral measurements for fixing detail points, are made at any angle to the chain line, the offsets are known as oblique offsets. CM and DM are oblique offsets on the right side of the chain line AB. (Fig. 2.17b)

2.7.2 Taking offsets

Offset measurements are taken and noted in the field and the complete operation is known as *taking offsets*. In the absence of an optical square or a cross-staff, an offset is taken as follows:

The leader holds the zero end of the tape at P for which offset is taken and the follower swings off the chain in a short arc about the point P as its centre. He finds the minimum reading on the tape which gives the position of the foot of the perpendicular from P on AB. (Fig. 2.18) Such an offset is called a *swing offset*.

The follower then fixes an arrow at C so found and reads the chainage and the length of the offset. The surveyor, after checking, records the readings in a field book.

The leader holds the zero end of the tape at P and follower swings an arc to cut chain at E and G to intersect the chain line at two points, (Fig. 2.18). He finds the mid-point of E and G at F which the foot of the offset.

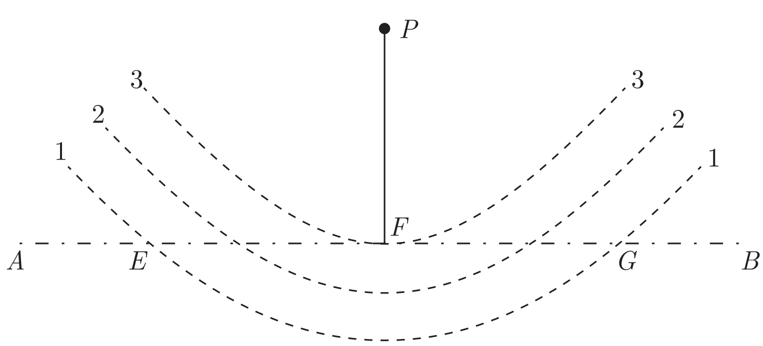


Figure 2.18: Swing offset.

2.7.3 Degree of Accuracy in Taking Offset

In addition to the factors of importance of object and length of offset, the most important factor which determines the degree of accuracy in taking offsets is the scale of plotting. The minimum distance which can be plotted or identified on paper is 0.25 mm. Hence, if the scale of plotting is known, the degree of accuracy can be determined. For instance, if the scale is $1\,\text{cm} = 10\,\text{m}$, the degree of accuracy can be worked out as follows:

$$1 \text{ cm paper} = 1000 \text{ cm on ground}$$

$$0.25 \text{ mm on paper} = 25 \text{ cm on ground.}$$

Hence, the offsets should be taken to the nearest 25 cm of length. Thus the scale of plotting should be kept in mind because on it depends the refinement of detail which can be reproduced on the plan.

2.8 OBSTACLES IN CHAINING

Though it is desirable to select stations so as to avoid obstacles to chaining occasionally obstacles are unavoidable. Various obstacles in chaining may be grouped into the following three types:

1. Obstacles to ranging (chaining free-vision obstructed)
2. Obstacles to chaining (chaining obstructed-vision free)
3. Obstacles to both ranging and chaining.

2.8.1 Obstacles to Ranging

There are two types of such obstacles:

(a) Both ends of the line may be visible from intermediate points. Examples of such obstacles are intervening hills or valleys. These obstacles to ranging can be overcome by resorting to reciprocal ranging.

(b) Both ends of the line may not be visible from intermediate points on the line. Examples of such obstacles are intervening jungles or bushes. Fig. 2.19 shows this situation. This obstacle to chaining can be overcome by measuring along a random line as shown in Fig. 2.20. In this case obstructed length $EB = \sqrt{EC^2 + CB^2}$.

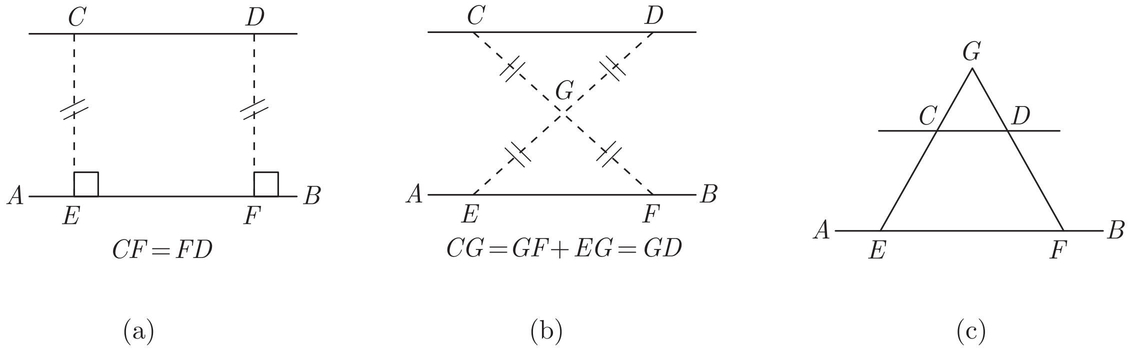


Figure 2.19:

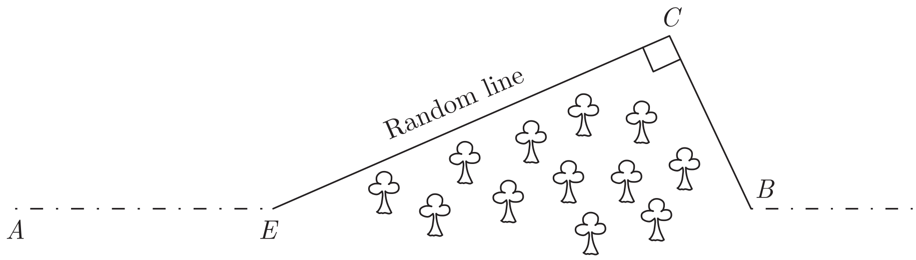


Figure 2.20:

2.8.2 Obstacle to Chaining

In this type also two types are possible: (a) Chaining Round the obstacle possible. Examples of such obstacles are marshy land, lakes and ponds. Various geometrical properties may be used to find obstructed length EB as shown in Fig. 2.21

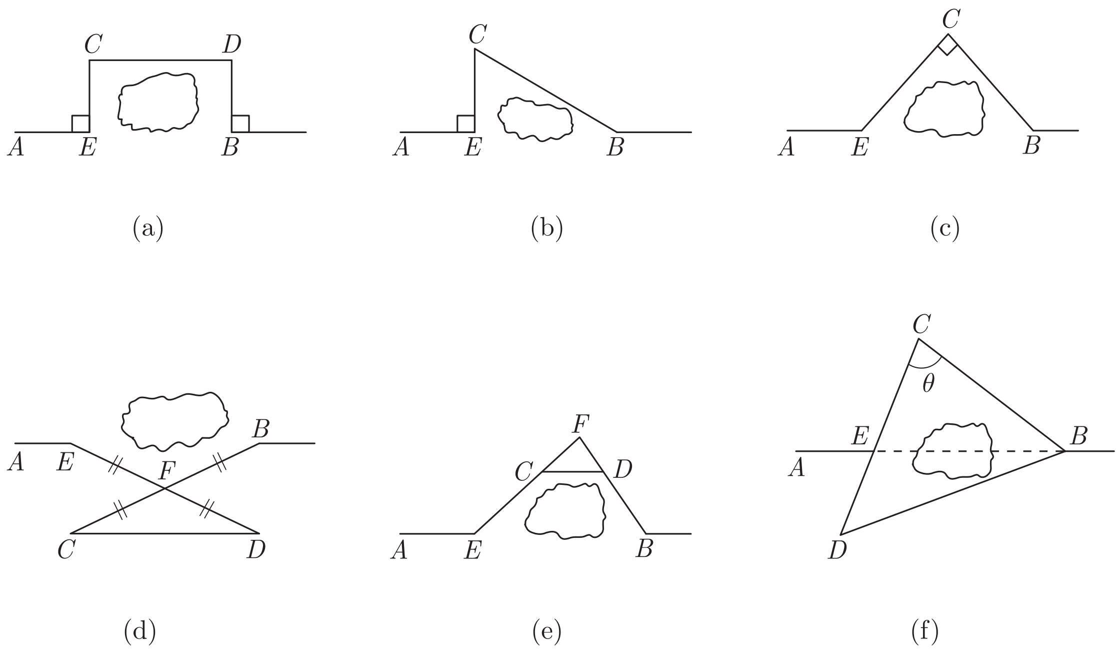


Figure 2.21:

(i) Set EC and BD perpendiculars to line AB, such that $EC = BD$. Then $EB = CD$. (Fig. 2.21a)

(ii) Set perpendicular EC to line AB and measure EC and BC. Then $EB = \sqrt{BC^2 - EC^2}$ (Ref. Fig. 2.21b).

(iii) Select a convenient point C. Fix E on line AB such that $EC \perp BC$. (Ref. Fig. 2.21c). Then $EB = \sqrt{EC^2 + BC^2}$

(iv) Referring to Fig. 2.21d, select a convenient point D. Find F such that $EF = FD$. Extend line BF such that $BF = FC$. Then $EB = CD$

(v) Referring to Fig. 2.21e, select a convenient point F. Mark point C on line AF. Mark point D on line FB such that

$$\frac{FC}{EF} = \frac{FD}{FB} = \frac{1}{n}$$

Then $EB = n \times CD$

(vi) Select convenient points C and D as shown in Fig. 2.21f. Measure the sides CE, ED, BD and BC. Then,

In ΔBCD, if $\theta = \angle BCD$,

$$\cos\theta = \frac{BC^2 + CD^2 - BD^2}{2BC \cdot CD} \quad ...(a)$$

From triangle BCE, we get

$$\cos\theta = \frac{BC^2 + CE^2 - EB^2}{2BC \cdot CE} \quad ...(b)$$

From eqn. (a) $\cos\theta$ can be found, since BC, CD and BD are known. Substituting this in eqn. (b), EB can be found since this is the only unknown in this equation.

2.8.3 Obstacle to Both Chaining and Ranging

Building is a typical obstacle of this type. Any one of the four methods shown in Fig. 2.22 can be employed.

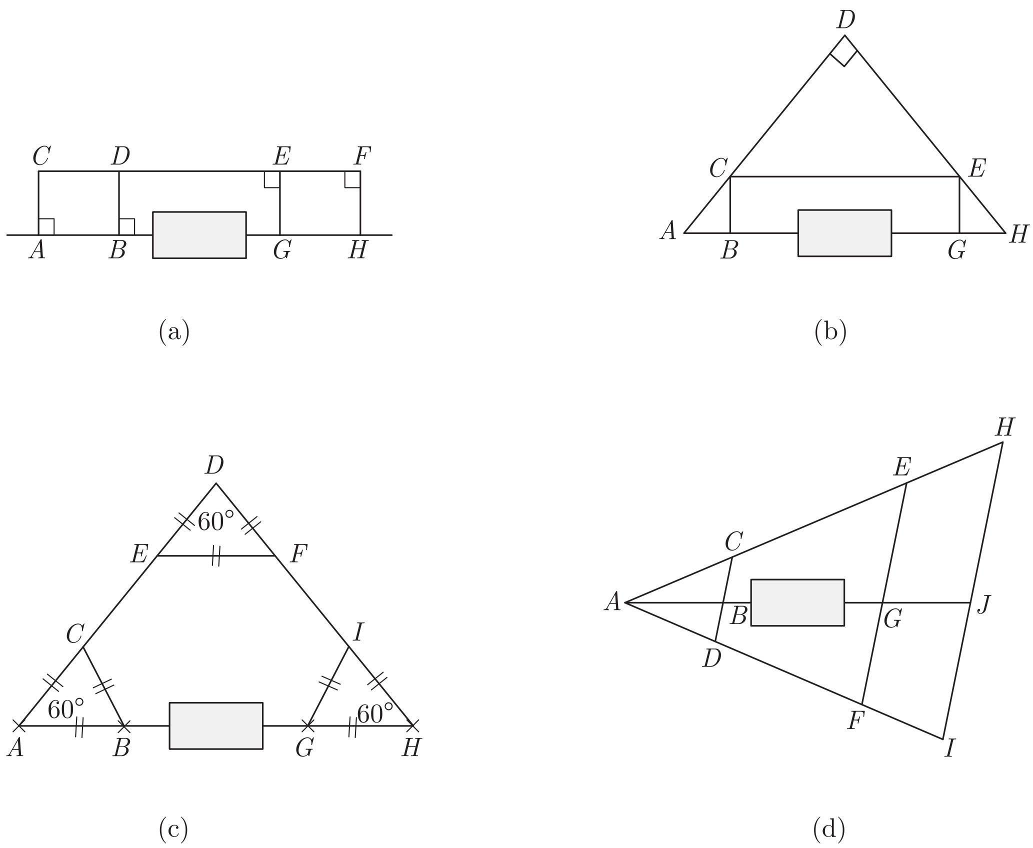


Figure 2.22:

1. Select two convenient points A and B on the line. Erect perpendiculars AC and BD to line AB and make $AC = BD$. Continue CD and select points E and F beyond obstacle. Drop perpendiculars to CF at E and F and make $EG = FH = AC$. Then GH is the orientation of the line beyond obstacle and obstructed length $BG = DE$. (Ref. Fig. 2.22a)
2. Select two convenient points A and B on the line. Erect perpendicular

BC to line AB such that $AB = BC$. Continue AC to D and set DH perpendicular to AD. Make $DH = AD$. Select E making $DE = DC$. With E as centre and radius $= BC$ draw an arc which intersects the arc drawn from H with radius $= BC$. Let the point of intersection be G. Then GH is the continuation of line AB and obstructed length $BC = CE$ (Ref Fig. 2.22b).

3. Referring to Fig. 2.22c, A and B are the two convenient points on line AB. By swining the tape from A and B with length AB, locate $C. \angle CAB = 60^\circ$. Continue AC to D. Select E on AD. By swinging tape from D and E with length DE, locate F. Locate H in the continuation of line DF such that $DH = AD$. Locate I on HD and construct equilateral

   $$BG = AH - AB - GH = AD - AB - GH$$

4. Points A and B are selected on the given line (Ref Fig. 2.22d). Take C and D such that CBD is in a line. Continue AC to E and H such that $AE = n \times AC$ and $AH = mAC$.

   Produce AD to F and I such that $AF = n \times AD$ and $AI = m \times AD$. Locate G such that $EG = n \times BC$ on line EF. Similarly, locate J on line HI such that $HJ = m \times BC$. Then J is the continuation of line AB and obstructed length BG can be found as,

   $$\begin{aligned} BG &= AG - AB \\ &= nAB - AB \\ &= (n-1)AB \end{aligned}$$

2.9 CROSS STAFF SURVEY

The object of a cross staff survey is to locate the boundaries of a field or plot, and to determine its area.

2.9.1 General Principles

Measurement by a chain and cross staff is based upon two formulae

1. that the area of a right angled triangle is equal to the base multiplied by half the perpendicular, and
2. that the area of a trapezoid is equal to the base multiplied by half the sum of the perpendiculars.

2.9.2 Instrument Required

In order, therefore, to calculate the area of any piece of ground, it is only necessary to divide the area into right-angled triangles and trapezoids, and measure their bases and perpendiculars. Two instruments are, therefore, required :

1. a cross staff to divide the area into triangles and trapezoids, and
2. a chain to measure the lengths of bases and perpendiculars.

The instruments required for a cross staff surveys are : two chains, arrows, ranging rods, a cross staff, and a plumb bob. Two chains are usually provided one for measuring distances along the chain line and the other for measuring long offsets. A cross-staff is used to set out the perpendicular directions of offsets which are usually more than 15 m in length. For accurate work, an optical square or a prism square is preferable.

2.9.3 Procedure

In this method of surveying a chain line is run through the centre and the whole length of the area under survey so that the offsets to the boundaries on either side of it are fairly equal. The offsets are taken as they occur (in the order of their chainages), and care should be taken that no offsets are overlooked before the chain is moved forward. To check the accuracy of the field work, the chainages of the points of intersections of the chain line and the boundaries should be noted, and the lengths of the boundary lines determined by direct measurement. After the field work is over, the survey is plotted to a suitable scale.

The figure thus formed by the boundary lines is divided into a number of triangles and trapezoids, the areas of which may be computed by the above formulae. The computations for areas should be written in a tabular form as given below.

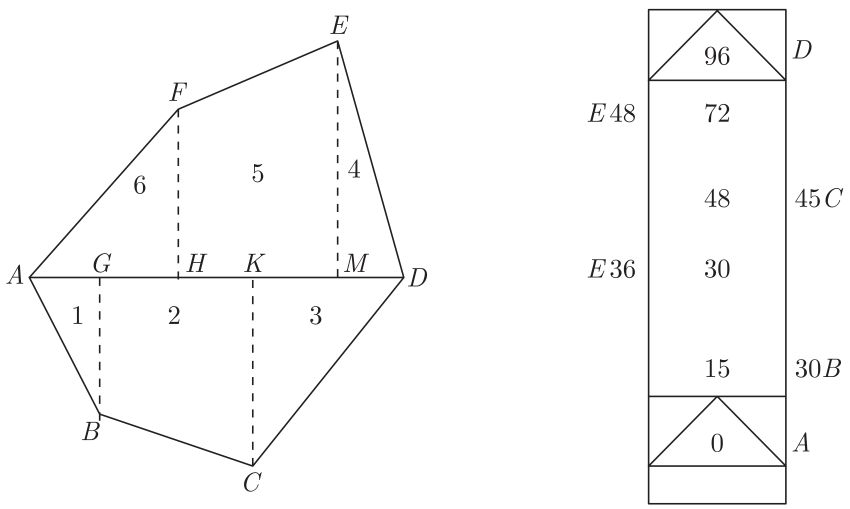


Figure 2.23:

Fig. 2.23 shows the field $ABCDEF$. Enter the five chainages and offsets as shown in the following table.

Table 2.2 :

S. No.	Figure	Chainage in m	Base in m	Offset in m	Mean offset in m	Area in m^2 +ve	–ve	Remarks
1	2	3	4	5	6	7	8	9

1	ΔABG	0 & 15	15	0 & 30	15.0	225.0		Area $=$ col.4 $\times$ col.6
2	*GBCK*	15 & 48	33	30 & 45	37.5	1237.5		
3	ΔKCD	48 & 96	48	45 & 0	22.5	1080.0		
4	ΔDEM	96 & 72	24	0 & 48	24.0	576.0		
5	*MEFH*	72 & 30	42	48 & 36	42.0	1764.0		
6	ΔHFA	30 & 0	30	36 & 0	18.0	540.0		
					Total	5422.5		

Thus Area of field $= 5422.5\,\text{m}^2$

2.10 ERRORS IN CHAIN SURVEYING

The errors that occur in chaining are classified as compensating and cumulative. These errors may be due to natural causes such as say variation in temperature, defects in construction and adjustment of the instrument, personal defects in vision etc.

2.10.1 Compensating Errors

The compensating errors are those which are liable to occur in either direction and hence tend to compensate i.e. they are not likely to make the apparent result too large or too small.

In chaining, these may be caused by the following:

1. Incorrect holding of the chain : The follower may not bring his handle of the chain to the arrow, but may hold it to one or other side of the arrow.
2. Fractional parts of the chain or tape may not be correct if the total length of the chain is adjusted by insertion or removal of a few connection rings from one portion of the chain, or tape is not calibrated uniformly throughout its length.
3. During stepping operation crude method of plumbing (such as dropping of stone from the end of chain) is adopted.
4. When chain angles are set out with a chain which is not uniformly adjusted or with a combination of chain and tape.

2.10.2 Cumulative Errors

The cumulative errors are those which occur in the same direction and tend to add up or accumulate i.e. either to make the apparent measurement always too long or too short.

1. Positive errors (Making the measured lengths more than the actual)

These are caused by the following :

1. The length of the chain or tape is shorter than the standard, because

of bending of links, removal of too many links in adjusting the length, 'knots' in the connecting links, clogging of rings with clay, temperature lower than that at which the tape was calibrated, shrinkage of tape when becoming wet.

2. The slope correction is not applied to the length measured along the sloping ground.
3. The sag correction is not applied when the tape or the chain is suspended in the air.
4. Measurements are made along the incorrectly aligned line.
5. The tape bellys out during offsetting when working in the windy weather.

2. Negative Errors (Making the measured lengths less than the actual)

These errors may be caused because the length of the tape or chain may be greater than the standard because of the wear or flattening of the connecting rings, opening of ring joints, temperature higher than the one at which it was calibrated.

2.10.3 Final Error

The final error in a linear measurement is composed of two portions (a) cumulative errors which are proportional to L and (b) compensating errors which are proportional to $\sqrt{L}$, where L is the length of the line.

2.11 CHAIN AND TAPE CORRECTIONS

Depending upon the accuracy required in taping, certain corrections are made to the original measured distance. It is a standard practice not to correct each tape length as it is measured, but to record the measurements as made with the tape used and then to apply corrections to the total distance. The major sources of error in taping can be identified in terms of the following corrections.

1. **Correction for Standard Length:** Before using a tape, the actual length is ascertained by comparing it with a standard tape of known length. If the actual tape length is not equal to the standard value, a correction will have to be applied to the measured length of the line

$$C_a = \frac{LC}{l}$$

$$\begin{aligned} \text{where } C_a &= \text{Correction for absolute length} \\ C &= \text{Correction to be applied to the tape} \\ L &= \text{Measured length of the line (in m)} \\ l &= \text{Nonal length of the tape (in m)} \end{aligned}$$

The sign of the correction of C_a will be same as that of C.

2. **Correction for Slope:** The distance measured along the slope is always greater than the horizontal distance between the points. Therefore, if the distance is measured on the slope, it must be immediately reduced to its corresponding horizontal distance

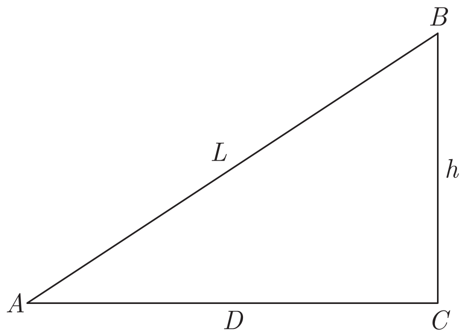


Figure 2.24:

$$
\begin{aligned}
D &= \sqrt{L^2 - h^2} \\
C_{sl} &= L - D \\
\text{The slope correction,} \quad C_l &= L - (L^2 - h^2)^{1/2} \\
&= L - L\left(1 - \frac{h^2}{L^2}\right)^{1/2} \\
&= L - L\left(1 - \frac{h^2}{2L^2} - \frac{h^2}{8L^4} - ...\right) \\
&= L - L + \frac{h^2}{2L} + \frac{h^4}{8L^3} + ... \\
&= \frac{h^2}{2L} \qquad \text{(Neglecting the higher order terms)} \\
C_{sl} &= \frac{h^2}{2L}
\end{aligned}
$$

where h = difference in elevations of A and B

L = measured length of the line (in m)

The slope correction is C_{sl} always subtractive.

3. **Correction for Tension (Pull):** If the pull applied to the tape during measurement is more than the standard pull at which the tape was standardised, its length increases. Hence the distance measured becomes less than the actual. The pull correction C_p is given by:

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

where, P_0 = standard pull

P = pull applied during measurement

A = area of cross section of the tape (in cm^2)

E = modulus of elasticity of tape

$= 2.1 \times 10^5\ \text{N/mm}^2$ for steel

$= 1.54 \times 10^5\ \text{N/mm}^2$ for invar

L = measured length (in m)

Tension correction is positive, if the applied pull is more than the standard pull, and negative, if the applied pull is less than the standard pull.

4. **Correction for Temperature:** The tape length of changes due to changes

in the temperature while taking the measurements. The temperature correction C_t which therefore, needs to be made is given by:

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

where, T_m = mean temperature during measurement

T_0 = temperature of standardisation

α = co-efficient of thermal expansion of material

= 0.0000035/°C for steel

= 0.000000122/°C for invar

L = measured length (in m)

The correction is positive, if the temperature during measurement is more than the standard temperature, and negative, if the temperature during measurement is less than the temperature at which the tape was standardized

5. **Sag Correction:** When the tape is stretched between two points, it takes the form of catenary (assumed to be a parabola). Consequently, the measured length is more and the correction is applied. The sag correction C_{sa} is given by:

$$C_{sa} = \frac{(wl_1)^2 l_1}{24P^2} = \frac{W^2 l_1}{24P^2}$$

If there are n equal spans per tape length, the correction per tape length is given by

$$C_{sa} = n\frac{(wl_1)^2 l_1}{24P^2} = \frac{(wl\ln)^2 nl_1}{24P^2}$$

$$= \frac{(wl)^2 l}{24n^2 P^2} = \frac{W^2 l}{24n^2 P^2}$$

where, w = weight of the tape per metre length

W = total weight of the tape

P = pull applied (in N)

l_1 = the length of tape suspended between two supports

l = length of the tape = nl_1 (in m)

Sag correction is always negative.

6. **Reduction to Mean Sea Level:** The length of a line measured at an altitude of a line measured at an altitude of h metres above mean sea level is always more as compared to the length measured on the mean sea level (m.s.l) surface. The necessity of reducing distances to a common datum arises when the surveys are to be connected to the national grid.

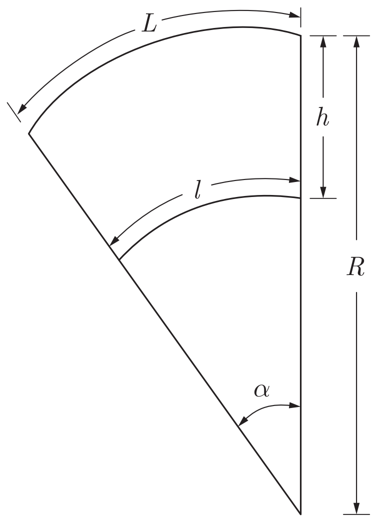


Figure 2.25:

The correction denoted by C_R is given by

$$C_R = \frac{h}{R} \cdot L$$

where R is the radius of the earth.
The correction is always substractive.

7. Combining Corrections: In actual, each of the above correction, based on the length recorded, are combined by addition. Correction should be combined by successive multiplication. Let us assume that for a given length, the following unit corrections have been computed and are to be applied.

$$\begin{aligned} \text{Unit sag correction} &= a \\ \text{Unit slope correction} &= b \\ \text{Unit temperature correction} &= c \\ \text{True length} &= L \\ \text{Recorded length} &= L' \end{aligned}$$

Then,

$$\begin{aligned} L &= L'(1+a)(1+b)(1+c) \\ &= L'(1+a+b+c+ab+bc+ca+abc) \end{aligned}$$

The values of a, b and c are very small and hence their products can be neglected.
Eliminating such products

$$\begin{aligned} L &= L'(1+a+b+c) \\ &= L' + L'a + L'b + L'c \end{aligned}$$

Thus each of the correction can be based on the length recorded and combined by addition.

8. Normal Tension: The pull or tension which, when applied to a tape suspended in the air, equalises the correction due to pull and sag is known as normal tension.

For one tape length,

$$C_P = \frac{P - P_0}{AE} l$$

and
$$C_{sa} = \frac{W^2 l}{24P^2}$$

since
$$C_P = C_{sa}$$

$$\frac{(P - P_0) l}{AE} = \frac{W^2 l}{24P^2}$$

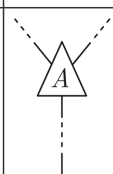
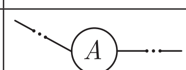
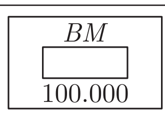
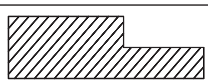
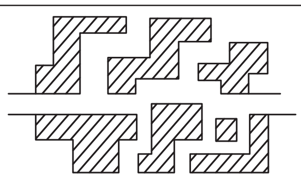
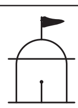
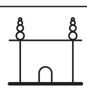
$$P = \frac{0.204 W \sqrt{AE}}{\sqrt{P - P_0}}$$

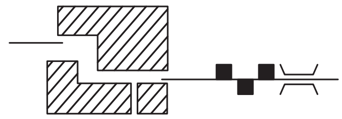
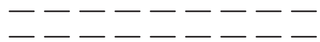
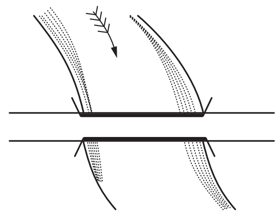
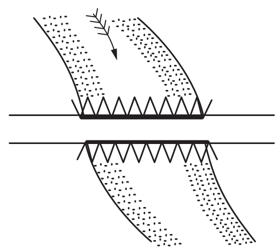
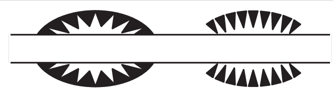
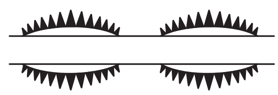
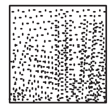
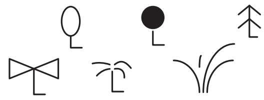
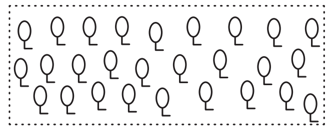
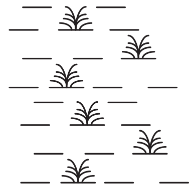
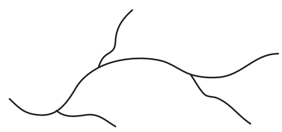
The value of P may be calculated by trial and error.

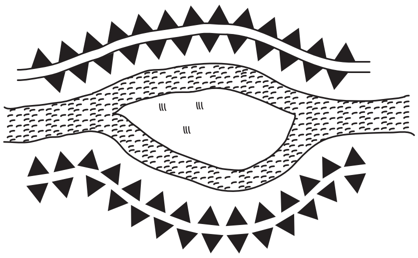
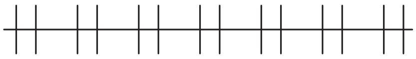
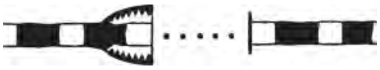
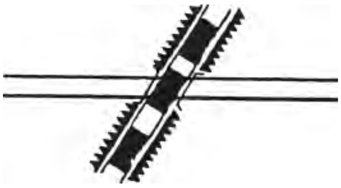
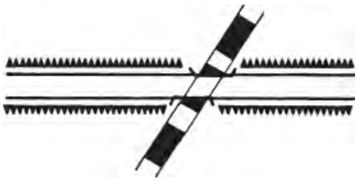
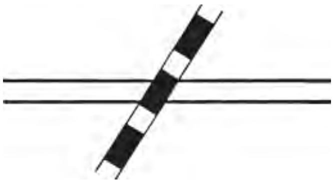
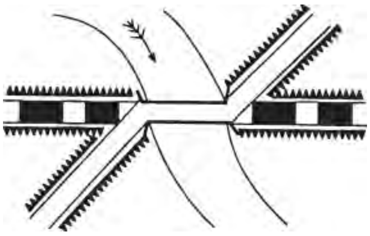
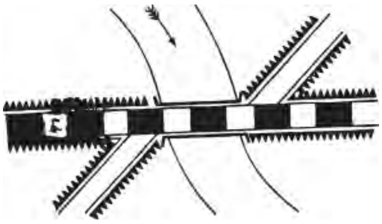
2.12 CONVENTIONAL SIGNS

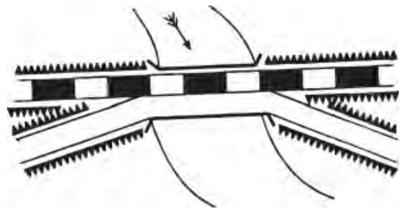
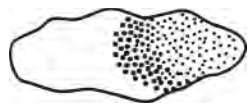
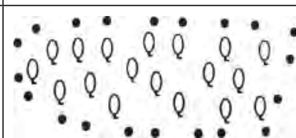
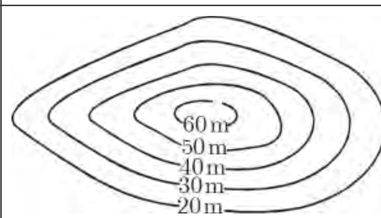
A map is a graphical representation of the earth's surface on a plane paper. As the earth surface contains varieties of natural and cultural features, their depiction graphically will not be possible unless their descriptions are typed, which consequently make a map overcrowded. Such crowded maps are of little utility to map readers and field engineers. To overcome this difficulty, standard symbols have been adopted for each type of details.

Some of the conventional signs in common use, are shown here under.

S.No.	Name	Conventional Sign
1.	Chain line	—···—···—
2.	Triangulation station	
3.	Traverse station	
4.	Bench mark	
5.	Building	
6.	Township	
7.	Temple	
8.	Mosque	
9.	Well lined	●
10.	Foot path	....

S.No.	Name	Conventional Sign
11.	Cart track with a bridge	
12.	Unmetalled road	
13.	Metalled road with a bridge	
14.	Metalled road with boat bridge	
15.	Road in cuttings	
16.	Road on embankments	
17.	Sand dunes	
18.	Pipe line	
19.	Telephone/ telegraph line	
20.	Main Power line	
21.	Power line	
22.	Trees	
23.	Orchard	
24.	Swamp or Marsh	
25.	Stream single line	

S.No.	Name	Conventional Sign
26.	River double line with embankments	
27.	Railway single line with station	
28.	Railways, other gauge	
29.	Railway bridge	
30.	Railway tunnel with or without cuttings	
31.	Railway over road	
32.	Road over railway	
33.	Level crossing	
34.	Bridge carrying railway below road	
35.	Bridge carrying railway over road	

S.No.	Name	Conventional Sign
36.	Bridge carrying road and railway	
37.	Ropeway with terminus	
38.	Lake as surveyed	
39.	Lake as surveyed with embankment	
40.	Quarry	
41.	Reserved protected forest	
42.	State boundary demarcated	—— . —— . —— . ——
43.	State boundary undemarcated	—— × —— × —— × ——
44.	District boundary	— — — — — — —
45.	Contours	

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EXAMPLES

Example on Calculation of True Length or Correct Distance

EXAMPLE 2.1

The length of a line measured with a 20 m chain was found to be 634.4 m. It was afterwards found that the chain was 0.05 m too long. Find the true length of the line.

SOLUTION :

$$\text{True length of line} = \frac{L'}{L} \times \text{measured length of line}$$

$$L' = 20.05\,\text{m}$$

$$L = 20.0\,\text{m}$$

$$\text{Measured length} = 634.4\,\text{m}$$

$$\text{True length of the line} = \frac{20.05}{20} \times 634.4$$

$$= 635.99\,\text{m}$$

EXAMPLE 2.2

Length of a survey line was measured with a 30 m chain and found to be 315.4 m. When the chain was compared with chain standard, it was found to be 0.2 m too short. Find correct length of the line.

SOLUTION :

We have $L = 30\,\text{m}$

$$\text{Measured length} = 315.4\,\text{m}$$

$$L_1 = 30 - 0.2 = 29.8\,\text{m}$$

$$\text{True length} = \frac{L_1}{L} \times \text{Measured length}$$

$$= \frac{29.8}{30} \times 315.4 = 313.29\,\text{m}$$

EXAMPLE 2.3

A 30 m chain was tested before commencement of chaining work. Line PQ was chained by it and observed length of PQ was 1230 m. The chain was tested at the end of work and was found to be 12 cm too short. Find the correct distance PQ.

SOLUTION :

$$\text{Correct distance} = \frac{L_1}{L} \times \text{measured distance}$$

$$\text{Error before commencement} = 0.0\,\text{m}$$

$$\text{Error at the end} = -\,0.12\,\text{m}$$

$$\text{Average error} = \frac{0 + (-\,0.12)}{2} = -\,0.06\,\text{m}$$

$$L_1 = 30 - 0.06 = 29.94\,\text{m};\ L = 30\,\text{m}$$

$$\text{Measured distance} = 1230\,\text{m}$$

Hence

$$\text{Correct length} = \frac{L_1}{L} \times \text{measured distance}$$

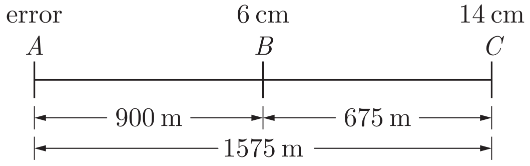
$$= \frac{29.94}{30} \times 1230$$

$$= 1227.54\,\text{m}$$

EXAMPLE 2.4

A line was measured by a 20 m chain which was accurate before starting the day's work. After chaining 900 m, the chain was found to be 6 cm too long. After changing a total distance of 1575 m, the chain was found to be 14 cms too long. Find the true distance of the line.

SOLUTION :



For first 900 m :

$$\text{Average error} = \frac{0 + 6}{2} = 3\,\text{cm} = 0.03\,\text{m}$$

$$\text{Length of the chain, } L_1 = 20 + 0.03 = 20.03\,\text{m}$$

$$\text{True distance} = \frac{20.03}{20} \times 900 = 901.35\,\text{m}$$

For next 675 m :

$$\text{Average error} = \frac{6 + 14}{2} = 10\,\text{cm} = 0.1\,\text{m}$$

$$\text{Incorrect length of chain, } L_1 = 20 + 0.1 = 20.01\,\text{m}$$

$$\text{True distance} = \frac{20.01}{20} \times 675 = 675.33\,\text{m}$$

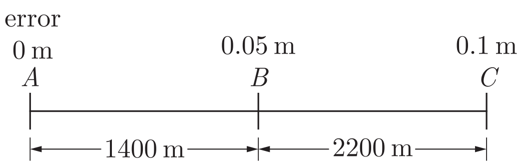
$$\text{Total true distance of the line} = 901.35 + 675.33$$

$$= 1576.68\,\text{m}$$

EXAMPLE 2.5

A 20 m chain was found to be 0.05 m too long after chaining 1400 m. It was found to be 0.10 m too long after chaining next 2200 m. If the chain was correct before commencement of work, find the true distance chained.

SOLUTION :



(i) Chain was 0.05 m too long.

$$\begin{aligned}\text{Actual length } (AB) &= 1400\text{ m}\\ \text{Length of chain, } L &= 20\text{ m}\\ \text{Error} &= \frac{0+0.05}{2} = 0.025\text{ m}\\ \text{Mean length of chain, } L_1 &= 20+0.025\\ &= 20.025\text{ m}\\ \text{Correct length} &= \frac{L_1}{L}\times 1400\\ &= \frac{20.025}{20}\times 1400\\ &= 1401.75\text{ m}\end{aligned}$$

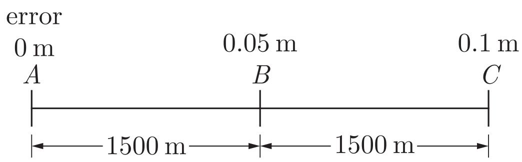
(ii) Chain was 0.10 m too long.

$$\begin{aligned}\text{Actual length } (BC) &= 2200\text{ m}\\ \text{Length of chain, } L &= 20\text{ m}\\ \text{Error} &= \frac{0.05+0.1}{2} = 0.075\\ \text{Mean length of chain, } L_1 &= 20.075\\ \text{Correct length} &= \frac{L_1}{L}\times 2200\\ &= \frac{20.075}{20}\times 2200\\ &= 2208.25\\ \text{Total distance} &= 1401.75+2208.25\\ &= 3610\text{ m}\end{aligned}$$

EXAMPLE 2.6

A 20 m chain was found to be 0.05 m too long after chaining 1500 m. It was found to be 0.1 m too long after chaining 3000 m. If the chain was correct before the commencement of the work, find the true distance.

SOLUTION :



$$\text{Error} = \frac{0+0.05}{2} = 0.025$$

$$\text{Correct distance} = \frac{L_1}{L} \times \text{measured distance}$$

For first 1500 m :

$$L_1 = 20 + \frac{0.025}{2} = 20.025$$

$$L = 20\text{ m}$$

Hence

$$\text{Correct distance} = \frac{20.025}{20} \times 1500 = 1501.875\text{ m}$$

For next 1500 m (i.e. 1500 to 3000 m) :

$$\text{Error in chain at 1500 m distance} = +\,0.05\text{ m}$$

$$\text{Error in chain at distance 3000 m} = +\,0.1\text{ m}$$

$$\text{Average error} = \frac{0.05+0.1}{2} = 0.075\text{ m}$$

$$L_1 = 20 + 0.075 = 20.075\text{ m}$$

and

$$L = 20\text{ m}$$

$$\text{Correction distance} = \frac{L_1}{L} \times 1500 = \frac{20.075}{20} \times 1500$$

$$= 1505.625\text{ m}$$

Hence

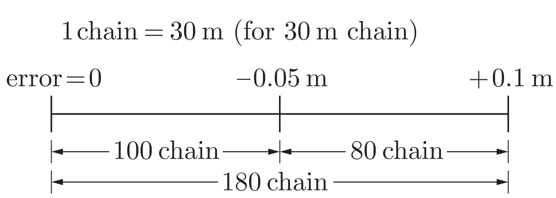
$$\text{Total true distance} = 1501.875 + 1505.625$$

$$= 3007.5\text{ m}$$

EXAMPLE 2.7

A 30 metre chain was tested before the commencement of the day's work and was found to be correct. After chaining a distance of 100 chains it was found to be 0.5 decimetre too short. At the end of the day's work after chaining a total distance of 180 chains, the chain was found to be 1 decimetre too long. What was the true distance chained?

SOLUTION :



For line AB :

$$\text{Error} = \frac{0 + (-\,0.05)}{2} = -\,0.025\text{ m}$$

$$L_1 = 30 - 0.025 = 29.975\text{ m}$$

$$\text{Measured length } AB = 100 \times 30 = 3000\text{ m}$$

$$\text{True length of line } AB = \left(\frac{L_1}{L}\right) \times \text{measured length}$$

$$= \left(\frac{29.975}{30}\right) \times 3000 = 2997.50\,\text{m}$$

For line BC :

$$\text{Error} = \frac{-0.05+0.1}{2} = 0.025$$

Hence

$$L_1 = 30 + 0.025 = 30.025\,\text{m}$$

$$\text{Measured length of } BC = 80 \times 30 = 2400\,\text{m}$$

$$\text{True length of line } BC = \left(\frac{L_1}{L}\right) \times \text{measured length}$$

$$\text{True length of line } BC = \left(\frac{30.025}{30}\right) \times 2400 = 2402\,\text{m}$$

$$\text{Total true length} = l(AB) + l(BC)$$

$$= 2997.5 + 2402 = 5399.60\,\text{m}$$

EXAMPLE 2.8

The length of a line measured by means of a 20 m chain was found to be 610.2 m known to be 612.0 m. What was the actual length of the chain?

SOLUTION :

Since the measured length of the line is less than its true length, the chain was too long.

$$\text{Now true length of the line} = \frac{L'}{L} \times \text{measured length}$$

$$\text{True length of the line} = 612.0\,\text{m}$$

$$\text{Measured length of the line} = 610.2\,\text{m}$$

$$L = 20.0\,\text{m}$$

Hence

$$612.0 = \frac{L'}{20.0} \times 610.2$$

$$L' = \frac{612.0 \times 20.0}{610.2} = 20.066\,\text{m}$$

EXAMPLE 2.9

A 20 m chain was found to be 0.05 m too long after chaining 1400 m. It was found to be 0.1 m too long after chaining 2200 m. If the chain was correct before commencement of the work, find the true distance.

SOLUTION :

(i) Since the chain was correct i.e. 20 m long at the beginning and was 20.05 m long after chaining 1400 m, the increase in length was gradual.

$$\text{Mean elongation} = \frac{0+0.05}{2} = 0.025\,\text{m}$$

$$\text{True distance} = \frac{20.025}{20} \times 1400 = 1401.75\,\text{m}$$

(ii) The remaining distance $(2200 - 1400) = 800\,\text{m}$ was measured with the same chain. If was 0.05 m too long at the commencement of chaining this distance and 0.10 m too long at the end of chaining.

$$\text{Mean elongation} = \frac{0.05 + 0.10}{2} = 0.075\,\text{m}$$

$$\text{True distance} = \frac{20.075}{20} \times 800 = 803.00\,\text{m}$$

$$\begin{aligned}\text{Hence, total true distance} &= 1401.75 + 803.00\,\text{m} \\ &= 2204.75\,\text{m}\end{aligned}$$

EXAMPLE 2.10

The surveyor measured the distance between two stations on a plan drawn to a scale of 40 m to 1 cm and the result was 2082 m. Later, it was discovered that he had used a scale of 80 m to 1 cm. Find the true distance between the stations.

SOLUTION :

The distance between the stations in cm, measured with a scale of 80 m to 1 cm $= \frac{2082}{80} = 26.025\,\text{cm}$.
The scale of the plan being 40 m to 1 cm, the true distance between the station $= 26.025 \times 40 = 1041\,\text{m}$.

$$\begin{aligned}\text{Alternatively true distance} &= \left(\frac{\text{wrong scale}}{\text{correct scale}}\right) \times \text{measured distance} \\ &= \frac{40 \times 100}{80 \times 100} \times 2082 \\ &= 1041\,\text{m}\end{aligned}$$

$$\text{Note: Wrong scale (R.F.)} = \frac{1}{80 \times 100} = \frac{1}{8000}$$

$$\text{Correct scale (R.F.)} = \frac{1}{40 \times 100} = \frac{1}{4000}$$

Example on Error in Chain

EXAMPLE 2.11

A road is actually 4, 250 m long but when measured by an incorrect chain which is 30 m long, was found to be 4,239 m long. What correction does the chain need?

SOLUTION :

$$\begin{aligned}L_1 &= \frac{\text{Correct length of line}}{\text{Incorrect length of line}} \times L \\ &= \frac{4250}{4239} \times 30 \\ L_1 &= 30.0778 \\ L_c &= 30.0778 - 30 = -0.0778\,\text{m}\end{aligned}$$

i.e. the chain is too long by 7.78 cm. Hence Correction needed for the chain is + 7.78 cm.

EXAMPLE 2.12

A road actually 1410 m long was found 1406 m when measured by a defective 30 m chain. How much correction does the chain need?

SOLUTION :

$$\text{Actual length of road} = 1410\,\text{m}$$
$$\text{Incorrect length of road} = 1406\,\text{m}$$
$$\text{Length of chain, } L = 30\,\text{m}$$

Incorrect length of chain, $L_1 = ?$

$$\text{Correct length of road} = \frac{L_1}{L} \times \text{Incorrect length of road}$$

Hence $$1410 = \frac{L_1}{30} \times 1406$$

Hence $$L_1 = 30.08$$

Now, $$\text{Correction in the chain} = 30.08 - 30\,\text{m} = 0.08\,\text{m}$$

Hence, Chain was 0.08 m too long.

EXAMPLE 2.13

The length of a survey line was measured with a 20 m chain and was found to be equal to 1500 metres. As a check the length was again measured with a 30 m chain and found to be 1476 metres. If the 20 m chain was 5 cm too short, what was the error in 30 m chain?

SOLUTION :

$$\text{True distance} = \frac{L_1}{L} \times \text{Measured distance}$$
$$L = 20\,\text{m}$$
$$L_1 = 20 - 0.05 = 19.95\,\text{m}$$
$$\text{Measured distance} = 1500\,\text{m}$$

Hence $$\text{True distance} = \frac{19.95}{20} \times 1500 = 1496.25\,\text{m}$$

For 30 m chain, $L = 30\,\text{m}$

$$\text{Measured distance} = 1476\,\text{m}$$
$$L_1 = ?$$
$$\text{True distance} = 1496.25\,\text{m}$$
$$\text{True distance} = \frac{L_1}{L} \times \text{Measured distance}$$
$$1496.25 = \frac{L_1}{30} \times 1476$$
$$L_1 = 30.411\,\text{m}$$
$$30.411 - 30 = 0.411\,\text{m to long}$$

The error in the 30 m chain was 0.411 m.

EXAMPLE 2.14

The distance between two towns measured by 20 m chain was 1701 m and when measured by a 30 m chain, it was 8510 links. The tests show that both the chain were incorrect. What correction is required in the 20 m chain, if the 30 m chain is 0.4 link too long.

SOLUTION :

(1) For 30 m chain

30 m chain was 0.4 link too long and 1 link = 0.20 m

$$\text{Error in 30 m chain} = 0.4 \times 0.20\,\text{m} = 0.08\,\text{m too long}$$

$$\text{Length of chain with error, } L_1 = 30 + 0.08 = 30.08\,\text{m}$$

and

$$\text{True distance} = \frac{L_1}{L} \times \text{Measured distance}$$

$$= \frac{30.08}{30}(8510 \times 0.20) = 1706.53\,\text{m}$$

(2) For 20 m chain

Now, $$\text{True distance} = 1706.53\,\text{m} \qquad \text{(From case 1)}$$

and $$\text{Measured distance} = 1701\,\text{m}$$

$$\text{Length of chain, } L = 20\,\text{m}$$

We have, $$\text{True distance} = \frac{L_1}{L} \times \text{Measured distance}$$

Hence $$1706.53 = \frac{L_1}{20} \times 1701$$

$$L_1 = \frac{1706.53 \times 20}{1701} = 20.065\,\text{m}$$

Hence $$\text{Error in 20 m chain} = 20.065 - 20 = 0.065\,\text{m}$$

The 20 m chain was 6.5 cm too long.

Example on Calculation of True Area

EXAMPLE 2.15

A certain field was measured with a 20 m chain and found to be 45 sq. km. It was afterward found that the chain was 0.1 m too short, what is the true area of the field?

SOLUTION :

$$\text{True area} = \left(\frac{L'}{L}\right)^2 \times \text{measured area}$$

$$L' = 20 - 0.1 = 19.90\,\text{m}$$

and $$L = 20\,\text{m}$$

Measured area is 45 sq. km. Therefore

$$\text{True area of the field} = \left(\frac{19.90}{20}\right)^2 \times 45 = 44.5511\,\text{km}^2$$

EXAMPLE 2.16

A survey of field was plotted to a scale of $1\,\text{cm} = 12\,\text{m}$. This plan was shrunk and area now obtained by planimeter is $294.4\,\text{cm}^2$.

It was found that a line measured 8 cm now, was originally 9 cm long. The $20\,\text{m}$ chain used was 7 cm too short as per remarks mentioned on the plan. What is the true area of the plot.

SOLUTION :

$$L = 9\,\text{cm}$$
$$L_1 = 8\,\text{cm}$$
$$\text{True area on paper} = \left(\frac{L_1}{L}\right)^2 \times \text{Measured area}$$
$$= \left(\frac{8}{9}\right)^2 \times 294.4 = 232.61\,\text{cm}^2$$
$$\text{Measured area} = 232.61 \times 12^2 = 576\,\text{m}^2$$
$$L = 20\,\text{m}$$
$$L_1 = 20 - 0.07 = 19.93\,\text{m}$$
$$\text{True area} = \left(\frac{L_1}{L}\right)^2 \times \text{Measured area}$$
$$= \left(\frac{19.93}{20}\right)^2 \times 576$$
$$= 571.97\,\text{m}^2$$

EXAMPLE 2.17

The plane of an old survey plotted to a scale of $1\,\text{cm} = 10\,\text{m}$ was found to have shrunk so that a line originally 10 cm long was found to measured $9.8\,\text{cm}$. There was a note on the plan that 30 m chain used was 0.03 m too short. If the area of the plan now measured with planimeter is $97.20\,\text{cm}^2$. Determine true area of survey.

SOLUTION :

Given, Scale in the map : $1\ \text{cm} = 10\,\text{m}$

Hence $1\,\text{cm}^2 = 100\,\text{m}^2$

Now, Original area of survey on paper

$$= \left(\frac{10}{9.8}\right)^2 \times 97.20 = 101.20\,\text{cm}^2$$

The area of plot measured on the ground

$$= 101.20 \times 100 = 10120\,\text{m}^2$$

Note given on the map was '30 m chain used was 0.03 m too short'.

i.e. length of the chain, $L_1 = 30 - 0.03 = 29.97\,\text{m}$

$$\text{Actual area on the ground} = \left(\frac{L_1}{L}\right)^2 \times \text{Measured area}$$

$$= \left(\frac{29.97}{30}\right)^2 \times 10120$$

$$= 10099.77 \text{ m}^2$$

EXAMPLE 2.18

The paper of an old map drawn to a scale of 100 m to 1 cm has shrunk, so that a line originally 10 cm has shrunk, has now become 9.6 cm. The survey was done with a 20 m chain 10 cm too short. If the area measured now is 71 cm^2. Find the correct area of the field.

SOLUTION :

10 cm line has shrunk to 9.6 cm.

$$\text{Area measured} = 9.6 \text{ cm}$$

Hence $$\text{Correct area of plane} = \left(\frac{10}{9.6}\right)^2 \times 71 = 77.04 \text{ cm}^2$$

$$\text{Scale used is, 1 cm} = 100 \text{ m}$$

Hence $$\text{Measured area of survey} = (77.04)(100)^2 = 770400 \text{ m}^2$$

$$\text{Incorrect length of chain used} = 20 - 0.1 = 19.9 \text{ m}$$

Hence $$\text{Correct area} = \left(\frac{19.9}{20}\right)^2 \times 770400$$

$$= 762715.26 \text{ m}^2$$

EXAMPLE 2.19

The plan of an old survey, plotted to a scale of $1 \text{ cm} = 40 \text{ m}$ was found to be shrunk, so that a line originally 20 cm long measured 19.7 cm. There was also a note on the plan that the 20 m chain used was 0.1 m too short. If the area on the plan measured now by planimeter is 100 sq. cm. Find the true area of the survey plot in hectares.

SOLUTION :

$$\text{Original Area (plotted)} = \left(\frac{20}{19.7}\right)^2 \times 100$$

$$= \frac{400}{388.09} \times 100$$

$$= 103 \text{ sq. cm on paper.}$$

$$\text{The scale of the map was 1 cm} = 40 \text{ m}$$

$$\text{i.e. } 1 \text{ cm}^2 \text{ represents } 40 \text{ m}^2 = 1600 \text{ sq.m.}$$

Hence, $$\text{Area of plot on the ground} = 103 \times 1600 = 164800 \text{ sq.m.}$$

But there was a note on the map that 20 m chain was 0.1 m (10 cm) too short.
i.e. it was $20 - 0.10 = 19.90$ only.

Hence, $$\text{actual area on the ground} = \left(\frac{L'}{L}\right) \times \text{measured area}$$

$$= \left(\frac{19.90}{20}\right)^2 \times 164800 = 163156 \text{ m}^2$$

or $$\frac{163156}{10^4} = 16.3156 \text{ Hectares}$$

EXAMPLE 2.20

A chain was tested before commencement of the work and was found to be exactly 20 m. At the end of the survey, it was found to measure 20.20 m. The area of the field drawn to a scale of 1 cm = 16 m was 60.25 sq.cm. Find the true area of the field in hectares.

SOLUTION :

$$\text{True length of chain} = 20 \text{ m}$$

$$\text{Length measured at the end of survey} = 20.20 \text{ m}$$

$$\text{Scale given is 1 cm} = 16 \text{ m}$$

Hence $$1 \text{ cm}^2 = (16)^2 \text{ m}^2$$

$$\text{Now, measured area of the field} = 60.25 \times 16 \times 16$$
$$= 15424 \text{ m}^2$$

Area of the field measured with 20.2 m chain is 15424 m^2.

Now, $$\text{Length of the chain, } L = 20 \text{ m}$$

Length of the chain at the end of survey

$$= 20.20 \text{ m}$$

Hence $$\text{Mean length of chain} = \frac{20 + 20.20}{2}$$
$$L_1 = 20.1 \text{ m}$$

$$\text{True area measured by 20 m chain} = \left[\frac{L_1}{L}\right]^2 \times \text{Measured area}$$

$$\text{True area} = \left[\frac{20.1}{20}\right]^2 \times 15424$$
$$= 1.01 \times 15424$$
$$= 15578.24 \text{ m}^2$$

$$\text{True area} = \frac{15578.24}{10^4} \qquad [\because 1 \text{ hectare} = 10^4 \text{ sq.m}]$$
$$= 1.55 \text{ Hectares}$$

EXAMPLE 2.21

A certain field was measured with a 30 m chain and found to contain 45 km^2. It was afterwards found that the chain was 0.1 m too short. What is the true area of the field?

SOLUTION :

$$\text{True area} = \left(\frac{L'}{L}\right)^2 \times \text{measured area}$$
$$L' = 29.9 \text{ m}$$

$$L = 30\,\text{m};\ \text{measured area} = 45\,\text{km}^2$$

$$\text{True area of the field} = \left(\frac{29.9}{30}\right)^2 \times 45 = 44.70\,\text{km}^2$$

EXAMPLE 2.22

The area of a field was computed from a plan drawn to a scale of 3 chains to 1 cm and found to be 96.0 ares. Through oversight, however, a scale of 4 chains to 1 cm was used in scaling the plan. Find the true area of the field.

SOLUTION :

$$\text{True scale} = \frac{(\text{wrong scale})^2}{(\text{correct scale})^2} = \left(\frac{3}{4}\right)^2 \times 96.0$$

$$= 54.0\,\text{ares}$$

EXAMPLE 2.23

A chain was tested before starting a survey of field and was found to be exactly 30 m. At the end of the survey, it was tested again and was found to measure 30.16 m. The area of the plan drawn to a scale of $1\,\text{cm} = 60\,\text{m}$ was $92.50\,\text{cm}^2$. Find the true area of the field.

SOLUTION :

The scale of the plan being 60 m to 1 cm, $1\,\text{cm}^2$ on the plan represents $3600\,\text{m}^2$ on the ground.

$$\text{Area of the plan} = 92.50\,\text{cm}^2$$

$$\text{Area of the field} = 92.50 \times 3600\,\text{cm}^2$$

$$L' = 30 + \text{mean elongation}$$

$$= 30 + \frac{0.16}{2} = 30.08\,\text{m}$$

$$L = 30\,\text{m}$$

$$\text{Measured area} = 92.50 \times 3600\,\text{m}^2$$

$$\text{True area of the field} = \left(\frac{30.08}{30}\right)^2 \times 92.5 \times 3600\,\text{m}^2$$

$$= 33.48\,\text{hectares}$$

EXAMPLE 2.24

The plan of an old survey plotted to a scale of 50 m to 1 cm was found to have shrunk so that a line originally 20 cm long was 19.6 cm. There was also a note on the plan that the 20 m chain used was 0.1 m too long. If the area of the plan measured now by a planimeter is $150.28\,\text{cm}^2$, find the true area of the survey.

SOLUTION :

Measured area on the plan $= 150.28\,\text{cm}^2$. Since the plan has shrunk an original area of $400\,\text{cm}^2$ now measured $(19.6)^2\,\text{cm}^2$

$$\text{Original area of the plan} = \left(\frac{20}{19.6}\right)^2 \times 150.28 = 156.48\,\text{cm}^2$$

The scale of the plan being 50 m to 1 cm, the area on the ground

$$= 156.48 \times 50^2$$
$$= 391200\,\text{m}^2$$

The chain being 0.1 m too long, the actual length of the chain 20.1 m

$$\text{True area on the ground} = \left(\frac{20.1}{20}\right)^2 \times 391200$$
$$= 395121.78\,\text{m}^2$$
$$= 39.51\,\text{hectares}$$

Examples on Tape Corrections

EXAMPLE 2.25

Find out the slope correction in links per 100 links of a 20 m chain for a line measured along a slope of 10°30'.

SOLUTION :

$$\text{Slope correction} = l(1-\cos\theta)$$
$$= 100\,(1-\cos 10^\circ 30')$$
$$= 100\,(1-0.9833)$$
$$= 1.67\,\text{links}$$

Hence slope correction is 1.67 links.

EXAMPLE 2.26

An offset is laid out 5° from its true direction on the field. Find the resulting displacement of the plotted point on the paper :

(i) In a direction parallel to chain line.

(ii) In a direction perpendicular to the chain line given that the length of offset is 20 m and scale is 10 cm to 1 cm.

SOLUTION :

Given $l = 20\,\text{m}$

$\alpha = 5^\circ$; Scale : 10 cm = 1 m

(i) Resulting displacement of the plotted point in a direction parallel to chain line

$$= l\sin\alpha$$
$$= 20\sin 5^\circ$$

Hence displacement on paper $= \dfrac{20\sin 5^\circ}{10} = 0.17$ cm

Since Scale : 10 m = 1 cm

(ii) Resulting displacement in a direction perpendicular to the chain line

$$= l(1-\cos\alpha)$$

$$= \frac{20(1-\cos 5)}{10} = 0.0076\,\text{cm}$$

Since Scale : 10 m = 1 cm

EXAMPLE 2.27

Find the maximum permissible error in a laying-off the direction of offset so that the maximum displacement may not exceed 0.25 mm on the paper, given that the length of the offset is 1 metres, the scale is 20 m to 1 cm and the maximum error in the length of the offset is 0.3 m.

SOLUTION :

$$\text{Displacement of the point} = l\sin\alpha = 10\sin\alpha$$

Given $\quad$ Error in measurement = 0.3

Displacement may not exceed 0.25 mm i.e. 0.025 cm.

Now, $\quad$ $\text{Total displacement} = \sqrt{(10\sin\alpha)^2 + (0.3)^2}\ \text{m}$

$$\text{Displacement on paper} = \frac{\sqrt{(10\sin\alpha) + (0.3)^2}}{20}\ \text{cm}$$

Hence $\quad$ $\sqrt{\dfrac{(10\sin\alpha)^2 + (0.3)^2}{20}} = 0.025$

$$\sqrt{(10\sin\alpha)^2 + (0.3)^2} = 0.025 \times 20$$

$$\sqrt{(10\sin\alpha)^2 + (0.3)^2} = 0.5$$

Squaring both the sides, we get

$$(10\sin\alpha)^2 + (0.3)^2 = 0.25$$

$$(10\sin\alpha)^2 = 0.25 - 0.09$$

$$(10\sin\alpha)^2 = 0.16$$

$$10\sin\alpha = 0.4$$

$$\sin\alpha = 0.04$$

$$\alpha = 2^\circ 17' 32''$$

EXAMPLE 2.28

A line was measured with a steel tape which was exactly 30 m long at 18°C and found to be 452.343 m. The temperature during measurement was 32°C . Find the true length of the line. Take coefficient of expansion of the tape per $^\circ$C = 0.0000117.

SOLUTION :

$$\text{Temperature correction per tape length} = C_t$$

$$= \alpha(T_m - T_o)\,l$$

Here $\quad$ $l = 30\,\text{m}$

$$T_o = 18^\circ\text{C}$$

$$T_m = 32^\circ\text{C}$$

$$\alpha = 0.0000117$$

Hence $$C_t = 0.0000117(32 - 18)30$$
$$= 0.004914 \text{ m} \ (+\text{ve})$$

Hence the length of the tape at 32°C

$$= 30 + C_t$$
$$= 30 + 0.004914$$
$$= 30.004914 \text{ m}$$

Now true length of a line $= \dfrac{L'}{L} \times$ its measured length

Here $$L = 30 \text{ m}$$
$$L' = 30.004914 \text{ m}$$
$$\text{Measured length} = 452.343 \text{ m}$$

Hence $$\text{True length} = \frac{30.004914}{30} \times 452.343 = 452.417 \text{ m}$$

EXAMPLE 2.29

A line was measured with a steel tape which was exactly 30 m at 18°C and a pull of 50 N and the measured length was 459.242 m. Temperature during measurement was 28°C and the pull applied was 100 N. The tape was uniformly supported during the measurement. Find the true length of the line if the cross-sectional area of the tape was 0.02 cm^2, the coefficient of expansion per $^\circ$C $= 0.0000117$ and the modulus of elasticity $= 21 \times 10^6 \text{ N/cm}^2$.

SOLUTION :

Temperature correction per tape length

$$= \alpha(T_m - T_a)L$$
$$= 0.0000117 \times (28 - 18)30$$
$$= 0.00351 \text{ m} \ (+\text{ve})$$

$$\text{Sag correction per tape length} = 0$$

$$\text{Pull correction per tape length} = \frac{(P_m - P_o)L}{AE}$$
$$= \frac{(100 - 50)30}{0.02 \times 21 \times 10^6}$$
$$= 0.00357 \text{ m} \ (+\text{ve})$$

Hence $$\text{Combined correction} = 0.00351 + 0.00357 \text{ m}$$
$$= 0.00708 \text{ m}$$
$$\text{True length of tape} = 30.00708 \text{ m}$$
$$\text{True length of the line} = \frac{30.00708}{30} \times 459.242$$
$$= 459.350 \text{ m}$$

EXAMPLE 2.30

A 50 m tape is suspended between the ends under a pull of 150 N. The mass of the tape is 1.52 kilograms. Find the corrected length of the tape.

SOLUTION :

$$\text{Correction for sag.} = C_s = \frac{l_1(Mg)^2}{24P^2}$$

$$l_1 = 50\,\text{m}$$

$$M = 1.52\,\text{kg}$$

$$P = 150\,\text{N}$$

Hence $$C_s = \frac{50 \times (1.52 \times 9.81)^2}{24 \times 150^2} = 0.0206\,\text{m}$$

Hence corrected length of the tape

$$= l - C_s$$

$$= 50 - 0.0206 = 49.9794\,\text{m}$$

EXAMPLE 2.31

The downhill end of the 30 m tape is held 80 cm too low. What is the horizontal length?

SOLUTION :

$$\text{Correction for slope} = \frac{h^2}{2l}$$

Here $$h = 0.8\,\text{m}$$

$$l = 30\,\text{m}$$

$$\text{Required correction} = \frac{0.8^2}{2 \times 30} = 0.0167\,\text{m}$$

Hence $$\text{horizontal length} = 30 - 0.0167 = 29.9833\,\text{m}$$

EXAMPLE 2.32

A 100 m tape is held 1.5 m out of line. What is the true length?

SOLUTION :

$$\text{Correction for incorrect alignment} = \frac{d^2}{2l}(-\,ve)$$

Here $$d = 1.5\,\text{m}$$

$$l = 100\,\text{m}$$

Hence $$\text{correction} = \frac{1.5^2}{2 \times 100} = 0.011\,\text{m}$$

$$\text{True length} = 100 - 0.011 = 99.989\,\text{m}$$

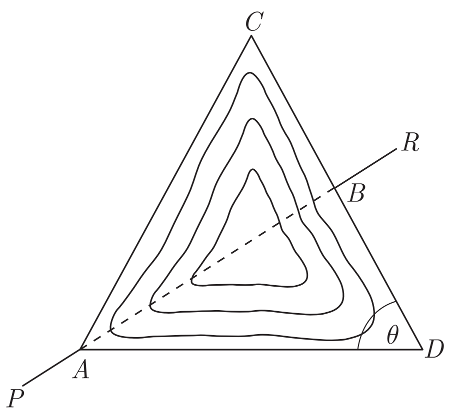
Example on Obstacles in Chaning

EXAMPLE 2.33

To continue a survey line past an obstacle in the form of a pond, stations A and B on the main line were taken on opposite sides of the pond. A line AC, 315 m long, was laid down on the left of AB, and a second line AD, 270 m long was laid down on the right of AB, the points C, B and D being in the same straight line. CB and BD were then measured and found to be 156 m and 174 m respectively. Find the length of AB.

SOLUTION :

As per problem statement the figure is as shown below :



In the triangle ADC,

$$
\begin{aligned}
\text{Let,}\quad \angle ADC &= \theta \\
AD &= 270\,\text{m} \\
AC &= 315\,\text{m} \\
\text{and}\quad DC &= DB + BC \\
&= 174 + 156 \\
&= 330\,\text{m} \\
\text{Now}\quad \cos\theta &= \frac{AD^2 + DC^2 - AC^2}{2 \times AD \times DC} \\
&= \frac{270^2 + 330^2 - 315^2}{2 \times 270 \times 330} \\
\text{or}\quad \log\cos\theta &= 1.6660 \\
\text{Hence}\quad \theta &= 62^\circ 23' \\
\text{In the } \Delta ABD,\quad BD &= 174\,\text{m} \\
AD &= 270\,\text{m} \\
\angle ADB &= \theta = 62^\circ 23' \\
AB^2 &= BD^2 + AD^2 - 2BD \times AD\cos ADB \\
&= 174^2 + 270^2 - 2 \times 174 \times 270\cos 62^\circ 23' \\
&= 59634
\end{aligned}
$$

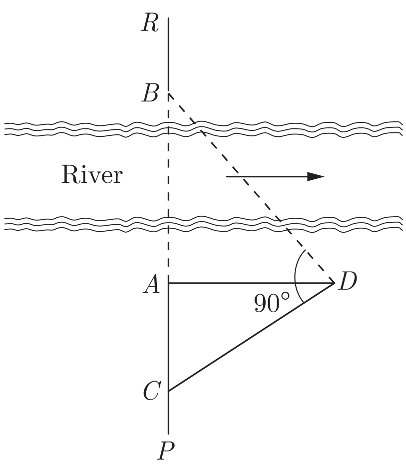
$$AB = \sqrt{59634} = 244.2 \text{ m}$$

EXAMPLE 2.34

A chain line ABC crosses a river, B and C being on the near and distant banks respectively. The respective bearing of C and B taken at D, a point 45 m measured at right angles to AB from B, are $300°$ and $210°$. AB being 24 m. Find the width of the river.

SOLUTION :

As per problem statement the figure is as shown below :



$$\text{Bearing of } DC = 300^\circ$$

$$\text{Bearing of } DA = 210^\circ$$

$$BD = 45 \text{ m}$$

$$AB = 24 \text{ m}$$

$$\angle ADC = \text{bearing of } DC - \text{bearing of } DA$$

$$= 300^\circ - 210^\circ = 90^\circ$$

Let BC = the width of the river

Since the Δs BCD and ABD are similar,

$$\frac{BC}{BD} = \frac{BD}{AB}$$

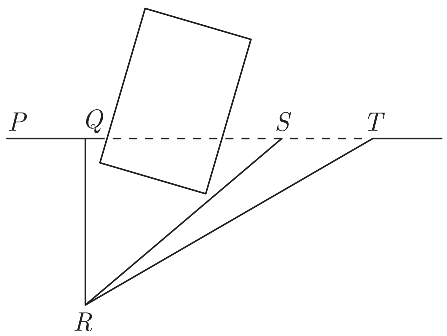
or
$$BC = \frac{BD^2}{AB} = \frac{45^2}{24} = 84.38 \text{ m}$$

EXAMPLE 2.35

A survey line PQ intersects a tall building. To continue the line PQ, QR of length 120 m was set out at right angles to PQ. From R two lines RS and RT , making angles of 45° and 60° with RQ, were ranged. Find the lengths of RS and RT in order that the stations S and T may be in PQ produced, and the length of QS past the building.

SOLUTION :

As per problem statement the figure is as shown below :



In the triangle TRQ,

$$RQ = 120\,\text{m}$$

$$\angle TRQ = 60^\circ$$

and $\angle TQR = 90^\circ$

Hence $$RT = RQ\sec TRQ = 120\sec 60^\circ = 120 \times 2 = 240\,\text{m}$$

In the triangle SRQ,

$$RQ = 120\,\text{m}$$

$$\angle SRQ = 45^\circ$$

Hence $$RS = RQ\sec 45^\circ$$

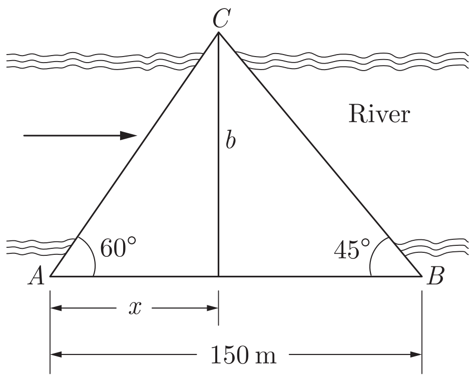
$$= 120\sqrt{2} = 169.68\,\text{m}$$

and $$QS = RQ\tan 45^\circ$$

$$= 120 \times 1 = 120.00\,\text{m}$$

EXAMPLE 2.36

A and B are two points 150 m apart on the nearer bank of a river, which flows east and west as in given Figure. The bearings of the tree on the other bank of a river as observed from A and B are $N.30^\circ E$, and $N.45^\circ W$. Find the width of the river.



SOLUTION :

Let b be the width of the river and x the distance, from A to the foot of the perpendicular from the tree to AB.

Then $$\frac{b}{x} = \tan 60^\circ = \sqrt{3}$$

or $$b = \sqrt{3}\,x$$

$$\frac{b}{(150 - x)} = \tan 45^\circ = 1$$

or $$b = 150 - x$$

Hence $$\sqrt{3} \times x = 150 - x$$

or $$(\sqrt{3} + 1)\,x = 150$$

where $$x = \frac{150}{2.732} = 54.9$$

and $$b = 54.9 \tan 60^\circ = 95.1\,\text{m}$$

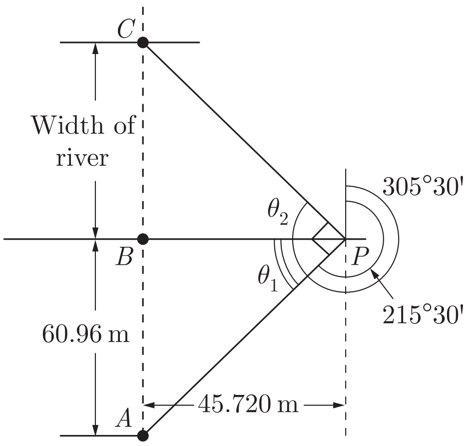
Also, $$b = 150 - x = 150 - 54.9 = 95.1\,\text{m}$$

EXAMPLE 2.37

B and C are two points on the opposite banks of a river along a chain line ABC which crosses the river at right angles to the bank. From a point P which is 42.270 m from B along the bank, the bearing of A is $215^\circ 30'$ and the bearing of C is $305^\circ 30'$. If the length AB is 60.960 m, find the width of the river.

SOLUTION :

As per problem statement the figure is as shown below :



$$\angle APC = 305^\circ 30' - 215^\circ 30' = 90^\circ$$

Given : In ΔABP $\quad l(AB) = 60.960\,\text{m}$

$$l(BP) = 45.720\,\text{m}$$

Hence $$\tan(\angle APB) = \frac{AB}{BP}$$

$$\tan \angle APB = \frac{60.960}{45.720}$$

$$\tan \angle APB = 1.33$$

$$\theta_1 = \angle APB = 53^\circ 7' 48''$$

From figure

$$\angle APC = 305^\circ 30' - 215^\circ 30' = 90^\circ$$

$$\angle BPC = \angle APC - \angle APB$$

$$\theta_2 = \angle BPC = 90^\circ - 53^\circ 7' 48'' = 36^\circ 53'$$

Now, from ΔBPC

$$\tan \angle BPC = \frac{BC}{BP}$$

$$BC = BP(\tan \angle BPC) = 45.720 (\tan 36^\circ 53') = 34.31\,\text{m}$$

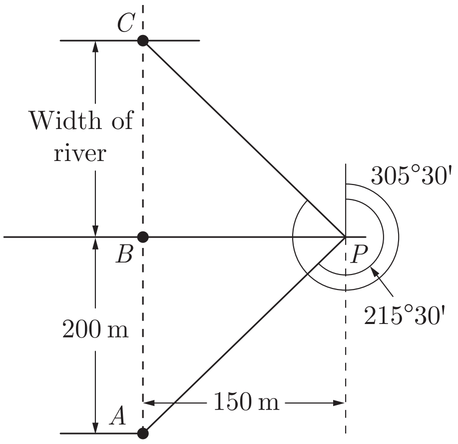
Thus width of river is 34.31 m.

EXAMPLE 2.38

B and C are two points on the opposite banks of a river along a chain line ABC which crosses the river at right angles to the bank. From a point P which is 150 m from B along the bank, the bearing of C is $305^\circ 30'$ and the bearing of A is $215^\circ 30'$. If the length AB is $200\,\text{m}$, find the width of river.

SOLUTION :

As per problem statement the figure is as shown below :



From figure we have

In ΔABP,

$$l(AB) = 200\,\text{m}$$

$$l(BP) = 150\,\text{m}$$

$$\tan(\angle APB) = \frac{AB}{BP}$$

$$= \frac{200}{150} = 1.33$$

$$\angle APB = 53^\circ 7' 48''$$

From Fig.,

$$\angle APC = 305^\circ 30' - 215^\circ 30'$$

$$\angle APC = 90^\circ$$

Now, $\angle BPC = \angle ACP - \angle APB$

$= 90° - 35°7'48'' = 36°53'$

Now, from ΔBPC, $\tan\angle BPC = \dfrac{BC}{BP}$

$$BC = BP\tan\angle BPC$$

$$= 150\tan 36°53' = 112.555\text{ m}$$

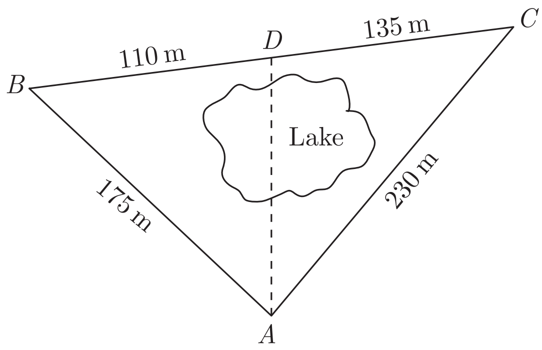
Width of river is 112.555 m.

EXAMPLE 2.39

AD is chain line which crosses a lake, A and B are on the opposite sides of the lake. A line AB of length 175 m is ranged to the left of AD so that it is clear of the lake, similarly another line AC of length 230 m is ranged the right of AD . Further, the points B, D and C are collinear. The lengths of BD and DC are 110 m and 135 m respectively. The chainage of A is 1052.55 m. Calculate the chainage of D.

SOLUTION :

As per problem statement the figure is as shown below :



Chainage $= 1052.55\text{ m}$

From Figre $AD = \sqrt{\dfrac{AB^2\times CD + AC^2\times BD}{BC} - BD\times CD}$

$$= \sqrt{\frac{175^2\times 135 + 230^2\times 110}{(110+135)} - (110\times 135)}$$

$$= 160.55\text{ m}$$

Now, Chainage of D = Chainage of $A + AD$

$$= 1052.55 + 160.55 = 1213.10\text{ m}$$

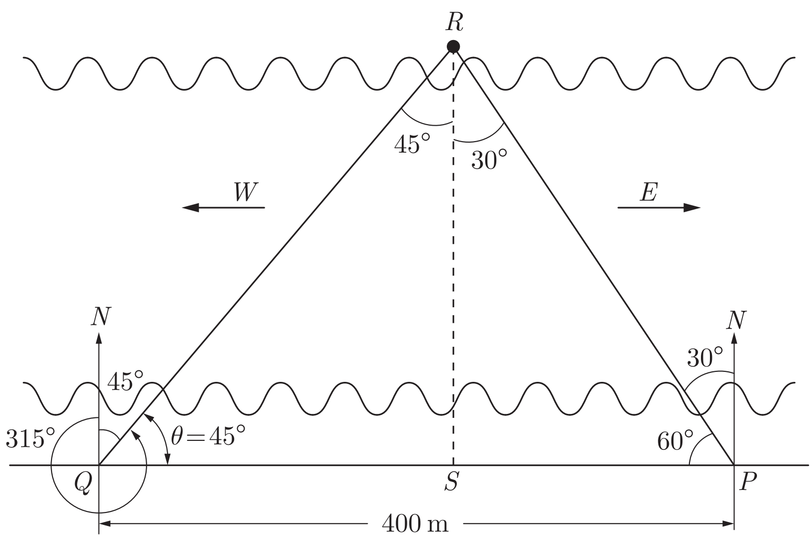
Chainage of D is 1213.10 m.

EXAMPLE 2.40

To find out the width of a river, flowing west-east, two points P and Q are fixed along a bank 400 m apart. The bearing of a pole R on the other bank of the river as observed from P and Q are 30° and 315°. Determine the width of the river.

SOLUTION :

As per problem statement the figure is as shown below :



From Figure

In ΔPSR $\tan 30^\circ = \frac{PS}{SR}$

$$PS = SR\tan 30^\circ$$

and in ΔQSR $\tan 45^\circ = \frac{QS}{SR}$

$$QS = SR\tan 45^\circ$$

or $PS + QS = SR\tan 30^\circ + SR\tan 45^\circ$

$$PQ = SR(\tan 30^\circ + \tan 45^\circ) \qquad [PS + QS = PQ]$$

$$400 = SR(0.577 + 1)$$

$$400 = SR(1.577)$$

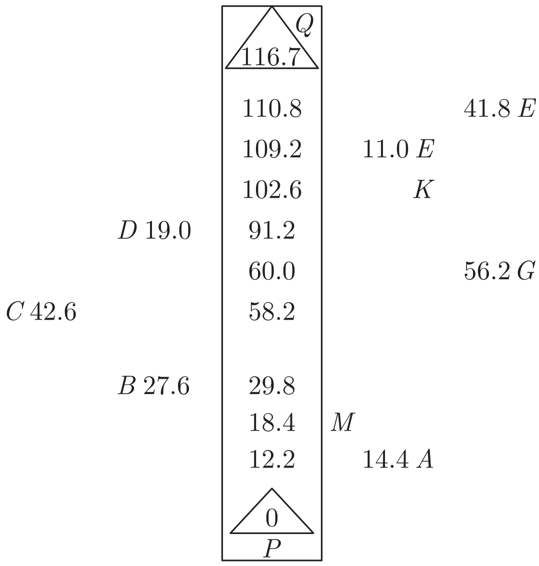
$$SR = 253.65\,\text{m}$$

Thus width of river is 253.65 m.

Example on Cross-staff Survey

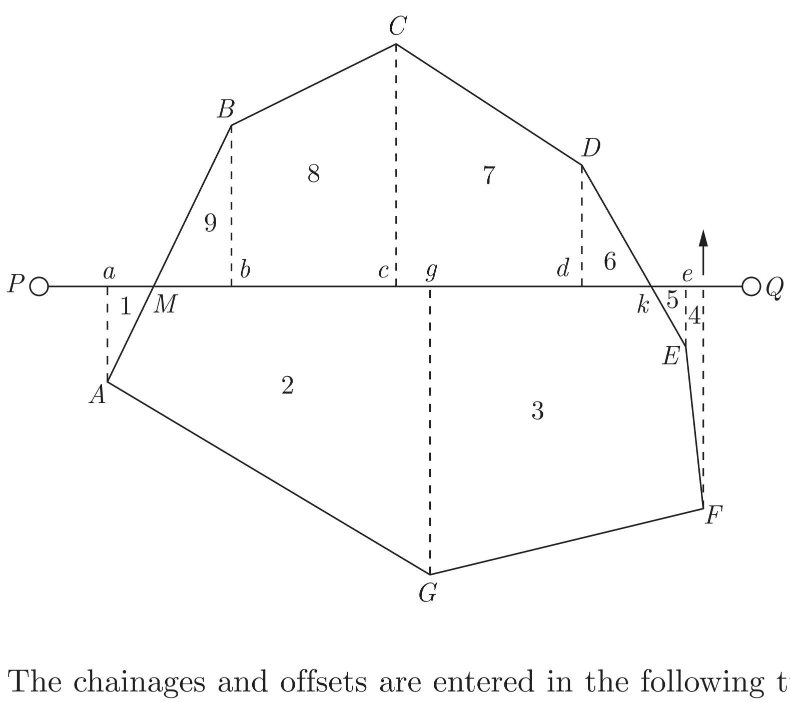
EXAMPLE 2.41

Plot the following cross staff survey of a field $ABCDEF$, and calculate its area.



SOLUTION :

From the given field data the area *ABCDEFG* is sketched as shown in following Figure. It is divided into right angled triangles and trapeziums. The chainages and offsets are entered in the following tubular form to compute the area.



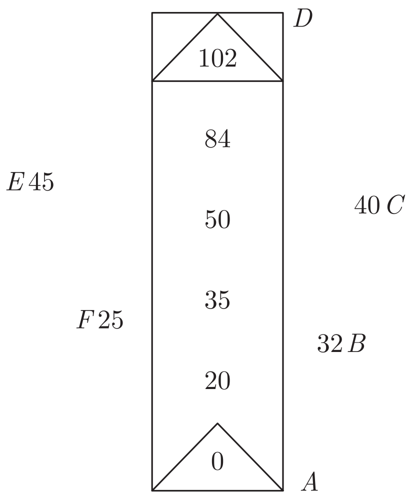
The chainages and offsets are entered in the following tubular form to compute the area :

S. No.	Figure	Chainage in m	Base in m	offset in m	Mean offset in m	Area in m^2 +ve	−ve	Remarks
1	2	3	4	5	6	7	8	9

1	ΔaAM	12.2 & 18.4	6.2	14.4 & 0	7.2		444.6	Area = col.4 × col.6
2	$aAGg$	1.2 & 60.0	47.8	14.4 & 56.2	35.3	1687.34		
3	$gGFf$	60.0 & 110.8	58.8	56.2 & 41.8	49.0	2489.20		
4	$eEFf$	109.2 & 110.8	1.6	11.0 & 41.8	26.4		42.24	
5	ΔcEK	109.2 & 102.6	11.4	11.0 & 0	5.5		36.30	
6.	ΔKDd	102.6 & 91.2	33.0	0 & 19.0	9.5	108.30		
7	$dDCc$	91.2 & 58.2	28.4	19.0 & 42.6	30.8	1016.40		
8	$cCBb$	58.2 & 29.8	11.4	42.6 & 27.6	35.1	996.84		
9	ΔbBM	29.8 & 18.4		27.6 & 0	13.8	157.32		
Total						6455.40	123.18	
Net area						6332.22		

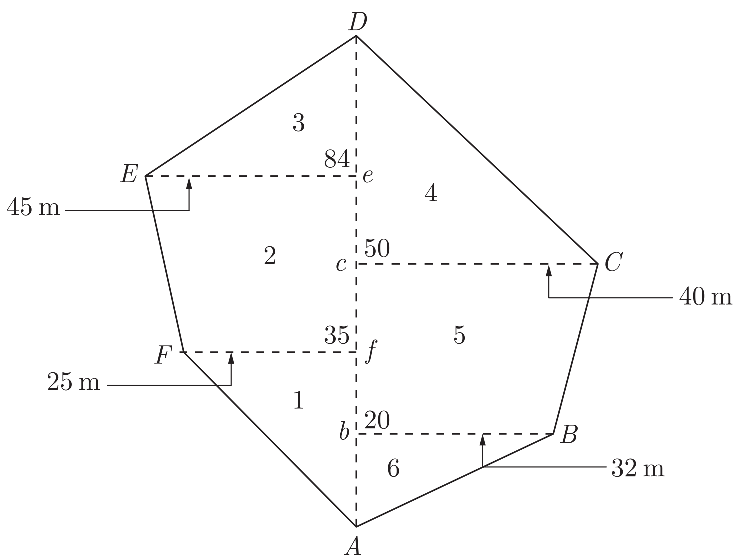
EXAMPLE 2.42

Calculate the area of a field from the following cross-staff survey.



SOLUTION :

From the given field data the area $ABCDEF$ is sketched as shown in following Figure. It is divided into right angled triangles and trapeziums.



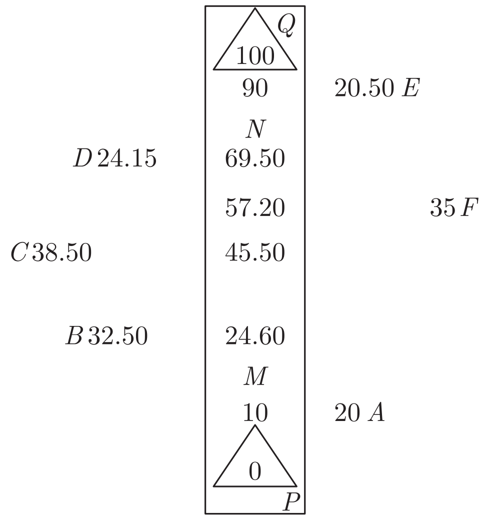
The chainages and offsets are entered in the following tubular form to compute the area :

S r . No.	Figure	Chainage in m.	Base in m.	Off-set in m.	M e a n offset	Area in m^2 = (base × mean offset)
				O_1 O_2	$\dfrac{O_1 + O_2}{2}$	+ve
1	2	3	4	5	6	7
1.	$\triangle$ AfF	0 and 35	35	0 and 25	12.5	437.50
2.	⏢ $FfeE$	35 and 84	49	25 and 45	35.00	1715.00
3.	$\triangle$ EeD	84 and 102	18	45 and 0	22.50	405.00
4.	$\triangle$ DCc	50 and 102	52	40 and 0	20.00	1040.00
5.	⏢ $cCBb$	20 and 50	30	32 and 40	36	1080.00
6.	$\triangle$ ABb	0 and 20	20	0 and 32	16	320.00
					Total	4997.5

Area of the field is $4997.5\,\text{m}^2$.

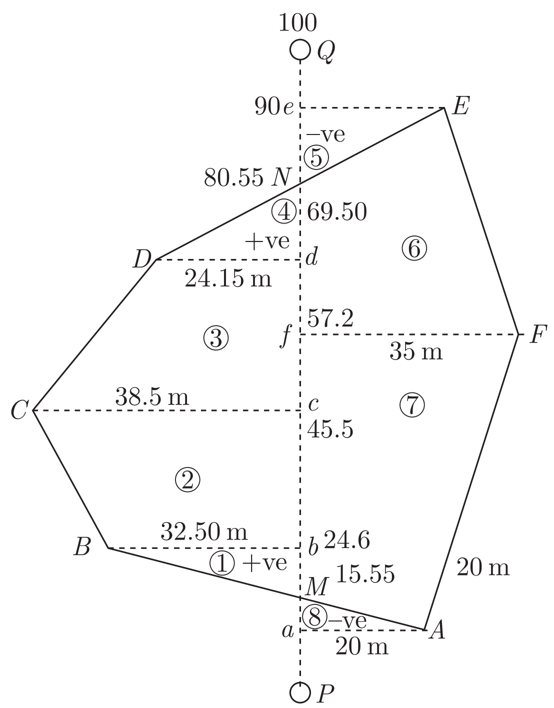
EXAMPLE 2.43

Plot the area of a field $ABCDEF$ surveyed with reference to a chain line PQ. The station P and Q are beyond boundary of the field.



SOLUTION :

From the given field data the area $ABCDEF$ is sketched as shown in following Figure. It is divided into right angled triangles and trapeziums.



In this type, the triangles i.e. AaM and EeN are beyond the boundary of field $ABCDEF$ and hence their area is taken as negative area.

The chainages of point M and N may be measured, directly from the plotted figure or it can be calculated from similar triangles, so formed. The same can also be found in the field by ranging lines A to B and D to E. The chain line cuts at points M and N.

The chainages of M and N are 15.55 and 80.55 respectively. The results are tabulated below to calculate the area of the field.

Sr. No.	Figure	Chainage in m.	Base in m.	Off-set in m.	Mean offset	Area in m^2 = (base × mean offset)
1.	△ Bbm	15.55 & 24.60	9.05	0 & 32.50	16.25	+ve
2.	⏢ $BbcC$	24.60 & 45.50	20.90	32.50 & 38.50	35.5	147.06
3.	⏢ $CcdD$	45.50 & 69.50	24	38.50 & 24.15	31.325	741.95
4.	△ DdN	69.50 & 80.55	11.05	24.15 & 0	12.075	751.80
5.	△ eEN	90&80.55	9.45	20.50&0	10.25	133.43
6.	⏢ $eEFf$	90 & 57.20	32.80	20.50 & 35	27.75	– 96.86
7.	⏢ $fFAa$	57.20 & 10.00	47.20	35 & 20	27.50	910.20
8.	△ aAM	15.55 & 10	5.55	20 & 0	10.00	– 55.50
					Total	=3830.58

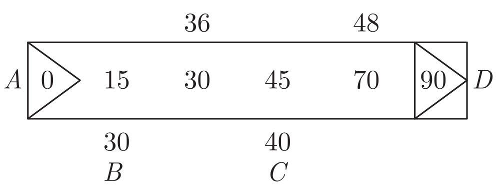
$$\text{Area of the field } ABCDEF = 3830.08 \text{ sq.m.}$$

$$OR = \frac{3830.58}{10000} = 0.383 \text{ Hectare}$$

(1 Hectare = 10,000 sq.m)

EXAMPLE 2.44

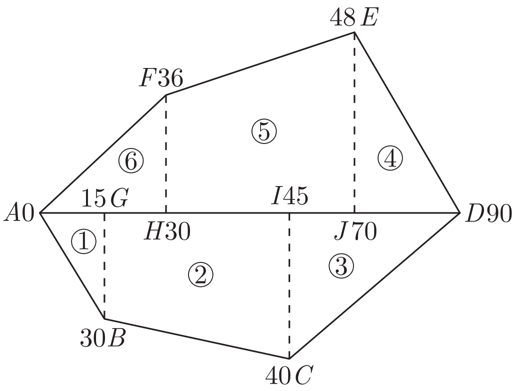
Plot the following cross-staff survey of field and calculate its area in m^2 as shown in Figure given below.



Line $AD \longrightarrow$ All dimensions in metres

SOLUTION :

From the given field data the area $ABCDEF$ is sketched as shown in following Figure. It is divided into right angled triangles and trapeziums.



The chainages and offsets are entered in the following tubular form to compute the area :

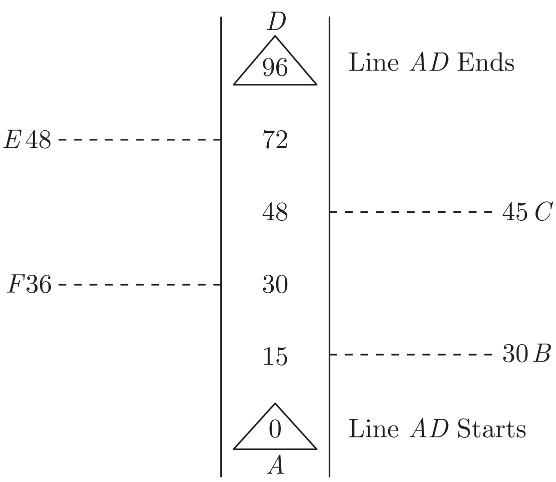
Sr. No.	Figure	Chainage in (m)		Base in (m)	Off-set in m.		Mean area (m)	Area in sq.m.
		From	To		No. 1	No. 2		
1	△ *ABG*	0	15	15	0	30	15	225
2	□ *GBCI*	15	45	30	30	40	35	1050
3	△ *CID*	45	90	45	40	0	20	900
4	△ *DJE*	70	90	20	0	48	24	480
5	□ *EJHF*	70	30	40	48	36	42	1680
6	△ *FHA*	30	0	30	36	0	18	540
						Total	$= 4875\ \text{m}^2$	

NOTE :

Area = base × mean offset

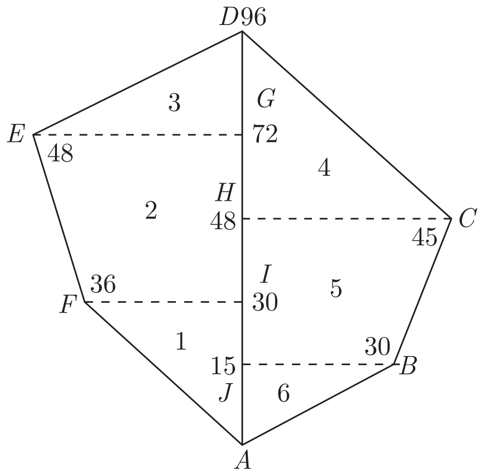
EXAMPLE 2.45

Plot the following cross-staff survey of a field and calculate the area *ABCDEF*.



SOLUTION :

From the given field data the area *ABCDEF* is sketched as shown in following Figure. It is divided into right angled triangles and trapeziums.

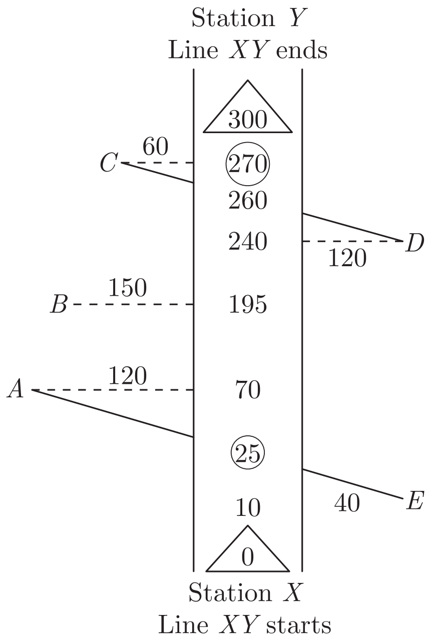


The chainages and offsets are entered in the following tubular form to compute the area :

Sr. No.	Figure	Chainages (m)		Base	Off-set O_1	O_2	Mean offset	Area in sq.m.
		From	To		No. 1	No. 2		
1	△ *AIF*	0	30	30	0	36	18	540.0
2	⏢ *FEGI*	30	72	42	36	48	42	1764.0
3	◺ *EGD*	72	96	24	48	0	24	576.0
4	◺ *DHC*	48	96	48	45	0	22.5	1080.0
5	⏢ *HJBC*	15	48	33	30	45	37.5	1237.5
6	◺ *BJA*	0	15	15	0	30	15	225.0
Total area $= 5422.5\ \mathrm{m}^2$								

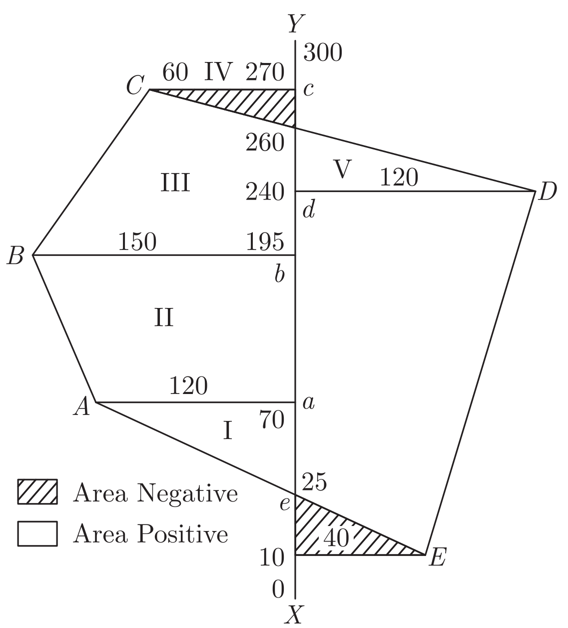
EXAMPLE 2.46

Plot the cross-staff survey of the field and calculate the area of the Fig. *ABCDEA* in hectares. Find the area of Fig. *ABCDEA*. (All dimensions are in metres.)



SOLUTION :

From the given field data the area $ABCDEA$ is sketched as shown in following Figure. It is divided into right angled triangles and trapeziums.



The chainages and offsets are entered in the following tubular form to compute the area :

Sr. No.	Figure	Chainages		Base	Off-set		Mean offset	Area in sq.m.
		From	To		No. 1	No. 2		
1	eaA	25	70	45	0	120	60	2700
2	$abBA$	70	195	125	120	150	135	16875

3	⏢ $bcCB$	195	270	75	150	60	105	7875
4	$\triangle$ VcC	260	270	10	00	60	30	–300
5	$\triangle$ dVD	240	260	20	0	120	60	1200
6	⏢ $OdDE$	10	240	230	40	120	80	18400
7	$\triangle$ OeE	10	25	15	40	0	20	–300
Total area = $46450\,\mathrm{m}^2$								

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REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS

2.1 Chain survey is generally used for

(a) Small area is open ground
(b) Small area which are crowded by features
(c) Large area in open ground
(d) Hilly areas

Ans. (a) Small area is open ground

2.2 Chain surveying is recommended when the area is

(a) Crowded
(b) Undulating
(c) Simply and fairly level.
(d) None of these

Ans. (c) Simply and fairly level

2.3 Chain surveying is a method in which it is required to measure

(a) Linear measurement
(b) Area measurement
(c) Volume measurement
(d) combination of a, b and c

Ans. (a) Linear measurement

2.4 In chain survey the area is divided into

(a) Rectangles
(b) Triangles
(c) Squares
(d) Circles

Ans. (b) Triangles

2.5 In chain surveying field work is limited to

(a) Linear measurement only
(b) Angular measurement only
(c) Both linear and angular measurement only
(d) None of the above

Ans. (a) Linear measurement only

2.6 Chainage in chain survey means

(a) The distance between and stations
(b) The perpendicular distance of an object from chain line
(c) Any distance measured by chain in field
(d) The distance of an object along chain line from zero and of the chain.

Ans. (d) The distance of an object along chain line from zero and of the chain

2.7 Another name of check line is

(a) tie line
(b) Proof line
(c) Base line
(d) None of the above

Ans. (b) Proof line

2.8 Each links of engineers chain is divided into links of

(a) 10
(b) 50
(c) 75
(d) 100

Ans. (d) 100

2.9 Ranging is defined as

(a) Measuring of the distance from starting point
(b) Measuring the distance from end point
(c) Establishing immediate points on a chain line
(d) To take an offset from a chain line.

Ans. (c) Establishing immediate points on a chain line

2.10 Cross staff is used for

(a) Setting out right angles
(b) Measuring horizontal angles
(c) Both a and b
(d) None of the above

Ans. (a) Setting out right angles

2.11 In chain survey, 3-4-5 method is used to determine

(a) Point to perpendicular to the chain line
(b) Length of chain line
(c) Instrument stations
(d) None of the above

Ans. (a) Point of perpendicular to the chain line

2.12 A 20 m chain is divided into

(a) 100 links
(b) 150 links
(c) 200 links
(d) 250 links

Ans. (a) 100 links

2.13 A 30 m chain is divided into

(a) 100 links
(b) 150 links
(c) 200 links
(d) 220 links

Ans. (b) 150 links

2.14 The length of Gunter's chain is

(a) 50 ft
(b) 66 ft
(c) 96 ft
(d) 106 ft

Ans. (b) 66 ft

2.15 Accurate measurement is made by

(a) Chain
(b) Invar tape
(c) Metallic
(d) None of the above

Ans. (c) Metallic

2.16 Each meter length of metric chain of divided into links of

(a) 15
(b) 20
(c) 5
(d) 30

Ans. (c) 5

2.17 Optical square is used to measure

(a) Distance
(b) Angles
(c) Setting right angles
(d) Area

Ans. (c) Setting right angles

2.18 A subsidiary line is the same as

(a) Range tie
(b) Survey line
(c) Base line
(d) Tie line

Ans. (d) Tie line

2.19 The angle of intersection of the two plain mirrors of the optical square is

(a) 30°
(b) 45°
(c) 60°
(d) 90°

Ans. (b) 45°

2.20 The principal of working from optical square is based on

(a) Double refraction
(b) Double reflection
(c) Single reflection
(d) None of the above

Ans. (b) Double reflection

2.21 The limiting length of offset depends upon
(a) Scale of plotting
(b) Method of measurement
(c) Method of layout
(d) Non of the above

Ans. (a) Scale of plotting

2.22 The angle of intersection in an optical square is
(a) 30°
(b) 45°
(c) 60°
(d) 90°

Ans. (b) 45°

2.23 A tie line is run
(a) To check accuracy of the field work
(b) To locate details which are away from the chain line
(c) Between main survey stations
(d) Parallel to the survey line

Ans. (b) To locate details which are away from the chain line

2.24 The principle chain surveying is to divide the area into
(a) Rectangles
(b) Squares
(c) Triangles
(d) Polygons

Ans. (c) Triangles

2.25 A chain triangles is said to be well conditioned if none of its angle is less than
(a) 15°
(b) 20°
(c) 30°
(d) 45°

Ans. (c) 30°

2.26 The main survey stations are located on the ground by
(a) Index sketches
(b) Reference sketches
(c) Line sketches
(d) None of the above

Ans. (b) Reference sketches

2.27 A straight line joining a station on main survey line and another station in another survey line is called
(a) Subsidiary line
(b) Tie line
(c) Check line
(d) Base line

Ans. (b) Tie line

2.28 The longest chain passing through the centre of the area is known as
(a) Check line
(b) Survey line
(c) Base line
(d) Tie line

Ans. (c) Base line

2.29 The method of stepping is used for measuring horizontal distances in case of
(a) Level surface
(b) Undulating surface
(c) Slopping surface
(d) In any surface

Ans. (c) Slopping surface

2.30 Prolongation of a chain line across an obstruction in chain surveying is done by
(a) Making angular measurement
(b) Drawing perpendiculars with a chain
(c) Solution of triangles
(d) All the above

Ans. (b) Drawing perpendiculars with a chain

2.31 Greater accuracies in linear measurements is obtained by
(a) Tacheometer
(b) Direct chaining
(c) Direct tapping
(d) none of the above

Ans. (c) Direct tapping

2.32 The correction of slope for a chain of length L and difference height h is given by
(a) $\frac{h}{2L}$
(b) $\frac{h^2}{L}$
(c) $\frac{h^2}{2L^2}$
(d) $\frac{h^2}{2L}$

Ans. (c) $\frac{h^2}{2L}$

2.33 The correction for sag is :
(a) Always additive
(b) Always Subtractive
(c) Always Zero
(d) None of the above

Ans. (b) Always Subtractive

2.34 If the length of chain line along slope of 0° is L, the required slope correction is

(a) $2L\cos\dfrac{\theta}{2}$

(b) $2L\sin^2\dfrac{\theta}{2}$

(c) $L\tan^2\dfrac{0}{2}$

(d) $L\cos^2\dfrac{\theta}{2}$

Ans. (b) $2L\sin^2\dfrac{\theta}{2}$

2.35 Temperature correction of a type

(a) Is always negative

(b) Is always positive

(c) May be negative or positive

(d) Zero

Ans. (c) May be negative or positive

2.36 If the length of a chain line along a slope of $\theta°$ is L, the required slope correction is

(a) $-2\sin^2\dfrac{\theta}{2}$

(b) $-2L\cos^2\dfrac{\theta}{2}$

(c) $+2L\sin^2\dfrac{\theta}{2}$

(d) $+2L\cos^2\dfrac{\theta}{2}$

Ans. (b) $-2L\cos^2\dfrac{\theta}{2}$

2.37 A tape of length L and weight W is suspended at its ends with a pull pf P, the sag correction is

(a) $\dfrac{WL^2}{24P^2}$

(b) $\dfrac{W^3L^2}{24P^2}$

(c) $\dfrac{W^2L^2}{24P^3}$

(d) $\dfrac{W^2L}{24P^2}$

Ans. (c) $\dfrac{W^2L^2}{24P^3}$

2.38 Correct distance obtained by an erroneous chain is

(a) Length

(b) $\dfrac{\text{Observed chain length}}{\text{Erroneous chain}} \times \text{Observed distance}$

(c) $\frac{\text{Correct chain length}}{\text{Observed distance}}$

(d) None of the above

Ans. (a) Length

2.39 The permissible error in chaining on rough or hilly areas is usually

(a) 1 in 100

(b) 1 in 250

(c) 1 in 1000

(d) 1 in 10,000

Ans. (b) 1 in 250

2.40 Compensating or accidental errors of length are proportional to

(a) L

(b) $\sqrt{L}$

(c) L^2

(d) $\frac{1}{\sqrt{L}}$

Ans. (b) $\sqrt{L}$

2.41 Correction for the slope is given by :

(a) $\frac{D^2}{2L}$

(b) $\frac{D}{L}$

(c) $\frac{D}{2L}$

(d) $\frac{2D^2}{L}$

Ans. (a) $\frac{D^2}{2L}$

2.42 The slope correction for a length of 30 m along a gradient of 1 in 20 is

(a) 0.375 m

(b) 3.75 cm

(c) 37.5 cm

(d) 2.75 m

Ans. (b) 3.75 cm

2.43 Correction to be applied to a 30 m chain length along θ° slope is

(a) $30(\sin\theta - 1)$

(b) $30(\cos\theta - 1)$

(c) $30(\tan\theta - 1)$

(d) $30(\sec\theta - 1)$

Ans. (d) $30(\sec\theta - 1)$

2.44 Plumb bob is used for

(a) Levelling

(b) Measuring distance

(c) Measuring angles
(d) Centering

Ans. (d) Centering

2.45 Clinometers is used to measure
(a) Length
(b) Slope of line
(c) Error in measurement
(d) None o the above

Ans. (b) Slope of line

2.46 A tie line is run
(a) To check the accuracy of field work
(b) To locate details which are away from the chain line
(c) Parallel line to the survey line
(d) Between main survey lines

Ans. (b) To locate details which are away from the chain line

2.47 The number of revolutions is registered in an instrument called.
(a) Passometer
(b) Odometer
(c) Speedometer
(d) Dynameters

Ans. (b) Odometer

2.48 An invar tape is made of an alloy of
(a) Brass and steel
(b) Nickel and steel
(c) Copper and steel
(d) None of the above

Ans. (b) Nickel and steel

2.49 A metallic tape is made up of
(a) Metallic wives and cloth
(b) Steel
(c) metal
(d) None of the above

Ans. (a) Metallic wives and cloth

2.50 A triangle is said to be well conditioned when its angles should lie between degrees
(a) 30° and 120°
(b) 30° and 150°
(c) 30° and 180°
(d) 15° and 115°

Ans. (a) 30° and 120°

2.51 The chain man who drags the chain is called

(a) Captain
(b) Leader
(c) Follower
(d) Labour

Ans. (b) Leader

2.52 Maximum tolerance in a 20 m and 30 m are :
(a) $\pm 2\,\text{mm} \pm 8\,\text{mm}$
(b) $\pm 3\,\text{mm} \pm 5\,\text{mm}$
(c) $\pm 5\,\text{mm} \pm 8\,\text{mm}$
(d) $\pm 5\,\text{mm} \pm 10\,\text{mm}$

Ans. (c) $\pm 5\,\text{mm} \pm 8\,\text{mm}$

2.53 Which of the following is an obstacle in chaining but not to ranging?
(a) River
(b) Hill
(c) Building
(d) None of the above

Ans. (a) River

2.54 The field record of the chain survey is entered in :
(a) Exercise book
(b) Field book
(c) Level book
(d) Account book

Ans. (b) Field book

2.55 If a wooded area obstructs the chain line, then it is crossed by the
(a) Profile line
(b) Random line
(c) Projection line
(d) None of the above

Ans. (b) Random line

2.56 The end link is considered
(a) Including the length of the handle
(b) Excluding the length of the handle
(c) From the centre of the handle
(d) None of the above

Ans. (a) Including the length of the handle

2.57 The walking step of a man is approximately equal to
(a) 80 cm
(b) 90 cm
(c) 100 cm
(d) None of the above

Ans. (a) 80 cm

2.58 The preliminary inspection of the area to be surveyed is known as

(a) Primary survey
(b) Reconnaissance survey
(c) Route survey
(d) None of the above

Ans. (b) Reconnaissance survey

2.59 One link means the distance from

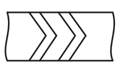
(a) Centre to centre of middle rings
(b) Centre to centre of outer rings
(c) Centre to centre of inner rings
(d) None of the above

Ans. (a) Centre to centre of middle rings

2.60 For taking an oblique offset which makes an angle of 45° with the chain line, the instrument use is the

(a) Adjustable cross-staff
(b) Open cross-staff
(c) French cross-staff
(d) None of the above

Ans. (c) French cross-staff

2.61 The conventional sign 
Canal lock
represents a

(a) Canal lock
(b) Road with culvert
(c) Tunnel
(d) Canal

Ans. (a) Canal lock

2.62 The conventional sign 
Church
represents a

(a) Temple
(b) Telephone line
(c) Tree
(d) Church

Ans. (d) Church

SHORT QUESTIONS

LONG QUESTIONS

NUMERICAL QUESTIONS