1

Introduction

1.1. DEFINITION

Surveying is the art of determining the relative positions of distinctive features on the surface of the earth or beneath the surface of the earth, by means of measurements of distances, directions and elevations. The branch of surveying which deals with the measurements of relative heights of different points on the surface of the earth, is known as *levelling*.

1.2. OBJECT OF SURVEYING

The objet of surveying is the preparation of plans and maps of the areas. The science of surveying has been developing since the very initial stage of human civilization according to the requirements. The art of surveying and preparation of maps has been practised from the ancient times. As soon as the man developed the sense of land property, he evolved methods for demarcating its boundaries. Hence, the earliest surveys were performed only for the purpose of recording the boundaries of plots of land. Due to advancement in technology, the science of surveying has also attained its due importance. The practical importance of surveying cannot be over-estimated. In the absence of accurate maps, it is impossible to lay out the alignments of roads, railways, canals, tunnels, transmission power lines, and microwave or television relaying towers. Detailed maps of the sites of engineering projects are necessary for the precision establishment of sophisticated instruments. Surveying is the first step for the execution of any project. As the success of any engineering project is based upon the accurate and complete survey work, an engineer must, therefore, be thoroughly familiar with the principles and different methods of surveying and mapping. It is for this reason, the subject of surveying has been made compulsory to all the disciplines of engineering at diploma and degree courses.

1.3. PRIMARY DIVISIONS OF SURVEYING

The surveying may primarily be divided into two divisions:

1. Plane surveying, 2. Geodetic surveying

1. Plane Surveying. The surveys in which earth surface is assumed as a plane and the curvature of the earth is ignored, are known as *Plane surveys.* As the plane survey extends only over small areas, the lines connecting any two points on the surface of the earth, are treated as straight lines and the angles between these lines are taken as plane angles. Hence, in dealing with plane surveys, plane geometry and trigonometry are only required. Surveys covering an area up to 260 sq. km may be treated as plane surveys because the difference in length between the arc and its subtended chord on the earth surface for a distance of 18.2 km, is only 0.1 m.

Scope and Use of Plane Surveying. Plane surveys which generally cover areas up to 260 sq. km, are carried out for engineering projects on sufficiently large scale to determine relative positions of individual features of the earth surface.

Plane surveys are used for the lay-out of highways, railways, canals, fixing boundary pillars, construction of bridges, factories etc. The scope and use of plane surveys is very wide. For majority of engineering projects, plane surveying is the first step to execute them. For proper, economical and accurate planning of projects, plane surveys are basically needed and their practical significance cannot be over-estimated.

2. Goedetic Surveying. The surveys in which curvature of the earth is taken into account and higher degree of accuracy in linear as well as in angular observations is achieved, are known as *'Geodetic Surveying'.* In geodetic surveying, curvature of the earth's surface is taken into account while making measurements on the earth's surface. As the surveys extend over large areas, lines connecting any two points on the surface of the earth, are treated as arcs. For calculating their projected plan distances for the plotting on the maps, the curvature correction is applied to the measured distances. The angles between the curved lines are treated as spherical angles. A knowledge of spherical trigonometry is necessary for making measurements for the geodetic surveys.

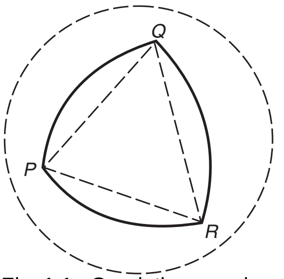

Fig. 1.1. Geodetic surveying.

Scope and use of Geodetic Surveying. Geodetic surveys are conducted with highest degree of accuracy to provide widely spaced control points on the earth's surface for subsequent plane surveys. Provision of such control points, is based on the principle of surveying from the whole to the part and not from the part to the whole. Geodetic surveys require the use of sophisticated instruments, accurate methods of observations and their computation with accurate adjustment. These surveys are generally carried out to provide plan control. To eliminate the errors in observations due to atmospheric refraction, angular observations are generally restricted to nights and arc lamps are used as signals on the survey stations.

Geodetic surveys are usually carried out by the department of National Surveys. In India, geodetic surveys are conducted by the department of the Survey of India under the direction of the Surveyor General of India.

1.4. CLASSIFICATION OF SURVEYS

According to the use and the purpose of the final maps, surveys may be classified, under the following different heads:

1.4.1. Classification based upon the nature of the field

Land Surveys. These include the following:

(*i*) **Topographic surveys.** The surveys which are carried out to depict the topography of the mountaineous terrain, rivers, water bodies, wooded areas and other cultural details such as roads, railways, townships etc., are called *topographical surveys.*

(*ii*) **Cadastral surveys.** The surveys which are generally plotted to a larger scale than topographical surveys and arc carried out for fixing the property lines, calculation of area of landed properties and preparation of revenue maps of states, are called *cadastral survey.* These are also sometimes used for surveying the boundaries of municipalities, corporations and cantonments.

(*iii*) **City surveys.** The surveys which are carried out for the construction of roads, parks, water supply system, sewer and other constructional work for any developing township, are called *City surveys.* The city maps which are prepared for the tourists are known as *Guide Maps.* Guide maps for every important city of India, are available from the offices of the department of Tourism.

2. Hydrographic Surveys. The surveys which deal with the mapping of large water bodies for the purpose of navigation, construction of harbour works, prediction of tides and determination of mean sea-level, are called *Hydrographic surveys.* Hydrographic surveys consist of preparation of topographical maps of the shores and banks, by taking soundings and determining the depth of water at a number of places and ultimately surveying bathymetric contours under water.

3. Astronomical Surveys. The surveys which are carried out for determining the absolute locations *i.e.*, latitudes of different places on the earth surface and the direction of any line on the surface of the earth by making observations to heavenly bodies, *i.e.,* stars and sun, are called *astronomical surveys.* In nothern hemisphere, when night observations are preferred to, observations are usually made to the Polaris, *i.e.,* the pole star.

1.4.2. Classification based on the purpose of the survey

1. Engineering Surveys. The surveys which are carried out for determination of quantities or to afford sufficient data for designing engineering works, such as roads, reservoirs, sewage disposal, water supply, etc., are called *Engineering Surveys.*

2. Military or Defence Surveys. The surveys which are carried out for preparation of maps of the areas of Military importance, are called *military surveys.*

3. Mine Surveys. The surveys which are carried out for exploration of mineral wealths beneath the surface of the ground, *i.e.,* coal, copper, gold, iron ores etc., are called *Mine surveys.*

4. Geological Surveys. The surveys which are carried out to ascertain the composition of the earth crust *i.e.*, different stratas of rocks of the earth crust, are called *Geological surveys.*

5. Archaelogical Surveys. The surveys which are carried out to prepare maps of ancient culture *i.e.*, antiquities, are called *Archaelogical surveys.*

1.4.3. Classification based on instruments used

According to the instruments used and method of surveying, the surveys may also be classified as under :

1. Chain surveying
2. Compass surveying
3. Plane table surveying
4. Theodolite surveying
5. Tacheometric surveying
6. Triangulation surveying
7. Aerial surveying
8. Photogrammetric surveying

1.5. GEOGRAPHICAL SURVEY

The following technical terms are generally used in surveying:

1. Plan. A plan is the graphical representation of the features on the earth surface or below the earth surface as projected on a horizontal plane. This may not necessarily show its geographical position on the globe. On a plan, horizontal distances and directions are generally shown.

2. Map. The representation of the earth surface on a small scale, is called a *map*. The map must show its geographical position on the globe. On a map the topography of the terrain, is depicted generally by contours, hachures and spot levels.

3. Topographical map. The maps which are on sufficiently large scale to enable the individual features shown on the map to be identified on the ground by their shapes and positions, are called *topographical maps.*

4. Geographical maps. The maps which are on such a small scale that the features shown on the map are suitably generalized and the map gives a picture of the country as a whole and not a strict representation of its individual features, are called *Geographical maps.*

1.6. PRINCIPLE OF SURVEYING

The fundamental principles upon which different methods of surveying are based, are very simple. These are stated as under:

1. Working from the whole to the part. The main principle of surveying whether plane or geodetic is to work from the whole to the part. To achieve this in actual practice, a sufficient number of primary control points, are established with higher precision in and around the area to be detail-surveyed. Minor control points in between the primary control points, are then established with less precise method. Further details are surveyed with the help of these minor control points by adopting any one of the survey methods. The main idea of working from the whole to the part is to prevent accumulation of errors and to localise minor errors within the frame work of the control points. On the other hand, if survey is carried out from the part to the whole, the errors would expand to greater magnitudes and the scale of the survey will be distorted beyond control.

In general practice the area is divided into a number of large triangles and the positions of their vertices are surveyed with greater accuracy, using sophisticated instruments. These triangles are further divided into smaller triangles and their vertices are surveyed with lesser accuracy.

2. Location of a point by measurement from two control points. The control points are selected in the area and the distance between them, is measured accurately. The line is then plotted to a convenient scale on a drawing sheet. In case, the control points are co-ordinated, their locations may be plotted with the system of coordinates, *i.e.,* cartesian or spherical. The location of the required point may then be plotted by making two measurements from the given control points as explained below.

Let P and Q be two given control points. Any other point, say, R can be located with reference to these points, by any one of the following methods (Fig.1.2).

(*a*) *By measuring the distances PR and QR.* The distances PR and QR may be measured and the location of R may be plotted by drawing arcs to the same scale to which line PQ has been drawn [Fig.1.2 (*a*)].

(*b*) *By Dropping a perpendicular from R on PQ.* A perpendicular *RT* may be dropped on the line *PQ*. Distances *PT*, *TQ* and *RT* are measured and the location of *R* may be plotted by drawing the perpendicular *RT* to the same scale to which line *PQ* has been drawn [Fig. 1.2 (*b*)].

Principles (*a*) and (*b*) are generally used in the method of 'Chain surveying'.

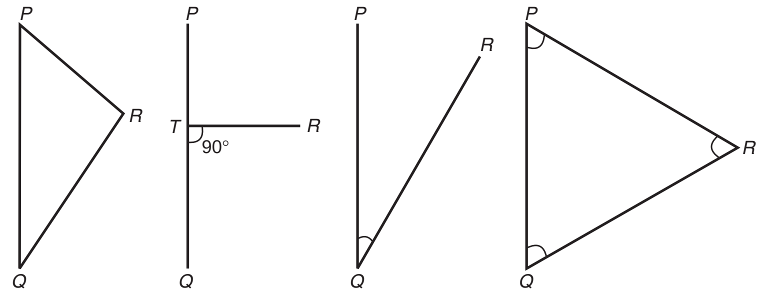

Fig.1.2. Location of a point.

(*c*) *By measuring the distance QR and the angle PQR.* The distance *QR* and the angle *PQR* equal to α are measured and the location of *R* may be plotted either by means of a protractor or trigonometrically [Fig. 1.2 (*c*)].

This principle is used in the method of '*Theodolite Traversing*'.

(*d*) *By measuring the interior anles of the triangle PQR*. The interior angles *P, Q* and *R* of the triangle *PQR* are measured with an angle-measuring instrument such as theodolites. The lenghts of the sides *PR* and *QR* are calculated by solving the triangle *PQR* and the coordinates of *R* are calculated in the same terms as those of *P* and *Q*. Even without calculating the coordinates, or sides the location of *R* can be obtained by plotting the angles *PQR* and *QPR* [Fig. 1.2 (*d*)].

This principle is used in the method of 'Triangulation'.

(*e*) *By measuring the sides of the triangle PQR.* The interior angles *P*, *Q* and *R* are calculated from the measured sides of the triangle *PQR* by applying cosine rule.

This principle is used in the method of Trilateration.

1.7. UNITS OF MEASUREMENTS

There are two kinds of measurements used in plane surveying;

1. Linear measure, *i.e.*, horizontal or vertical distances.

2. Angular measure, *i.e.,* horizontal or vertical angles.

1. Linear Measures. According to the standards of Weight and Measure Act (India) 1956, the metric system has been introduced in

India. The units of measurement of distances, have been recommended as metre and centimetre for the execution of surveys.

(*a*) *Basic units of length in metric system:*

10 millimetres= 1 centimetre

10 centimetres = 1 decimetre

10 decimetres = 1 metre

10 metres = 1 dekametre

10 dekametres = 1 hectametre

10 hectametres = 1 kilometre

1.852 kilometres = 1 nautical mile.

(*b*) Basic units of area in metric system:

100 sq. metres = 1 are

10 ares = 1 *deka–are*

10 deka ares = 1 hecta–are

(*c*) *Basic units of volume in metric system:*

1000 cub. milimetres = 1 cub. centimetre

1000 cub. centimetres = 1 cub. decimetre

1000 cub. decimetres = 1 cub. metre.

Before 1956, F.P.S. (Foot, pound, second) system was used for the measurement of lenghts, areas and volumes. These units which are known as British units, are:

(*a*) *Basic units of length in F.P.S. System:*

12 inches = 1 foot

3 feet = 1 *yard*

5.5. yards = 1 *rod*, *pole or* 1 *sq*. *perch*

4 poles = 1 *chain*(66 feet)

10 chains = 1 *furlong*

8 furlongs = 1 *mile*

6 feet = 1 *fathom*

120 fathoms = 1 *cable length*

6080 feet = 1 *nautical mile*

(*b*) *Basic units of area in F.P.S. System :*

144 sq. inch = 1sq. foot

9 sq. feet = 1sq. yard

30.25 sq. yard = 1sq. rod or pole

40 sq. rods = 1 rood

4 roods = 1 acre

640 acres = 1 sq. mile

484 sq. yards = 1 sq. chain

10 sq. chains = 1 acre.

(c) Basic units of volume in F.P.S. System :

1728 cu. inches = 1 cu. foot.

27 cu. feet = 1 cu. yard.

Conversion Factors for Lengths

(Metres, yards, feet and inches)

Metres	*Yards*	*Feet*	*Inches*
1	1.0936	3.2808	39.37
0.9144	1	3	36
0.3048	0.3333	1	12
0.0254	0.0278	0.0833	1

Conversion Factors for Areas

(Sq. metres, sq. yards, sq. feet and sq. inches)

Sq. metres	*Sq. yards*	*Sq. feet*	*Sq. inches*
1	1.196	10.7639	1550
0.8361	1	9	1296
0.0929	0.1111	1	144
0.00065	0.00077	0.0069	1

Conversion Factors for Areas

(Ares, acres and sq. yards)

Ares	*Acres*	*Sq. metres*	*Sq. yards*
1	0.0247	100	119.6
40.469	1	4046.9	4840
0.01	0.000247	1	1.196
0.0084	0.00021	0.8361	1

Conversion Factors for Volumes

(Cub. metres, cub. yards, gallons)

Cub. metres	*Cub. yards*	*Gallons (Imps)*
1	1.308	219.969
0.7645	1	168.178
0.00455	0.00595	1

2. **Angular Measures.** An angle may be defined as the difference in directions of two intersecting lines, or it is the inclination of two straight lines. The unit of a plane angle is 'radian'. Radian is defined as the measure of the angle between two radii of a circle which contain an arc equal to the radius of the circle [Fig. 1.3].

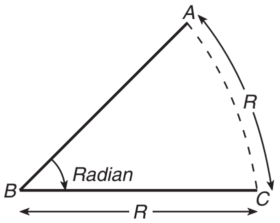

Fig. 1.3. A radian.

The popular systems of angular measurements, are:

(*i*) *Sexagesimal System of Angular Measurements*

In this system the circumference of a circle, is divided into 360 equal parts, each part is known as *one degree.* 1/60th part of a degree is called *a minute* and 1/60th part of a minute, is called a *second. i.e.*

$$1\text{circumference} = 360 \text{ degrees of arc}$$

$$1° = 60 \text{ minutes of arc}$$

$$1 \text{ minute} = 60 \text{ seconds of arc.}$$

(*ii*) *Centesimal System of Angular Measurements*

In this system, the circumference of a circle, is divided into 400 equal parts, each part is known as *one grad.* One hundredth part of a grad is known *as centigrad* and one hundredth part of a centigrad is known as *centi-centigrad i.e.,*

$$1 \text{ circumference} = 400 \text{ grads}$$

$$1 \text{ gard} = 100 \text{ centigrads}$$

$$1 \text{ centigrad} = 100 \text{ centi–centigrads.}$$

From the ancient times, sexagesimal system is widely used in different countries of the world. Most complete mathematical tables are available in this system and most of surveying instruments *i.e.,* theodolites, sextants etc., are graduated according to this system. However, due to facility in computation and interpolation, the centesimal system for angular measurements is gaining popularity in the western countries these days.

Conversion Factors from one System to other

Degrees	*Grads*	*Minutes*	*Centigrads*	*Seconds*	*Centi-centigrads*
1	1.1111	60	111.11	3600	11111
0.9	1	54	100	3240	10000
0.0167	0.01852	1	1.8518	60	185.18
0.0090	0.0100	0.5405	1	32.4	100
0.00027	0.0003	0.0167	0.0309	1	3.0864
0.00009	0.0001	0.0054	0.0100	0.324	1

1.8. MAP SCALES

Considering the actual surface dimensions, drawings are made to smaller scale of the area. It is never possible to make its drawing to full size. This operation is generally known as *'drawing to scale'*.

The scale of a map may be defined as the fixed proportion which every distance between the locations of the points on the map, bears to the corresponding distances between their positions on the ground. For an example, if 1 cm on a map represents a distance of 5 metres on the ground, the scale of the map is said to be 1 cm = 5 m. The scale of a map is also sometimes expressed by a fraction generally called, *'Representative Fraction'* (R.F.). Scales of the maps are represented by the following two methods:

(*i*) Numerical scales. (*ii*) Graphical scales.

1. Numerical scales. Numerical scales are further divided into two types, *i.e.*, (*a*) Engineer's scale (*b*) Fraction scale.

(*a*) **Engineer's scale.** The scale on which one cm on the plan represents some whole number of metres on the ground, is known as *Engineer's scale.* For example, 1 cm = 5 m ; 1 cm = 10 m, etc.

(*b*) **Fraction scale.** The scale on which an unit of length on the plan represents some number of the same unit of length on the ground is known as *Fraction Scale.* For example, 1 : 500; 1 : 1000; 1 : 5,000, etc.

To convert an engineer's scale into fraction scale, multiply the whole number of metres by 100. Similarly, a fraction scale may be converted into engineer's scale by dividing the denominator by 100 and equating the quotient to 1 cm.

Example 1.1. *The engineer's scale of a drawing, is stated to be 1 cm = 4 m. Convert this to fraction scale.*

Solution.

Engineer's scale is 1 cm = 4 m

$\therefore$ Fraction scale is 4×100 *or* 1 : 400. **Ans.**

Example 1.2. *The fraction scale of a map is stated to be 1 : 50,000. Convert this to Engineer's scale.*

Solution.

1 unit on plan = 50,000 units on the ground

$\therefore$ 1 cm on plan = 50,000 cm on the ground

or 1 cm on plan = 500 m on the ground

Hence, Engineer's scale is 1 cm = 500 m. **Ans.**

2. Graphical scales. A graphical scale is a line subdivided into plan distances corresponding to some convenient units of length on the surface of the earth.

1.9. NECESSITY OF DRAWING SCALES ON MAPS

When a map is used after a considerable time or in different climatic conditions, the dimensions of the paper usually get distorted. Due to distortion in the paper the numerical scales will not give accurate results. On the other hand, if a graphical scale is drawn on the map, there will also be a proportional distortion in the length of the scale and the distances from the distorted map will be accurately scaled off. This is why scales are always drawn on the maps and charts whcih are maintained for future reference.

1.10. REQUIREMENTS OF A USEFUL SCALE

A useful map scale should possess the following essential requirements.

1. It should be sufficiently long and should not be less than 18 cm and more than 32 cm.
2. Inter-divisions should be accurately done and correctly numbered.
3. The zero must always be placed between unit and its subdivisions.
4. The name of scale and its R.F. should always be written on the plan.
5. It should be easily readable without making any arithmetical calculations for measuring the distances on a map. The main divisions should, therefore, represent one, ten, hundred or thousand units.

1.11. CLASSIFICATION OF SCALES

The scales drawn on the maps or plans, may be classified as under :

(*i*) Plain scale

(*ii*) Diagonal scale

(*iii*) Scale of chords

(*iv*) Vernier scale.

1. **Plain Scales.** A plain scale is one on which it is possible to measure only two dimensions, *i.e.*, metres and decimetres; kilometres and hectametres; miles and furlongs, etc.

Plain Scales as Recommended by IS : 1491 – 1959

Full Size	1 : 1
50 cm to a metre	1 : 2
40 cm to a metre	1 : 2.5
20 cm to a metre	1 : 5
10 cm to a metre	1 : 10

5 cm to a metre	1 : 20
2 cm to a metre	1 : 50
1 cm to a metre	1 : 100
5 mm to a metre	1 : 200
2 mm to a metre	1 : 500
1 mm to a metre	1 : 1000
0.5 mm to a metre	1 : 200

Example 1.3. *Construct a plain scale whose R.F. is 1 : 50,000, to measure miles and furlongs.*

Solution.

$$\therefore \qquad 50{,}000 \text{ yds} = 1 \text{ yd} = 36''$$

$$= 36 \times 2.54 \text{ cm}$$

$$\therefore \qquad 1 \text{ mile or } 1760 \text{ yds} = \frac{36 \times 2.54}{50{,}000} \times 1760 = 3.219 \text{ cm.}$$

To have the length of the scale more than 18 cm, multiply 3.219 by 6.

$\therefore$ The length representing 6 miles

$$= 3.219 \times 6 = 19.314 \text{ cm.}$$

Take a length of 19.314 cm and divide it into 6 equal parts, each part representing one mile. Subdivide the left hand division into 8 equal parts, each part representing one furlong. Place zero of the scale between the undivided part and divided part and mark the readings on the scale as shown in Fig. 1.4.

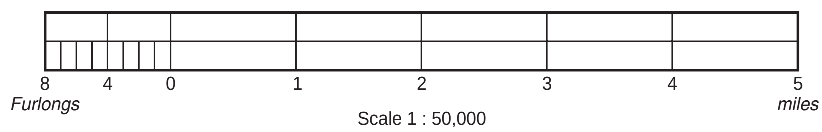

Fig. 1.4. Plain scale.

Example 1.4. *Construct a plain scale 1 cm = 250 m and show 3 kilometres and 7 hectametres thereon.*

Solution. (Fig. 1.5).

$$\therefore \qquad 250\, m = 1 \text{ cm}$$

$$1000\, m = \frac{1}{250} \times 1000 = 4 \text{ cm}$$

Take a 24 cm length and divide it into 6 equal parts, each part representing 1 kilometre. Subdivide the left hand part into 10 divisions, each representing one hectametre. Place the zero of the scale between the sub divided part and undivided part and mark the scale as shown in Fig. 1.5.

To measure a distance of 3 kilometres and 7 hectametres, place one leg of the divider at 3 kilometres and the other at 7 hectametres, as shown in Fig.1.5.

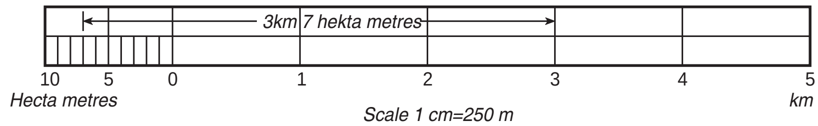

Fig. 1.5. Plain Scale.

2. Diagonal Scales. On a diagonal scale, it is possible to measure three dimensions such as kilometres, hectametres and decametres; or yards, feet and inches, etc.

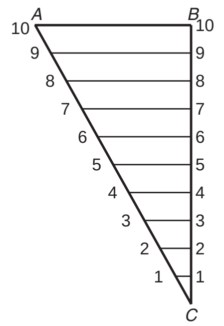

Fig. 1.6. Principle of diagonal scale

Principle of 'a Diagonal Scale.' The construction of a diagonal scale is based on the principle of similar triangles in which corresponding sides are proportional.

Take a line *BC*. Erect a perpendicular *BA* at *B*. Divide length *BC* into ten (or as required) equal parts. Draw lines parallel to *AB* from each point on *BC*, so that they cut the diagonal *AC* at points 1′, 2′, etc. In this way diagonal *AC* is also divided into 10 equal parts (Fig. 1.6).

It may be noted that the distance

$$1 - 1' = \frac{1}{10} \text{ th of } AB$$

$$2 - 2' = \frac{2}{10} \text{ th of } AB$$

....

....

$$\text{distance } 9 - 9' = \frac{9}{10} \text{th of } AB.$$

Example 1.5. *Construct a diagonal scale 1 cm = 5 metres to read metres and decimetres.*

Solution. (Fig. 1.7)

$\therefore$ 1 cm= 5 metres

$\therefore$ 22 cm = 5 × 22 = 110 m.

Construction. Take a length *AB* of 22 cm and divide it into 11 equal parts, each part represents 10 metres. Subdivide the left hand part into 10 equal parts, each part represents one metre. Draw ten lines equidistant and parallel to *AB*. Erect perpendiculars at *A, B* and other division

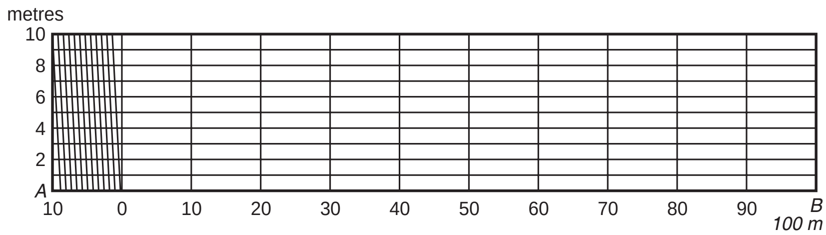

Fig. 1.7. Diagonal scale.

points. Subdivide the left-hand division of the topmost line, *i.e.*, the tenth line and join these diagonally to the corresponding subdivisions on the bottom line *AB*.

Example 1.6. *The area of a field is 45,000 sq.m. The length and breadth of a field on the map are 9 cm and 8 cm. Construct a diagonal scale which can be read up to one metre. Find out the representative fraction of the scale.*

Solution.

The area of the field on paper = $8 \times 9 = 72$ sq. cm.

The area of the field on ground = 45,000 sq. m (given)

$$\therefore \qquad 1 \text{ sq. cm} = \frac{45{,}000}{72} = 625 \text{ sq m}$$

or
$$1 \text{ cm} = \sqrt{625} = 25 \text{ m.}$$

$\therefore$ Representative fraction = 1:2500. **Ans.**

To read, up to one metre, we must have a length

$$= 1 \times 10 \times 10 = 100 \text{ metres}$$

Now
$$25 \text{ m} = 1 \text{ cm}$$

$$\therefore \qquad 100 \text{ m} = 4 \text{ cm.}$$

Take a 24 cm length and divide it into 6 equal parts, each representng 100 metres. Divide the left hand division into 10 equal parts and finally draw 10 parallel lines. Construct the diagonal scale as shown in Fig. 1.8.

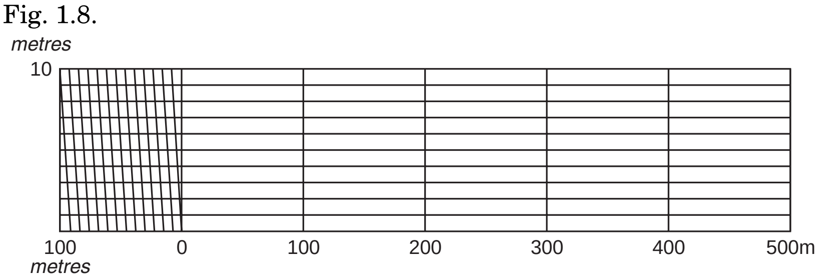

Fig.1.8. Diagonal scale.

Example 1.7. *An aeroplane at an altitude of 1000 metres covers a horizontal distance of 5 kilometres in one minute. Draw a scale of* $R.F. = \dfrac{1}{200{,}000}$ *to measure minutes and seconds. Show on the scale a distance the aeroplane covers in 4 minutes and 25 seconds.*

Solution.

$$\therefore \quad 200{,}000 \text{ metres} = 1 \text{ metre}$$

$$\therefore \quad 5{,}000 \text{ metres} = \frac{1 \times 5{,}000}{200{,}000} \times 100 \text{ cm}$$

$$= 2.5 \text{ cm.}$$

A 2.5 cm distance on the scale represents a distance covered in one minute.

$\therefore$ 25 cm distance on the scale represents

$$= \frac{1 \times 25}{2.5} = 10 \text{ minutes.}$$

Take a 25 cm length and divide it into 10 equal parts, each representing one minute. Divide the left hand division into six equal parts, each representing 10 seconds. Finally draw 10 parallel lines and construct the diagonal scale as shown in Fig. 1.9.

The distance covered in 4 minutes and 25 seconds is marked by AB in Fig. 1.9.

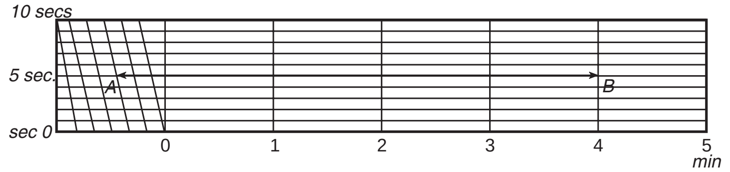

Fig.1.9. Diagonal scale.

3. Scale of Chords. A scale of chords is used to measure or to set off angles. It is marked either on a rectangular protractor or on an ordinary box wooden scale.

1. Construction of a Chord Scale. The following steps are followed:

1. Draw a quadrant ABC, making $AB = AC$. Prolong BA to D, making $BD = BC$.

2. Divide the arc BC into eighteen equal parts, each part representing 5°.

3. With B as a centre describe the arcs from each of the division, cutting BAD at points marked 5°, 10°, 15°, 20°, 25°, 30°,....

4. Subdivide these parts if required by first subdividing each division of the arc *BC*, and then drawing arcs with *B* as centre, as in step (3).

5. Complete the scale as shown in Fig. 1.10. It should be noted that the arc through the 60° division will always pass through the point *A* (since the chord of 60° is always equal to radius *BA*). The distance from *B* to any mark on the scale is equal to the chord of the angle of that mark. For example, the distance between *B* to 50° mark on the scale is equal to the chord of 50°.

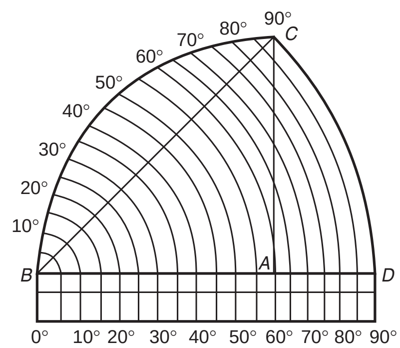

Fig. 1.10. A scale of chords.

2. Construction of Angles of 40° and 70° with a Scale of Chords (Fig. 1.11). The following steps are followed :

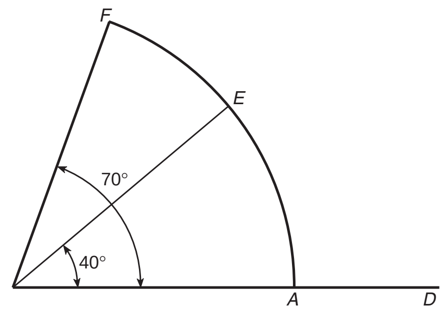

Fig. 1.11.

1. Draw a line *BD* and mark *BA* = chord of 40° from the scale of chords.
2. With *B* as centre and *BA* as radius, draw an arc.
3. With *A* as centre and radius equal to chord of 40° (*i.e.*, distance from 0° to 40° on to the scale of chords) draw an arc to cut the previous arc at *E*. Join *BE*. Then the angle *FBA* = 40°.
4. Similarly, with *B* as centre and radius equal to the chord of 70° (*i.e.* distance from 0° to 70° on the scale of chords), draw an arc to cut the previous arc at *F*. Join *BF*. Then, the angle *FBA* = 70°.

3. Measurement of an Angle EBD with the Scale of Chords (Fig. 1.12). The following steps are followed:

1. On BD, measure BA = chord of 60°.
2. With B as centre and BA as radius, draw an arc to cut line BE at F.
3. With the help of a pair of dividers, take the chord distance AF and measure it on the scale of chords to get the value of the angle θ, which is found to be 34°.

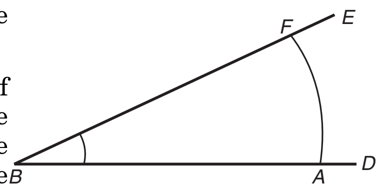

Fig. 1.12.

4. Vernier Scales. In 1631, Pierre Vernier invented a device for the purpose of measuring a fractional part of a graduated scale. It consists of two approximating scales, one of them is fixed and is called the *primary scale*, the other is movable and is called the *vernier*. The fineness of reading or the least count of a vernier is equal to the difference between the smallest division on the main scale and the smallest division on the vernier. The principle of vernier is based on the fact that the eye can perceive without strain and with considerable precision when two graduations coincide to form one continuous straight line. Depending upon the graduations of the main scale, the vernier may be called either single vernier or double vernier.

(*a*) **Single Vernier.** If the graduations of the main scale are numbered in one direction only, and the vernier extends also in one direction, is called a *single vernier*.

(*b*) **Double Vernier.** If the graduations of the main scale are numbered in both directions and the vernier also extends in both directions, having its index mark in the middle, then, the vernier is called a *double vernier*.

5. Classification of Verniers. Verniers are further classified primarily into two types :

(*a*) Direct verniers, (*b*) Retrograde verniers.

(*a*) **Direct Vernier. (Fig. 1.13).** The verniers which extend or increase in the same direction in which the graduations of their main scale increase and in which the smallest division is shorter than the smallest division of the main scales, are called as *Direct Verniers*. In such verniers, n divisions of the main scale equal in length to $(n + 1)$ divisions of the vernier scale.

If p = value of the smallest division of the primary scale

v = value of the smallest division of the vernier scale

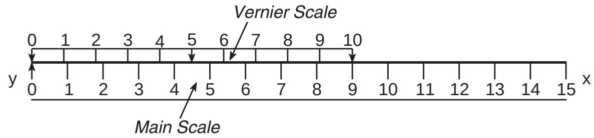

Fig. 1.13. A vernier scale.

n = number of divisions of the primary scale of a specified length.

$n + 1$ = number of divisions of the vernier scale of the same length.

As the length occupied by $(n + 1)$ divisions of the vernier scale is the same as occupied by n divisions of the primary scale.

$$\therefore \quad (n + 1) \cdot v = n \cdot p$$

or
$$v = \frac{n \cdot p}{n + 1}$$

$\therefore$ Difference between the value of a primary scale division and that of a vernier scale *i.e.*, least count.

Least count (L.C.) $= p - v$

$$= p - \frac{np}{n+1} = \frac{p}{n+1} \qquad \text{...(1.1)}$$

$$= \frac{\text{Value of one division of primary scale}}{\text{Number of divisions of vernier scale}}$$

Hence, the least count (L.C.) of a vernier can be obtained by dividing the value of one primary scale division by the total number of the divisions of the vernier scale.

Example 1.8. *Calculate the least count of a vernier whose 60 divisions coincide with 59 divisions of its primary scale and if each degree on the primary scale is subdivided into10′intervals.*

Solution.

Here

$n = 59$, the number of divisions of primary scale

$n + 1 = 60$, the number of divisions of vernier scale

$p = 10'$, the value of one division of primary scale

Substituting the values in eqn. (1.1) we get

$$\therefore \quad L.C. = \frac{p}{n+1} = \frac{10}{60} \text{ minutes}$$

or
$$= \mathbf{10''}. \qquad \textbf{Ans.}$$

Example 1.9. *The primary scale of a box sextant is graduated to read 30 minutes. Construct a direct vernier to read to one minute and also show thereon a reading of 35° 14′.*

Solution.

We know that the least count of the vernier

$$\text{L.C.} = \frac{p}{n+1}$$

p = value of one division of primary scale = 30′

Required L.C. = 1 ′.

Substituting the values in eqn. (1.1) we get

$$p = 30'$$

$$\therefore \quad 1 = \frac{30}{n+1}$$

$$n + 1 = 30$$

or $$n = 29$$

$\therefore$ Length of vernier scale

$$= 29 \times 30 = 870' = 14° \; 30'$$

Take an arc of 14° 30′ and divide it into 30 equal parts.

The vernier scale is shown in Fig.1.14.

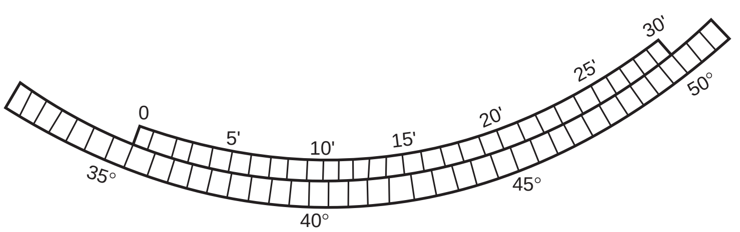

Fig.1.14.

Example 1.10. *Construct a direct vernier reading to 1 mm for a scale graduated to 5 mm.*

Solution. We know from eqn. (1.1) that

$$L.C. = \frac{p}{n+1}$$

where L.C. = least count of vernier

p = value of one division of primary scale

$n + 1$ = number of divisions of vernier scale

Substituting the values in eqn. (1.1) we get

Here L.C. = 1 mm

$$\therefore \quad 1 = \frac{5}{n+1}$$

or $\quad n = 4$

$\therefore$ Length of vernier scale

$= 4 \times 5 = 20$ mm.

Take a 20 mm length and divide it into 5 equal parts.

The vernier scale is shown in Fig. 1.15.

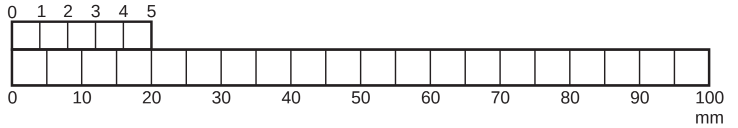

Fig 1.15. Vernier scale.

(*b*) **Retrograde Verniers.** The verniers which extend or increase in opposite direction of their main scales and also in which the smallest division of the vernier is longer than the smallest division of their main scales, are called *'retrograde verniers'*.

In such verniers, $(n + 1)$ divisions of the primary scale are equal, in length, to n divisions of the vernier scale.

Let p = value of smallest division of the primary scale

v = value of smallest division of the vernier scale

n = number of divisions of vernier scale

n + 1 = number of divisions of primary scale

Then, $n \,.\, v = (n + 1) \,.\, p$

or $$v = \frac{(n+1)\,.\,p}{n}$$

$\therefore$ Least count $= v - p$

$$= \frac{(n+1)\,.\,p}{n} - p = \frac{p}{n}$$

or $$\text{L.C.} = \frac{p}{n} \qquad ...(1.2)$$

or $$\text{Least count} = \frac{\text{Value of one division of primary scale}}{\text{Total number of divisions of vernier scale}}$$

Hence, the least count of a retrograde vernier can be obtained by dividing the value of one primary scale division by the total number of divisions of the vernier scale.

A retrograde vernier in which 11 divisons of the main scale coincide with 10 divisions of the vernier scale, is illustrated in Fig. 1.16.

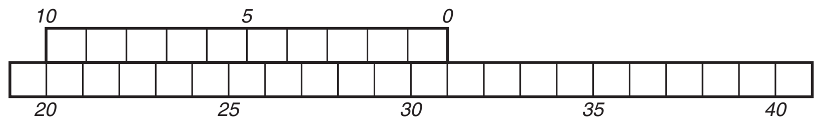

Fig. 1.16. A retrograde vernier.

Example 1.11. *Design a retrograde vernier for a theodolite circle divided into degrees and one-third degree to read up to 20".*

Solution.

From eqn. (1.2) We know that L.C. = $\frac{p}{n}$

where p = measure of one division of primary scale

n = number of divisions of vernier scale.

L.C. = $20'' = \frac{20}{60}$ minutes (Given)

Substituting the values in eqn. (1.2) we get

$$\frac{20}{60} = \frac{20}{n}$$

or $n = 60.$

i.e., sixty-one divisions of the theodolite circle should be taken for the vernier scale and divided into 60 parts for a retrograde vernier.

6. Reading a Vernier Scale. The following steps are followed :

(*i*) Bring the zero of the vernier scale against a full division mark of the primary scale.

(*ii*) Ascertain the number of primary scale divisions equivalent in the length of the vernier scale.

(*iii*) Ascertain the value of the smallest division of the primary scale.

(*iv*) Calculate the least count of the direct vernier by the formula *i.e.*, L.C. = $\frac{p}{n+1}$ where p is the value of the smallest division of the primary scale and (n +1) is the total number of divisions of the vrenier scale.

or

Calculate the least count of the retrograde vernier by the formula $L.C. = \frac{P}{n}$ where p is the value of the smallest division of the primary scale and n is the total number of divisions of vernier scale.

(*v*) Note the exact coincidence of the vernier division with the primary scale division.

(*vi*) Multiply the value of least count by the number of divisions of vernier scale coincident with the main scale division.

(*vii*) Note the reading of the main scale just before the vernier index.

(*viii*) Add the value obtained in step (*vi*) to the reading obtained in step (*vii*).

Example 1.12. *The least count of a theodolite vernier is 10″ and 53rd division of the vernier is coincident with a division of the graduated circle. If the vernier index is between 27° 30′* and 27° *40′*, find the reading of the theodolite.

Solution.

The reading of the main scale = 27° 30′

Least count of the vernier = 10″

$\therefore$ Reading of the vernier scale = 53 × 10″ = 530″ = 8′ 50″

$\therefore$ The theodolite reading = 27° 30′ + 8′ 50″

= 27° 38′ 50″ **Ans.**

Example 1.13. *A theodolite circle is divided into degrees and one-third degree, 59 divisions of the main scale coincide with 60 divisions of the vernier. If, for a particular setting of the instrument, the vernier index is between 30° 20′ and* 30° 40′ *and 35th division of the vernier coincides with a division of main scale, calculate the reading of the theodolite for the setting.*

Solution. We know

$$\text{L.C.} = \frac{p}{n+1}$$

Here $$p = \frac{1}{3} \text{ rd degree} = 20'$$

$$n + 1 = 59 + 1 = 60$$

$\therefore$ Substituting the values in eqn. (1.1) we get

$$\text{L.C.} = \frac{20}{60} \text{ minutes} = \frac{1}{3} \times 60 = 20''$$

Reading of the main scale = 30° 20′

Reading of the vernier scale = 35 × 20″ = 0° 11′ 40″

∴ The theodolite reading = 30° 31′ 40″. **Ans.**

Example 1.14. *The value of the smallest division of a theodolite graduated circle is 10 minutes. Design a suitable vernier to read up to 10″.*

Solution.

We know $$\text{L.C.} = \frac{p}{n+1}$$

Hence, $$\text{L.C.} = \frac{10}{60} \text{ minutes where } p = 10'$$

$$\therefore \quad \frac{10}{60} = \frac{10}{n+1}$$

or $$n + 1 = 60$$

$$\therefore \quad n = 59.$$

Take a length of 59 primary scale divisions and divide it into 60 equal parts to have the required vernier.

1.12. THE MICROMETER MICROSCOPE

To achieve a finer degree of accuracy, micrometer microscopes are used. A micrometer miroscope generally consists of a small low-powered microscope with an eyepiece, a diaphragm and an object glass. The diaphgram can be moved at right angles to the longitudinal axis of the tube. A typical micrometer is shown in Fig. 1.17 (*a*) and the field of view while taking a reading, is shown in Fig. 1.17 (*b*).

In the present case, the circle of the horizontal plate is divided into 10 minute divisions. The objective of micrometer is placed close to the circle graduations and thus it enlarges the image. Two vertical wires mounted on a movable frame placed in the plane of the image can be moved left or right by a micrometer screw drum. One complete revolution of the graduated drum moves the vertical wire across one division of the circle (10′) division. Graduated drum is divided into 10 large divisions and each large division is further divided into 6 small divisions. The fractional part of a division on the horizontal circle may be read on the graduated drum against an index mark fitted on one side.

The approximate reading is determined with the help of a specially marked *V* notch at the mid point of the lower side of the field of view. In Fig 1.17 (*a*) the circle reading is between 52° 10′ and 52° 20′ and the double wire index is in between the readings. With the help of the drum, move the index till the nearest reading seems to be mid way between

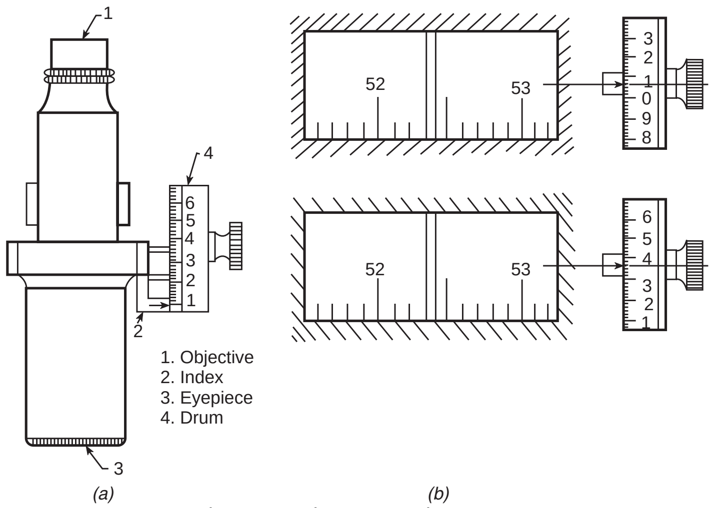

Fig. 1.17. Micrometer microscope.

the vertical wires. Note the reading on the drum. The complete reading is 52° 16′ 10″. Two vertical wires are used to increase the precision of observations.

Example 1.15. *The horizontal circle of a theodolite is graduated to read to 15 minutes. Design a suitable micrometer drum to read to 10 seconds.*

Solution.

The value of one division of the circle = 15′

Divide the circumference of the drum into 15 equal parts, each representing one minute.

Divide each one minute division into 6 equal parts, each representing 10 seconds. **Ans.**

1.13. MEASURING A CORRECT LENGTH WITH A WRONG SCALE

To obtain true measurements of lines and areas on a map using a wrong scale, the following formulae are used :

(1) Correct length

$$= \frac{\text{R.F. of wrong scale}}{\text{R.F. of correct scale}} \times \text{measured length.} \qquad ...(1.3)$$

(2) Correct area

$$= \left(\frac{\text{R.F. of wrong scale}}{\text{R.F. of correct scale}}\right)^2 \times \text{measured area.} \qquad ...(1.4)$$

Example 1.16. *A surveyor measured the distance between two points on a plan and calculated the length to be equal to 650 m assuming the scale of plan to be 1 cm = 50 m. Later, it was discovered that the scale of plan was 1 cm = 40 m. Find the true distance between the points.*

Solution.

Measured length = 650 m (Given)

$$\text{R.F. of wrong scale} = \frac{1}{50 \times 100} = \frac{1}{5000}$$

$$\text{R.F. of correct scale} = \frac{1}{40 \times 100} = \frac{1}{4000}$$

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

$$= \frac{\frac{1}{5000}}{\frac{1}{4000}} \times 650$$

$= 520$ m. **Ans.**

Example 1.17. *A plot of land acquired for a factory site measures* 25 cm × 20 cm *on village map drawn on a scale 1 cm = 100 m. What is its area in hectares ? What will be its area on a toposheet on 1 : 50,000 scale ?*

Solution.

Scale of village map

1 cm = 100 m

$\therefore$ 1 cm^2 on the village map = 100 × 100

= 10,000 sq. m. on ground

The area of the plot on map = 25 × 20 = 500 sq. cm.

$\therefore$ Area of the plot on the ground = 500 × 10,000

= 50,00,000 sq. m. = 500 hectares. **Ans.**

On the topo sheet

50,000 m = 1 m = 100 cm

$$\therefore \quad 1000 \text{ m} = \frac{100}{50{,}000} \times 1000 = 2\ cm$$

$\therefore$ 1 sq. km = 4 sq. cm.

$\therefore$ Area on the topo sheet

$$= \frac{50,00,000}{1000 \times 1000} \times 4$$

$$= \mathbf{20\ sq.\ cm.\ Ans.}$$

1.14. DISTORTED OR SHRUNK SCALES

Due to change in climatic conditions, the plans and maps generally get distorted. If no graphical scale is drawn on the plan, correct scale of the distorted plan (or map), may be calculated by the following method:

(1) Measure a distance between any two well defined points on the plan and calculate its corresponding ground distance from the scale *i.e.,*

1 cm = x metres. Let it be l metres.

(2) Measure the horizontal distance between the same points on the ground by chaining. Calculate the distance on plan with the scale. Let it be y cm.

(3) Calculate the shrinkage ratio or shrinkage factor which is equal to shrunk length / the actual length.

(4) Shrunk scale of plan = Shrinkage factor × Original scale.

Example 1.18. *The area of a plot on a map is found, by planimeter, to be 10.22 cm^2. The scale of the map was 1 : 25000, but at present it is shrunk such that a line originally 5 cm on the map is now 4.8 cm. What is the correct field area in hectares ?*

Solution.

The area of the plot measured by the planimeter on the shrunk map

$$= 10.22 \text{ cm}^2 \qquad \text{(Given)}$$

The ratio of shrinkage $= \dfrac{4.8}{5.0} = 0.96$

The ratio of shrinkage of the area

$$= (0.96)^2 = 0.9216$$

The area of the plot on unshrunk map on 1 : 25,000 scale

$$= \frac{10.22}{0.9216} = 11.08941 \text{ cm}^2$$

Area of 1 cm^2 on scale 1 : 25000

$$= 250 \times 250 = 62500 \text{ m}^2$$

∴ Area of 11.08941 cm on scale 1 : 25000

$$= 62500 \times 11.08941 = 693088.12 \text{ m}^2$$

$$= 69.3088 \text{ hectares.} \qquad \textbf{Ans.}$$

Example 1.19. *A rectangular plot of land measures* 30 *cm* × *40 cm on a cadastral map drawn on scale : 1 : 5000. Calculate its area in hectares. If a topographical sheet of the area is compiled on scale 1 : 50,000, what will be its area on the toposheet ?*

Solution.

(*i*) ***Cadastral map***

$\because$ 1 m on map = 5000 m on the ground.

$\therefore$ 1 cm on map = 50 m on the ground.

$\therefore$ $1 cm^2$ on map = $(50)^2$ m^2 on the ground.

The plot measures 30 cm × 40 cm *i.e.*, 1200 sq. cm on the map.

$\therefore$ Area of the plot = 1200 × 50 × 50 sq. metres.

= 300 hectares **Ans.**

(*ii*) ***Topo sheet***

50,000 m is represented by 1 m.

or $(50{,}000)^2$ m^2 is represented by 1 m^2,

$$\therefore \quad 300{,}0000 \text{ m}^2 \text{ is represented} = \frac{1 \times 30{,}00{,}000 \times 100 \times 100}{50{,}000 \times 50{,}000}$$

$\therefore$ The area on the topo sheet = 12 cm^2 **Ans.**

1.15 STAGES OF SURVEY OPERATIONS

The entire work of a survey operation may be divided into three distinct stages :

(*i*) Field work (*ii*) Office work

(*iii*) Care and adjustment of the instruments.

1. Field work. The field work consists of measurement of distances and angles required for plotting to scale and also keeping a systematic record of what has been done in the form of a field book or measurement book. Field work is further divided into three stages.

(*a*) Reconnaissance, (*b*) Observations, (*c*) Field Record.

(*a*) **Reconnaissance.** During reconnaissance, the surveyor goes over the area to fix a number of stations, ensuring necessary inter-visibility between survey stations, to establish a system of horizontal control. A few permanent stations are also selected for an extension of the survey in future.

(*b*) **Observations.** The surveyor makes necessary observations with survey instruments for linear and angular measurements. The observations also include determination of differences in elevations between the stations, establishment of points at given elevations and surveying contours of land areas and bathymetric contours (fathoms) of water bodies. Method of observation depends upon the nature of the terrain, type of the instruments and the method of surveying.

(*c*) **Field records.** All the measurements are recorded in a field book. Every care is made to ensure correct entries of all the observations otherwise the survey records may be useless. The competency of a surveyor is judged by his field records.

Some of the operations which a field surveyor is required to do in the field, are as follow:

1. Selection of the sites and establishment of stations and bench marks in the area.
2. Measuring the horizontal distances between stations either by chaining on the surface of the earth or by trigonometrical computation.
3. Locating the detail points with respect to survey lines such as in chain surveying or by methods of planetabling.
4. Determination of elevations of stations and bench marks either by spirit levelling or by trigonometrical levelling.
5. Surveying contours of land areas and bathymetric contours for water bodies.
6. Determination of latitude, longitude or local time by making astronomical observations to either the sun or stars.

Important rules for note keeping. These include the following:

1. As soon as observations are made, readings should be recorded in the field book. Nothing should be kept in mind for recording later.
2. Only one field book should be maintained.
3. Entries should be made by a sharp 2H or 3H pencil and not by a soft pencil. This keeps the field book neat and clean.
4. Style of writing should be consistent and numericals should be bold and legibly written.
5. Neat sketches should invariably be drawn to explain relative positions and directions.
6. Never erase wrong readings. If readings are to be scored out, rule one line through the incorrect value and record the correct reading above it. All cuttings must always be initialled.
7. Each day's work and field notes must be signed daily.

2. Office work. The field notes are brought to the office and necessary drafting, computing and designing work, are done by draftsmen and computors.

1. Drafting. This process consists of preparation of plans and sections (longitudinal or cross section) by plotting the field measurements to the desired scale.

2. Computing. This process consists of calculating data necessary for plotting and also includes determining the areas and volumes for the earth work.

3. Designing. This process consists of selection of best alignments of roads, railways, canals etc. on the plotting plans.

3. Care and adjustments of instruments. A great care is required to handle survey instruments. A beginner should always be made familiar with care and adjustment of the instruments and its limitations. Precision instruments such as theodolite, level, prismatic compass need more care than the equipment such as chains, arrows, ranging rods, etc. Following precautions must be taken:

1. While removing a theodolite or a level from its box, do not lift it by its telescope. It should be lifted by its standards by placing hands under the levelling head or the foot plate.
2. While carrying an instrument from one place to the other, it should be carried on the shoulder if the distance is short, otherwise it should be carried in its box.
3. Do not set an instrument on smooth surfaces, to avoid spreading its tripod legs and ultimately falling of the instrument. In unavoidable circumstances, tripod legs should be inserted in the joints or cracks.
4. The instruments must be kept clean and frequently dusted with a small brush. Lenses should be dusted lightly with a brush.
5. Keep the hands off the vertical circles and other exposed graduations to avoid tarnishing.
6. Do not expose the instrument to dust, dampness and scorching sun. An umbrella may be conveniently used to protect it from these.
7. Do not leave the instrument on the road, foot path or in an unguarded posture.
8. Do not force the foot-screws and tangent screws too hard.
9. Whenever observations are interrupted, the cap of the objective should be placed.
10. In case of a compass, its needle should never be left to swing unnecessarily. When not in use, it should be lifted off the pivot.
11. After day's work the steel tapes should be wiped clean and dried with a dry cloth slightly oily.
12. The theodolite should be turned a few revolutions in altitude and azimuth before starting actual work.

It may be remembered that if you respect an instrument, the instrument will respect you by giving good results. It is an old proverb.

1.16. PRECISION IN SURVEYING

The degree of precision required in surveying mainly depends upon the purpose and scale of the map. Larger the scale, better the precision required and *vice versa.* If a map is required to be on scale 1 cm = 1 km and the plotted permissible error on a map is 0.25 mm. It is therefore necessary to have a precision in linear measurements to 25 metres *i.e.,* an error of 25 metres in linear measurement of a line does not affect the accuracy of the map. On the other hand, if the scale is 1 cm = 5 m, the plotted permissible error on the map is given by $0.5 \times 0.25 = 0.125$ *m i.e*., an error of 12.5 cm can hardly be tolerated.

Similarly, the degree of precision required in a topographical map is not the same as that required of a cadastral map. Since the value of land in the city is more than the value of land in the rural areas, greater precision in the measurements is required in cities and hence nearest fraction of a centimetre is observed. The cost of survey is directly proportional to the accuracy of the map. Before commencing a survey work, the surveyor must, therefore, consider the following factors to decide the method to be adopted and instruments best suited to the particular case.

1. The purpose of surveying
2. The degree of precision required
3. The scale of the map
4. The extent of the area
5. The nature of the country
6. The time available
7. The fund available for the survey

EXERCISE 1

1. Fill in the blanks with suitable word(s).

(*i*) Surveying is the art of determining.........positions of different features on the surface of the earth.

(*ii*) The object of surveying is the preparation of ....of the area.

(*iii*) In the absence of accurate ....it is difficult to layout the alignment of roads, railways and canals.

(*iv*) Surveying is the first...............for the execution of any engineering project.

(*v*) Surveys in which curvature of the earth is ignored, are known as..........surveys whereas surveys in which curvature of the earth is taken into account, are known as.......surveys.

(*vi*) The branch of surveying which deals with the measurements in vertical planes, is known as...........

(*vii*) Surveys which are carried out to depict the general topography of the terrain, are known as ....surveys.

(*viii*) The small scale maps on which features are suitably generalised so that a picture of the country as a whole can only be visualised, are known as........maps.

(*ix*) The main principle of surveying is to work from the........to the........

(*x*) Location of a point can be fixed with respect to given two points by measuring............between the known point and the point.

(*xi*) The smallest basic unit of length in metric system, is ....

(*xii*) The measure of the angle between two radii of a circle which contain an arc equal to the radius on the circumference of the circle, is known as...........

(*xiii*) In sexagesimal system the circumference in divided into.............equal part whereas in centesimal system, it is divided into..........equal parts.

(*xiv*) π radians =.............rt angles = ...degrees = ...grads.

(*xv*) Diagonal scales are............accurate than plane scales.

(*xvi*) The difference between the smallest division on the main scale and the smallest division on the vernier is called........ of the vernier.

(*xvii*) Least count of a vernier can be found out by dividing the value of one primary scale division by.........number of divisions of the vernier.

(*xviii*) If the smallest division of a vernier is longer than the smallest division of the main scale, the vernier is called a........

2. Define surveying. Explain its importance for Civil Engineers.

3. Explain the fundamental principles on which the art of surveying is based.

4. (*i*) What are the objects of plane surveying ?

(*ii*) Give a classification of surveys based on the instruments used.

5. What are the different kinds of verniers ? Explain the object of vernier and the principle of its working.

6. What is the difference between direct vernier and retrograde vernier? Construct a dircet vernier reading to 1 mm to a scale graduated to 5 mm.

7. Explain the main characteristics of 'plain' and 'diagonal' scales and also show the utility of a vernier scale.

8. A boat in the Ganges is timed to move down a distance of 60 metres in one minute. Draw a scale of R.F. $\frac{1}{5500}$ to meature minutes and diagonally spaces of 5 seconds. Show on the scale the distance the boat moves down in 7 minutes and 35 seconds.

9. The horizontal circle of a theodolite is graduated to read to 10 minutes. Design a suitable vernier to read to 10″.

10. The least count of a vernier theodolite is 20′ and the smallest division of the main scale is 20′. If the zero of the vernier is in between 120° 40′ and 121° 0′ and 27th division of the vernier is in exact coincidence with the division of the main scale, calculate the exact reading on the theodolite. Draw a neat diagram.

ANSWERS

1. (*i*) relative; (*ii*) a map; (*iii*) maps; (*iv*) step; (*v*) plain, geodetic; (*vi*) levelling; (*vii*) topographical; (*viii*) geographical; (*ix*) whole, part; (*x*) distances; (*xi*) centimetre; (*xii*) radian; (*xiii*) 360, 400 (*xiv*) 2, 180°, 200; (*xv*) more; (*xvi*) least count; (*xvii*) total; (*xviii*) retrograde.

10. 120° 49′.