UPPSC-AE 2025

Uttar Pradesh Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Civil Engineering

Surveying & Engineering Geology

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY PUBLICATIONS

Surveying & Engineering Geology

Contents

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CHAPTER 1

Fundamental of Surveying

1.1 Introduction

- Surveying is defined as the science of making measurements of the earth specially the surface of the earth. This is being carried out by finding the spatial location (relative/absolute) of points on or near the surface of the earth.
- The primary aims of field surveying are:
  - to measure the horizontal distance between points
  - to measure the vertical elevation between points
  - to find out relative direction of lines by measuring horizontal angles with reference to any arbitrary direction
  - to find out absolute direction by measuring horizontal angles with reference to a fixed direction

1.2 Importance of Surveying to Civil Engineers

- The planning and design of all Civil Engineering projects such as construction of highways, bridges, tunnels, dams etc. are based upon surveying measurements.
- Moreover, during execution, project of any magnitude is constructed along the lines and points established by surveying.
- Thus, surveying is the basic requirement for all Civil Engineering projects.
- Other principal works in which surveying is primarily utilized are:
  - to fix the national and state boundaries
  - to chart coastlines, navigable streams and lakes.
  - to establish control point. (Control point → Stations having known position)
  - to execute hydrographic and oceanographic charting and mapping; and
  - to prepare topographic map of land surface of the earth.

1.3 Objectives of Surveying

- To collect field data.
- To prepare plan or map of the area surveyed.
- To analyse and to calculate the field parameters for setting out operation of actual engineering works.
- To set out field parameters at the site for further engineering works.

1.4 Primary Division of Surveying

- Primary division is based on whether the curvature of earth is considered or not.
- The approximate shape of the earth can best be defined as an oblate or spheroid.

NOTE: **Oblate/Spheroid:** An oblate (spheroid) is a surface of revolution obtained by rotating an ellipse about its minor axis i.e., having equatorial radius greater then the polar radius.

Based upon the consideration of the shape of the earth, surveying is broadly divided into two types:

(i) Geodetic surveying (ii) Plane surveying

1.4.1 Geodetic Surveying

- In this branch of surveying, true shape of the earth, i.e., curvature of earth is taken into account.
- This type of surveying is being carried out for highly precise work and is adopted for surveying of large area.
- All lines lying on the surface are curved lines and triangles are spherical triangles.
- The directions of plumb lines at various points are converging towards centre of earth.
- Geodetic survey is needed to fix the widely spaced control points that are later on used as necessary control points for fixing the minor control points.
- Geodetic survey is carried out by Department of National Survey of India.

1.4.2 Plane Surveying

- In this branch of surveying curvature of earth is neglected and is assumed to be a flat surface.
- In plane surveying, relatively small areas are under consideration (lees then 200 square kilometer).
- The vertical line is indicated by the direction of a freely suspended plumb bob. A single horizontal plane of reference is selected. There the plumb bob lines at all points of the area are assumed to be parallel. The curved line on the earth's surface is considered as straight.
- In plane survey difference in length between the arc and its substanded chord on the earth surface for a distance of 18.2 km, in only 10 mm.
- Also, the difference between the sum of angles in a plane triangle and spherical triangle is only one second (1″) for a triangle at the earth's surface having an area of 195 square kilometer.

1.5 Classification of Surveys

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

1.5.1 Classification based upon the Nature of the Field/purpose

(a) **Topographical survey:** These surveys are used to obtain maps which shows details of natural and man-made features on the earth surface including elevation.

Scale = (1 : 25000 to 1 : 10 lakh)

(b) **Engineering survey:** These are surveys used for engineering works like railway, highway, canal, bridge, etc.

Building: 1 : 50 to 1 : 200

Bridge and other Civil Engineering Works: 1 : 500 to 1 : 2500

Highway: 1 : 1250 to 1 : 50000

(c) **Cadastral survey:** The surveys which are generally plotted to a larger scale then topographical surveys and are carried out for fixing the property lines.

Scale: 1 : 1000 to 1 : 5000

(d) **Hydrographic survey:** The survey which deals 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 Survey.

Hydrographic survey consists of preparation of topographical maps of the shores and banks, by taking soundings end determining the depth of water at a number of places and ultimately surveying bathymetric contours under water.

NOTE

The equipment needed for sounding are:

(i) Sounding boat (ii) Sounding rod or poles
(iii) Lead lines (iv) Sounding machine
(v) Fathometer

(e) **Astronomical survey:** With the help of this survey we can determine latitude, longitude and LMT at any place on the earth's surface.

(f) **Geological survey:** It is done to determine information about various strata of earth surface.

1.5.2 Classification based on Instrument

(a) **Chain survey:** It is simplest type of surveying in which only linear measurements are done with the help of chain or tape and no angular measurements are done.

(b) **Compass surveying:** It is a branch of surveying in which horizontal angles and direction of lines are measured with compass and length of line are measured with chain and tape.

(c) **Theodolite surveying:** In this surveying horizontal and vertical angles are measured with theodolite and distances are measured with chain or tape.

(d) **Levelling:** In this type of surveying elevations of various points are measured with a levelling instrument and vertical staff.

(e) **Plane table survey:** In plane table surveying plan or map is produced by determining direction of various points and taking linear measurement with chain or tape.

(f) **Tacheometric surveying:** In this surveying horizontal and vertical distances are measured with a instrument called tacheometer.

(g) **Photogrammetric surveying:** In this survey photographs are taken for an area which are inaccessible or time available is less and area to be survey is large.

1.6 Principle of Surveying

The fundamental principles upon which different methods of surveying are based; these are stated as under:

(i) **Working from the whole to the pert**

- 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 the detail surveyed.
- Minor control points in between the primary control points, are then established with less precise method.

- The main idea of working from whole to part is to prevent accumulation of errors and to localize minor errors within the framework of control points.

(ii) **Location of a point by measurement of two control points**

- 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:

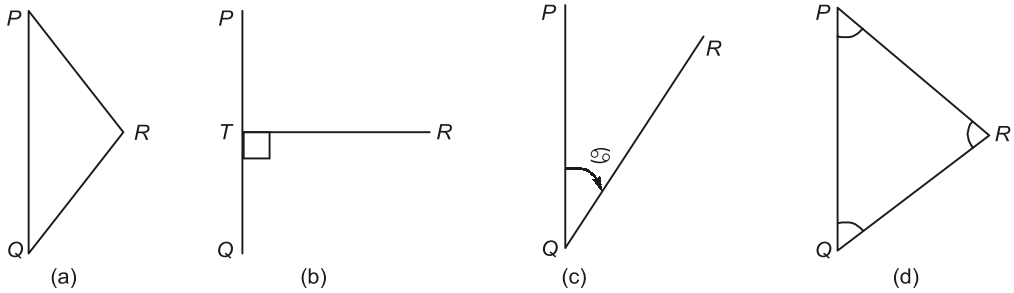


Fig. *Shows location of points*

- Principles (a) and (b) are generally used in the method of chain survey.
- Principle (c) are used in the method of 'Theodolite traversing'.
- Principle (d) is used in the method of 'Triangulation'.

The following terms are generally used in surveying:

(i) **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.

(ii) **Map**

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

1.7 Units of Measurement

- There are many units of measurement that are prevalent worldwide like the CGS System, FPS System, MKS System but the standard one is the **SI System**.
- Past records of all survey works are usually in FPS System. Thus to use those records and any other records that are in different units, those have to be converted into SI unit or other unit that is in use.

Length Unit Conversion	
Unit	Conversion factor for m
1 astronomical unit	149597870691
1 angstrom	1×10^{-10}
1 chain	20.1168
1 fathom	1.8288
1 foot	0.3048
1 furlong	201.168
1 inch	0.0254
1 light year	9460730472581000
1 mile	1609.344
1 nautical mile	1852
1 yard	0.9144

Area Unit Conversion	
Unit	Conversion factor for m^2
1 acre	4046.85
1 hectare	10^4
1 ft^2	0.0929
1 $inch^2$	6.4516×10^4
1 $mile^2$	2589988.11
1 $yard^2$	0.8361

Volume Unit Conversion	
Unit	Conversion factor for m^3
1 barrel	0.1589873
1 $yard^3$	0.765
1 US gallon	3.785×10^{-3}
1 UK gallon	4.546×10^{-3}
1 liter	0.001

Pressure Unit Conversion	
Unit	Conversion factor for N/m^2
1 atm	101325
1 bar	1×10^5
1 mm Hg	133.3
1 pound per sq. feet (psf)	47.88
1 pound per sq. inch (psi)	6894.75
1 torr	133.32

1.8 Various Measurements in Surveying

- In surveying, the direction of gravity can always be taken as reference for all measurements.
- The direction of gravity is established by suspending a plumb bob freely. This direction of gravity is taken as the vertical direction. Thus horizontal direction is at right angles to the vertical direction.
- Any plane which contains the horizontal line and perpendicular to the vertical direction is called as **horizontal plane**. The plane containing the vertical line is called as **vertical plane**.

In surveying, the following basic measurements are made :

(a) **Horizontal distance:** The horizontal distance is measured in horizontal plane. On slopping ground, the distance between two points is reduced to horizontal equivalent.

(b) **Horizontal angle:** The horizontal angle is measured between two lines in horizontal plane. Theoretically the angle between two lines can vary from 0° to 360°.

(c) **Vertical distance:** As stated above, the direction of gravity is taken as vertical direction and thus vertical distances are measured in the direction of gravity. The vertical distances are measured to determine the difference of elevations between the various points.

(d) **Vertical angle:** Vertical angle is measured between two lines in vertical plane.

1.9 Instruments Used for Various Types of Measurement

(a) **For horizontal distance measurement :** Tape, chain, tacheometer, EDM etc.

(b) **For horizontal angle measurement :** Magnetic compass, theodolites, total station, sextant etc.

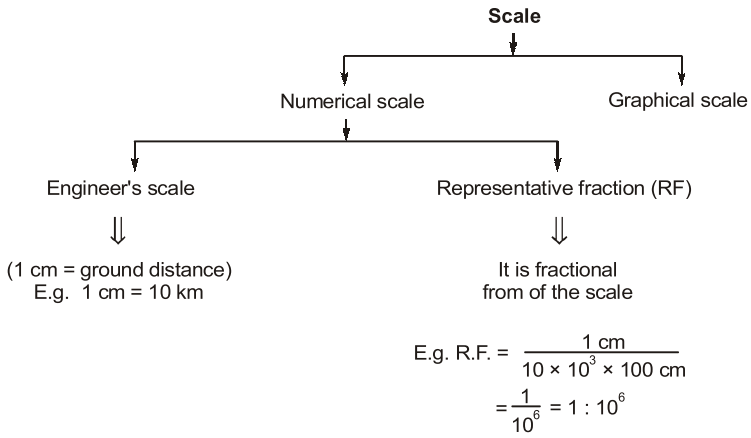
(c) **For vertical distance measurement :** Tacheometer, levelling instruments like dumpy level etc.

(d) **For vertical angle measurement :** Sextant, clinometer, theodolite etc.

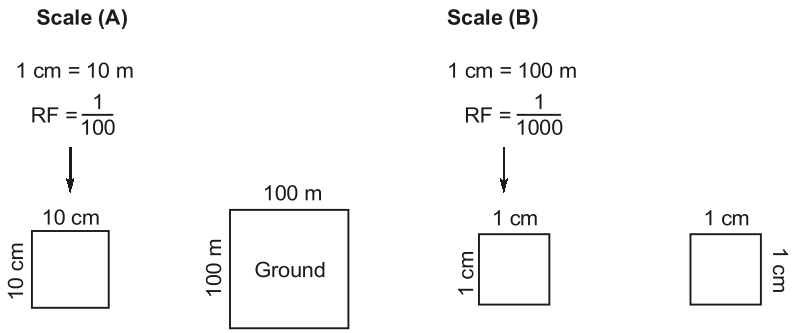
1.10 Scale

Technique through which we represent the ground distance on map.

$$\text{Scale} = \frac{\text{Map distance}}{\text{Ground distance}}$$



1.10.1 Large/small Scale



Larger is the denominator of RF smaller is the scale.

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

Solution:

Scale; $1\text{ cm} = 4\text{ m}$

$\therefore$ $$RF = \frac{1}{4\times 100} = \frac{1}{400}$$

Example - 1.2 The fraction scale of a map is stated to the 1 : 50000 convert this to engineer's scale.

Solution:

$$RF = \frac{1}{50000}$$

(1 cm on plan = 50000 cm on ground)

1 cm on plan = 500 m on ground

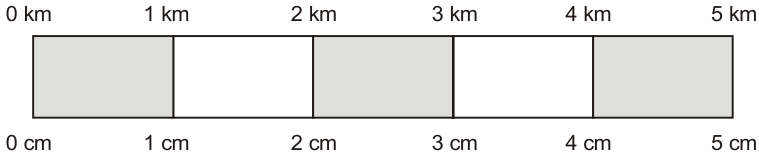
$\therefore$ Engineer's scale

$$1\text{ cm} = 500\text{ m}$$

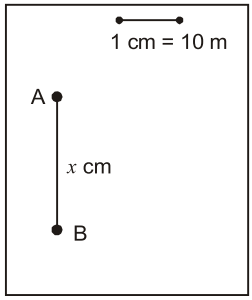
1.10.2 Graphical Scale

- Graphical scale is a line drawn on the plan or map on which ground distance is directly marked.

- Graphical scale has the advantage over numerical scale such that distance on the plan or map can be determine by actual scale even through plan or map has shrunk.
- In case of shrinkage of map graphical scale also changes with the map and therefore ratio is unaffected.



1.10.3 Errors Incurring Due to Shrinkage of a Map



Before shrinkage, let scale 1 cm = 10 m

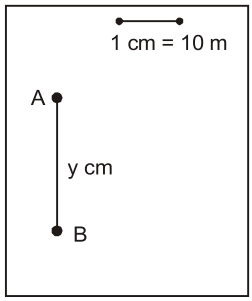
Also, let distance between two points on the map = x cm

$\Rightarrow$ x cm on the map represent $1000x$ cm on ground

After shrinkage,

Now, distance between the two points = y cm

$\therefore$ Ground distance = 1000 y cm



$$\text{Shrunk scale} = \frac{y \text{ cm}}{1000x \text{ cm}} = \left(\frac{y}{x}\right)\frac{1}{1000}$$

Shrunk scale = (Shrinkage factor) × RF

y = Shrunk length

x = Original length

$$SF = \frac{y}{x}$$

$$\text{Shrinkage factor/Shrinkage ratio} = \frac{\text{Shrunk length}}{\text{Original length}} = \frac{\text{Shrunk scale}}{\text{Original scale}} = \frac{\text{Shrunk R.F.}}{\text{Original R.F.}}$$

NOTE: Shrinkage factor always < 1.

Example - 1.3 Plan of an area has shrunk such that a line originally 10 cm long now measures as 9.5 cm. If original scale was 1 cm = 10 m, determine

(a) Correct length corresponding to measured length of 100 m

(b) Correct area corresponding to measured are of 100 m^2

(c) Shrinkage factor

(d) Shrunk scale

Solution:

Scale = 1 cm = 10 m

Shrinkage factor, $SF = \frac{9.5}{10} = 0.95$

$$\text{Shrunk scale} = 0.95 \times \frac{1}{1000} = \frac{1}{1052.63}$$

$$SF = \frac{\text{Measured distance}}{\text{Correct distance}}$$

$$0.95 = \frac{100}{\text{Correct distance}}$$

$$\text{Correct distance} = \frac{100}{0.95} = 105.263 \text{ m}$$

$$\text{Correct area} = \frac{\text{Measured area}}{(SF)^2} = \frac{100}{(0.95)^2} = 110.803 \text{ m}^2$$

1.10.4 Error Due to Wrong Measuring Scale

$$\text{Correct length} = \left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right) \times \text{Measured distance}$$

Example - 1.4 A surveyor measures a distance between two points drawn on the map drawn to a scale of 1 cm = 1 m (RF = 1/100) and found it to be 50 m. Later he discovered that he used a wrong scale of 1 cm = 50 cm (RF = 18/50) for immurement. Determine the correct length, what would be the correct area if measured area is 60 m²?

Solution:

$$\text{Correct length} = \left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right) \times \text{Measured length}$$

$$= \left(\frac{1/50}{1/100}\right) \times 50 = 100 \text{ m}$$

$$\text{Correct area} = \left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right)^2 \times \text{Measured area}$$

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

1.11 Use of Verniers

- A vernier is a device for measuring accurately the fractional part of the smallest division on a graduated scale.
- The actual reading is given by
  (Reading on main scale before index mark + N × LC)
  N = No. of graduations on vernier scale
  LC (Latest count) = 1 division on main scale – 1 division on vernier scale

1.11.1 Type of Vernier

- **Direct Vernier :** In direct vernier, n divisions on vernier scale are equal to (n – 1) division on main scale

$$\eta v = (n - 1)s$$

$$\therefore \quad LC = S - V = S - \left(\frac{n-1}{n}\right)S$$

$$LC = \frac{S}{n}$$

- **Retrograde Vernier :** In case of retrograde vernier, n division on vernier scale are equal to (n + 1) divisions on main scale

$$nv = (n+1)S$$

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

- **In direct vernier**, vernier division and main scale division increases in same direction whereas in retrograde vernier both increases in opposite direction.

Example - 1.5 The main plate of a theodolite is divided into 1080 equal parts and 60th division on vernier scale coincides exactly with 59th division on main scale. Determine LC (least count) of theodolite.

Solution:

$$LC = \frac{S}{n} = \frac{360^\circ / 1080}{60}$$

$$= \frac{360}{1080 \times 60} \times 60 \times 60 = 20''$$

Example - 1.6 Calculate the least count of a vernier whose 60 divisions coincides with 59 divisions of its primary scale and if each degree on the primary scale is subdivided into 10′ intervals.

Solution:

Given: S = 10′; n = 60

$$\therefore \quad LC = \frac{S}{n} = \frac{10}{60} = \left(\frac{1}{6}\right)' = 10''$$

1.11.2 Special Type of Vernier

Double Vernier

- If graduations of main scale increases in one direction only we have a single vernier, when mains scale is numbered in both the direction. A double vernier is used. (Ex. theodolite)
- Double vernier consist of two direct verniers extending in both directions with index mark in centre.
- It is a combination of both direct and retrograde vernier.

Double Folded Vernier

- Double folded vernier is a special type of double vernier whose total length is half of combined length of corresponding double vernier.
- A double fold vernier is used when it is required to reduce the length of corresponding double vernier when it is very large and impracticable to provide. Ex. Compass and Sextant)

- In double folded vernier, the vernier is read from the index mark towards either of the extreme division and then from other extreme division towards the centre in same direction.

Extended Vernier

- When division of main scale are very close and it becomes difficult to determine exact graduation, where coincidence occurs if vernier of normal length is used. Hence extended vernier is very useful when available length of vernier scale is small but it is required to have small least count without making vernier divisions very close.
- In extended vernier

$$nv = (2n - 1)S$$

$$LC = 2S - v = 2s - \left(\frac{2n-1}{n}\right)S$$

$$LC = \frac{S}{n}$$

- In this n division of vernier scale coincides with (2n – 1) division of main scale.

Example - 1.7 A box sextant has the main scale reading in 10′ (Ten Minute) graduations. If the LC desired for an extended vernier is 10″. Design an extended vernier

Solution:

$$LC = \frac{S}{n}$$

$$10'' = \frac{10 \times 60}{n}$$

$$n = 60$$

$$(2n - 1) = 119$$

∴ 119 spaces of main scale are equal to 60 spaces of vernier.

Example - 1.8 Which of the following statement is correct:

(a) In a retrograde vernier, (n + 1) division on primary scale are divided n division n vernier scale.

(b) A double vernier consist of two simple verniers placed and to end forming one scale with zero in the centre.

(c) In an extended vernier (2n – 1) primary division are divided into n divisions on vernier.

(d) In a direct vernier (n + 1) primary divisions are divided into n equal parts on vernier scale.

Solution: (b)

1.12 Precision and Accuracy

1.12.1 Precision

Degree of fineness and care with which any physical measurement is done.

1.12.2 Accuracy (Degree of Perfection)

- A value is considered to be accurate when it is close to true value.
- Precise value represents group of observations that are closely grouped and have small deviation from true value.

NOTE

To plot or draw a map or plan accuracy required is also define by the scale of the plan. A good draftmen can plot smallest length of 0.25 mm. Now for a scale of 1/1000 (1 mm = 1m) smallest plottable distance is 0.25 mm hence for survey done at a scale of (1 : 1000) should have field accuracy of 0.25 mm.

1.13 Mistakes and Errors

1.13.1 Mistakes

These are discrepancy caused due to carelessness, misunderstanding and poor judgement. Ex. Miscounting of tape length, 5 m reading taken as 8 m.

1.13.2 Error

These are discrepancy other than mistake

Error = MV – TV

Correction = TV – MV

E = –Correction

TV = True value

MV = Measured value

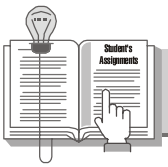
Error
- Systemetic/Cumulative error
- Random/Accidental/Compensating error

– ***Systematic Error*** : These error follow a definite mathematical or physical low. Cumulative in nature

– ***Random error*** : These are errors left out after mistakes and systematic errors are eliminated.

NOTE

- Systematic error is directly proportional to length of line.
- Random error is directly proportional to square root of length of line.



Student's Assignment

Q.1 The representative fraction is 1/5000 means that the scale is
(a) 1 cm = 0.50 m (b) 1 cm = 5.0 m
(c) 1 cm = 50 m (d) 1 cm = 500 m

Q.2 Which of the following scale is the smallest one?
(a) 4 : 200000 (b) 1 cm = 5000 m
(c) 1 cm = 50 m (d) RF = 1/500

Q.3 When the curvature of earth is taken into account, the surveying is called as
(a) Plane surveying
(b) Preliminary surveying
(c) Geodetic surveying
(d) Hydrographic surveying [UKPSC]

Q.4 The main principle of surveying is to work from
(a) higher level to lower level
(b) lower level to higher level
(c) part to whole
(d) whole to part

Q.5 Which of the following statement is respect of a map A having scale 1 : 1000 and another map B having scale 1 : 5000 is true?
(a) map A is a large scale map compared to map B
(b) map B is a large scale map compared to map A
(c) map B is more detailed map compared to map A
(d) None of these

Q.6 A scale representing either three units or only one unit and its fraction upto second plane of decimal point is
(a) Diagonal scale (b) Comparative scale
(c) Vernier scale (d) Shrunk scale

Q.7 If the smallest division of vernier is longer then the largest division of its primary scale, the vernier is known as
(a) Direct vernier (b) Double vernier
(c) Simple vernier (d) Retrograde vernier

Q.8 Which one of the following is the largest scale?
(a) 1 : 500 (b) 1 : 1000
(c) 1 : 2500 (d) 1 : 50000

Q.9 In case of a direct vernier scale
(a) graduations increases in opposite direction in which graduations of the main scale increase
(b) Smallest division is longer then smallest division of main scale
(c) graduations increases in same direction in which graduations of the main sale increases
(d) None of these

Q.10 What is the difference between the sum of interior angle of plane triangle and spherical triangle for area of triangle 195 km^2 on the Earth's surface
(a) one degree (b) one minute
(c) one second (d) one radian

Q.11 Which one of the following survey is used to define the property line?
(a) city survey
(b) cadastral survey
(c) land survey
(d) topographical survey [MPSC]

Q.12 The vernier that is celebrated in the direction opposite to the main scale is called
(a) direct vernier
(b) double vernier
(c) extended vernier
(d) retrograde vernier

Q.13 Which one is the upper limit of survey area (square kilometer) for use of plane survey?
(a) 250 (b) 300
(c) 350 (d) 450

Q.14 Calculate the length of one division of the vernier scale, if the least count of the combination of main scale and vernier scale is 0.02 mm. The least count of main scale is 1 mm

(a) 1 mm (b) 0.98 mm
(c) 10.2 mm (d) 1.03 mm

Q.15 An area of field is 250 sq. centimeters from a shrunk map having shrunk factor of 0.9. Calculate the original area (sq. m) on the field, if the original scale of the map is 1 cm = 50 m

(a) 309 (b) 625000
(c) 694444 (d) 771450

Q.16 A line of 5 m on the original map is shrunk to 4.6 m. Calculate the shrunk scale if the original scale of the map was 1 cm = 80 m

(a) 1 cm = 73.8 m (b) 1 cm = 79.6 m
(c) 1 cm = 86.95 m (d) 1 cm = 92.4 m

Q.17 The scale in which three successive dimensions can be measured at a time is called

(a) chord scale (b) diagonal scale
(c) plain scale (d) vernier scale

Q.18 A surveyor measures a distance between two points on a map of RF of 1/100 is 60 m but later he found that he used wrong RF of 1/50. What is the correct distance between the two points?

(a) 30 (b) 45
(c) 90 (d) 120 [APPSC]

Q.19 10 division of vernier scale are equal to 11 division of main scale of each 0.1 mm. What is the least count of the vernier scale?

(a) 0.009 (b) 0.01
(c) 0.1 (d) 1.1

Q.20 With an increase in the denominator of the representative fraction, the scale of the map will

(a) decrease
(b) either decrease or increase
(c) increase
(d) remain same

Q.21 Which of the following figures are equal to one acre?

1. 43560 sq. ft.
2. 40 gunthas
3. 10 sq. gunter's chain
4. 4850 sq. yards

Select the correct answer using the codes:

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 2 and 4 (d) 1, 3 and 4

Q.22 Which of the following conditions require geodetic surveying?

(a) Horizontal curve ranging
(b) Vertical curve ranging
(c) Survey of a country
(d) Reconnaissance survey

Q.23 A scale of 1 inch = 50 ft, is mention on old map. What is the corresponding equivalent scale?

(a) 1 cm = 5 m (b) 1 cm = 6 m
(c) 1 cm = 10 m (d) 1 cm = 12 m

Q.24 Survey of India publishing toposheets using a scale of

(a) 1 : 1000 (b) 1 : 5000
(c) 1 : 10000 (d) 1 : 50000

ANSWER KEY // STUDENT'S ASSIGNMENT

1. (c)	**2.** (b)	**3.** (c)	**4.** (d)	**5.** (a)
6. (c)	**7.** (d)	**8.** (a)	**9.** (c)	**10.** (d)
11. (b)	**12.** (d)	**13.** (a)	**14.** (b)	**15.** (d)
16. (c)	**17.** (b)	**18.** (d)	**19.** (b)	**20.** (a)
21. (a)	**22.** (c)	**23.** (b)	**24.** (d)	

HINTS & SOLUTIONS // STUDENT'S ASSIGNMENT

1. (c)

$$RF = \frac{1}{5000}$$

1 cm = 5000 cm

1 cm = 50 m

2. (b)

(a) $RF = \frac{1}{50000}$

(b) $RF = \frac{1}{500000}$

(c) $RF = \frac{1}{5000}$

(d) $RF = \frac{1}{50000}$

14. (b)

Length of one division of vernier scale

= least count of main ale – least count of combination of main and vernier scale

= 1 – 0.02 = 0.98

15. (d)

$$\text{Original area} = \frac{250\ \text{cm}^2}{(0.9)^2} \times (50)^2$$

$$= 77160.493\ \text{m}^2$$

16. (c)

$$\text{Shrunk scale} = \text{SF} \times (\text{RF})$$

$$= \frac{4.6}{5} \times \frac{1}{8000}$$

$$= \frac{1}{8695.65}$$

$$\Rightarrow \quad 1\ \text{cm} = 8695\ \text{cm}$$

$$1\ \text{cm} = 86.95\ \text{m}$$

18. (d)

$$CD = \frac{1/50}{1/100} \times 60 = 120\ \text{m}$$

21. (a)

$$1\ \text{acre} = 4840\ \text{sq. yard}$$

$$1\ \text{sq. yard} = 9\ \text{sq. feet}$$

$$1\ \text{acre} = 43560\ \text{sq. feet}$$

$$1\ \text{acre} = 10 \times (\text{Gunter's chain})^2$$

$$1\ \text{Gunter's chain} = 66\ \text{ft}$$

$$1\ \text{Guntha} = (33\ \text{ft})^2$$

$$1\ \text{acre} = 40\ \text{Guntha}$$

23. (b)

$$1\ \text{inch} = 50\ \text{ft.} = 50 \times 12\ \text{inch}$$

$$\therefore \quad RF = \frac{1}{600}$$

$$\Rightarrow \quad 1\ \text{cm} = 600\ \text{cm}$$

$$1\ \text{cm} = 6\ \text{m}$$

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