Scales

Scale

The proportion by which we either reduce or increase the actual size of the object on a drawing is known as scale.
It is not possible always to make drawings of an object to its actual size as the extent of drawing paper is limited and also sometimes the objects are too small to make it clearly understandable by drawing its actual size in drawing paper. Scale is the technique by which one can represent an object comfortably as well as precisely within the extent of drawing paper.
In other words, a scale is a measuring stick, graduated with different divisions to represent the corresponding actual distance according to some proportion. Numerically scales indicate the relation between the dimensions on drawing and actual dimensions of the objects.

Uses of scale

- To prepare reduced or enlarged size drawings.
- To set off dimensions.
- To measure distances directly.

Sizes of Scales

- Full size scale
- Reducing scale
- Enlarging scale

Full Size Scale

The scale in which the actual measurements of the object are drawn to the same size on the drawing is known as full size scale. It is represented as 1:1 scale. If possible, drawing should be done in full scale.

Reducing Scale

The scale in which the actual measurements of the object are reduced to some proportion is known as reducing scale. The standard formats of reducing proportions are:

1:2 - drawing made to one-half of the actual size
1:5 - drawing made to one-fifth of the actual size
1:10 - drawing made to one-tenth of the actual size
1:50 - drawing made to one-fiftieth of the actual size
1:100 - drawing made to one-hundredth of the actual size

Enlarging Scale

The scale in which the actual measurements of the object are increased to some proportion is known as reducing scale. The standard formats of enlarging proportions are:

2:1 - drawing made to twice the actual size
5:1 - drawing made to five times the actual size
10:1 - drawing made to ten times the actual size

Classification of Scales

- Plain Scales
- Diagonal Scales
- Comparative Scales
- Vernier Scales
- Chord Scales

The first two type (plain and diagonal) of scales are usually used in engineering drawings.

Plain Scale

The scale that can measure one main unit and one sub-unit of the main unit or up to a fraction of 1^{st} decimal point of the main unit is known to be a plain scale. It is simply a line divided into a number of equal parts and the 1^{st} part is further sub-divided into small parts.

Kilometers and Hectometers, Meters and Decimeters, Meters and $1/10^{th}$ of Meters etc. can be measured using plain scales.

Diagonal Scale

The scale that can measure one main unit and two sub-units of the main unit or up to a fraction of 2^{nd} decimal point of the main unit is known to be a diagonal scale. It is so named because the 2^{nd} sub-unit or 2^{nd} decimal of main unit is obtained by the principle of diagonal division.

Kilometers-Hectometers-Decameters, Decameters-Meters-Decimeters, Meters-$1/10^{th}$ of Meters- $1/100^{th}$ of Meters etc. can be measured using diagonal scales.

Table 1. Difference between Plain Scale and Diagonal Scale

Plain Scale	Diagonal Scale
It can measure one main unit and one sub-units of the main unit	It can measure one main unit and two sub-units of the main unit
It can measure up to a fraction of 1^{st} decimal point of the main unit.	It can measure up to a fraction of 2^{nd} decimal point of the main unit.
Scale is constructed by simply dividing the line longitudinally.	Scale is constructed by dividing the line longitudinally as well as vertically and diagonally.

Comparative Scale

When the given scale of a plan reads a certain measure and it is required to construct a new scale for the same plan to read in some other measures, the new scale is called comparative scale or corresponding scale.

For example let us consider a plan drawn in inch units and scale provided with drawing can measure in feet and inch. If we draw another scale taking same R.F. that can measure in feet, inch and $1/8^{th}$ of inch it will be a comparative scale. Also if we draw another scale that can measure in cm and mm with same R.F. it will also be a comparative scale.

Vernier Scale

It is device for measuring fractional parts of the smallest division of the main scale. It consists of a fixed main scale and a movable vernier scale. The vernier part is graduated in "n" number of divisions in such a way that it coincides with "n-1" number of smallest divisions of main scale.

Chord Scale

The scale which is used to make or to measure angles of any magnitude is known as chord scale. This scale is usually marked on a rectangular protractor.

Necessity of Construction of Scale on Drawing

In most of the cases the distances in a drawing is found to be different than the corresponding actual distance. Therefore, to get the actual measurements, it is a must to know the proportion using which the drawing is prepared. Sometimes the drawing may need to be prepared to an odd proportion (like 1:2.7 or 13.2:1) for which a physical scale is not available. In such case individual scale construction is required for that specific drawing. It is often found helpful and convenient to construct and draw the corresponding scale on the drawing than mentioning the proportion in language. On the other hand if a drawing is to be used after decades, the paper may shrink or expand by absorbing or leaving moisture due to temperature effect. Taking measurements from such a drawing using the proportion mentioned will give some inaccurate result. But if a scale is constructed an drawn during the preparation of 1st time, the drawn scale will also shrink or expand in the same proportion to the drawing. Thus if one take measurements with the help of the drawn scale, accurate measurements will be obtained.

Information Necessary for Construction of a Scale

Following are the necessary information required for construction of a scale:

- The representative fraction (R.F.) of the scale.
- The unit or units to be presented.
- The maximum length to be measured.

The Representative Fraction (R.F.) or Scale Factor (S.F.)

The ratio of the distance on drawing paper of an object to the corresponding actual distance of the object is known as the representative fraction (R.F.) or the scale factor (S.F.). It is to be remembered that for finding RF the distances used for calculation must be in same unit. And being a ratio of same units, R.F. itself has no unit. Mathematically,

$$R.F. = \frac{Distance\ of\ object\ on\ drawing\ sheet}{Corresponding\ actual\ distance\ of\ the\ object} \quad [In\ same\ unit]$$

Worked out Examples of R.F. Calculation

Example 1: In a certain map, 2.5 centimeters of measured length represents 5 hectometers of actual distance. Calculate R.F. for the scale of this map.

Solution:

Representative Fraction of the scale for this map,

$$R.F. = \frac{2.5}{5\times10\times10\times10\times10} = \frac{1}{20000} \quad or \quad 1:20000$$

Example 2: To draw a microscopic element of a machine part, it is to be enlarged in drawing such a manner that one-fifth of one millimeter is to be represented by 1.5 meters. Find out RF of the scale for this drawing.

Solution:

Representative Fraction of the scale,

$$R.F. = \frac{1.5 \times 10 \times 10 \times 10}{\frac{1}{5}} = 7500 \quad or \quad 7500:1$$

Example 3: A scale is to be constructed for a drawing of a plot such that 100 square feet of area is to be represented by 1 square inch. What will be the R.F. of this scale?

Solution:

Here 1 sq. inch represents 100 sq.ft. or we can write 1 inc$h \approx 100$ ft^2
Taking under root on both sides, we get

$$\sqrt{1\ inch^2} \approx \sqrt{100\ ft^2}$$

$$\therefore 1\ inch \approx 10\ ft$$

$$Now, \quad R.F. = \frac{1}{10 \times 12} = \frac{1}{120} \quad or \quad 1:120$$

Units of Measurement

It is modern practice to use metric system of units in engineering drawing. However, sometimes British system is also used. It is important to have clear understanding about unit conversion in both system. Table 6.2 to Table 6.7 presents the units of measurements, their symbols and conversions.

Table 2 Metric Units for Linear Measurement

10 millimeters (mm)	= 1 centimeter (cm)
10 centimeters (cm)	= 1 decimeter (dm)
10 decimeters (dm)	= 1 meter (m)
10 meters (m)	= 1 decameter (dam)
10 decameters (dam)	= 1 hectometer (hm)
10 hectometers (hm)	= 1 kilometer (km)

Table 4 Metric Units for Area Measurement

100 square millimeters (mm^2)	= 1 square centimeter (cm^2)
100 square centimeters (cm^2)	= 1 square decimeter (dm^2)
100 square decimeters (dm^2)	= 1 square meter (m^2)
100 square meters (m^2)	= 1 acre (a)
100 acres (a)	= 1 hectare
100 hectares	= 1 square kilometer (km^2)

Table 6 Metric Units for Volumetric Measurement

1000 cubic millimeters (mm^3)	= 1 cubic centimeter (cm^3)
1000 cubic centimeters (cm^3)	= 1 cubic decimeter (dm^3)
1000 cubic decimeters (dm^3)	= 1 cubic meter (m^3)

Table 3 British Units for Linear Measurement

12 inches	= 1 foot
3 feet	= 1 yard
220 yards	= 1 furlong
8 furlong	= 1 mile

Table 5 British Units for Area Measurement

144 square inches	= 1 square foot
9 square feet	= 1 square yard
4840 square yards	= 1 acre
640 acres	= 1 square mile

Table 7 British Units for Volumetric Measurement

1728 cubic inches	= 1	cubic foot
27 cubic feet	= 1	cubic yard

Construction of Plain Scale

Following are the steps for constructing a plain scale

- Find out the R.F., if not given directly.
- Find out the length of scale

$= R.F. \times Actual\ length\ of\ object\ or\ Maximum\ length\ to\ be\ measured$

[Note: If length of object or maximum length to be measured is not mentioned in problem, for convenience, take the length of scale about 15 cm or 6 inches]

- Draw a straight line, preferably horizontal, of required length as found in previous step.
- Divide the line into a number of divisions relating to the length of object and maximum length to be measured such that one segment represents one major unit. Avoid fractions, consider the next integer value. For instance, if maximum length to be measured is 6.2 km, then number of divisions will be 7.
- Place mark 0 at the end of 1st main division (Remember, not at the starting point of 1st division) and mark the other divisions sequentially toward right as 1,2,3….. etc.
- Divide the 1st main division into a number of divisions such that each of these smallest division represents one sub-unit. For instance if the scale need to measure in feet and inches, number of minor divisions will be 12. On the other hand if the scale is to measure in centimeters and millimeters or in meters and 1/10th of meter number of divisions will be 10.
- Mark the sub-unit sequentially toward left as 1, 2, 3…… etc. or 0.1, 0.2, 0.3……. etc. If space is limited they can be marked after every 2 division like 0, 2,4,….. etc.
- Mention the R.F. of the scale below the figure.
- Mention the name of main unit and sub-unit either at below or at the respective ends of the scale.

Worked-out Examples of Plain Scale Construction

Example 4: Construct a plain scale to show kilometers and hectometers when 2.5 centimeters are equal to 1 kilometer and long enough to measure upto 5.7 kilometers. Find R.F. of the scale and indicate distances (i) 4 kilometers and 5 hectometers and (ii) 5.4 kilometers on the scale.

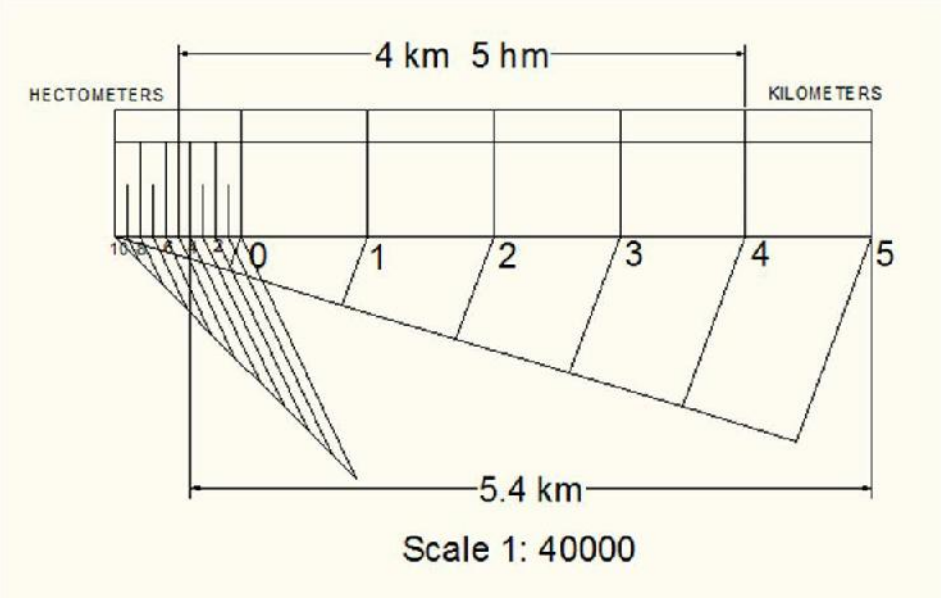
Solution:

$$R.F. = \frac{2.5}{1 \times 10 \times 10 \times 10 \times 10 \times 10} = \frac{1}{40000} \quad or \quad 1:40000$$

$$Length\ of\ Scale\ =\ R.F.\ \times Maximum\ length\ to\ measure$$
$$= \frac{1}{40000} \times 6\ km = \frac{1}{40000} \times 6 \times 1000 \times 100\ cm = 15\ cm$$

[To avoid fraction, maximum distance is taken 6 km instead of 5.7 km]

Now a horizontal line 15 cm long is drawn and is divided into 6 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3, 4 and 5. The 1st division is further divided into 10 divisions and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 2, 4, 6, 8 and 10 toward left. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



Example 5: A rectangular plot of land of area 64 square mile is represented on a certain map by area of 1 square inch. Draw a plain scale to show units of 10 miles and single miles. Find R.F. and mark a distance of 63 mile on this scale.

Solution: Given,

$$1\ inch^2 \approx 16\ mile^2$$

$$\sqrt{1\ inch^2} \approx \sqrt{64\ mile^2}$$

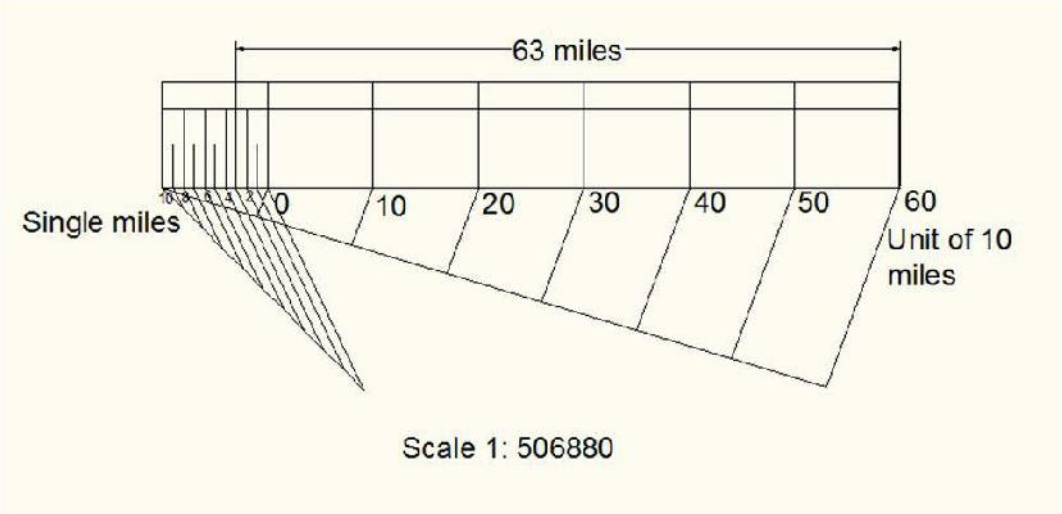
$$\therefore 1\ inch\ \approx\ 8\ miles$$

$$Now, \quad R.F. = \frac{1}{8 \times 1760 \times 3 \times 12} = \frac{1}{506880} \quad or \quad 1:506880$$

Here maximum distance to be measured is not given, but we need to ensure the measuring a distance of 63 mile. Thus we have to construct the scale for 70 miles of maximum distance.

$$Length\ of\ Scale\ = R.F.\ \times Maximum\ length\ to\ measure$$
$$= \frac{1}{506880} \times 70\ miles = \frac{1}{506880} \times 70 \times 1760 \times 3 \times 12\ inch = 8.75\ inch$$

Now a horizontal line 8.75 inch long is drawn and is divided into 7 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 10, 20, 30, 40, 50 and 60. The 1st division is further divided into 10 divisions and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 2, 4, 6, 8 and 10 toward left. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



Example 6: A car is moving at a speed of 60 kmph. On a scale one centimeter represents one third of a kilometer. Construct the scale and show the distance travelled by the car in 3 minutes and 30 seconds. What is the R.F. of the scale?

Solution:

$$R.F. = \frac{1}{\frac{1}{3} \times 1000 \times 100} = \frac{1}{33333} \quad or \quad 1:33333$$

$$Speed\ of\ the\ car\ = 60kmph = 60\frac{km}{hr} = \frac{60}{60}\frac{km}{mt} = \frac{1km}{1mt}$$

$$Therefore, we\ get, \quad 1km \approx 1mt - - - - - - - - (1)$$

$$Also, Given, \quad \frac{1}{3}km \approx 1cm$$

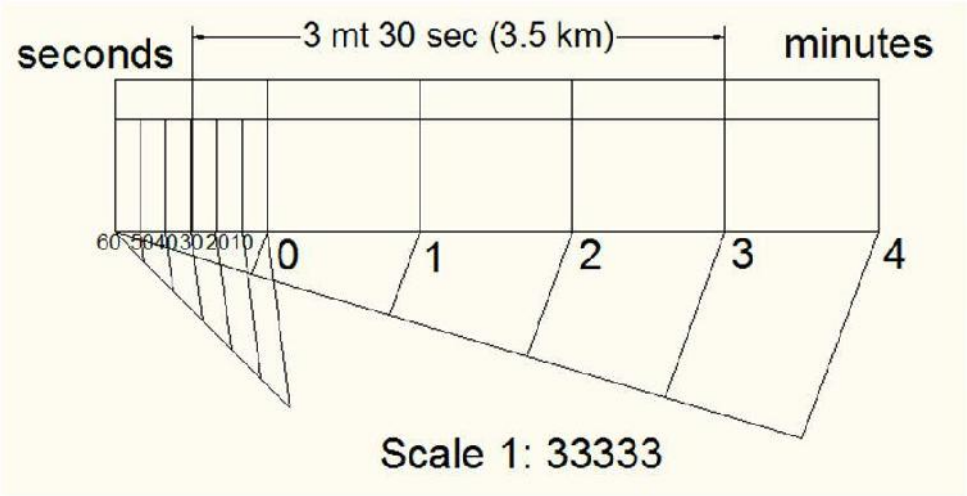
$$\therefore \quad 1km \approx 3\ cm\ - - - - - - - - (2)$$

$$From\ (1)\ and\ (2), for\ the\ scale, \quad 1mt = 3\ cm$$

$$Now, if\ we\ consider\ length\ of\ the\ scale\ as\ 15\ cm, it\ will\ cover \frac{15}{3} = 5\ minutes$$

$$and\ therefore\ the\ required\ time\ 3\ mt\ and\ 30\ sec\ can\ be\ shown\ in\ this\ scale$$

Now a horizontal line 15 cm long is drawn and is divided into 5 equal parts so that each major division shows one minute. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3 and 4. The 1st division is further divided into 6 divisions so that each minor division shows 10 seconds and starting at 0 mark placed earlier the sub-divisions are marked as 10, 20, 30, 40, 50 and 60 toward left. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required time is indicated.



Principle of Diagonal Scales

The principle of diagonal scale is to obtain any fractional part of a short line by following the diagonal division method. In this method we get fractional part of a line, say 1/9th of length, 1/15th of length etc. Let the given short line AB which is required to be divided into 12 equal parts.

- Erect a perpendicular BC of any suitable length and divide it into 12 equal parts.
- Join AC and draw lines 1-1', 2-2', 3-3'… etc. parallel to AB at each division point. Thus dividing is complete indirectly.
- If you need 1/12th of AB, 1-1' will be your required length. If you need 2/12th of AB, 2-2' is your required length. Similarly 3-3' represents 3/12th of AB, 4-4' represents 4/12th of AB and so on.

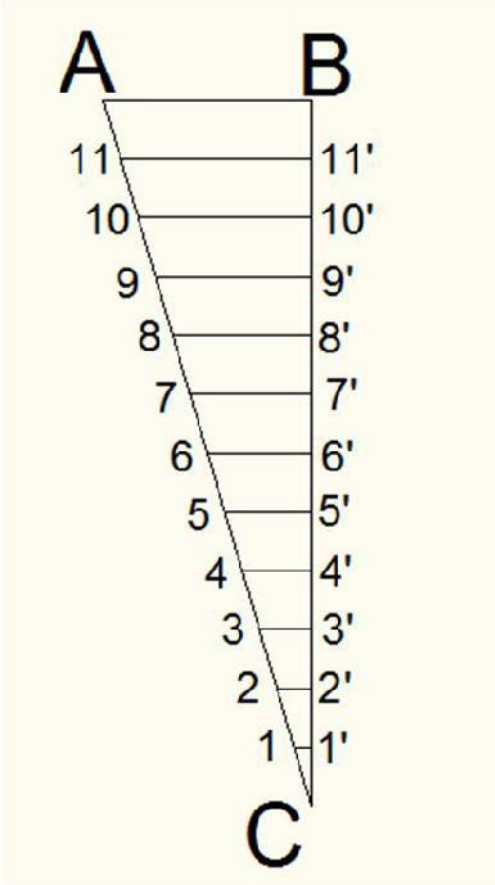


Fig. 1 Diagonal division technique

Proof:

From figure it is obvious that triangle ABC and triangle 4-4'-C are similar triangles.

$$\text{So, } \frac{4-4'}{AB} = \frac{C-4'}{BC} = \frac{\frac{4}{12}BC}{BC} = \frac{4}{12}$$

$$\therefore \quad 4-4' = \frac{4}{12}AB$$

Construction of Diagonal Scales

Following are the steps for constructing a plain scale

- Find out the R.F., if not given directly.
- Find out the length of scale

$= R.F. \times Actual\ length\ of\ object\ or\ Maximum\ length\ to\ be\ measured$

[Note: If data is not available take the length of scale about 15 cm or 6 inches]

- Draw a straight line, preferably horizontal, of required length as found in previous step.
- Divide the line into a number of divisions relating to the length of object and maximum length to be measured such that one segment represents one major unit.
- Place mark 0 at the end of 1st main division and mark the other divisions sequentially toward right as 1,2,3….. etc.
- Divide the 1st main division into a number of divisions such that each of these sub-divisions represents one 1st sub-unit. For instance if the scale need to measure in yards, feet and inches, number of horizontal sub-divisions will be 3. On the other hand if the scale is to measure in decimeter, centimeters and millimeters or in meters, 1/10th of meter and 1/100th of meter number of horizontal sub-divisions will be 10.
- Mark the sub-unit sequentially toward left as 1, 2, 3…… etc. or 0.1, 0.2, 0.3……. etc. If space is limited they can be marked after every 2 division like 0, 2,4,….. etc.
- Draw a perpendicular of suitable length at the left end and complete the rectangle considering the two mutually perpendiculars lines as length of two sides.
- Divide the vertical line at left end into a number of divisions such that each of one sub-division represents one 2nd sub-unit. For instance if the scale need to measure in yards, feet and inches, number of vertical sub-divisions will be 12. On the other hand if the scale is to measure in decimeter, centimeters and millimeters or in meters, 1/10th of meter and 1/100th of meter number of vertical sub-divisions will be 10.
- At each vertical sub-division point draw a line parallel to the baseline.
- Draw a diagonal line by joining left-top corner point and the horizontal sub-division point immediately before the left-bottom corner. At every horizontal sub-division point draw a parallel line to this diagonal line.
- Mention the R.F. of the scale below the figure.
- Mention the name of main unit and sub-units either at below or at the respective ends of the scale.

Worked-out Examples of Diagonal Scale Construction

Example 7: Construct a diagonal scale to show kilometers, hectometers and decameters when 2.5 centimeters are equal to 1 kilometer and long enough to measure upto 5.7 kilometers. Find R.F. of the scale and indicate distances (i) 4 kilometers 5 hectometers 4 decameters and (ii) 5.86 kilometers on the scale.

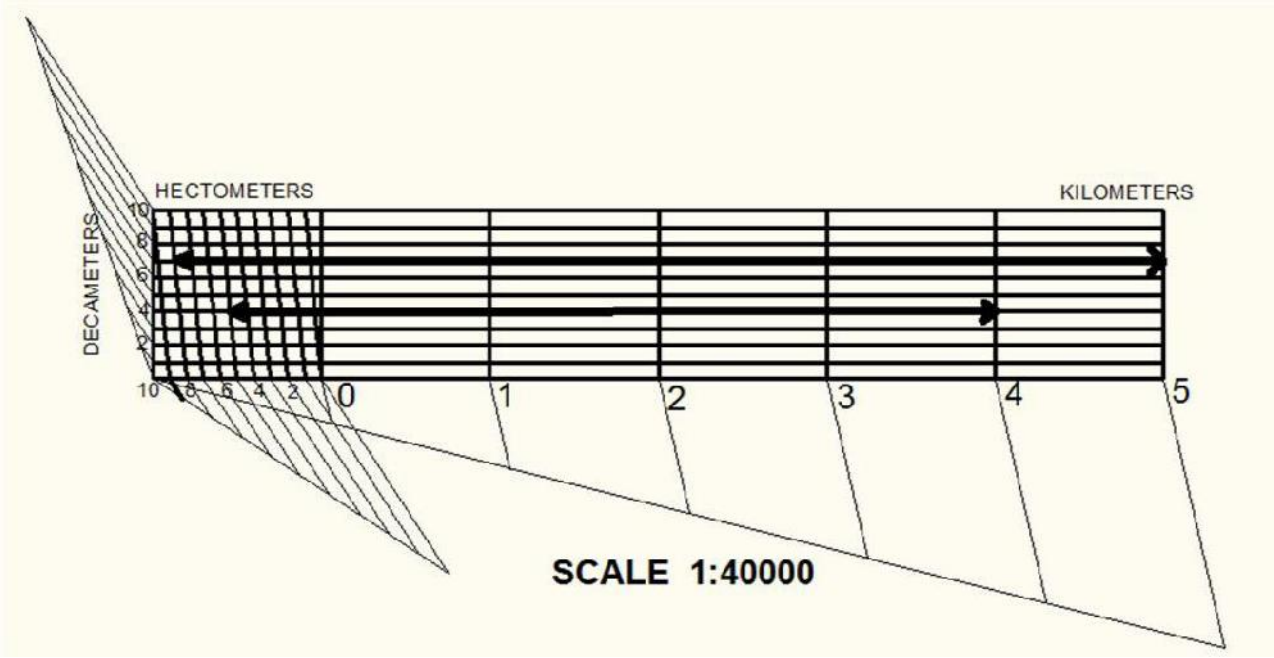
Solution:

$$R.F. = \frac{2.5}{1 \times 10 \times 10 \times 10 \times 10 \times 10} = \frac{1}{40000} \quad or \quad 1:40000$$

$$Length\ of\ Scale\ =\ R.F.\ \times Maximum\ length\ to\ measure$$
$$= \frac{1}{40000} \times 6\ km = \frac{1}{40000} \times 6 \times 1000 \times 100\ cm = 15\ cm$$

[To avoid fraction, maximum distance is taken 6 km instead of 5.7 km]

Now a horizontal line 15cm long is drawn and is divided into 6 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3, 4 and 5. The 1st division is further divided into 10 divisions and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 2, 4, 6, 8 and 10 toward left. At left end a perpendicular of length equal to one major division is drawn and a rectangle is completed considering the mutually perpendicular lines as two sides. The vertical line at left end is divided into 10 equal parts and at each division point a line parallel and equal length of the base line is drawn. Top left corner and the point corresponding to 9hm is connected with a diagonal line. At the remaining 9 horizontal sub-division points parallel lines are drawn to the 1st diagonal line. Vertical divisions are marked sequentially from bottom toward top at every 2 division as 2, 4, 6, 8 and 10. At all the horizontal major division points vertical lines are drawn. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



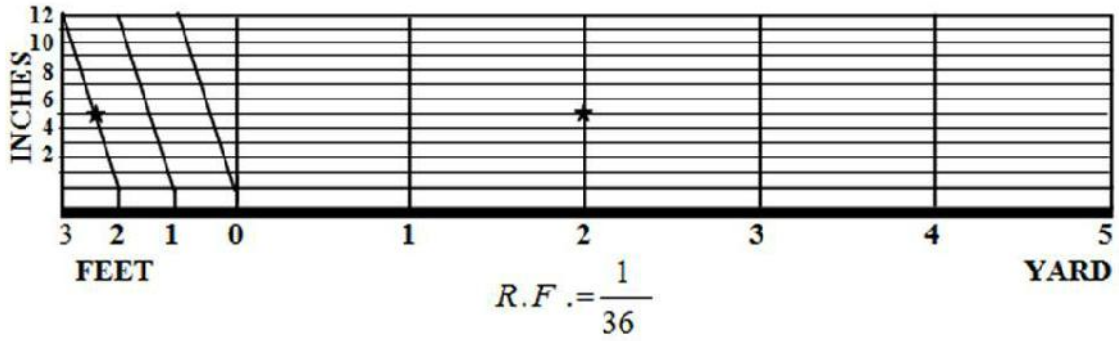
Example 8: Construct a diagonal scale that measures 1 inch for an equivalent actual length of 1 yard, can show yards, feet and inches and can measure length up to 6 yds. Also show 2 yds. 2 ft 5 inch on it.

Solution:

$$R.F. = \frac{1}{1 \times 3 \times 12} = \frac{1}{36} \quad or \quad 1:36$$

$$Length\ of\ Scale\ = R.F.\ \times Maximum\ length\ to\ measure$$
$$= \frac{1}{36} \times 6\,yd = \frac{1}{36} \times 6 \times 3 \times 12\,inch = 6\,inch$$

Now a horizontal line 6 inch long is drawn and is divided into 6 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3, 4 and 5. The 1st division is further divided into 3 divisions and starting at 0 mark placed earlier the sub-divisions are marked as 1, 2 and 3 toward left. At left end a perpendicular of length equal to one major division is drawn and a rectangle is completed considering the mutually perpendicular lines as two sides. The vertical line at left end is divided into 12 equal parts and at each division point a line parallel and equal length of the base line is drawn. Top left corner and the point corresponding to 2ft is connected with a diagonal line. At the remaining two horizontal sub-division points parallel lines are drawn to the 1st diagonal line. Vertical divisions are marked sequentially from bottom toward top at every 2 division as 2, 4, 6, 8, 10 and 12. At all the horizontal major division points vertical lines are drawn. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



Example 9: In a certain engineering drawing 1m length is represented by 20mm. Construct a scale for this drawing showing meters, decimeters and centimeters and measure 2 meters, 5 decimeters and 8 centimeters on it.

Solution:

$$R.F. = \frac{20}{1 \times 1000} = \frac{1}{50} \quad or \quad 1:50$$

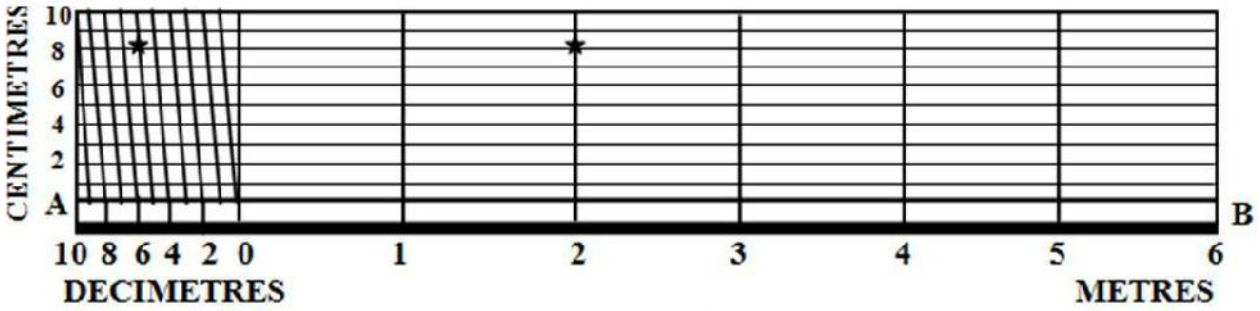
Maximum measuring length is not given here. Assume the drawing scale length is 15 cm (standard value).

$$\therefore Maximum\ measuring\ length\ = \frac{Drawing\ Scale\ length}{R.F.} = \frac{15}{1/50} = 750\,cm\ = 7.5\,m$$

As the maximum length is a fractional number, so number of major division may either be 7 (for which maximum measuring length will be 7 m) or 8 (for which maximum measuring length will be 8 m). Both are acceptable as we have to show a distance only 2m 5dm 8cm on this scale. Let us take 7.

Now a horizontal line 15cm long is drawn and is divided into 7 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3, 4, 5 and 6. The 1st division is further divided into 10 divisions and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 2, 4, 6, 8 and 10 toward left. At left end a perpendicular of length equal to one major division is drawn and a rectangle is completed considering the mutually perpendicular lines as two sides. The

vertical line at left end is divided into 10 equal parts and at each division point a line parallel and equal length of the base line is drawn. Top left corner and the point corresponding to 9dm is connected with a diagonal line. At the remaining 9 horizontal sub-division points parallel lines are drawn to the 1st diagonal line. Vertical divisions are marked sequentially from bottom toward top at every 2 division as 2, 4, 6, 8 and 10. At all the horizontal major division points vertical lines are drawn. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



$R.F.=1:50$

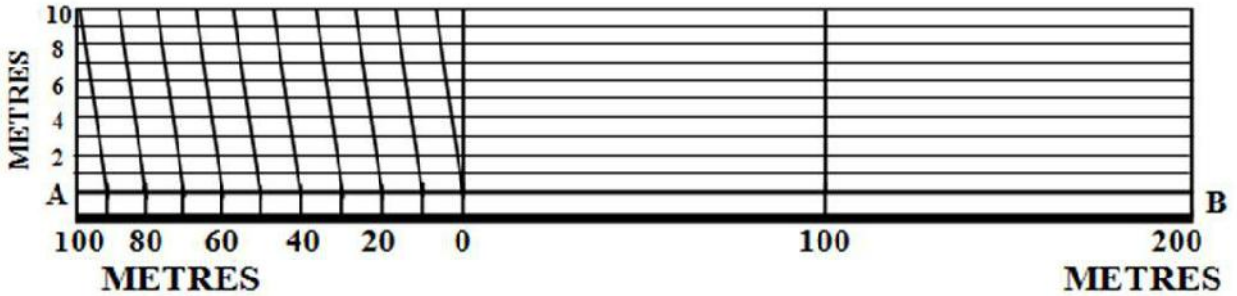
Example 10: Construct a scale to read 1m to 300m.

Maximum measuring length is given here i.e. 300 m. Considering a drawing scale length as 15 cm.

$$\therefore \text{Drawing scale length} = R.F. \times \text{Maximum measuring length}$$

$$\therefore R.F. = \frac{\text{Drawing scale length}}{\text{Maximum measuring length}} = \frac{15}{300 \times 100} = \frac{1}{2000} \quad or\ 1:2000$$

Here, we have to measure single meter as well as 300 meter. So our major unit should be 100th of meters, 1st sub-unit should be 10th of meter and 2nd sub-unit or diagonal sub-unit should be single meters.
Now a horizontal line 15cm long is drawn and is divided into 3 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, and 2. The 1st division is further divided into 10 divisions and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 20, 40, 60, 80 and 100 toward left. At left end a perpendicular of length equal to one major division is drawn and a rectangle is completed considering the mutually perpendicular lines as two sides. The vertical line at left end is divided into 10 equal parts and at each division point a line parallel and equal length of the base line is drawn. Top left corner and the point corresponding to 90m is connected with a diagonal line. At the remaining 9 horizontal sub-division points parallel lines are drawn to the 1st diagonal line. Vertical divisions are marked sequentially from bottom toward top at every 2 division as 2, 4, 6, 8 and 10. At all the horizontal major division points vertical lines are drawn. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



$$R.F. = \frac{1}{2000}$$

Example 11: On a map 1 inch represents 1 mile. Construct a scale to read miles, furlongs and minimum 20 yards distance and mark 4 miles 6 furlongs and 120 yards on it.

Solution:

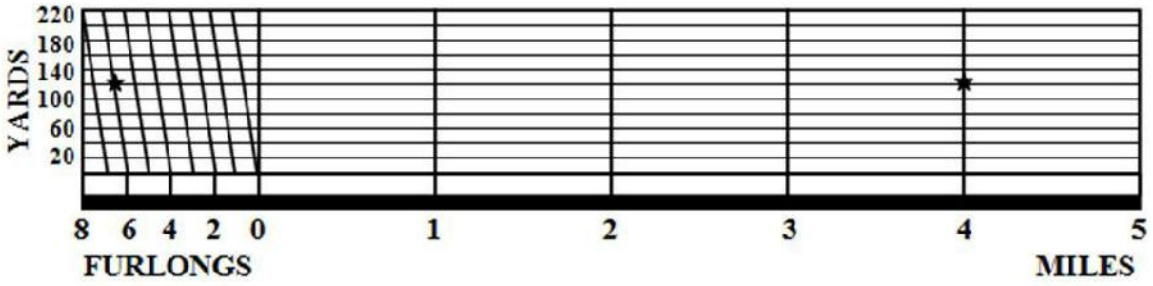
Here given, 1 inch = 1 mile

$$\therefore R.F. = \frac{1inch}{1mile} = \frac{1}{1 \times 1760 \times 3 \times 12} = \frac{1}{63360}$$

Here maximum measuring length is not given. Let us assume the drawing scale length is 6 inch.
Maximum measuring length = Drawing scale length R.F.

$$= 6 \div \frac{1}{63360} = 6 \times 63360 \ = 380160 \text{ inch} = 6 \text{ miles}$$

Now a horizontal line 6 inch long is drawn and is divided into 6 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3, 4 and 5. The 1st division is further divided into 8 divisions and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 2, 4, 6 and 80 toward left. At left end a perpendicular of length equal to one major division is drawn and a rectangle is completed considering the mutually perpendicular lines as two sides. The vertical line at left end is divided into 11 equal parts and at each division point a line parallel and equal length of the base line is drawn. Top left corner and the point corresponding to 7 furlongs is connected with a diagonal line. At the remaining 7 horizontal sub-division points parallel lines are drawn to the 1st diagonal line. Vertical divisions are marked sequentially from bottom toward top at every 2 division as 20, 60, 100, 140, 180 and 220. At all the horizontal major division points vertical lines are drawn. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



Example 12: An engineering drawing is prepared for microscopic parts of a machine. It is required to construct a scale for this drawing that can measure in millimeters, 1/10th of single millimeter and 1/100th of single millimeters. The scale should be such that 4mm length is represented by 10cm and it should be able to measure upto 5mm. Construct the scale and measure 3.33mm and 1.09mm on this scale.

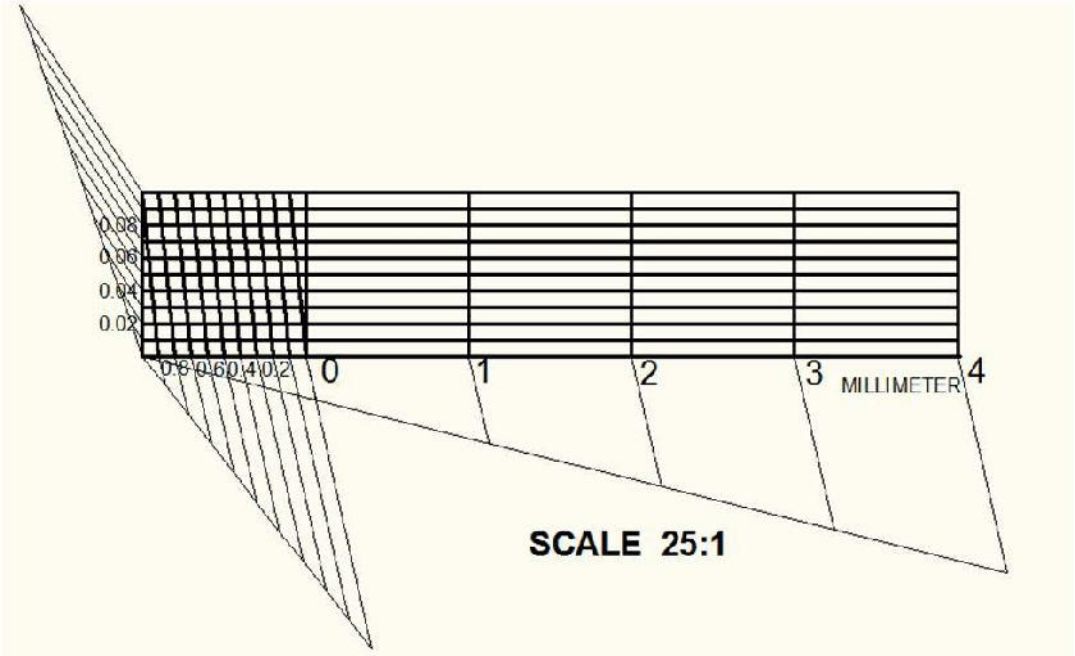
Solution:

$$R.F. = \frac{10 \times 10}{4} = 25 \quad or \quad 25:1$$

$$Length\ of\ Scale \ = \ R.F. \ \times Maximum\ length\ to\ measure$$
$$= \ 25 \ \times 5\ mm \ = 125mm \ = 12.5\ cm$$

Now a horizontal line 12.5cm long is drawn and is divided into 5 equal parts. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3 and 4. The 1st division is further divided into 10 divisions and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 0.2, 0.4, 0.6 and 0.8 toward left. At left end a perpendicular of length equal to one major division is drawn and a rectangle is completed considering the mutually perpendicular lines as two sides. The vertical line at left end is divided into 10 equal parts and at each division point a line parallel and

equal length of the base line is drawn. Top left corner and the point corresponding to 0.9mm is connected with a diagonal line. At the remaining 9 horizontal sub-division points parallel lines are drawn to the 1st diagonal line. Vertical divisions are marked sequentially from bottom toward top at every 2 division as 0.02, 0.04, 0.06 and 0.08. At all the horizontal major division points vertical lines are drawn. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



Example 13: An aeroplane is flying at a speed of 360 kmph. Draw a scale to represent 6 km by 1 cm and to show distance upto 60 km. Find R.F. of the scale and on the scale show distances covered by the aeroplane in

1. 3 minutes 22 seconds
2. 5 minutes 36 seconds

Solution:

$$R.F. = \frac{1cm}{6km} = \frac{1}{6 \times 1000 \times 100} = \frac{1}{600000} \quad or \quad 1:600000$$

$$Length\ of\ Scale\ = R.F.\ \times Maximum\ length\ to\ measure$$

$$= \frac{1}{600000} \times 60km = \frac{1}{600000} \times 60 \times 1000 \times 100\ cm = 10\ cm$$

$$Speed\ of\ aeroplane\ = 360\ kmph = \frac{360\ km}{1\ hr} = \frac{360\ km}{60\ mt} = \frac{1\ km}{\frac{1}{6}\ mt}$$

$$\therefore 1\ km \approx \frac{1}{6}\ mt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

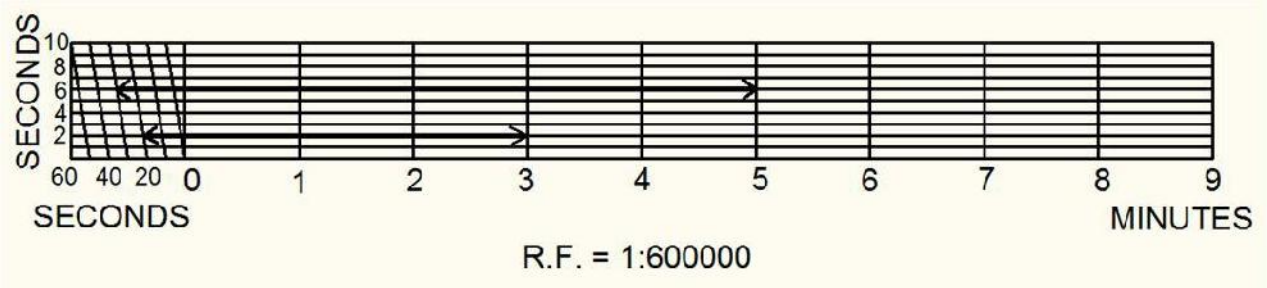
From R.F.,

$$6\ km \approx 1\ cm \qquad \therefore 1\ km \approx \frac{1}{6}\ cm \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From equations (1) and (2), $\frac{1}{6}\ mt \approx \frac{1}{6}\ cm \qquad \therefore 1\ mt \approx 1\ cm$

Now a horizontal line 10cm long is drawn and is divided into 10 equal parts so that each division represents 1 minute. From left staring 0 at 2nd division major units are marked sequentially toward right as 0, 1, 2, 3…… and 9. The 1st division is further divided into 6 divisions so that each sub-division represents 10 seconds and starting at 0 mark placed earlier the sub-divisions are marked after every 2 division as 20, 40

and 60 toward left. At left end a perpendicular of length equal to one major division is drawn and a rectangle is completed considering the mutually perpendicular lines as two sides. The vertical line at left end is divided into 10 equal parts and at each division point a line parallel and equal length of the base line is drawn. Top left corner and the point corresponding to 50 seconds is connected with a diagonal line. At the remaining 5 horizontal sub-division points parallel lines are drawn to the 1st diagonal line. Vertical divisions are marked sequentially from bottom toward top at every 2 division as 2, 4, 6, 8 and 10. At all the horizontal major division points vertical lines are drawn. R.F. and unit names are mentioned accordingly. Thus the scale is constructed and the required distances are indicated.



Exercise and Assignments:

1. Construct a plain scale to show meters and decimeters, when 3 centimeters are equal to 2 meters and long enough to measure upto 5 meters. Show a distance of 2 meters 7 decimeter and 4.8 meters on the scale.
2. Construct a plain scale that can measure 1m to 50m. Show a distance 38m on the scale.
3. Construct a scale to show miles and furlongs, when 2.5ft on the scale represents 30 mile and long enough to measure upto 6 miles.
4. In a certain map 1 acre represents 2500 square kilometers of land area. Construct a scale for a portion of that map which can measure in kilometers and its 1st decimal point. The scale should be long enough to measure upto 9.7 km.
5. On a map a land of 5 sq. cm represents 45 sq. km. Construct a plain scale to measure a maximum distance of 55 km and show the measurement of 42 km on it.
6. The volume of a room is 640 cubic metre. It is represented by a volume of 80 cubic cm. By measuring R.F. construct a plain scale to measure upto 30 metre. Also show the measurement of 12 metre on it.
7. The distance between Dinajpur and Joypurhat railway station is 144 km and it is covered by the Drutajan Express in 4 hours. Draw a plain scale to measure the time upto single minute. Take R.F. of the scale as $\frac{1}{240000}$. Calculate and show the distance covered by the train in 45 minutes on the scale.
8. Construct a diagonal scale to read meters, decimeters and centimeters and long enough to measure upto 5 meters when 1 meter is represented by 3 centimeters. Indicate on the scale a distance of
    a. 4 meters 7 decimets 6 centimeters.
    b. 3.33 meters.
9. Construct a diagonal scale of R.F. = 1/25 showing millimetre, centimetre and metre and show the measurement of 3 metre 50 cm and 60 mm on it.
10. A plan of a house 12 cm represents 240 m. Construct a diagonal scale to read 250 metres to one metre and show the measurement 137 metres on it.
11. The distance between two stations is 480 km. On a map it is represented by a 12 cm length line. Construct a diagonal scale to show kilometers and to measure a distance of 275 km.
12. On a map 15 cm × 8 cm represents an area of 1920 square metres. Find the R.F. and draw the scale of the map to read upto metre and decimeter. Also mark a distance 46 metres and 5 decimetres on it.
13. Ina drawing of machine parts, the original shapes are magnified 50 times. Construct a scale to measure upto 2nd decimal point of a single millimeter and long enough to measure upto 4mm. Show a length of 2.22mm and 1.11mm on the scale.
14. A person is running at a speed of 6 kmph. Draw a scale to represent 6 km by 1 cm and to show distance upto 60 km. Find R.F. of the scale and on the scale show distances covered by the person in
    i. 3 hours 22 minutes
    ii. 5 hours 36 minutes