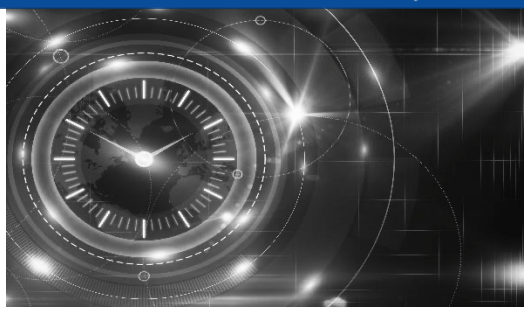




LEARNING HOW TO MEASURE

Concepts Covered

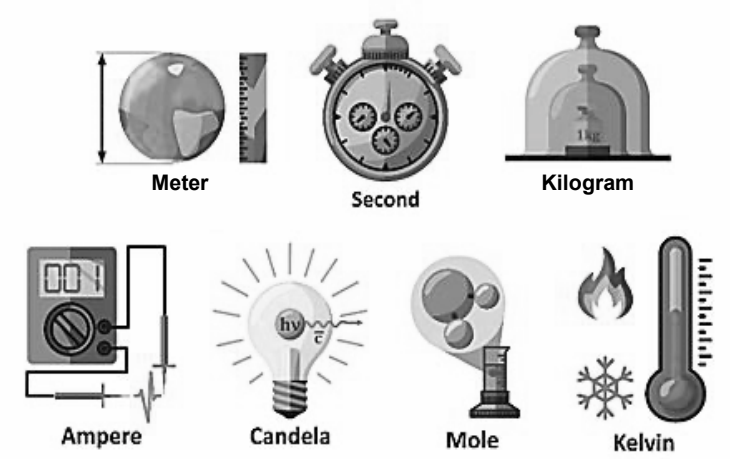
- Physical Quantities and their Types
- Standard unit; its Types and Characteristics
- System of Unit
- Rules for Writing Units
- Representation of Measurement
- History of Length Measurement
- Measurement of Length
- Measurement of Mass
- Measurement of Time
- Conversion of Units

Introduction

In Physics, quantities that can be measured or calculated are called **physical quantities**. The measurement of these physical quantities is required for scientific as well as for routine life purposes. In this chapter, we will understand about some important physical quantities (like length, mass, and time) and different ways of measuring them.

Physical Quantity

A physical quantity is a quantity that can be measured or calculated.
Physical quantity is expressed by stating
(i) the Magnitude of the physical quantity.
(ii) the unit employed.
∴ Physical quantity = magnitude × unit.



Types of Physical Quantities

(A) Fundamental Quantities: These are the quantities which do not depend upon other physical quantities. Length, mass, and time are some examples of the fundamental quantities out of seven fundamental quantities.

(B) Derived Quantities: These quantities are defined in terms of fundamental quantities. Area, density, and volume are derived quantities.

Standard Unit

The chosen reference standard of measurement in multiples of which a physical quantity is expressed is called the standard unit.

Characteristics of Standard unit

- It should be of convenient size.
- It should not change with respect to space and time.
- It should be easy to define, without any doubt or ambiguity.
- It should not be perishable.
- It can be easily reproduced.

Types of Units

DID you KNOW

Lightning strikes the Earth 6,000 times every minute.

(A) Fundamental Units

The units of fundamental (basic) quantities are called fundamental units. Metre, kilogram, second, etc. are fundamental units.

(B) Derived Units

The units of derived quantities are called derived units. Square metre, cubic metre, kilogram per metre cube, etc. are derived units.

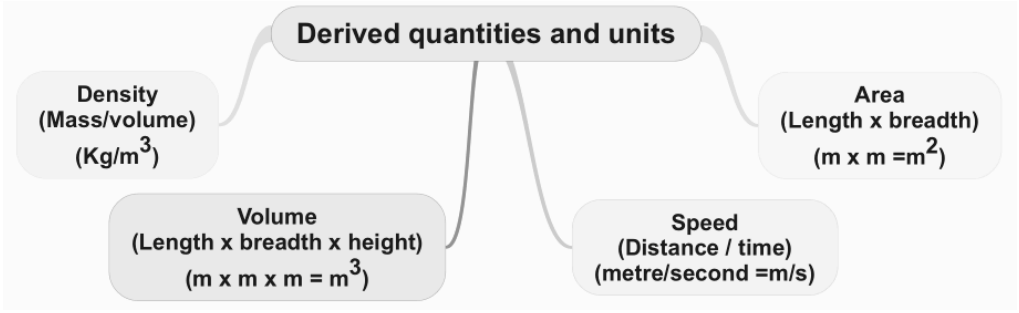
Rules to Obtain Units of Derived Quantities

The unit of a physical quantity can be obtained with the help of its formula or expression.

How to obtain a derived unit of a physical quantity?

- Step 1: Write the measurement formula of the physical quantity.
- Step 2: Check the terms present in the measurement formula.
- Step 3: Substitute the units of the terms identified.

Mind Map



Example:

Find the derived unit for area.

Solution: Area = Length × Breadth

Unit of area = m × m = **m^2**.

In ancient times, the length of a foot, the width of a finger, and the distance of a step were all accepted measurements.

Check Your Concept - 1

(i) Find the derived unit for density.

(ii) Which of the following is a unit of volume?

(A) m^2 (B) m^3

(C) m^4 (D) m

System of Units

The fundamental units of length, mass, and time are taken together to form a system of units.

For measuring various physical quantities, the following systems are commonly adopted:

Sedrial day is the time taken by the earth to complete one rotation about its own axis with respect to a distant star.

System	Length	Mass	Time
F.P.S.	foot	pound	second
C.G.S.	centimetre	gram	second
M.K.S.	metre	kilogram	second

Shake is the smallest practical unit of time.
1 shake = 10^{-8} s.

SI System

In 1960, the General Conference of Weights and Measures introduced a new system of units known as SI units. It stands for International System of Units. The SI system is the metric system that is used universally as a standard for measurements.

CGS system

The CGS system is a coherent system of units based on the fundamental units of centimeter for distance, gram for mass, and second for time

Rules for Writing Units

1. The first letter of the unit is used as a symbol for some units.
   Example: 'm' for metre, 's' for a second, etc.
2. The units may be written in full or using agreed symbols, but not in abbreviated form.
   Example: metre or 'm', second or 's', kilogram or 'kg'.
3. Symbols for units do not take the plural form.
   Example: (A) If the mass of a stone is 50 kilograms, it should be expressed as 50 kg but should not be expressed as 50 kgs.
   (B) If the length of a stick is 10 metre, it should be expressed as 10 m but should not be expressed as 10 ms or 10 mts.
4. No full stop or other punctuation marks should be used within or at the end of symbols for units.
   Example: A mass of a body can be written as 50 kg but should not be expressed as 50 kg.

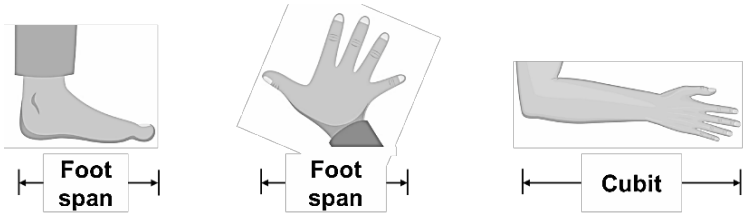
Measurement

Measurement is the comparison of an unknown quantity with a known standard quantity of the same kind.

History of length Measurement

Arbitrary Units of Measurement

Before the development of standard units of measurement, people used arbitrary units of measurement. Some of them are still in use at some places. Handspan, finger-length, cubit (length between the elbow and finger tips), foot-length and arms-length are some examples of arbitrary units of measurement.



Disadvantages of Arbitrary Units of Measurement

You have seen that arbitrary units are made up of lengths of different body parts. These lengths can vary from one person to another. This can create lot of confusion as there would be no uniformity in measurement. We need standard units of length and other physical quantities to obtain the same value for a measurement.

Representation of Measurement

The result of measurement has two parts; one part is the number and another part is the unit. The known quantity which is used in measurement is called a unit.

Example: When you say that your height is 150 cm then the measurement of your height is being expressed in a number, i.e., 150 and a unit, i.e., centimeter.

Activity:

Aim: To measure the height of a person.

Materials required: Measuring tape, a thick book, and a pencil.

Procedure: To measure the height of your friend, make him/her stand absolutely straight with his/her back against a wall. Place a thick rigid book on his/her head and make a mark on the wall where the underside of the book touches the wall. Measure the length from this mark to the floor with the help of the measuring tape.

Result: This gives the height of your friend make sure he/she is not wearing shoes to gain some extra inches.

Measurement of Length

Length is the distance between two fixed points.
The SI unit of length is metre (m) while the CGS unit is centimetre (cm).

Length can be measured using a metre scale, a vernier calipers or a measuring tape.

The **least count** of an instrument is the smallest measurement that the instrument can measure accurately.

The least count of a meter scale is 0.1 cm.

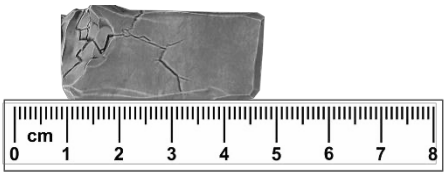
Common devices used to measure length are:

- Ruler
- Micrometer
- Odometer
- Vernier calipers

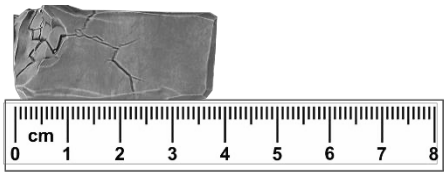
- Tape measure

While measuring length using a ruler, we have to take the following precautions:

(i) Care should be taken to keep the ruler along the length of the object.
(ii) If the edge of the ruler is worn out or broken, the measurement should be seen from any other mark that is fully clear.



The ruler should be kept along the length of the object



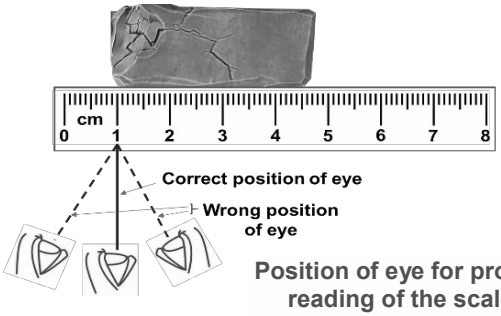
Measurement should be only started from a mark that is fully clear

(iii) Eyes should be exactly above of the point where the measurement is to be taken otherwise it can result in parallax error.

Parallax Error: A parallax error is the apparent shift in an object's position as it is viewed from different angles.

For example, the error is most easily noticed by looking at a nearby object with one eye closed, then looking at it through the other eye.

Light year is a unit of length and is defined as length travelled by light in one year. 1 ly = 9.467 × 10^{15} m



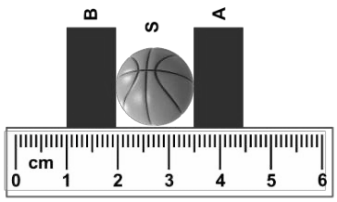
Position of eye for proper reading of the scale

Activity:

Aim: To measure the diameter of a ball with the help of metre scale.

Procedure: The diameter of a ball can be measured correctly with the help of metre scale. It is one of the ways in which diameters of spherical surface can be measured easily. In this method, the two wooden blocks A and B must be exactly parallel to each other and the ball should be placed in between them so that, both the ends of the ball touch the surface of wooden blocks.

Now, measure the inner length between two wooden blocks and you will get the measure of the diameter of ball.

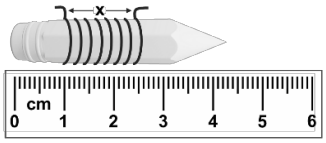


Measurement of the diameter of a spherical object

Activity:

Aim: To measure the thickness of a thin wire.

Procedure: Take a round pencil and wrap the given wire around the pencil making 25 turns forming a coil. Measure the length of the so formed coil. Divide the total length of the coil by number of turns. This is the thickness of the wire.



Diameter of a wire coiled around a pencil

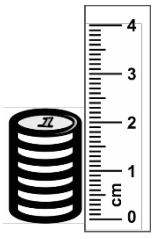
Activity:

Aim: To measure the thickness of a coin.

Procedure: Take ten coins and put them one over another. Find the total thickness of ten coins with the help of a scale. Divide the total thickness by the number of coins.

Result: Thickness of 1 coin $= \frac{\text{Total thickness of coins}}{\text{Number of coins}} = \frac{24}{10}$ cm $= 0.24$ cm

Astronomical unit is a unit of a length and is defined as the distance between the Earth and Sun.
1 AU = 1.496 × 10^{11} m



Measuring the thickness of one rupee coin

Activity:

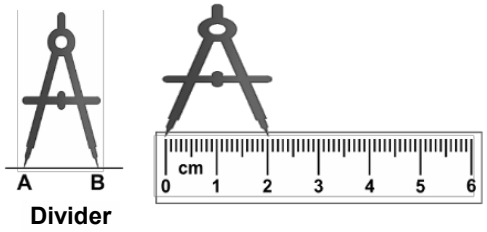
Aim: To measure the thickness of a sheet of paper of your science book.

Procedure: It is not easy to measure the thickness of a single sheet of paper by using metre scale. The method used to find the thickness of a single sheet is as follows:
Take 100 sheets of paper together. Find their combined thickness by using a centimetre scale. Divide the total thickness by the number of sheets. It is the thickness of a single sheet.
Result: For example: If the thickness of 100 sheets $= 1.5$ cm.

$$\text{Thickness of a single sheet} = \frac{\text{Total thickness}}{\text{No. of sheets}} = \frac{1.5}{100} \text{ cm}$$

Using a Divider to Measure Length

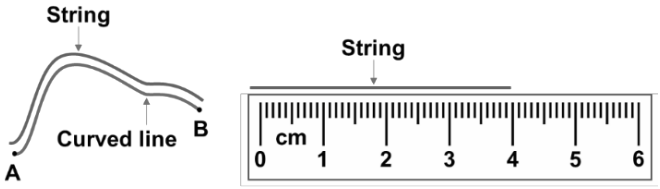
A divider is used to measure the distance between two points. The correct use of a divider can give a fairly accurate measurement. The divider is placed such that its two points are at the two ends of the length to be measured. Then, without disturbing the divider, the distance between the two points is measured with a ruler.



Divider

Measuring the Length of a Curved Line

We can measure the length of a curved line by using a string. The string is placed along the curved line and its ends are marked on the string. The length of the string between the marked points is measured with a ruler.



Extended Learning

Conversion of Units

Conversion of units is the conversion between different units of measurement for the same quantity, typically through multiplicative conversion factors.

In order to have accuracy and avoid confusion in measurement, we need to convert one unit to another. For instance, we do not measure the length of a pencil in kilometres. In such a case, one has to convert kilometre (km) to centimetre (cm). Generally, the conversion of one unit to another unit of the same quantity is performed using multiplicative conversion factors. Let us see how to convert a different unit of length and mass.

Table for Length Conversion

The conversion of units related to length can be represented as:

Unit conversion for Length	
1 millimetre	0.001 metre
1 centimetre	0.01 metre
1 decimetre	0.1 metre
1 decametre	10 metres
1 hectometre	100 metres
1 kilometre	1000 metres
1 inch	2.54×10^{-2} metres
1 foot	0.3048 metres
1 mile	1609.344 metres

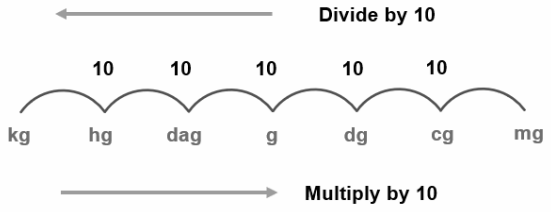
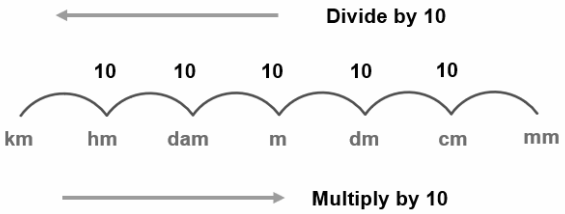


Table for Mass Conversion

The conversion of units related to mass can be represented as:

Unit conversion for Mass	
1 milligram	0.001 gram
1 centigram	0.01 gram
1 decigram	0.1 gram
1 decagram	10 gram
1 hectogram	100 gram
1 kilogram	1000 gram



Example:

A boy has a piece of cloth that measures 3.5 metres. How many smaller pieces can he make of each measuring 50 cm in length?

Solution: Length of whole cloth piece $= 3.5$ m $= 350$ cm (as 1 m $= 100$ cm $= 3.5 \times 100 = 350$ cm)

Length of smaller cloth piece $= 50$ cm

$$\text{Number of smaller cloth pieces made from the whole cloth piece} = \frac{\text{Length of large cloth}}{\text{Length of small cloth}}$$

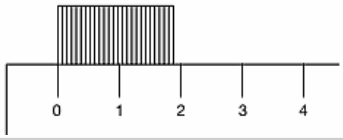
$$= \frac{350}{50} = \textbf{7 cloth pieces}$$

Check Your Concept - 2

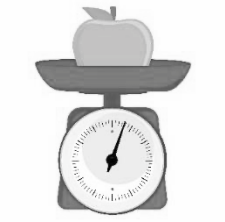
(i) Fifteen identical coins are placed beside one another as shown in the adjacent figure. The thickness of a coin is _____.

(A) 0.3 cm (B) 1.33 cm

(C) 13.3 mm (D) 1.33 mm



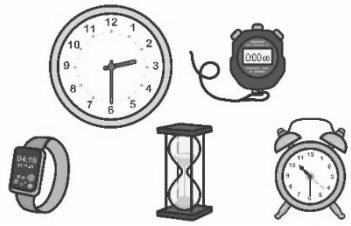
Measurement of Mass



It is the amount of matter contained in a body. It is a fundamental quantity and its S.I. unit is kilogram (kg) while CGS unit is gram (g).

- The mass of a body always remains constant and is generally measured using a common balance or beam balance.
- Spring balance, table balance, platform balance, and beam balance are a few of the many types of balances.

Measurement of Time



Time plays an important role in our life. Any change or movement which takes place is understood in terms of a physical dimension called 'time'.

There are many phenomena by which we can understand time.

(i) The time between one sunrise and the next is called a solar day.

(ii) A month is measured from one new moon to the next.

(iii) The time taken by the Earth to complete one revolution around the Sun is called a year.

Early scientists developed many devices to measure time intervals. All of them make use of some periodic motion.

Sundial

People in ancient times measured intervals of time shorter than a day with a device called a sundial. The device worked on the principle that as the position of the Sun in the sky changed, so did the position and length of the shadow cast by an object. The decrease and then increase in the length of the shadow during daytime was used to measure time in sundials. The sundial has a triangular metallic plate called a **gnomon**, fixed vertically at the centre of a circular plate. The device is placed in the open in such a way that the gnomon points in the north-south direction. The shadow of the gnomon on the circular scale shows the time at that particular moment. Sundials indicate time quite accurately but the problem with them is that they cannot be used after sunset or on a cloudy day and also, they cannot be carried along to different places. One of the largest sundials can be seen at Jantar Mantar in New Delhi.

Sand clocks

Romans used sand clocks which worked on the principle that a definite amount of sand takes constant time to fall from the upper chamber to the lower chamber. That constant time was the unit of measurement of time commonly called an hour. The sand clock is also called an hourglass. Once the upper chamber is emptied, the hourglass is turned upside down to record the time again.

Units of Time

The basic unit of time is second. Its symbol is s or sec.
Some other units are:

Minutes (1 min = 60 s)
Hour (1 hr = 60 min = 3,600 s)
Solar day (1 solar day = 24 hr = 1,440 min = 86,400 s)
Year (1 year = 365 solar days = 8,760 hr = 5,25,600 min = 3,15,36,000 s)

Note:
(i) The symbols of all units are written in singular.
(ii) Other smaller units of time are:
millisecond (1 s = 10^3 ms).
microsecond (1 s = 10^6 μs).
nanosecond (1 s = 10^9 ns).

Examples:

(1) Convert 25 millimetres into centimetres.

Solution: We know that $1\ \text{mm} = \frac{1}{10}\ \text{cm}$

$$\text{So}, 25\ \text{mm} = \frac{25}{10}\ \text{cm} = \mathbf{2.5\ cm}$$

(2) Convert 69 kilometres into centimetres.
Solution: We know that 1 km = 1,00,000 cm
So, 69 km = **69,00,000 cm**

Check Your Concept - 3

(i) Convert 86 kilometres into decimeters.
(ii) Convert 27 decagrams into centigrams.
(iii) Convert 102 grams into kilograms.

Solved Examples

Level – 1

(1) **What do you understand by unit?**
Answer: A quantity adopted as a standard of measurement of a physical quantity is called unit.

(2) **A run faster than B. To compare the speed of A and B, which of the following fundamental physical quantities are involved**
(A) length only **(B) time only**
(C) length and time **(D) neither length nor time**
Answer: (C) length and time
$\text{As Speed} = \frac{\text{Distance}}{\text{time}}$ so, there is a need to measure both length and time.

(3) **The length of a curved surface is measured by using**
(A) metre scale only **(B) thread only**
(C) Both metre scale and thread **(D) None of these**
Answer: (C) Both metre scale and thread
The length of a curved surface is measured by using metre scale and thread.

(4) **Name the two parts which must be mentioned to state the results of a measurement.**
Answer: Magnitude and unit are the two parts which must be mentioned to state the results of a measurement.

(5) **What type of measuring device would you use to measure the girth of a tree?**
Answer: Measuring tape is suitable to measure the girth of a tree.

(6) **Name the unit of length, which you would like to use while expressing the distance between Delhi and Lucknow.**
Answer: Kilometre (km).

(7) **What is measurement?**
Answer: Measurement is a comparison of an unknown quantity with a known fixed quantity of the same kind. The value obtained from measuring a quantity is called its magnitude. The magnitude of a quantity is expressed as numbers in its unit

(8) **Why a cubit cannot be used as the standard unit of length?**
Answer: Length of hand and cubit are not same for all the people. So, these cannot be used as the standard unit of length.

(9) **Define cubit and foot.**
Answer: Cubit is the length between the tip of the elbow and the middle finger. The length of the foot of a person is called foot.

Level – 2

(1) **If the smallest measurement that can be measured by using a scale is $0.1\ \text{mm}$, the length of $1\ \text{m}$ in the scale is divided into how many equal parts?**
(A) 1,000 **(B) 5,000**
(C) 10,000 **(D) 50,000**
Solution: Smallest measurement $= 0.1\ \text{mm} = 0.1 \times 10^{-3}\ \text{m} = 10^{-4}\ \text{m}$.
So, the length of $1\ \text{m}$ is divided into $\frac{1}{10^{-4}}$ equal parts that are $10^4 = \mathbf{10,000}$.

(2) **Convert 7 decigrams to milligrams.**
Solution: We have to convert 7 decigrams to milligrams.
We know, 1 dg = 100 mg ⇒ Thus, 7 dg = 7 × 100 = **700 mg**

(3) **A 30 cm scale has one end broken. The mark at the broken end is 2.6 cm. How? would you use it to measure the length of your pencil?**
Answer: Put one end of the pencil at nearest full mark say 3.0 cm in this case. Take the reading of the other end. Now subtract 3 from the previous reading and this will be the required length of pencil.

(4) **State two precautions, which should be taken while using a metre scale to measure the length of an object.**
Answer: Two precautions are:
(i) Place the scale in contact with the object along its length.
(ii) Most important, eye should be correctly positioned above the point to be measured to make a correct measurement.

(5) **Convert 400 cm into metres.**
Answer: There are 100 cm in 1m. This is our conversion factor.
To convert from cm to m we need to divide.

So, 400 ÷ 100 = **4m.**

(6) **Convert 5 minutes 24 seconds into seconds.**

Answer: 1 minute = 60 seconds
5 minutes = 5 × 60 = 300 seconds
∴ 5 minutes 24 seconds = **324 seconds.**

(7) **Which of the following quantities are fundamental quantities:**
Length, Density, Speed, Mass, Time, Velocity, Area, Volume

Answer: Length, Mass and Time.

(8) **Write CGS unit and SI unit for the following physical quantities:**
Area, Volume, Speed, Velocity, Density

Answer:

Quantity	CGS unit	S.I. unit
Area	cm^2	m^2
Volume	cm^3	m^3
Speed	cm/s	m/s
Velocity	cm/s	m/s
Density	g/cm^3	Kg/m^3

Exercise

FILL IN THE BLANKS

(1) The SI unit of time is _____.
(2) 1 cm = _____ mm.
(3) The CGS unit of speed is _____.
(4) Each centimetre has _____ equal divisions called millimetre.
(5) 1 dm = _____ metre.
(6) Measurement means the comparison of an _____ quantity with some _____ quantity of the same kind.
(7) System of units now used is known as _____ system.
(8) The least count of a metre scale is _____cm.
(9) In 1790, the French created a standard unit of measurement called the _____ system.

TRUE OR FALSE

(1) SI unit of length is 'Foot'.
(2) Standard units should be easy to define, without any doubt or ambiguity.
(3) For measuring large distances metre is not a convenient unit.
(4) The result of a measurement is expressed in two parts.
(5) SI unit of length is 'Foot'.
(6) For measuring large distances metre is not a convenient unit.
(7) The result of a measurement is expressed in two parts.
(8) The distance between Delhi and Kolkata is usually expressed in units of millimetre.
(9) The height of a human can be measured in either "feet" or "meter".
(10) 1 Kilometre is equal to 100000 centimetres.

OBJECTIVE TYPE QUESTIONS

(1) Which is a standard unit of measurement?
(A) Finger (B) Fist
(C) Step (D) Inch

(2) What is the SI unit of length?
(A) Metre (B) Centimetre
(C) Kilometre (D) All of these

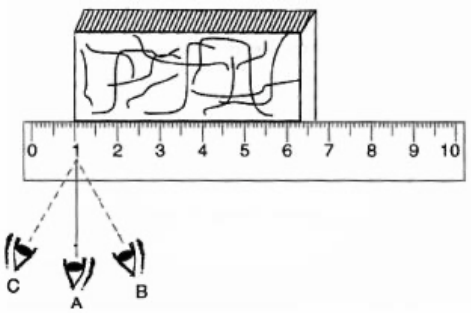
(3) 4 kilometres are equal to
(A) 4,00,000 metre (B) 40,000 metre
(C) 4,000 metre (D) 400 metre

(4) 15 cm is equal to
(A) 150 mm (B) 15 mm
(C) 1.5 mm (D) 0.15 mm

(5) The appropriate unit for measuring thickness of a coin is
(A) centimeter (B) kilometer
(C) millimeter (D) micrometer

(6) Which is a correct relationship?
(A) 1 m = 100 cm (B) 1 cm = 100 mm
(C) 1 km = 100 m (D) All of these

(7) In the following figure, the proper way of reading scale is
(A) C
(B) B
(C) A
(D) Any way can be chosen



(8) One metre is equal to _____ millimetre.
(A) 10 (B) 1000
(C) 100 (D) 10000

(10) One metre is equal to _____ kilometre.
(A) 10 (B) 1000
(C) 100 (D) 10000

SUBJECTIVE TYPE QUESTIONS

(1) What are the C.G.S. and M.K.S. units of distance and displacement?

(2) The height of a person is 1.65 m. Express it in cm and mm.

(3) The distance between Radha's home and her school is 3250 m. Express this distance into km.

(4) While measuring the length of a knitting needle, the reading of the scale at one end is 3.0 cm and at the other end is 33.1 cm. What is the length of the needle?

(5) Why could you not use an elastic measuring tape to measure distance? What would be some of the problems you would meet in telling someone about a distance you measured with an elastic tape?

(6) Explore and find out what kind of scale is used by cloth merchants, tailors, carpenters and mechanics to measure length.

(7) Why a cubit cannot be used as the standard unit of length?

(8) Using a thread how will you find the circumference of a one-rupee coin.

(9) What do you mean by Fundamental and Derived quantities?

(10) Convert 500 kilometres into centimetres.

Answer Key

CHECK YOUR CONCEPTS

(1) **(i)** kg/m^3. **(ii)** (B) m^3

(2) **(i)** 1.33 mm

(3) **(i)** 86,000 **(ii)** 27,000 **(iii)** 0.102

FILL IN THE BLANKS

(1) second (s)
(2) 10
(3) cms^{-1}
(4) ten
(5) 1/10
(6) Unknown, known
(7) S.I.
(8) 0.1 cm
(9) metric

TRUE OR FALSE

(1) False
(2) True
(3) True
(4) True
(5) False
(6) True
(7) True
(8) False
(9) True
(10) True

OBJECTIVE TYPE QUESTIONS

(1) (D)
(2) (A)
(3) (C)
(4) (A)
(5) (C)
(6) (A)
(7) (D)
(8) (B)
(9) (B)

SUBJECTIVE TYPE QUESTIONS

(1) CGS unit of both is cm while MKS unit of both is m

(2) (a) 165 cm
(b) 1650 mm

(3) 3.250 km

(4) 30.1

(10) 5×10^5