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Science and Mathematics

(Class 6-7)

Volume - 1

Physics

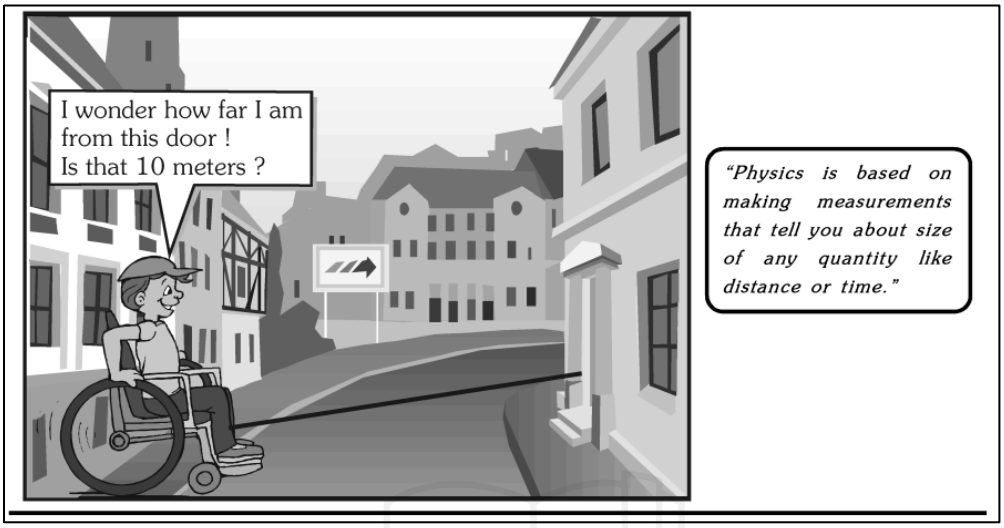
SIERRA INNOVATIONS

INDEX

1

CHAPTER

Measurement and Motion



1.0 <u>Introduction</u>

- ✓ Physics is about the world around you and how everything in it works. As you go about your daily life, you're doing physics all the time! But the thought of actually learning physics may sometimes feel like falling into a well! Don't worry... we will teach you how to think like a physicist. We are surrounded by principles of physics in our everyday lives. In fact, most people know much more about physics than they realise. For example, when you buy a carton of ice cream from the store and put it in the refrigerator at home, you do so because from past experience you know enough about the laws of physics to know that the ice cream will melt if you leave it outside the refrigerator. Any problem that deals with temperature, size, motion, position, shape, or color involves physics.
- ✓ Physics has been around as long as people have tried to make sense of their world. The word "physics" is derived from the Greek word "physika," which means "natural things." Physical quantities: Physical quantities are building blocks of physics in terms of which the laws of physics are expressed. These quantities are measurable and represented by a number, followed by a unit. Physical quantities are divided into two types:
- ✓ Fundamental quantities: These quantities are those which cannot be defined in terms of any other physical quantity. Those physical quantities which do not depend on any other quantity are called fundamental quantities. These quantities are also called base quantities. Examples: Length, mass, time, electric current etc.
- ✓ Derived quantities: These quantities are those whose formulae are based on fundamental quantities. The physical quantities which are derived from fundamental quantities and which depend on them are called derived quantities. Derived quantities are obtained by dividing or multiplying two or more fundamental quantities. Examples: Speed, density, force, work, energy, power, etc. Scalar quantities: The physical quantities which are defined by their magnitudes only are called 'scalar quantities'. Examples: Mass, volume, density, time, distance, pressure, work, energy, power, temperature, electric charge, electric current, etc.
- ✓ Vector quantities: The physical quantities which are defined by their magnitude as well as direction are called 'vector quantities'. Examples: Displacement, velocity, acceleration, force, etc.

2.0 <u>Measurement</u>

- ✓ In physics, many things are described with measurements. For example, 2 metres is a measurement of length. Measurements such as length, mass, speed, temperature, etc. are important in physics because they are the 'terms' that allows us to communicate information so everyone understands exactly what we mean. This chapter is about length, one of the most important measurable quantities in physics. For example, you could not communicate how far away something is without having a way to measure length.
- ✓ A measurement is a precise value that tells "how much". The important concept in measurement is that it communicates the amount in a way that can be understood by others.
- ✓ A measurement consists of two parts: (1) A number (2) A unit
- ✓ For example, 1.6 metres is a measurement because it has a number '1.6' and a unit 'metres' (see fig. 1). The unit 'metre' is a standard length that is known to you. So when you measure length, you compare the unknown length with this known length. 3 metres means the length you have measured is 3 times as much as the known unit.

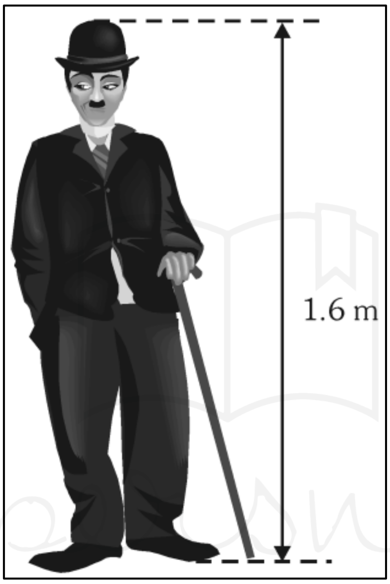
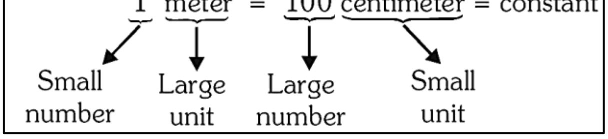


Fig. 1 Measurements always include both a number and a unit.

- A measurement is the comparison of the unknown quantity with some standard quantity of the same kind.

Units

- **Units:** A unit is the smallest quantity in terms of which other quantities can be measured.
- For measuring of a physical quantity a definite magnitude of quantity is taken as standard and the name given to this standard is called unit.
- Measure of a physical quantity = Numerical value x size of unit = N x U
- Nx U = constant. That is, $N_1U_1 = N_2U_2$, this means, on increasing the size of unit, its numerical value decreases and vice-versa.



Units are also divided into two parts

- **Fundamental units:** The units which cannot be derived from any other units are called fundamental units. In other words, the units of fundamental quantities are called fundamental units. Examples: unit of length is meter, unit of mass is kilogram, unit of time is second, etc.
- **Derived units:** The units which can be derived from the fundamental units are called derived units. In other words, the units of derived quantities are called derived units. Examples: unit of speed and velocity is m/s, unit of density is kg/m3, unit of electric current is ampere etc.

- All measurements need units. Without a unit, a measurement cannot be understood. For example, if you told someone to walk 10, she would not know what to do: 10 feet, 10 meters, 10 miles, 10 kilometers are all 10-but the units are different and therefore the distances are also different. Units allow people to communicate amounts. For communication to be successful, physics uses a set of units that have been agreed upon around the world.
- A **unit** is the smallest quantity in terms of which other quantities can be measured.
  - ✓ Physical quantity in physics is that which can be quantified and measured. Example - mass, length time etc.
  - ✓ A quantitative prediction can be tested against reality, and an explanation or theory can be accepted or rejected based on the results of measurements. The rapid growth and success of physics began when the idea of making precise measurements as a test was accepted.

Illustrations

Illustration 1.	**What do we measure in physics?**
Solution	We measure physical quantities in physics. Physical quantities are building blocks of physics in terms of which the laws of physics are expressed. These quantities are measurable and represented by a number, followed by a unit.
Illustration 2.	Why are measurements so important?
Solution	Suppose a carpenter makes a door without taking proper measurement and tries to fit it in the door frame. You know that, the door may not get closed. Similarly, if an engineer constructs buildings and bridges without taking proper measurements, the buildings may get collapsed. If you went to grain merchant and purchased grains without being weighed, you are not sure whether you have paid more or less for the quantity received. Thus, measurement allows us to work systematically and accurately. It also helps us make comparisons, understand one another and work together easily.

3.0 Need For Standard Units Of Measurement

(1) We know that, a measurement consists of two parts, a number (also called magnitude), and a unit. Without a unit, a measurement has no meaning. For example, if you say your height is 4, it could mean 4 inches, 4 feet or 4 yards, 4 miles, etc. Thus, we require a standard unit to make a sense to the measurement. In other words, units are necessary to sensibly describe a physical quantity.

(2) It is also important that the unit must be accurate and it must not change with respect to a person or time. For example, history shows that many societies used dry grains as a unit of measurement. In due course of time, grains could absorb moisture, swell up and increase in size and affect the measurement.

(3) It is also important to have units that are understood by all. For example, the barleycorns (see fig.2) of the English would not be understood by an Indian, and the 'angul' of the Indian would not be understood by the Englishman.

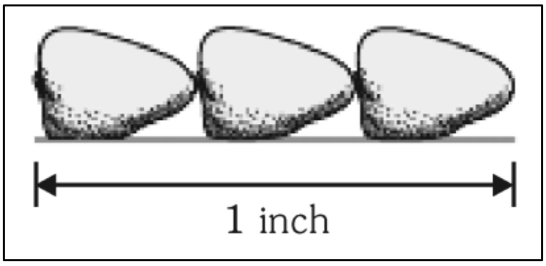


Fig.2 At one time, three barley corns were used to define one inch.

Thus, we need some standard units that must be accurately defined, does not change with time or person and must be internationally accepted.

4.0 Measurement Of Length

- ✓ Length is a fundamental quantity and it is commonly used to measure the distance between two points.
- ✓ There are two common systems of standardised units that are used for measuring length, the English system and the metric system. The English system uses inches (in.), feet (ft), yards (yd), and miles (mi) for length. The metric system uses millimeters (mm) centimeters (cm), meters (m), and kilometers (km). You probably have contact with both systems of units every day.
- ✓ For example, driving distances are sometimes expressed in miles (see fig.3), but races in track and field are usually expressed in metres (see fig.4).

Fig.3 Some distances are measured using British units such as miles.

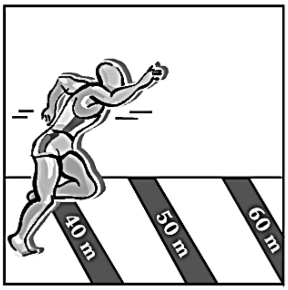


Fig.4 Some distances are measured using metric units, such as metres.

Illustrations

Illustration 3.	Which system of units is preferred by scientists, a metric system or a British system? Why is it so?
Solution	Scientists prefer metric system of units. Almost all fields of science use metric units because they are so much easier to work with. In the English system, there are 12 inches in a foot, 3 feet in a yard, and nearly 5,280 feet in a mile. In the metric system, there are 10 millimeters in a centimeter, 100 centimeters in a metre, and 1,000 metres in a kilometer. Factors of 10 are easier to remember than 12, 3, and 5,280.

- ✓ To solve problems by applying science in the real world, you will need to know both sets of units, English and metric. For example, a doctor will measure your height and weight in English units. The same doctor will prescribe medicine in milliliters (mL) and grams (g), which are metric units. Plywood is sold in 4 feet by 8 feet sheets but the thickness of many types of plywood is given in millimeters. Some of the bolts on a car have English dimensions, such as 1/2 inch. Others have metric dimensions, such as 13 millimeters. Because both units are used, it is a good idea to know both metric and English units.

<u>Metric length</u>

- ➢ The SI unit of length is the metre (m). We use the centimetre (cm) to measure short distances, such as the length of the book. The millimetre (mm) is used to measure very small lengths, such as the thickness of a coin. Long distances are measured in kilometres (km).

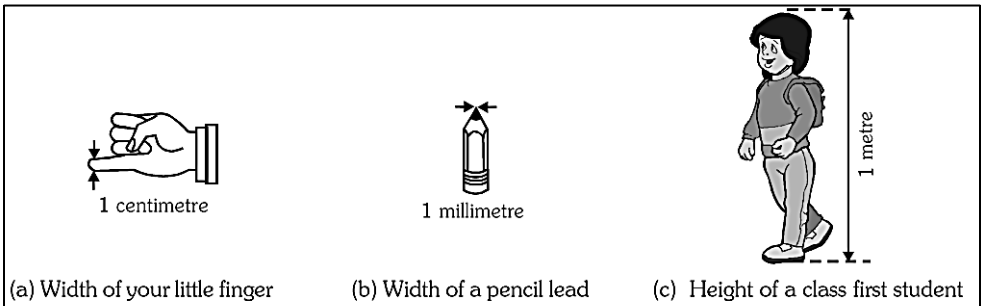


Fig.5 Getting an idea of the metric units of distance.

Commonly used units/conversion factors for length

Metric system

1 metre 100 centimetre	or	1m = 100cm
1 metre 1000 millimetre	or	1m = 1000mm
1 kilometre = 1000 metre	or	1km = 1000m
1 centimetre = 10 millimetre	or	1cm = 10mm

Metric Prefixes	
10^{-1}	deci (d)
10^{-2}	centi (c)
10^{-3}	milli (m)
10^{-6}	micro (μ)
10^{1}	deca (da)
10^{2}	hecto (h)
10^{3}	kilo (k)
10^{6}	mega (M)

Table 1: Some common metric prefixes used inmetric system.

A rod made of the metals platinum and iridium, is kept at the Bureau of weights and measures, at Paris. The distance between the two end marks on this rod at 0 deg * C represents one metre. A copy of this standard metre is kept in Delhi at the National physical laboratory.

- Light year is a large unit of length commonly used to measure the distances of stars from the Earth. One light year is equal to the distance travelled by light in one year in a vacuum.
  1 light year = 9.46×10^{15} metres.
- Light year is a large unit of length commonly used to measure the distances of stars from the Earth.
- One light year is equal to the the distance travelled by light in one year in a vacuum.
  1 light year = 9.46×10^{15} metres.

Illustrations

Illustration 4.	Change 25cm to metres.
Solution	As we know 1m = 100cm, the two possible conversion factors are $\frac{1m}{100m}$ and $\frac{100cm}{1m}$ Since we have to convert cm to m, choose the conversion factor with cm in the denominator so that the cm units cancel each other. $25\ \cancel{cm} \times \frac{1\ m}{100\ \cancel{cm}} = \frac{25}{100} = \mathbf{0.25\ m}$

- Suppose we have to write the metric abbreviation for 36 centimetres. The symbol for the prefix centi is 'c'. The symbol for the unit metre is 'm'. Thus, 36 cm is the SI abbreviation for 36 centimetres. Conversely, if we have to write the SI metric unit for the abbreviation 45 km, the prefix for 'k' is kilo and the unit for 'm' is metre. Thus, 45 kilometres is the metric unit for 45 km.

<u>A metre stick (metre ruler/metre scale)</u>

- A metre stick is a good tool to use for measuring ordinary lengths in the laboratory. It is based on metric system. A metre stick is 1 metre long and is divided into millimetres and centimetres [see fig.6].

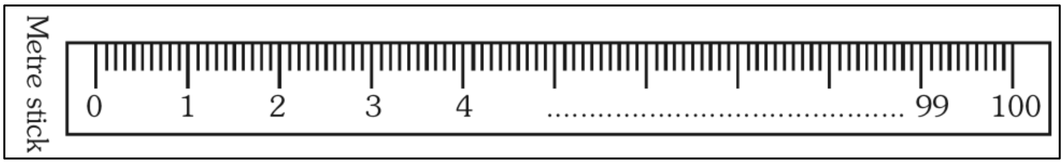


Fig.6 A metre stick is one metre long

5.0 CORRECT PROCEDURE TO MEASURE LENGTH

✓ In our daily life we use various types of measuring devices. We use a metre scale for measuring length. A tailor uses a 'measuring tape', whereas a cloth merchant uses a metre rod. For measuring the length of an object, you must choose a suitable device. You cannot measure the circumference or girth of a tree, the size of your waist using a metre scale. Measuring tape is more suitable for this. For small measurements, such as the length of your pencil, or making a 8 cm line in your copy, you can use a '15 cm scale' from your geometry box.

Care to be taken while measuring a length:

(1) Place the scale in contact with the object along its length (see fig.7).

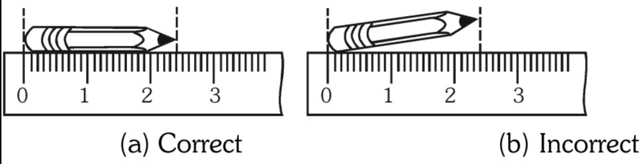


Fig.7 Placing the scale along the length to be measured.

(2) In some scales, the ends may be broken. You may not be able to see the zero mark clearly [see fig.8(a)]. In such cases, you should avoid taking measurements from the zero mark of the scale. You can use any other full mark of the scale, say, 1.0 cm [see fig.8(b)]. Then you must subtract the reading of this mark from the reading at the other end. For example, the reading at one end is 1.0 cm and at the other end it is 4.1 cm. Therefore, the length of the object is (4.1-1) cm =3.1 cm.

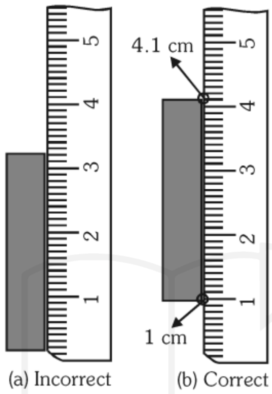


Fig. 8 Correct method of placing the scale with broken edge.

(3) Correct position of the eye is also important for taking measurement. Your eye must be exactly in front of the point where the mearsurement is to be taken (see fig.9) Position 'B' is the correct position of the eye. Note that from position 'B' the reading is 2.4cm. From positions 'A' and 'C', the readings may be different.

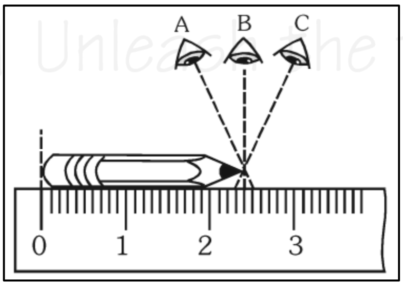


Fig.9 Correct position of the eye for taking reading of the scale. Here, position B is the correct position.

Active Physics

1. Take a tennis ball (a sphere) and let us try to measure its diameter using a 15cm scale or ruler. Keep the tennis ball on a flat surface like a table. Hold the ball between two rectangular blocks with smooth edges.
2. Now, place the ruler over the block (see fig.10). The distance between the inner edges of the rectangular blocks gives the diameter of the tennis ball.

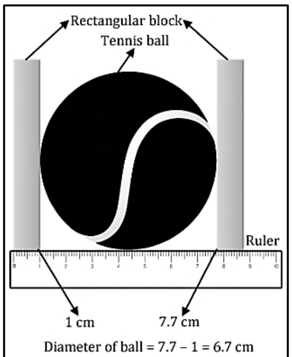


Fig. 10

Active Physics

1. It is not possible to measure the thickness of size of an object that is very small in size by ruler or metre scale. Therefore, the thickness of object like a thin wire have to be determined indirectly. Let us try to fine the thickness or diameter of a thin copper wire.

2. First, wrap the wire tightly around a rod. Make 50 turns around the rod. Now, place this ruler in contact with this coil and measure the length of the coil (see fig.11).
3. The thickness of wire can be determined by the following formula,

   Thickness of wire= $\frac{Length\ of\ the\ coil}{total\ no.of\ turns}$

   Suppose, the length of coil is 25mm and the number of turns is 50 turns, then the thickness of wire is 25mm/50=0.5mm.

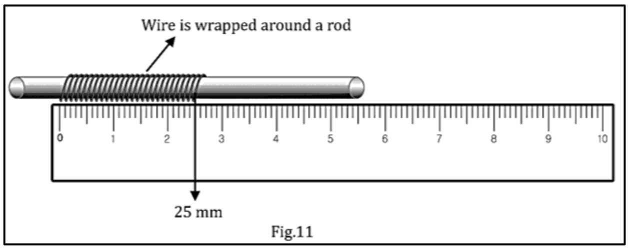


Fig.11

ACTIVE PHYSICS

1. Suppose we have to find the thickness of a paper sheet. Take about 100 paper sheet and stack the paper sheets vertically as shown in fig.12.
2. Now, put a ruler vertically in contact with the stack of paper sheet. Measure the height of the of the stack. The thickness of the paper sheet is given by following formula,

   Thickness of paper sheet = $\frac{Height\ of\ the\ stack}{total\ no.of\ paper\ sheets}$

   Suppose the height of the stack is 25mm and the number of paper sheets is 100. Then the thickness of a paper sheet is 10mm/ 100= 0.10mm.

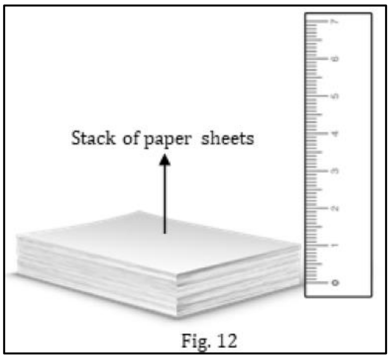


Fig. 12

5.1 Measuring length of a curved line or surface

- ✓ You can measure the length of a curved line or surface using a measuring tape. You have observed this while you visit a tailor's shop to stitch your clothes. The tailor measures the periphery or circumference of your neck or waist using the measuring tape. But you can use a string or thread and a ruler to measure the length of a curved line or surface indirectly.

ACTIVE PHYSICS

- ➢ Choose two points on a curved surface like that of a cup. Put a thread along the surface between these points such that it is in contact with the curve tightly [see fig. 13(a)]. Use a sketch pen to make marks on the thread that coincide with the end points of the curve. Straighten the thread, and place it on a ruler [see fig. 13(b)]. Note down the length of the thread between the marks. This gives the length of the curved portion of the cup.

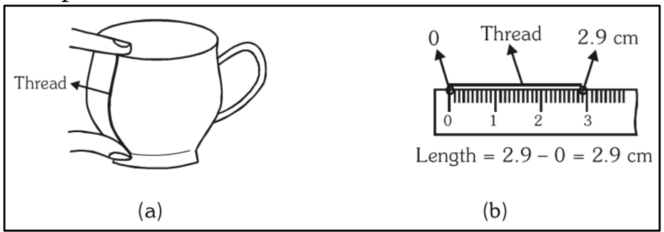


Fig. 13 Active physics

5.2 Using a divider to measure length

- ✓ A divider has tow legs with pointed ends. The other ends of two legs are joined together with a screw tightly. But the legs can be moved according to the need by applying force on the legs. A divider is used to measure the distance between two points. The divider is placed such that its two points are at the two ends of the length to be measured [see fig.14(a)]. Now, without disturbing the divider, the distance between the two points is measured with a ruler [see fig. 14(b)].

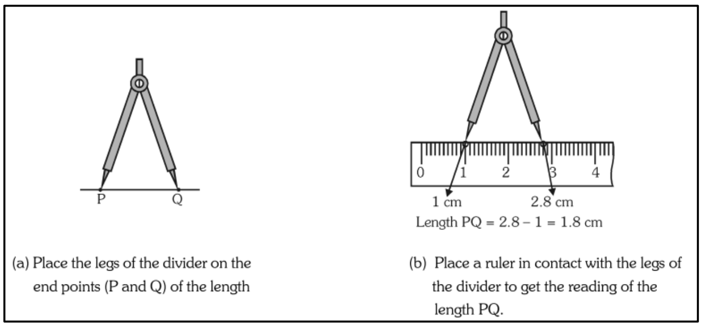


Fig. 14 Measuring length using a divider.

5.3 Use of our body parts for measurement of length

- ✓ In ancient days, long before measuring instruments were invented, people actually used different parts of their body to measure length. But since these measurements are dependent on the size of the person, they may vary from person to person. The length of the cubit, for example, depends on the arm length of the measurer. Thus, cubits had different lengths.
- ✓ Some hand units which were used in many places around the world are:

  (1) Span (or hand span) : Stretch out your hand so that the tip of your thumb is as far away as possible from the tip of your little finger. That distance is called a "span", which for most people is almost exactly half a cubit [see fig15(a)].

  (2) Thumb: The width of a thumb, which was later used as the basis for the inch [see fig15(b)].

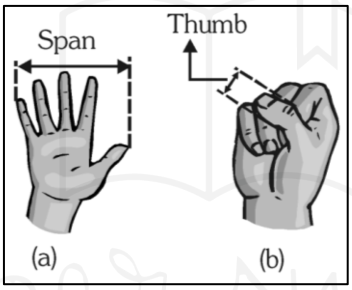


Fig. 15 Body units: Span and thumb

  (3) Fathom : If you stretch out your arms to either side of your body as far as they'll go, the distance between the tips of your middle fingers is fathom [see fig. 16(a)].

  (4) Cubit : The cubit is the distance from a person's elbow to the tip of the extended middle finger [see fig.16(b)].

  (5) Pace: It is the measure of a full stride from the position of the heel when it is raised from the ground to the point the same heel is set down again at the end of the step [see fig.16(c)].

  (6) Foot : It is the length of a man's foot [see fig. 16(d)].

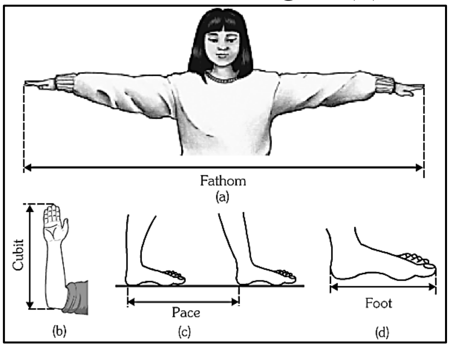


Fig. 16 Different body units which were used earlier to measure length

- ✓ For the sake of uniformity, scientists all over the world have accepted a set of standard units of measurement. The system of units now used is known as the **International System of Units (SI units).**
- ✓ Everyone's body parts could be of slightly different sizes. This must have caused confusion in measurement. In 1790, the French created a standard unit of measurement called the metric system.

5.4 Limitations of our senses and body parts

- ✓ Though we use our senses and body parts for various measurements, we cannot trust them to measure exactly and accurately. Look at fig. 17. Which circle is larger P or Q? Well, both are of the same size. Larger circles around the central one make it appear smaller. Small circles around the central circle make the other appear larger. The use of senses or body parts for measurement does not provide, (1) accuracy of measurement, (2) reliability of measurement, (3) uniformity of measurement.

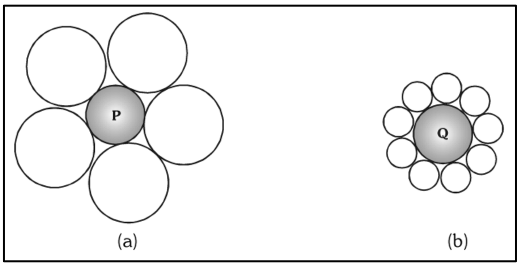


Fig. 17 Limitations of our senses and body parts in measurement

- ✓ The limitations of the use of senses and body parts have made us to develop some devices and instruments for accurate measurement.

<u>Check Your Concepts : 1</u>

1. When we say that the distance between Mumbai and Kolkata is nearly 2000 kilometres, what does it mean?
2. Why are metric units preferred over other units?
3. Ashok, Rakesh and Ketan were asked by their teacher to measure the length of their geometric box. Ashok wrote: 20; Rakesh wrote: 20 cm; Ketan wrote: 20 m. Which one of these answers is correct?

6.0 Measurement Of Mass

- ✓ The mass of an object is a measure of the amount of matter it contains. Objects that contain a large amount of matter have a larger mass than objects containing a small amount of matter.
  The SI unit of mass is the kilogram (kg).
  Commonly used units/conversion factors for mass

1 kg = 1000 g	1 quintal = 100 kg	1 tonne = 1000 kg
1 pound = 0.454 kg	1 carat = 200 mg	1 atomic mass unit (amu) = 1.66 x 10^{-27} kg

7.0 Measurement Of Time

- ✓ Our ancestors noticed that many events in nature repeat themselves after definite intervals of time. For example, they found that the sun rises everyday in the morning. The time between one sunrise and the next was called a day. Similarly, a month was measured from one new moon to the next. A year was fixed as the time taken by the earth to complete one revolution of the sun.
  The S.I. unit of time is second (s).
  Commonly used units/conversion factors for time

1 minute = 60 s	1 hour = 60 minutes	1 hour = 3600s

8.0 Measurement Of Weight

- ✓ The **weight** of an object is the amount of gravitational pull exerted on an object by the earth. In other words, 'the force of gravity on an object is called its weight'. This force is directed toward the centre of the Earth. It is denoted by letter **W.**
- ✓ At the Earth's surface, gravity exerts a force of 9.8 N on every kilogram of mass. That means a 1 kilogram mass has a weight of 9.8 N, a 2 kilogram mass has a weight of 19.6 N, and so on. On Earth's surface, the weight (W) of any object (in newtons) is its mass (m) in kilogram multiplied by a factor 9.8.

- ✓ Weight of a body on Earth's surface, **W = m x 9.8**
- ✓ Unit of Weight: S.I. unit of force is 'newton' (N). Since weight is a force, it is measured in unit of force i.e., newtons (N).
- ✓ Weight of an object is measured by **a weighing machine or spring balance.**

9.0 Measurement Of Volume

- ✓ The space occupied by an object is called its volume.

  Unit of volume: SI unit of volume is m3 (called cubic metre). Commonly used units/conversion factors for volume

  1 litre (L) 10^{-3} m^3 1 litre (L) = 1000 millilitre (mL)

  1 mL = 1 cm^3 1 gallon = 3.786 litres
- ✓ **Finding volume of solids using a measuring cylinder:** A measuring cylinder is a glass jar with a scale on it. When a liquid is filled in the measuring cylinder, the markings on the scale indicate the volume of the liquid. The unit on the scale used for measurement is generally in litres or millilitres. The method for measuring the volume of an irregular solid is as follows:
- ✓ First, fill some water in the measuring cylinder.
- ✓ Note down the initial level of water using the scale provided on the measuring cylinder. Let the initial reading be V_1.
- ✓ Now tie the irregularly shaped heavy solid with a string and submerge it in the water present in the measuring cylinder. You will observe that the level of water in the cylinder rises.
- ✓ Note the final level of water. Let the final reading be V. The difference between the two levels gives the volume of the solid, i.e., Volume of solid = Final reading - Initial reading = V_2- V_1

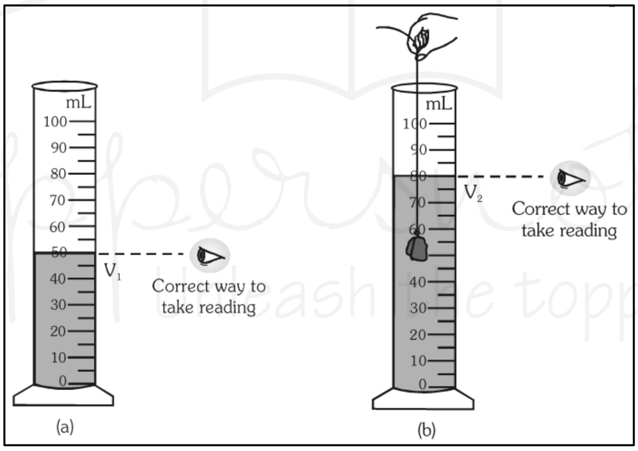


Fig. 18 Finding volume of solid using a measuring cylinder

10.0 Measurement Of Density

- ✓ Density is the amount of mass per unit volume of a material. Matter is made of particles, such as atoms or molecules, that have mass. The density of a material depends on the mass and the number of particles packed into a given volume.
- ✓ Which would have more mass, the balloon filled with air or the bottle of water shown in figure below? The mass of an object depends not only on the size of the object, but also on the material the object contains. All materials, such as the air in the balloon and the water in the bottle, have a property called density.
- ✓ Density is the amount of mass per unit volume of a material. Matter is made of particles, such as atoms of molecules, that have mass. The density of a material depends on the masses and the number of particles packed into a given volume. Figure below shows that the volume of air has fewer particles and less mass than the same volume of water. As a result, the density of air is less than the density of water.

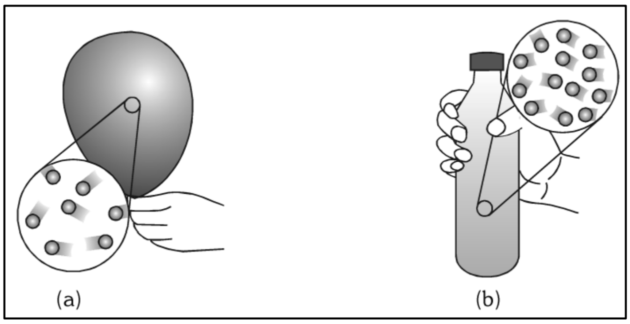


Fig. 19 The balloon has less mass because it contains fewer particles of matter than the water in the bottle does.

Calculating density:

- The density (D) of an object is the mass (M) of an object divided by its volume (V).
- Density = $\frac{Mass}{Volume}$ or D=$\frac{M}{V}$
- Units of density : SI unit of density is kg/m^3. Another common unit of density is of g/cm^3.
- $1\ kg/m^3 = 10^{-3}\ g/cm^3$. Also, $1\ g/cm^3 = 1000\ kg/m^3$

Check Your Answer

1. When we say that the distance between Mumbai and Kolkata is nearly 2000 kilometres, we are comparing this unit with a basic unit in mind, called a kilometre. That is, 2000 kilometres means, a length or distance which is 2000 times as much as the known unit 'kilometre'.
2. The main advantage of the metric system is its use of standard prefixes to represent multiples of 10, making unit conversion within the system quite easy. The fact that a kilometer (km) is 1000 meters and a centimeter (cm) is 1/100 of a meter, and that the prefixes kilo and centi always mean 1000 and 1/100, makes these conversions easy to remember.
3. The first one has no units. Therefore, we do not know what it means. The third is also not correct because length of geometry box can not be 20 metres. The second one is the only correct answer. A geometry box can be 20 cm long. Thus, the reading taken by Rakesh is correct.

11.0 Understanding Motion

- ✓ Motion is one of the more common events in your surroundings. You can see motion in natural events such as clouds moving, rain and snow falling, and streams of water moving, etc. Motion can also be seen in the activities of people who walk, jog, or drive various vehicles from place to place. Motion is so common that you may think that everyone understand the concepts of motion. But history indicates that it was only during the past three hundred years or so that people began to understand motion correctly. The foundations for the study of motion were laid down more than 300 years ago by Galileo in Italy and later by Isaac Newton in England.
- ✓ The study of motion is called 'mechanics'. It is broken down into two parts, kinematics and dynamics. Kinematics is the "how" of motion, that is, the study of how objects move, without concerning that why they move. Dynamics is the "why" of motion. In dynamics, we are concerned with the causes of motion, which is the study of forces.
- ✓ Consider a ball that you notice one morning in the middle of a lawn. Later in the afternoon, you notice that the ball is at the edge of the lawn, against a fence, and you wonder if the wind or some person moved the ball. You do not know if the wind blew it at a steady rate, or even if some children kicked it all over the yard. All you know for sure is that the ball has been moved because it is in a different position after some time passed. These are the two important aspects of motion:

  (1) A change of position (2) The passage of time
- ✓ Moving involves a change of position during some time period. Motion is the act or process of something changing position. The motion of an object is usually described with respect to a stationary object. Such a stationary object is said to be 'at rest'.

- ✓ Motion is a change in an object's position with respect to time compared to a fixed object. If you ride in a car, your position changes compared to a tree or an electric pole.
- ✓ An object is said to be at rest if it does not change its position with time.
- ✓ Motion can be defined as the act or process of changing position relative to some fixed point during a period of time.

Rest and motion are relative terms:

- ➢ Imagine that you are traveling in an automobile with another person. You know that you are moving across the land outside the car since your location on the highway changes from one moment to another. Observing your fellow passenger shows that there is no change of position. You are in motion relative to the ground but you are not in motion relative to your fellow passenger. The motion of any object or body is the process of a change in position 'relative' to some reference object or location.

12.0 Different Types Of Motion

12.1 Translational motion (or translatory motion)

- ✓ Motion of a body in which all the points in the body follow parallel paths is called 'translational motion'. It is a motion in which the orientation of an object remains the same throughout the journey. The path of a translatory motion can be straight or curved. (see fig. 20)

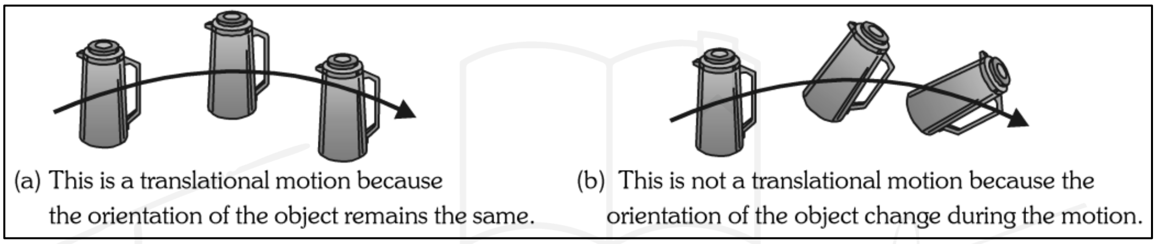


Fig.20 In a translational motion, the orientation of an object remains the same throughout the journey.

Examples : A car moving down a highway, a person walking on the road, an athlete running on the track, motion of piston in the cylinder, a train running on the rails.

On the basis of the path travelled by an object, the translational motion can classified as:

(1) Rectilinear motion : if an object moves in a straight line, its motion is called rectilinear motion or one dimensional motion. Motion of car along a straight path, motion of a piston in the cylinder are examples of rectilinear motion. (see fig. 21(a))

(2) Curvilinear motion : If an object moves along a curved path without change in its orientation, its motion is called curvilinear motion. Motion of a car along a curved or circular path, motion of an athlete on a circular track are examples of curvilinear motion. (see fig. 21(b))

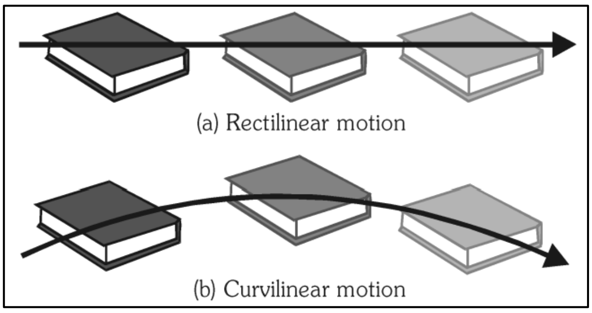


Fig.21 Translational motion: Rectilinear and curvilinear motion

<u>Active Physics</u>

1. Take a motorised toy car and tie it to one end of a string. Hold the other end of the string with your finger on a table top as shown in fig. 22.

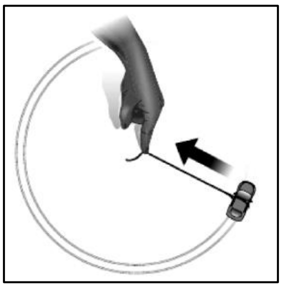


Fig.22 Active physics

2. Now, 'turn on' the car's motor, so that the car starts moving. You will observe that the car travels in a circle with your finger at the centre. This type of motion is called 'circular motion'. Circular motion When an object moves along a circular path, this type of curvilinear motion is called 'circular motion'. For example, motion of an athlete along a circular **track** is a circular motion. (see fig. 23(a))

12.2 Rotational motion (Rotatory motion)

✓ Motion of a body turning about an axis is called rotational motion. In other words, 'a motion in which an object spins about a fixed axis is called rotational motion'. It is a motion in which the orientation of an object continuously changes throughout the motion. The path of an object in a rotational motion is always circular. (see fig. 24)

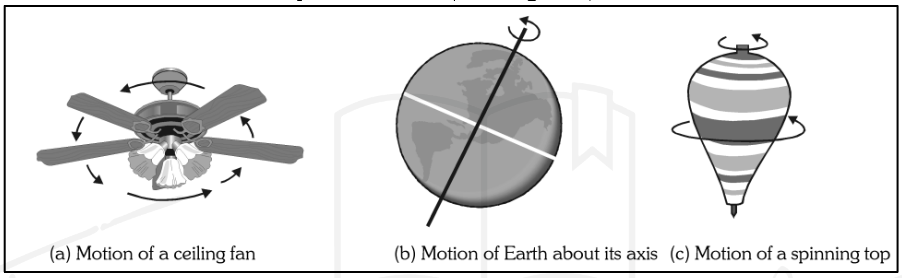


Fig.24 Examples of rotational motion

Examples : The Earth's spin on its axis, motion of a fan or motor, motion of blades of windmill, Motion of a spinning top, Motion of a grinding stone.

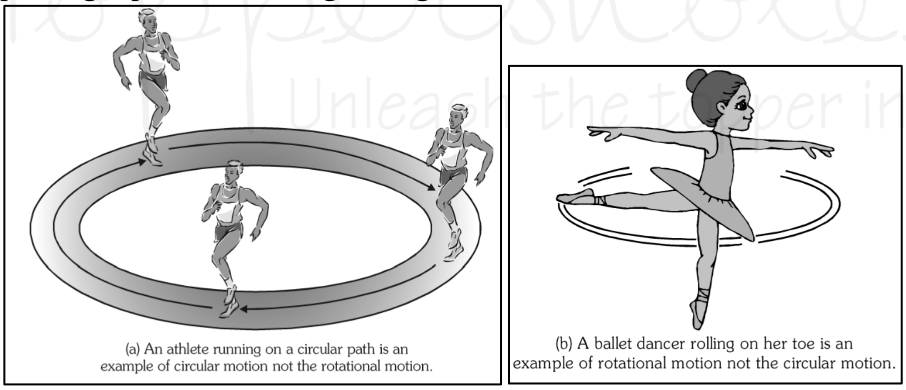


Fig.23 Circular motion and rotational motion are different.

Motion of a car or cycle wheels is a combination of translational and rotational motion (see fig. 25).

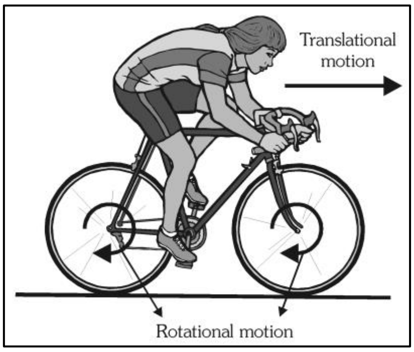


Fig.25 Motion of a cycle wheel is a combination of translational and rotational motion. Motion of a wheel is also called 'rolling motion'.

12.3 Periodic motion

- ✓ A motion that occurs when an object moves in a repeated pattern (a cycle) over equal periods of time is called a periodic motion.
- ✓ Examples: Motion of a pendulum, rotational motion of Earth, revolution of Earth around the Sun, all are periodic motions.

12.4 Oscillatory motion

- ✓ A motion that occurs when an object moves to and fro about its mean position over equal periods of time is called an oscillatory motion or vibratory motion.
- ✓ The vibration (or oscillation) of an object is a cycle or a motion that is repeated over and over with the same time interval each time.
- ✓ **Examples:** Motion of a simple pendulum (see fig. 26), motion of a vibrating stretched string, motion of an oscillating spring, a child swinging on a swing. (see fig. 27)

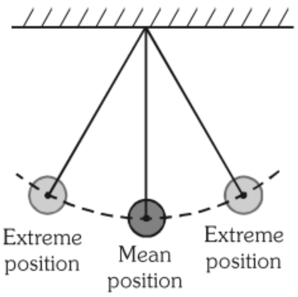


Fig.26 Motion of simple pendulum


Fig.27 A girl swinging on a swing, an oscillatory motion.

- ✓ Commonly, the term 'vibratory motion' is used when an object oscillates very fast. For example, motion of an oscillating (vibrating) string is very fast and thus, its motion is usually called vibratory motion.

Mean position:

- ➢ A position in the path of an oscillating particle at which the net force acting on the particle is zero is called its mean position.
- ➢ **Examples**: The vertical position or the lowest position of an oscillating pendulum is its mean position (see fig.21). When a pendulum is moved away from the mean position and then released, then it again comes towards the mean position and starts oscillating about its mean position. It moves both sides of the mean position and reaches an extreme position on both sides.
- ➢ A circular motion or a rotational motion can be a periodic motion. For example, a car moving with constant speed is an example of periodic circular motion. A fan rotating with constant speed is an example of periodic rotational motion.
- ➢ Random Motion: A type of motion in which object doesn't have fixed pattern of following fixed direction is called as random motion.

Illustrations

Illustration 5.	Rotation of the Earth about its axis is a periodic motion but it is not an oscillatory motion. Why?
Solution	A rotational motion and an oscillatory motion both can be periodic but a rotational motion is not an oscillatory motion. In an oscillatory motion, an object moves to and fro about its mean position i.e., it reverses its direction of motion in regular intervals. But, the Earth does not reverses its direction of motion in regular intervals, it always rotates in a fixed direction. Thus, rotation of the Earth is not an oscillatory motion.

13.0 Position And Reference Point

- ✓ Suppose you live in near Allen Career Institute (Samanvaya building), Kota. Fig.28 shows the aerial view (top view) of your locality. To reach Allen's Samanvaya building, you follow a path shown in the fig.28. Your house is the starting place for you to find the location, or position, of Allen's Samanvaya building.

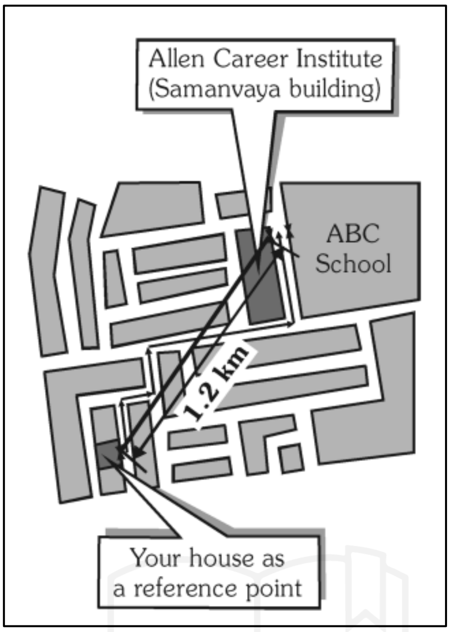


Fig.28 A reference point is needed in order to describe the location of a an object.

- ✓ A reference point is a starting point used to describe the position of an object. A reference point is also called the origin.
- ✓ To describe an object's position, three things must be included in the description: (i) a reference point, (ii) a direction from the reference point, (iii) distance from the reference point (the length of the line segment joining the reference point and the object).
- ✓ For example, in the fig. 28, choose your house as the reference point. Next, choose a direction from the reference point, let it be 'towards the ABC school' [see fig.28]. Finally, give the distance from the reference point: let it be 1.2 km.

13.1 How to describe the reference direction?

- ✓ One way of indicating the direction is to use a plus (+) or a minus (-) sign. The plus sign can be the direction from the reference point is in the reference direction [see fig.29]. A minus sign means the direction is opposite to the reference direction. For example, plus (+) sign can be used to indicate 'towards the school' in the fig.28 and minus (-) sign to indicate 'away from the school' towards house.

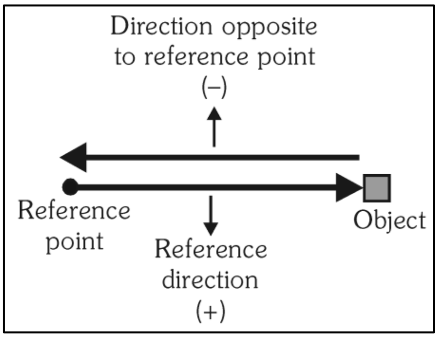


Fig.29 Describing the reference direction: sign conventions

- ✓ The position of an object can be described as a distance from the origin together with a plus or minus sign that indicates the direction.

Illustrations

Illustration 6.	In the fig.30, a car is parked at 100 m from the centre of a crossing. Also a tree is located 75 m from the car as shown in fig.30. The reference direction and its sign is mentioned in the fig.30. How will you express the car's position (i) when the centre of the crossing is taken as reference point (or origin), (ii) when the tree is taken as reference point (or origin)?

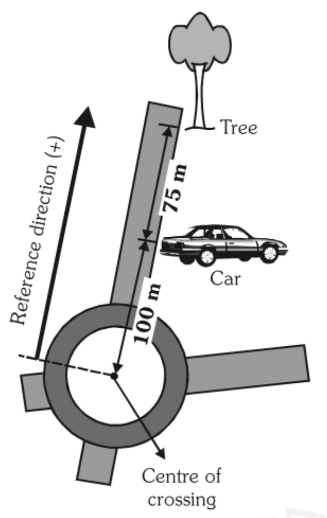


Fig.30 Illustration-6

Solution	(i) Here, the reference point is centre of the crossing. The car is 100 m away from this reference point. If we draw a direction from this reference point to the car, this direction is same as the reference direction [see fig 31]. Thus, the sign of this direction must be taken positive. Hence, the position of car is expressed or represented as + 100 m.

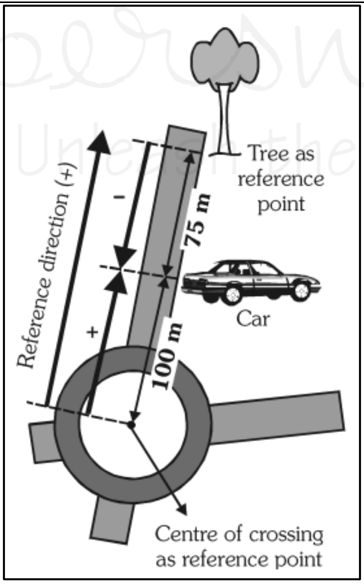


Fig.30 Illustration-6

	(ii) Here, the reference point is the tree. The car is 75 m away from this reference point. If we draw a direction from this reference point to the car, this direction is opposite to the reference direction [see fig 31]. Thus, the sign of this direction must be taken negative. Hence, the position of car is expressed or represented as -75 m. Thus, an object's position is its location compared to other things. Position of an object is not absolute, it is a variable that gives location of an object relative to a reference point or origin.

14.0 Uniform and Non-Uniform Motion

14.1 Uniform motion

- ✓ If a body covers equal distances in equal intervals of time in a particular direction, its motion is called 'uniform motion'.
- ✓ A uniform motion always takes place in straight line. Any motion along a curved path is not a uniform motion.
- ✓ In uniform motion magnitdue as well as direction remains constant.

Examples:

(i) A car moving with a constant speed in straight line

(ii) Motion of an athelete along straight path with constant speed.

In real world, we are rarely in uniform motion. We can be in uniform motion for a short time period when we have to take turn, reduce speed or increase speed according to our need.

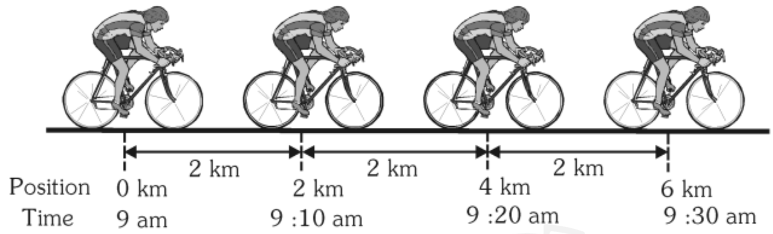


Fig.32 Motion of this cyclist is uniform motion ; she is covering equal distances in equal intervals of time; she is moving in straight line in a particular direction.

14.2 Non-uniform motion

- ✓ If a body covers unequal distances in equal intervals of time, its motion is called 'non-uniform motion'. Even if a body covers equal distances in equal intervals of time but it changes its direction, still its motion is said to be 'non-uniform'.
- ✓ Motion of a particle along a curved path is always a non-uniform motion. If particle changes its direction during the journey, its motion is always non-uniform.

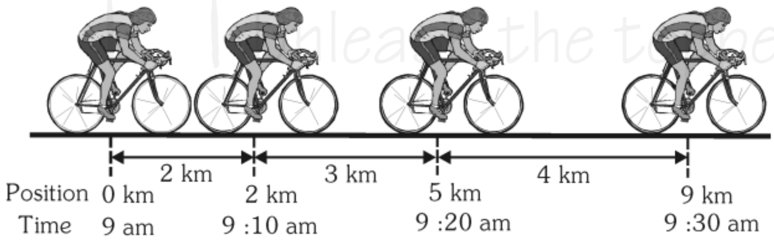


Fig.33 Motion of this cyclist is 'non-uniform' ; she is covering unequal distances in equal intervals of time; she is moving in straight line in a particular direction.

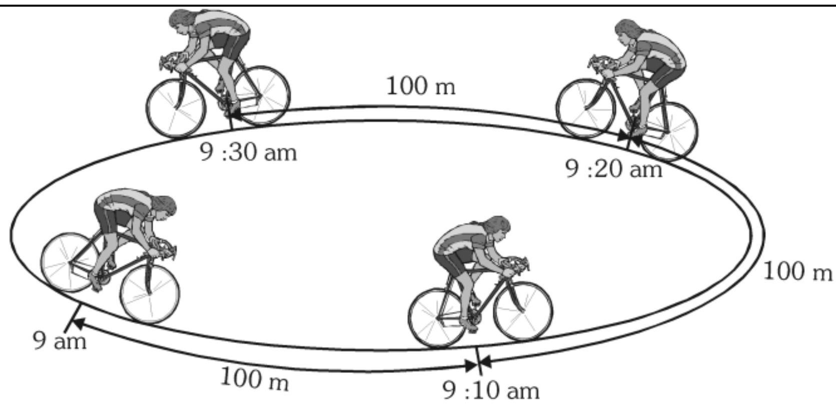


Fig.34 This cyclist is moving along a circular path ; she is covering equal distances in equal intervals of time ; still this is a non-uniform motion as this is not in a straight line.

Active Physics

1. Set up an arrangement as shown in fig.35(a). It consists of a pulley, a moving block with a dropper consisting of ink, a string attached to the moving block and free end of string is used to attach 'weights'.

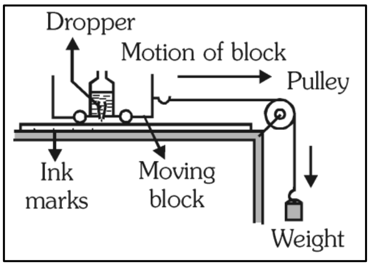


Fig.35 (a) Weight is put such that the block just start sliding.

2. Now initially, the block is at rest. Attach a small weight to the free end of string. You may see that the block does not move at all. Gradually increase the weight attached to the string till the block starts moving [see fig.35(a)]. As the block moves, the drops of ink falls on a paper placed below the moving block. In this case, you will find that the distance between marks of the ink on the paper are equal [see fig.35(b)]. This means 'the block has covered equal distances in equal interval of time' i.e., it is in uniform motion.

Fig.35 (b) Marks of ink are equidistant, this indicates the uniform motion of block.

3. Now, attach a bigger weight than that used in previous case. You will find that the block moves with faster rate than before [see fig.35(c)]. It actually speeds up as it moves. In this case, you will find that distance between marks of the ink on the paper are unequal [see fig.35(d)]. This means 'the block has covered unequal distances in equal intervals of time' i.e., it is in non-uniform motion.

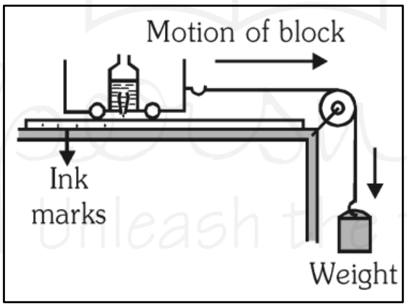


Fig.35 (c) A weight with greater mass is now attached to the string. The block is moving fast and it is speeding up.

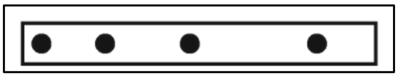


Fig.35 (d) Marks of ink are not equidistant, this indicates the non-uniform motion of block.

Fig.35 Active physics

15.0 Distance and Displacement

15.1 Distance

- ✓ The length of the actual path between initial and final positions of a moving object is called 'distance'.
- ✓ **Important points related to distance**
  (1) Distance is a scalar quantity.
  (2) Distance depends on the path.
  (3) Distance is always taken positive
- ✓ **Unit of distance:** In S.I. system unit of distance is metre (m). Some other popular units are millimetre (mm), centimetre (cm), kilometre (km).
- ✓ Distance travelled by a vehicle is measured by a device called 'odometer'.