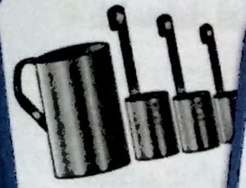


Chapter 1

Physical Quantities and Measurement

Chapter Objectives

In this chapter, you will learn about:

- The concept of unit volume
- How to measure volume and area of objects
- Estimating the area of irregular shapes using a graph paper
- Measuring the density of regular solids
- 'Density' and its formula
- The basic concept of speed
- 'Speed' and its formula
- Simple numericals based on density and speed

Shaina wanted to cover the floor of her room with square-shaped tiles. What does she need to find in order to do so—volume of the floor or area of the floor?

INTRODUCTION

Arvind wanted to get his house painted. The painter wanted to know the 'area' of the walls and ceilings so that he could bring the required buckets of paint for the work. The more the area to be painted, more is the number of paint buckets required.

Observe a milk packet, or a packed bottle of juice. You would find the quantity of liquid mentioned on the packet/bottle. This represents the 'volume' of the substance present. Therefore, we need to measure area and volume very often in our everyday lives. Both area and volume are **derived physical quantities.**

All matter occupies space and has volume. Solids, liquids and gases—each of these has volume.

The SI unit of volume is **cubic metre**, denoted as **m^3**. Another smaller unit, **cubic centimetre (cm^3)** is also used. For measuring volume of liquids or capacity of containers, other standard units such as litre, millilitre, gallon and pint are used.

Fig. 1.1 Jars of different capacities

MEASUREMENT OF VOLUME

Volume is defined as the amount of space that an object occupies. In other words, it is the three-dimensional space occupied by an object or enclosed within a container.

Volume of simple, regular solid shapes such as cubes, cylinders and spheres can be easily calculated using arithmetic formulae. However, volume of irregular solids is determined using indirect methods.

Teaching Tip: It is important for students to differentiate between area and volume. Give examples from daily life where we need to measure area and where we need to measure volume. Give reasons why measurement of area and volume is needed for different purposes. | **Pint:** A unit of liquid or dry capacity

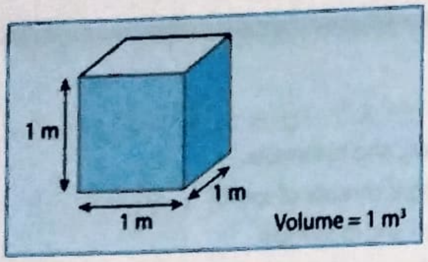
Concept of Unit Volume

Suppose there is a cube with each side measuring 1 m.

Its volume will be, length × breadth × height.

So, volume of given cube = 1 m × 1 m × 1 m

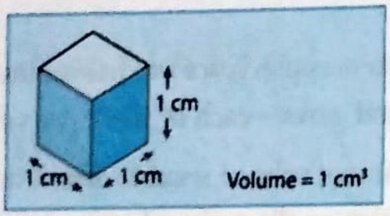
= 1 cubic metre.



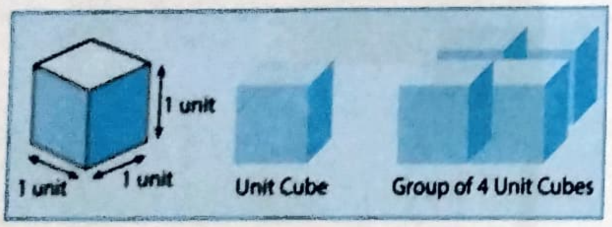
Let us consider a cube with each side measuring 1 cm.

Volume of given cube = 1 cm × 1 cm × 1 cm

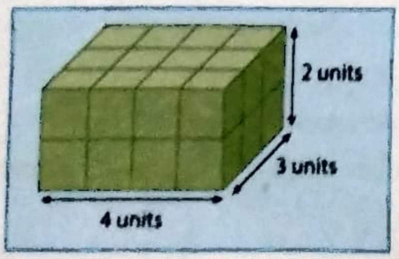
= 1 cubic centimetre



Thus, the volume of a cube with sides measuring 1 unit will be 1 cubic units. In other words, the cube is said to have a unit volume. Such a cube is referred to as a unit cube.



What is the volume of the given shape if each cube has unit volume?



In the given figure, length = 4 units, breadth = 3 units, height = 2 units.

So, the volume of the given figure is calculated as, 4 units × 3 units × 2 units = 24 cubic units.

Alternate method

The given figure has two layers, bottom layer and top layer of cubic units.

Bottom layer has 4 × 3 unit cubes. Its volume is 12 cubic units.

Top layer is identical to the bottom layer. Its volume is also 12 cubic units.

So, the volume of the given figure

= Volume of bottom layer + Volume of top layer

= 12 cubic units + 12 cubic units

= 24 cubic units

Relation Between Units of Volume

Various units of volume are related as follows:

Cubic metre and cubic centimetre

$1\ m^3 = 1\ m \times 1\ m \times 1\ m$

$= 100\ cm \times 100\ cm \times 100\ cm$

(Since, 1 m = 100 cm)

$= 1000000 = 10^6\ cm^3$

Thus, $1\ m^3 = 10^6\ cm^3$

Litre and millilitre

1 litre = 1000 millilitres or 1 L = 1000 ml

Cubic metre and litre

$1\ ml = 1\ cm^3$

$1\ L = 1000\ ml = 1000\ cm^3$

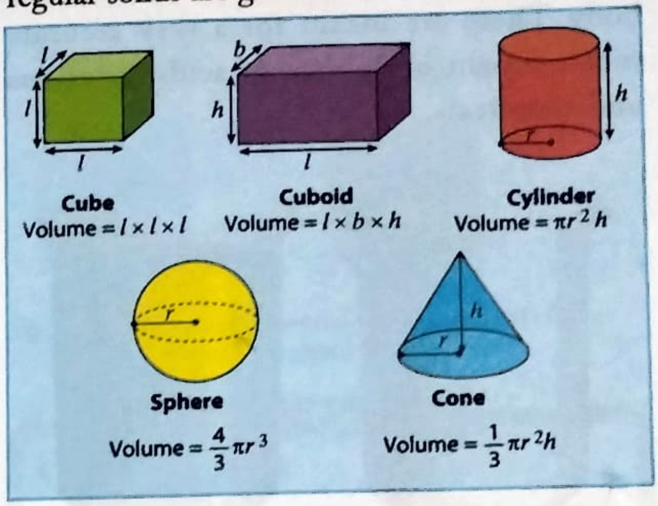
Since, $1\ cm^3 = (1/1000000)\ m^3$; therefore, $1000\ cm^3 = (1000/1000000)\ m^3 = (1/1000)\ m^3$

So, $1\ L = (1/1000)\ m^3$ or $0.001\ m^3$

Conversely, $1\ m^3 = 1000\ L$

Formulae for Volume of Regular Solids

The formulae for calculating volume of common regular solids are given here.



Volume of Irregular Solids

How can we find the volume of an irregular solid, say a stone? This is done through the **displacement** method. In this method, a measuring jar with a certain amount of water is taken and the volume of water is measured. The solid is dipped completely in water. *When completely immersed in water, the solid displaces an amount of water equal to its own volume.* Therefore, *the volume of solid and volume of water displaced is the same.*

This method can be used to estimate the volume of other irregular solids as well.

ACTION TIME 1

Aim: To measure the volume of an irregular solid using displacement method.

Materials required: A measuring jar, a stone (irregular solid), string and water

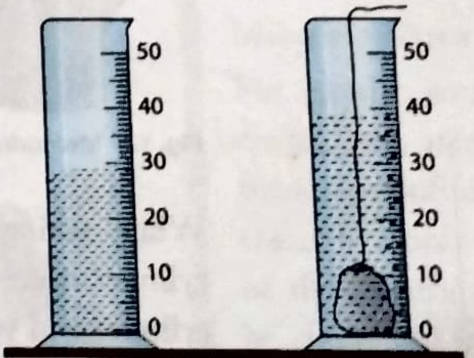
Procedure:

1. Take sufficient amount of water in the measuring jar.
2. Note the reading as 'Initial volume of water'.
3. Tie the stone with a string and gently immerse it completely in water.
4. As the stone gets dipped into water, the level of water increases.
5. Note the new level of water as 'Final volume of water'.
6. The difference between the final and initial levels of water gives the volume of the stone. It is equal to the volume of water displaced by the stone.

   Volume of stone = Final volume of water – Initial volume of water

   = ... ml – .... ml

   = ... ml or .... cm³ (Since, 1 ml = 1 cm³)



Conclusion: The volume of an irregular solid can be determined through the displacement method.

Volume of Liquids

We know that liquids are substances which have a definite volume but no definite shape. A given quantity of liquid takes the shape of the container it is poured in.

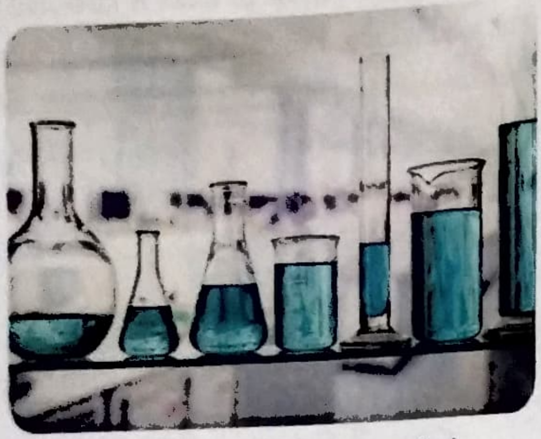


Fig. 1.2 The shape of a liquid is not fixed

Liquids have the ability to flow. Therefore, they are stored in vessels or containers. Containers that hold liquids come in various **capacities.**

The capacity of a container gives the amount of liquid it can hold. In laboratories, measuring cylinders and measuring beakers are used to measure the desired volume of liquid. For other purposes, measuring cans, jugs, cups, etc., are used.

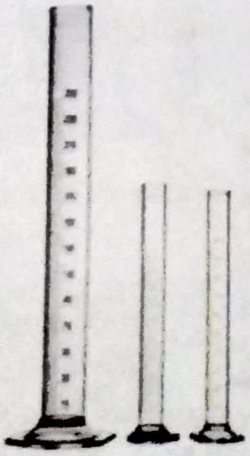


Fig. 1.3 Measuring cylinders

Measuring cylinders and measuring beakers are made of glass or plastic. They have clear markings or graduations on their body. These are meant for a very accurate measurement of volume of acids, solutions and chemicals.

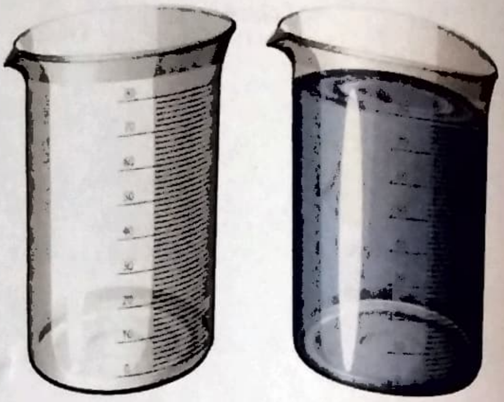


Fig. 1.4 Measuring beakers

Items such as milk and oil are measured using metal containers with fixed capacities. Measuring cans have a fixed capacity, for example, for measuring oil or milk the cans used have capacities of 100 ml, 250 ml, 500 ml, 1000 ml (1 litre), etc.

The volume of liquids is measured in litres and millilitres.

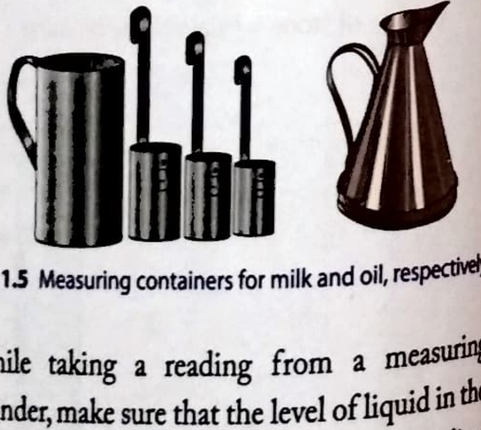


Fig. 1.5 Measuring containers for milk and oil, respectively

While taking a reading from a measuring cylinder, make sure that the level of liquid in the cylinder and your eye are on a horizontal line. In measuring cylinders, liquid surface is slightly curved. This curved surface of a liquid is known as meniscus, having upper and lower points. To avoid any error, *the reading should always be taken from the top of a convex meniscus and the bottom of a concave meniscus.*

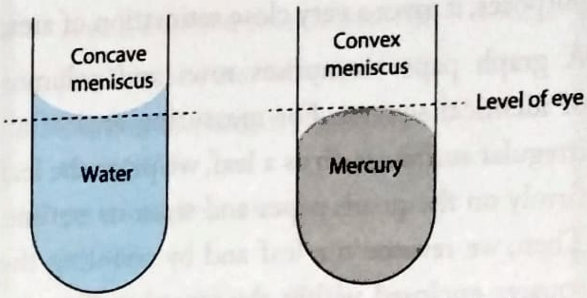


Fig. 1.6 Level of eye for correct measurement of volume using measuring cylinders

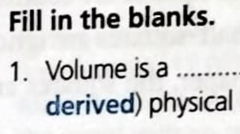
Quick Check 1

A. Fill in the blanks.

1. Volume is a .... (**fundamental/ derived**) physical quantity.
2. One cubic metre = ... (**1000/ 1000000**) cubic centimetres.
3. One litre = ... (**1000/10000**) millilitres.
4. Volume of .... (**regular/ irregular**) solids can be measured using the displacement method.
5. Water, when poured into a thin tube, has a .... (**concave/convex**) meniscus.

B. Find the volume of each of the given figures. Let us consider the volume of each cube as 1 cubic unit.

1.



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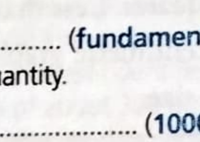

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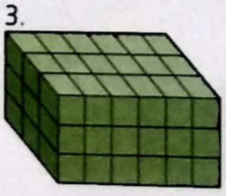

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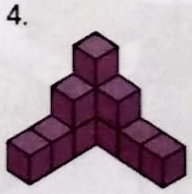


....

Measurement of Area

***Area** is defined as the space occupied by a plane object or a two-dimensional figure.* In case of three-dimensional bodies, we measure the surface area, that is, the area of its enclosing surfaces.

As area is a derived physical quantity, its units depend on factors on which it depends. The SI unit for measuring area is, metre × metre = **metre^2** (called as **square metre**). For expressing areas of different-sized objects, several other units are also used. For instance, to measure the area of cities or countries, the larger unit kilometre^2 (km^2) is used and for areas of farms, or houses, hectare is the commonly used unit. Besides these, mm^2, cm^2, dm^2, etc., are used to express areas of smaller objects.

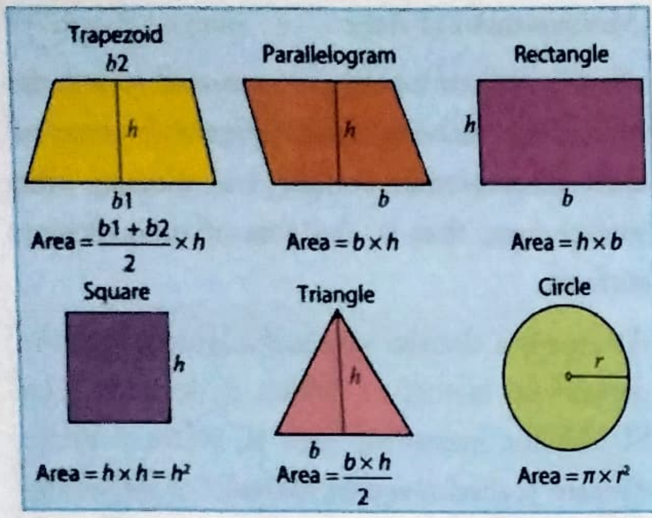
Table 1.1 gives the relationship between different units of area.

Table 1.1 Relationship between different units of area

1 mm^2 = 1 mm × 1 mm = 10^{-3} m × 10^{-3} m = 10^{-6} m^2
1 cm^2 = 1 cm × 1 cm = 10 mm × 10 mm = 10^2 mm^2
1 m^2 = 1 m × 1 m = 100 cm × 100 cm = 10^4 cm^2
1 hectare = 100 m × 100 m = 10^4 m^2
1 km^2 = 1 km × 1 km = 1000 m^2 × 1000 m^2 = 10^6 m^2

Measuring Area of Regular Surfaces

For regular surfaces like squares, rectangles, circles, etc., area measurement is very easy as there are definite formulae corresponding to them. We only need to determine the length of the specific **parameters**, and the area can be computed by substituting the values in the formula. The formulae for calculating the area of some common 2D figures are shown here.



Measuring Area of Irregular Surfaces

Irregular surfaces are those surfaces which do not have a regular shape and hence there are no definite formulae for calculating their area.

To calculate the area of irregular surfaces, we use the graphical method. Though this method does not give a very accurate result, for practical purposes, it gives a very close estimation of area.

A graph paper comprises rows and columns of identical squares. For measuring area of an irregular surface, such as a leaf, we place the leaf firmly on the graph paper and trace its outline. Then, we remove the leaf and by counting the squares enclosed within the traced outline, we estimate the area covered. In this method, each full square or more than half square is counted as one complete square. Half squares are counted as half squares. Less than half-squares are ignored. In a centimetre graph paper, the squares are of 1-cm size.

ACTION TIME 2

Aim: To measure the area of an irregular object using graphical method.

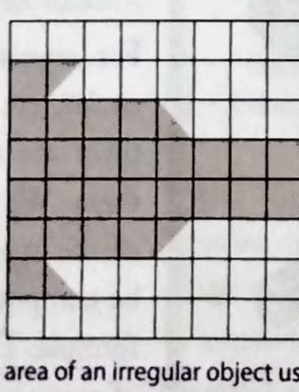
Materials required: an irregular-shaped object, graph paper and pencil

Procedure: To find the area of the irregular object, we should place it over a graph paper and mark its boundary with a fine, sharpened pencil.

- On removing the object, we will find that its boundary encloses a number of square boxes on the graph paper, some complete and some incomplete. Using a pencil, mark and calculate the complete half or more than half-squares within the boundary marked.
- Ignore the squares which are covered less than half, within the boundary.
- Multiply the number of marked squares with the area of each square (equal to 1 cm^2) to obtain the area of the object.
- In the given figure:

Number of marked squares = **No. of squares fully covered + No of squares half covered.**

So, the area of the object = ... × 1 cm^2 = ... cm^2



Measuring the area of an irregular object using graph paper

Conclusion: The area of the given irregular object = ... cm^2

Quick Check 2

State whether the following sentences are True (T) or False (F).

1. Area is a derived physical quantity. ....
2. The SI unit of area is hectare. ....
3. The area of a circle is pi times square of its radius. ....
4. Square metre is a smaller unit than hectare. ....
5. 1 sq. cm = 1000 sq. mm ....

INFO HUB

- Russia is a country with the largest area. Its area is nearly 17,075,200 km^2.
- Maldives is one of the smallest countries in the world with an area of about 300 km^2.
- The Amazon River is the world's largest river in volume.
- Khone Falls, lying between Cambodia and Laos, is the waterfall with the highest volume of water per second. It lets out about 9.5 million litres of water each second!

MEASUREMENT OF DENSITY

We have learnt about mass in previous class. *Mass of an object is defined as the amount of matter contained in it.* Mass is a fundamental physical quantity. Its SI unit is kilogram (kg). The mass of an object is its inherent property. It remains the same irrespective of surroundings.

Density of an object depends upon its mass. Density is, however, a **derived physical quantity.** Before learning further about density, let us consider two different cases.

Case 1: Equal volumes of different substances having different masses

Suppose you are given a plastic ball and a steel ball of the same diameter. Will they have equal masses? Though their sizes are same, they can have different masses. What could be the reason for that?

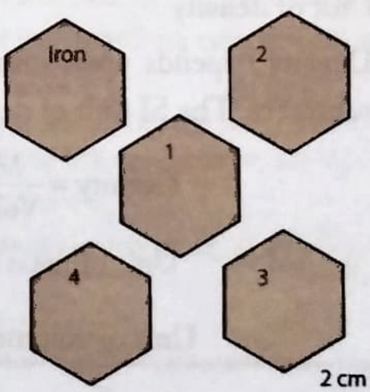
Let us perform an activity which helps us to figure out the reason for that.

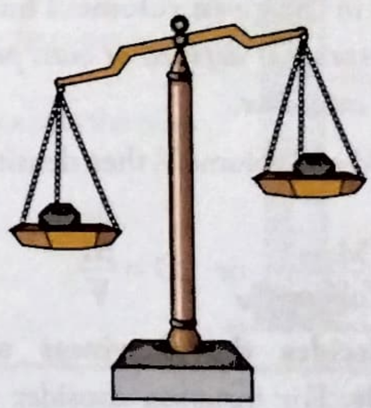
ACTION TIME 3

Aim: To identify the object (material) that can balance an iron weight.

Materials required: two iron weights, one styrofoam object, beam balance, copper object, steel object, thin cover wrapper, sticker.

Note: All the objects used should be of the same shape and size.





Teaching Tip: Ask students to investigate whether equal volumes of different substances have different masses using another method. In this regard, they should consider objects of daily use and record their findings in the notebook. | **Inherent:** Existing in something as a permanent or characteristic attribute

Procedure:

1. Place the iron weight on one of the metal pans of the beam balance.
2. Wrap all the other objects with a cover wrapper and stick a number sticker on each of them.
3. Label them with numbers (1–4).
4. Mix all the wrapped objects.
5. Try out one by one to find out the object that balances the iron weight.
6. Unwrap and observe which object could balance the iron weight.
7. Measure the mass of each object and note down your observations. Discuss why other objects could not balance the iron weight, though they are of same volume.

Conclusion: Another iron weight having the same mass could balance, while the rest of the objects have different masses though they have equal volume. Thus, equal volumes of different substances have different masses.

Case 2: Equal masses having different volumes

A vegetable seller weighs vegetables using standard weights, though the volumes of standard weights and that of the vegetables are different, but they have equal mass.

From the two cases studied, we can conclude that objects having the same mass can have different volumes, whereas the objects having equal volume can have different masses. How can this happen?

This is because different objects have different densities. Therefore, density is the property of an object which depicts the amount of matter in the given volume. Thus, *the density of a substance is defined as mass per unit volume of the substance.*

If a body has mass M and volume V, then density is given as:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad \text{or} \quad D = \frac{M}{V}$$

Thus, **density decides the heaviness or lightness of a body**. For instance, consider a body A, which is heavier than another body B, having the same volume. This means large number of molecules are packed within the same volume in A than in B.

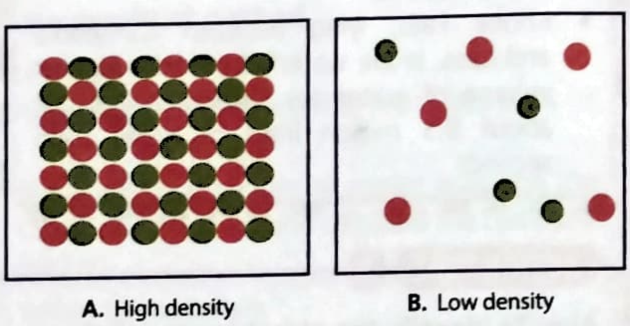


Fig. 1.7 Density is the amount of matter packed in a given volume

Unit of density

Density depends upon mass and volume of a substance. The SI unit of density is kg/m^3.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Unit of mass} = \text{kg}$$

$$\text{Unit of volume} = \text{m}^3$$

$$\text{Unit of density} = \frac{(\text{kg})}{(\text{m}^3)}$$

Teaching Tip: Discuss with students what CGS system for measurement is and make them understand, how it is different from SI units.

If mass is expressed in gram (g) and volume in cubic centimetres (cm^3) then in CGS system, the unit of density will be g/cm^3.

Table 1.2 lists the densities of some common substances.

Table 1.2 Densities of some common substances

Substance	Density (gcm^{-3})
Water at 4 °C	1.0000
Water at 20 °C	0.998
Gasoline	0.70
Mercury	13.6
Aluminium	2.7
Gold	19.3
Ice	0.92

From the table, we observe that, materials differ in their densities.

Determining the Density of Solids

Density is given by the formula, D = M/V. It is the ratio of mass to volume of a given substance. To find out the density of a substance, first we should know its mass and its volume.

Let us consider a cube. We can measure its mass using a beam balance. We can also find its volume as: side × side × side or $(\text{side})^3$. The density of the cube can be determined by dividing its mass with its volume.

Let us consider a cuboid. Again, we can measure its mass using a beam balance. Its volume will be, length × breadth × height. By dividing its mass with its volume, the cuboid's density can be calculated.

How will you measure the density of an irregular solid? Measure its mass as we did earlier. Find out its volume using the displacement method. Find the ratio of its mass to its volume.

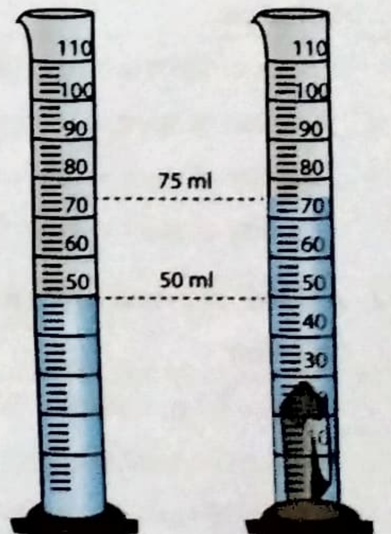
ACTION TIME 4

Aim: To determine the density of an irregular solid.

Materials required: irregular solid (say a stone), weighing scale, measuring cylinder and water

Procedure:

1. Measure the mass of the irregular solid (stone) using a weighing balance or a physical balance. Let the mass be M.
2. Fill about half of the measuring cylinder with water. Note the initial volume, say V_1.
3. Immerse the stone gently into the water, without touching the sides of the cylinder. Note the new volume, say V_2.
4. Volume of the stone = $V_2 - V_1$
5. Compute the density of the stone, $D = \dfrac{M}{V_2 - V_1}$



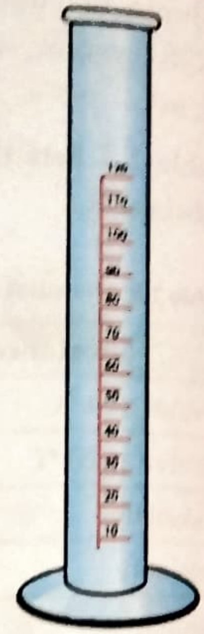
ACTION TIME 5

Aim: To determine the density of a liquid.

Materials required: liquid, measuring cylinder, weighing balance.

Procedure:

1. Measure the mass of an empty measuring cylinder using a weighing balance. Let it be m_1.
2. Pour any liquid into the measuring cylinder and weigh its mass again. Let it be m_2.
3. Calculate the mass of the liquid by finding the difference between the two masses as, $M = m_2 - m_1$.
4. Note down the volume that the liquid is occupying in the measuring cylinder as V.
5. Calculate the density of the liquid using the formula, D = M/V.



Measuring Cylinder

NUMERICALS

1. Ten litres of spirit has a mass of 8 kg. Calculate its density in

a. $g\ cm^{-3}$ **b. $kg\ m^{-3}$**

Solution:

Mass of spirit = 8 kg or 8000 g

Volume of spirit = 10 litres or 10,000 cm^3

Density of spirit = M/V = 8000 g/10,000 cm^3 = 0.8 $g\ cm^{-3}$

Density of spirit in $kg\ m^{-3}$ = 1000 × 0.8 = 800 $kg\ m^{-3}$

2. A piece of metal has a mass of 50 g and volume of 30 cm^3. Find its density.

Solution:

Mass = 50 g, volume = 30 cm^3

Density = Mass/Volume

= 50 g/30 cm^3 = 1.67 g/cm^3

3. Density of water is 1 g cm^{-3}. Write its value in SI units.

Solution:

Density of water $= 1\ g\ cm^{-3} = 1 \dfrac{g}{cm^3}$

$= 10^{-3} \dfrac{kg}{10^{-6} m^3}$

$= 10^3\ kg m^{-3}$

It must be noted that $1\ g\ cm^{-3} = 1000 kg m^{-3}$

SPEED

A body is said to be at rest if it doesn't change its position with time, with respect to a reference point. On the other hand, a body is said to be in motion when it changes its position with time, with respect to any reference point. Objects which are in motion, either move fast or slow. Speed is the parameter which helps us to determine, whether an object moves at a faster or slower rate. *Speed is defined as the rate of change of motion or the distance travelled by an object in a given unit of time.* The SI unit of speed is m/s. For calculating the speed of a slow moving object, unit used is cm/s.

$\therefore$ Speed $= \dfrac{\text{Distance covered}}{\text{Time taken}}$ or $v = \dfrac{s}{t}$

There are mainly two types of motions— uniform motion and non-uniform motion. In a uniform motion, an object covers equal distances at equal intervals of time, thus the speed of the object remains the same at all intervals of time. However, in a non-uniform motion, an object covers unequal distances in equal intervals or equal distances in unequal intervals of time, thus speed of the object is not constant throughout motion. In such cases, average speed is calculated.

NUMERICALS

1. A cyclist covers 140 km in 7 hours. Express the speed of the cyclist in km/hr.

Solution:

Speed (v) = distance/time = 140 km/7 h

$= 20\ km\ h^{-1}$

2. Indira Express moves at a uniform speed of 240 km h^{-1}. How long will it take to cover 30 km?

Solution:

Speed (v) $= 240\ km\ h^{-1}$

Distance covered, s = 30 km

We have, $v = \dfrac{s}{t}$

$\therefore t = \dfrac{s}{v} = \dfrac{30}{240} = 0.125\ h$

3. Express 18 km h^{-1} in m s^{-1}.

Solution:

$$18 \text{ km } h^{-1} = 18 \frac{\text{km}}{\text{h}}$$
$$= 18 \times \frac{1000}{3600} \frac{\text{m}}{\text{s}}$$
$$= 18 \times \frac{10}{36} \frac{\text{m}}{\text{s}}$$
$$= 5 \text{ m}s^{-1}$$

We can say that,

$18 \text{ km } h^{-1} = 5 \text{ m } s^{-1}$

KEY TERMS

Volume: The amount of space occupied by an object
Matter: Anything that has mass and takes up space
Displacement: The change in the position of an object
Capacity: Measure of space available to hold something
Parameter: A rule or limit that controls how something should be done
Mass: Amount of matter contained in an object
Density: The amount of matter present in a unit volume

QUICK NOTES

- Density of an object depends on its mass and volume.
- Objects with equal mass may not have equal volumes.
- We can measure the density of irregular solids also.
- Density defines the heaviness or lightness of a body.
- A body is said to be at rest if it does not change its position with time.
- SI unit of volume is m^3, other units for measuring volume are cm^3, litre (l), millilitre (ml), pint and gallon.
- The volume of liquids can be measured using measuring containers.
- The amount of space or surface covered by a two-dimensional shape is called its area.
- SI unit of area is m^2. Other units used to measure area are cm^2, m^2, km^2, and hectare.
- The area of irregular shapes can be measured using graph sheets.
- The density of a substance is defined as mass per unit volume of the substance. Density = mass/volume.
- The SI unit of density is kg/m^3.
- The speed of an object is defined as the distance travelled by it in a given unit of time.
- Speed of an object can be calculated by the formula: speed (v) = distance (s)/time taken (t)

RUN-THROUGH

I. Very Short Answer Questions.

A. Tick (✓) the correct option.

1. 1 kg m^{-3} is equal to:
   a. 1 gcm^{-3} ☐ b. 10^{-3} gcm^{-3} ☐ c. 1 kg cm^{-3} ☐ d. 10 kg cm^{-3} ☐
2. The SI unit of density is:
   a. newton ☐ b. g m^{-3} ☐ c. kg m^{-3} ☐ d. m^{-3} ☐
3. The SI unit of volume is cubic metre, denoted as:
   a. m^3 ☐ b. cm^3 ☐ c. g/cm^3 ☐ d. km^3 ☐
4. This definition 'amount of space that an object occupies' is correct for which of the following terms?
   a. Speed ☐ b. Density ☐ c. Volume ☐ d. None of these ☐
5. What will be the volume of a cuboid with length 4 cm, breadth 3 cm and height 2 cm?
   a. 18 cm^3 ☐ b. 16 cm^3 ☐ c. 20 cm^3 ☐ d. 24 cm^3 ☐

B. Fill in the blanks.

1. Volume is the amount of .... (space/mass) that a body occupies.
2. Both area and volume are derived from .... (physical/structural) quantities.
3. Liquids are substances with a definite volume but no definite .... (mass/shape).
4. Milk and oil are measured using metal .... (buckets/containers) with fixed capacities.
5. 15 litres of milk = ... (15000/1500) ml.
6. The SI unit for measuring area is .... (m^3/m^2)

C. Match the following:

Column A	Column B
1. Graph paper	a. Depends on mass and volume of an object
2. Liquids	b. A body changes its position with time
3. Density	c. Take the shape of the container in which they are kept
4. Motion	d. Equal distances in equal intervals of time
5. Uniform motion	e. Used to calculate area of irregular surfaces

D. State whether the following statements are True or False. Correct the False statements.

1. Volume is the distance travelled by an object in a unit time. ☐
2. All states of matter occupy space and have volume. ☐
3. The SI unit of volume is m^3. ☐
4. We use metre and centimetre to measure the volume of a liquid substance. ☐
5. The capacity of a container gives the amount of density it contains. ☐
6. We can derive the area of a circle by using a formula. ☐