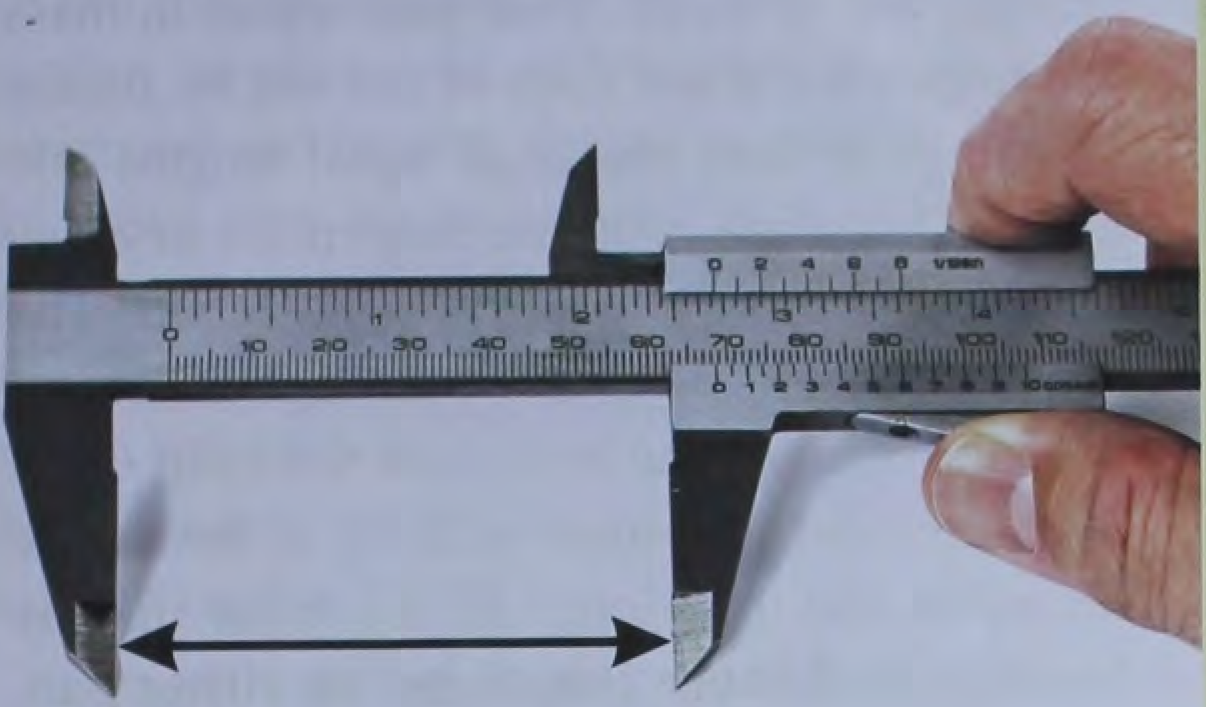


1 Measurement

SYLLABUS

1. Mass and Weight — The difference between them — units used — spring-balance, beam-balance.
2. Density — definition — units of measurement — simple calculations based on the formula :
   D = M ÷ V — variations in the density of gases and liquids with temperature — convection currents (in liquids/gases) arise as a result of this — floating and sinking (with reference to density).
   - Using a spring-balance / beam-balance (D).
   - Using a density-bottle to find the density of liquids (D).

MASS AND WEIGHT

The *mass* of a body is the quantity of matter the body contains, regardless of its volume and size. Mass of a body does not change due to any force acting on it.

Do You Know ?

The earth has a unique property to attract every object towards its centre regardless of its shape, size, state, volume, temperature, *etc*. This is called gravitation of earth.

The *weight* of a body is the force with which earth attracts the body towards its centre *i.e.*, it is a measure of the force of gravity of earth acting on the body. It always acts vertically downwards.

Remember, mass and weight are not the same.

Mass remains constant and has the same value at different places. Weight however, varies from place to place. The value of weight depends upon the location of the body in the gravitational field of the earth or other heavenly bodies. Thus, the mass of a body on the surface of the moon is same as that on the earth. But, the weight of the body on the surface of the moon is about one-sixth of the weight as measured on the earth. *For example*, if you go to moon your mass remains same, but your weight measures $\frac{1}{6}$ of previous weight, since moon's gravity is $\frac{1}{6}$ that of earth.

UNIT OF MASS

According to the Standard International System (S.I.) of units, the unit of mass is **kilogram** (kg). In CGS system, the unit of mass is gram (g).

One kilogram is the mass of one litre (1000 ml) of pure water at 4°C.

The sub-units of mass are gram (g) and milligram (mg), etc.

$$1 \text{ g} = \frac{1}{1000} \text{ kg} = 10^{-3} \text{ kg}$$

$$1 \text{ mg} = \frac{1}{1000} \text{ g} = 10^{-3} \text{ g} = 10^{-6} \text{ kg}$$

= a millionth part of a kg.

Higher units of mass are quintal and metric tonne, etc.

1 quintal (q) = 100 kg.

1 metric tonne (t) = 1000 kg

Fundamental particles like protons, neutrons and electrons are expressed in atomic mass unit (a.m.u) or unified atomic mass unit (u).

$$1\text{u} = 1{\cdot}66 \times 10^{-27} \text{ kg}$$

However, if you ask for any substance in liquid like, petrol, milk, etc. it is measured by volume in litre.

MEASUREMENT OF MASS

We measure the mass of an object by comparing it with a standard mass, generally called weight. These weights are made of iron or brass.

> Remember, that these weights have a different meaning than the term 'weight' as used in physics.

We measure mass of a body with the help of a balance. There are several kinds of balances such as a beam balance, a physical balance, a platform balance, a digital balance, and a weighing scale. Normally, we use a beam balance to measure mass.

Beam Balance

The commonly used beam balance is shown in Fig. 1.1. This balance consists of a straight rod of metal. Two pans equal in mass are suspended at the ends of the rod by means of strings or iron chains of equal lengths and mass. Also these pans are suspended at equal distances from the centre of the beam. The beam-balance is suspended through its centre (middle point of the rod) with the help of an iron loop and a pointer is fixed at the centre between the iron loop. **If we hold up the balance, and there is nothing on either pan, the rod is horizontal whereas the pointer is vertical.**

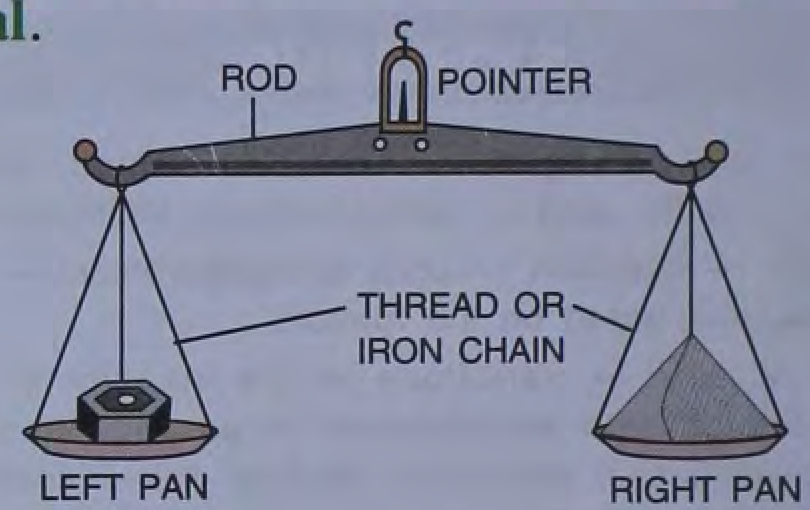


Fig. 1.1 Beam balance

Principle of a Beam balance

According to the principle of a beam balance, two bodies of equal or same mass would secure a balance on the beam balance having arms of equal length and pans of equal masses.

Characteristics of a True Beam Balance

A true beam balance has the following characteristics :

1. Both the arms must be of equal length.
2. Both the pans must be of equal mass.
3. On lifting up the beam balance, without putting anything on either pan, the rod should be horizontal and pointer vertical.

Working of a Beam Balance

When we use a beam balance, first of all we see that on holding up the balance without putting anything on either pan, the rod is horizontal and pointer should be vertical. Then we keep the body whose mass is to be measured on the right pan and the standard weights are placed on the left pan. The weights on the left pan are adjusted in such a way that the rod again takes the horizontal position on holding up the balance.

Thus, the sum total of the standard weights placed on the left pan gives us the mass of the body.

Some shopkeepers use the grocer's balance (Fig. 1.2) for weighing articles like sugar, rice, pulses, vegetables, *etc*.

Fig. 1.2 Grocer's balance

UNIT OF WEIGHT

The unit of weight in the Standard International System (S.I.) is Newton (N) while in CGS system or the sub-unit of weight is dyne.

$$1N = 10^5 \text{ dyne}$$

> The weight of a body is very often expressed in kgf and gf.

The weight of a body of mass 1 kg is equal to 1 kgf. Likewise, the weight of a body of mass 1 g is equal to 1 gf.

$$1 \text{ kgf} = 9{\cdot}8 \text{ N } (\approx 10\text{N})$$

$$1 \text{ gf} = 980 \text{ dyne } (\approx 1000 \text{ dyne}).$$

MEASUREMENT OF WEIGHT

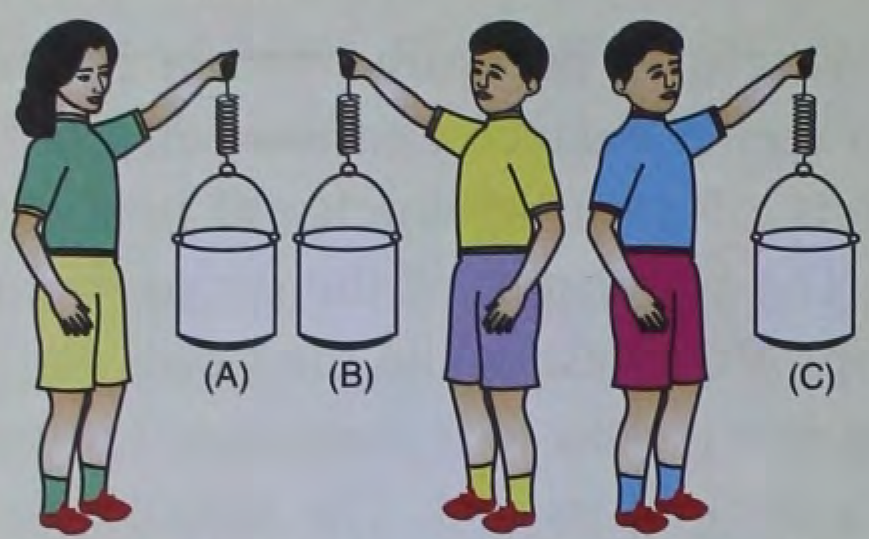
Weight is measured by an instrument called spring balance as shown in Fig. 1.3. It consists of a spring enclosed in a metallic case. The upper end of the spring is fixed at the top of the case while the lower end of the spring is attached to a pointer and a long rod with a hook at its end. The metallic case has a slit cut along its length through which the pointer projects out and the rod can be seen. The metallic case is graduated at the top with zero mark and the weights in the increasing order in downward direction (*e.g.*, 0 gf, 100 gf, 200 gf, 300 gf, 400 gf, 500 gf, ... 1 kgf, etc.). Till no object is suspended on the hook, the pointer reads zero. When an object is suspended on the hook, the spring extends and the pointer moves down the scale. A ring is provided at the top of the metallic case to hang it from a rigid support.

Principle of a Spring-balance

When a load is suspended on the hook at the lower end of the spring, the spring elongates due to the weight of the load suspended. If the weight suspended is increased, the spring will elongate further. Thus, spring-balance works on the principle that more the weight is attached (or more the force is applied) to the spring, the more it gets stretched (elongated).

ACTIVITY 1

Take three empty cans A, B and C of equal size and equal weight. Suspend them separately with a support using springs. Now lift the cans upwards one by one. You will see that lifting the empty cans is easy and the extension of the springs in all the three cans is equal.



Now fill can A half with water and lift the cans (A) and (B). You will notice that the extension of the spring in can A is more than in can B. Now fill

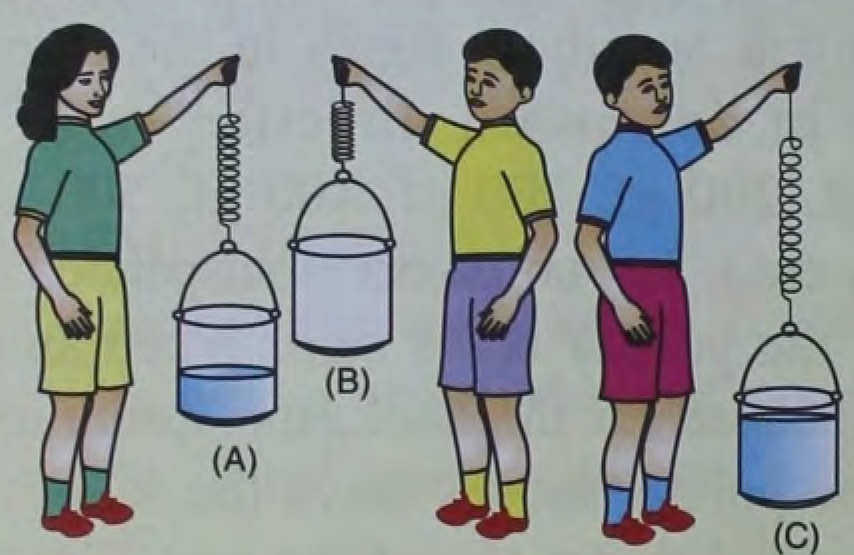


Fig. 1.3 Principle of a spring-balance

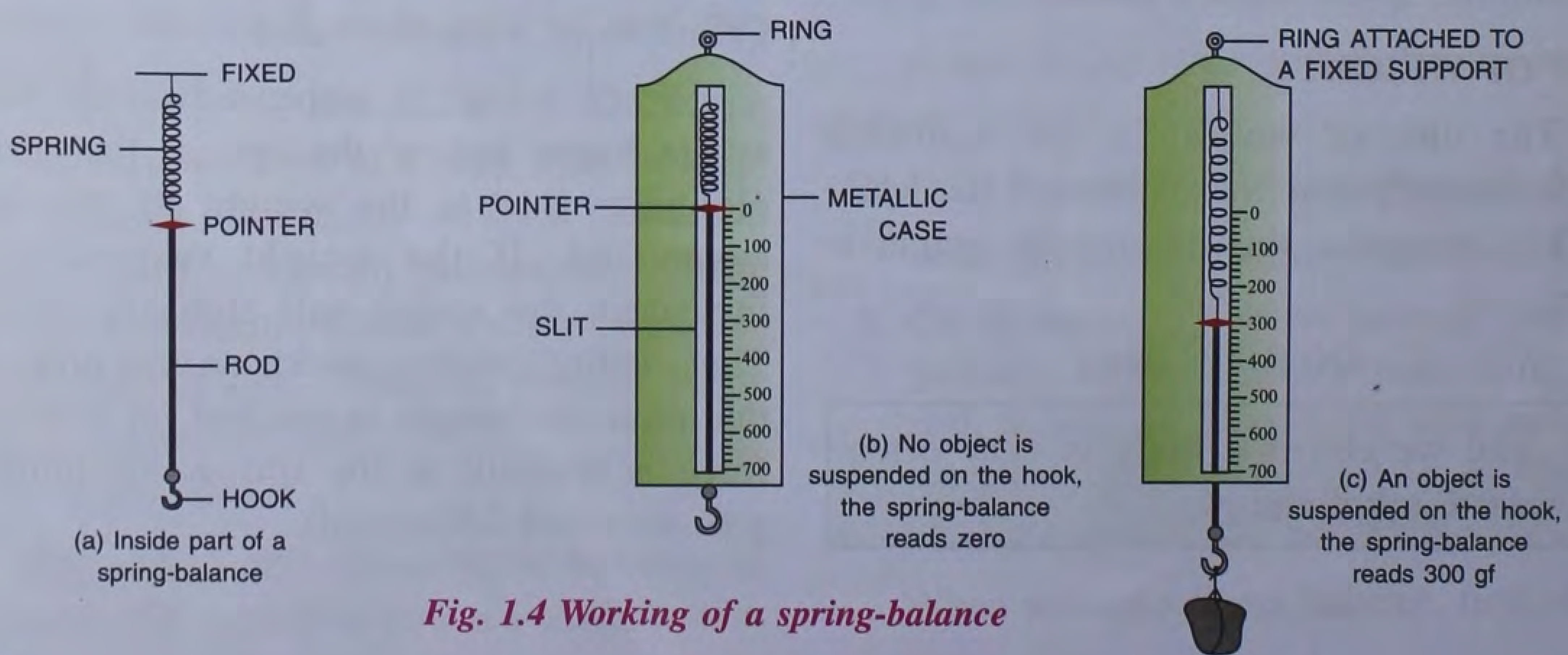
can C almost completely with water and lift the cans (A), (B) and (C) upwards.

What do you observe ?

You will see that the spring attached with can (C) is stretched more than both cans (A) and (B). But the spring attached with can (A) will stretch more than the spring attached to can (B). Also, greater effort is needed to lift the can completely filled with water, *i.e.*, can C. We conclude that, more the weight, more will be the extension in the spring.

Working of a Spring-balance

To use a spring-balance, first hang it vertically from a rigid support. Make sure that the pointer reads zero. Then the object whose weight is to be measured is suspended on the hook, attached to the spring balance. The pointer moves down. Wait till the pointer becomes stationary. Then read the position of the pointer through the calibrated scale. This reading gives the weight of the object. Fig. 1.4(c) shows that weight of the object hanging from a spring balance is 300 gf.



(a) Inside part of a spring-balance

(b) No object is suspended on the hook, the spring-balance reads zero

(c) An object is suspended on the hook, the spring-balance reads 300 gf

Fig. 1.4 Working of a spring-balance

ACTIVITY 2

1. Take two equal pans of equal weight, some thread, a straight stick about 50 cm long and try to make a beam-balance.
2. Take a card board, graph paper, spring, some wire, pins and a hook. See, how can you make a spring-balance. You may require your teacher's help.

Table 1.1 Differences between mass and weight

Mass	*Weight*
1. It is the quantity of matter contained in a body.	1. It is the force with which a body is attracted towards the earth.
2. Mass of an object can never be zero.	2. Weight of an object can be zero, if $g = 0$.
3. Mass is a scalar quantity.	3. Weight is a vector quantity.
4. It is measured by a beam-balance or a physical-balance.	4. It is measured by a spring-balance.
5. The S.I. unit of mass is kilogram (kg).	5. The S.I. unit of weight is newton (N).
6. It is constant and is independent of the place and position of the body.	6. It varies from place to place and also depends on gravity at the place.

NUMERICALS

Example 1 : Express 1 mg in kg.

Solution :

$$1 \text{ mg} = \frac{1}{1000000} \text{ kg} = 0{\cdot}000001 \text{ kg or } 10^{-6} \text{ kg}$$

Example 2 : Express 1 metric tonne in quintals.

Solution :

1 metric tonne (1 t) = 1000 kg

Since, 1 quintal (1 q) = 100 kg

$$\therefore \quad \frac{1\ t}{1\ q} = \frac{1000 \text{ kg}}{100 \text{ kg}} = 10$$

$$\Rightarrow \quad 1\ t = 10\ q$$

Example 3 : The mass of a body is 5 kg. Express its weight in (i) kgf and (ii) N.

Solution :

(i) Weight of a body of mass 5 kg = 5 kgf.

(ii) Weight of a body of mass 5kg = $5 \times 9{\cdot}8$ N = 49N (≈ 50N).

Intext Questions

1. State the S.I. unit of mass.
2. Define 1 kgf of weight.
3. In what units would you preferably measure the following ?
   (a) Mass of a man.
   (b) Mass of an electron.
   (c) Mass of a loaded truck.

   Ans. (a) *kg* (b) Atomic Mass Unit (a.m.u.) (c) Metric Tonne (t)
4. (a) Convert 2 kg into g.
   (b) Convert 3 kg into kgf.
   Ans. (a) 2000 g (b) 3 kgf
5. Express 1 metric tonne in kg. **Ans. 1000 kg**
6. What is the mass of 2500 ml of water at 4 °C ? **Ans. 2·5 kg**

Do You Know ?

The acceleration due to gravity at poles is maximum and minimum at the equator of earth's surface. Therefore, the weight of the body will be maximum at poles and minimum at the equator but mass remains the same.

Also acceleration due to gravity decreases with altitude. So the weight of the body will decrease as it is taken to higher altitudes.

Similarly the acceleration due to gravity decreases when we go inside the surface of the earth. At the centre of the earth the acceleration due to gravity is zero.

ACTIVITY 3

Take two equal sized glasses. Fill one glass completely with water and the other with kerosene oil. Place the glasses on the pans of a beam balance.

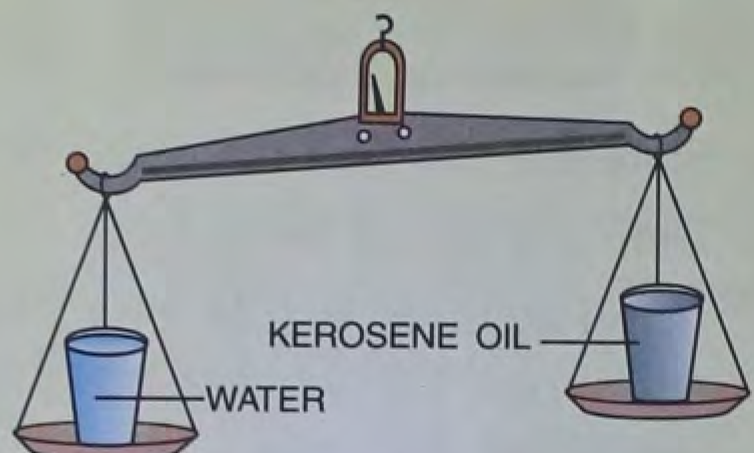


Fig. 1.5 Comparison of masses having equal volume

It is noticed that the glass filled with water has more mass than the glass filled with kerosene oil. Why is it so when their volumes are equal ?

Because the matter in water is more densely packed than in kerosene oil.

We can also say that the molecules in water are more densely packed than in kerosene oil.

Hence, we conclude that equal volumes of two different substances may have different masses.

ACTIVITY 4

Take a common beam-balance and place 500 g iron weight on its left hand side pan.

Put some common salt on the right hand side pan till the beam is horizontal. At this moment, the mass of iron weight is equal to the mass of common salt.

Now look at the space occupied (volume) by common salt and iron weight. You will observe that the volume of common salt is far more than iron weight, even if their masses are same.

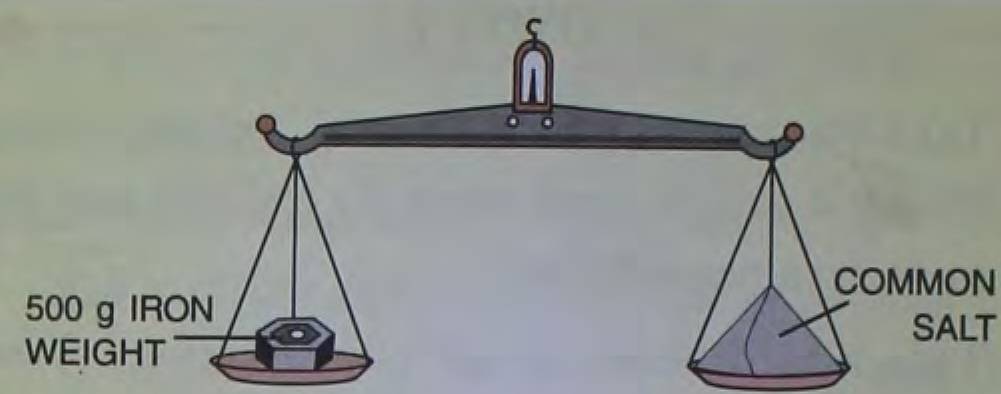


Fig. 1.6 Equal masses of different substances have different volumes

Why is it so?

The answer is that the matter in iron is more densely packed than in common salt.

ACTIVITY 5

Suppose you have four cubes of iron, zinc, aluminium and wood, such that side of each cube is 1 cm. Hence, the volume of each cube is 1 cm^3.

Weigh each cube on the physical balance. It will be found that the mass of iron cube is 7·8 g; the mass of zinc cube is 4·2 g; the mass of aluminium cube is 2·7 g and the mass of wooden cube is 0·8 g.

Why is there a difference in the masses of the cubes although they have the same volume ?

From activities 3 and 4, we can conclude that iron is denser than zinc, zinc is denser than aluminium and aluminium is denser than wood.

A substance is said to be more dense when molecules in it are more densely (closely) packed.

The matter (atoms or molecules) is more densely packed in iron than in zinc, aluminium or wood. Thus, in the language of science, we can say that the density of iron is more than zinc; the density of zinc is more than that of aluminium and so on.

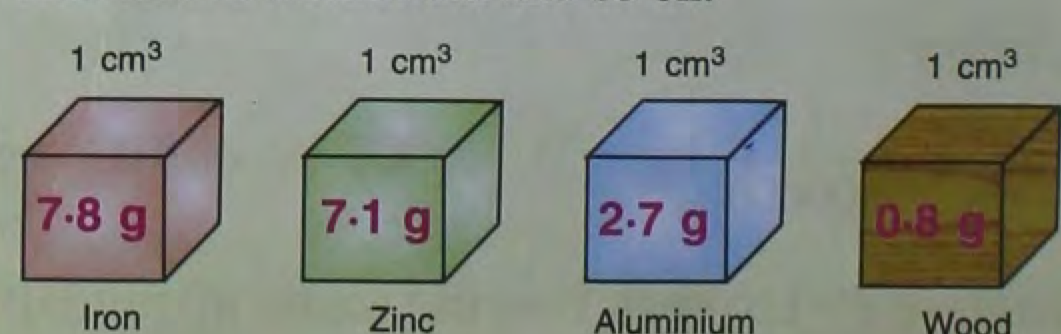


Fig. 1.7 Equal volumes of different substances have different masses

DENSITY

Density is a physical property of matter. It has been explained in a simple description given below.

Whether an object sinks or floats on water, depends upon its lightness or heaviness, as compared to water. It will float if its density is less than the density of water and it sinks, if its density is more than that of water. Whether an object has greater density or less density depends upon how densely the molecules are packed in the same volume of that object.

Therefore, to know about the nature of an object (whether it is heavy or light), we need to measure its *density*. When we take different objects of the same volume, we at once think about their heaviness or lightness. Out of these objects with same volume, an object which has greater mass is called the heavy object and the object which has less mass is called the light object. We can also say that heavy objects have greater density and light objects have less density. Hence, to measure the density of a given object, the mass present in its unit volume should be known. Keeping in view the above facts, *the density of an object is defined as the mass per unit volume of that object.*

If V is the volume of an object and M is its mass, then density of the substance is,

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

The symbol used to represent density is "ρ". It is a Greek letter and is pronounced as 'rho'.

Units of Density

The S.I. unit of density is kg/m^3 (kg m^{-3}).

If mass = 1 kg and volume = 1 m^3,

$$\text{Density} = \frac{1\,\text{kg}}{1\,\text{m}^3}$$

$$\therefore \quad \text{Density} = 1\ \text{kg/m}^3 \text{ or } 1\ \text{kg m}^{-3}$$

In CGS system, the unit of density is g/cm^3 (g cm^{-3}).

If mass = 1 g and volume = 1 cm^3,

$$\text{Density} = \frac{1\,\text{g}}{1\,\text{cm}^3} \text{ or } 1\ \text{g cm}^{-3}$$

$$\therefore \quad \text{Density} = 1\ \text{g/cm}^3$$

Relation between S.I. and C.G.S. units of density

$$1\ \text{kg/m}^3 = \frac{1\,\text{kg}}{1\,\text{m}^3}$$

$$= \frac{1000\,\text{g}}{1\,\text{m} \times 1\,\text{m} \times 1\,\text{m}}$$

$$= \frac{1000\,\text{g}}{100\,\text{cm} \times 100\,\text{cm} \times 100\,\text{cm}}$$

$$1\ \text{kg/m}^3 = \frac{1}{1000}\ \frac{\text{g}}{\text{cm}^3}$$

$$\therefore 1000\ \text{kg/m}^3 = 1\ \text{g/cm}^3.$$

The mass of water having a volume of 1 cm^3 at 4°C is found to be 1 g. Therefore, the density of water at 4°C is 1 g cm^{-3} in CGS system and 1000 kg m^{-3} in S.I. system.

The mass of an iron cube having a volume of 10 cm^3 is 78 g. Therefore, in CGS system, density of iron = $\frac{78\,\text{g}}{10\,\text{cm}^3}$ = 7·8 g cm^{-3} which is equivalent to 7800 kg m^{-3} in S.I. system.

Determination of Density of a Solid Heavier than Water

Suppose you want to determine the density of a stone which obviously is heavier than water. First of all, determine the mass of the stone with the help of a physical-balance. Let the mass of the stone be M. Next we need to know is the volume of the stone. We use the displacement of water method to determine the volume. There is a simple procedure.

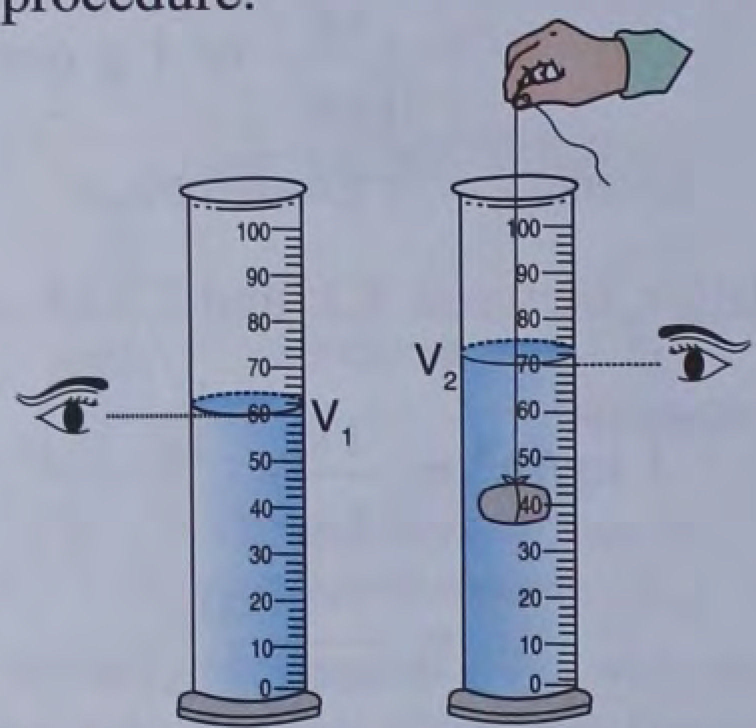


Fig. 1.8 Measuring the volume of a stone

Take a measuring cylinder partially filled with water. Tie the stone with a string (Fig. 1.8). Note the initial reading V_1 of water level in the measuring cylinder. Now immerse the stone into the cylinder containing water. Note the reading of the new water level. Say, it is V_2. The difference of the final and initial readings ($V_2 - V_1$) gives the volume of the stone. Since,

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

Hence, Density of stone = $\frac{M}{V_2 - V_1}$

Substituting the values of M, V_2 and V_1, we can calculate the density of the stone.

Example 1 : A piece of iron of volume 30 cm^3 has a mass of 234 g. Find the density of iron.

Solution : Given $M = 234$ g

$V = 30$ cm^3

$\rho = ?$

$$\rho = \frac{M}{V} = \frac{234\text{ g}}{30\text{ cm}^3} = 7{\cdot}8 \text{ g cm}^{-3}.$$

Example 2 : 10 cm^3 of silver weighs 103 g. Find the density of silver in kg m^{-3}.

Solution :

Given $M = 103$ g and volume = 10 cm^3

Since, $\rho = \frac{M}{V}$

$$\therefore \rho \text{ of silver} = \frac{103\text{ g}}{10\text{ cm}^3} = 10{\cdot}3 \text{ g cm}^{-3}$$
$$= 10{\cdot}3 \times 1000 \text{ kg m}^{-3}$$
$$= 10300 \text{ kg m}^{-3}$$

Alternative Method

Given $M = 103$ g

$$= \frac{103}{1000} \text{ kg} = 0{\cdot}103 \text{ kg}$$

$$V = 10 \text{ cm}^3 = \frac{10}{100\times100\times100} \text{ m}^3$$
$$= 0{\cdot}00001 \text{ m}^3$$

Since, $\rho = \frac{M}{V}$

$$\therefore \rho \text{ of silver} = \frac{0{\cdot}103\text{ kg}}{0{\cdot}00001\text{ m}^3} = 10300 \text{ kg m}^{-3}.$$

Example 3 : A substance having a density of 0·8 g/cm^3 has a mass of 64 g. Find the volume of the substance.

Solution : $\rho = 0{\cdot}8$ g cm^{-3}

$M = 64$ g

Since, $\rho = \frac{M}{V}$

$$\therefore \quad V = \frac{M}{D} = \frac{64\text{ g}}{0{\cdot}8\text{ g cm}^{-3}}$$

$$= \frac{640}{8}\text{ cm}^3 = 80\text{ cm}^3$$

Example 4 : The density of a substance is $2{\cdot}7$ g cm^{-3}. Find the mass of a block of the substance of volume 100 cm^3.

Solution : $\rho = 2{\cdot}7$ g cm^{-3}

$V = 100$ cm^3

Mass = ?

Since, $\rho = \frac{M}{V}$

$$\therefore \quad M = \rho \times V$$

$$= 2{\cdot}7\text{ g cm}^{-3} \times 100\text{ cm}^3 = 270\text{ g}$$

Example 5 : 3 litres of spirit has a mass of 6 kg. Calculate the density of spirit in (i) g cm^{-3} and (ii) density of spirit in kg m^{-3} (Given 1 lit. = 1000 cm^3).

Solution :

Mass of spirit = 6 kg = 6000 g

Volume of spirit = 3 litres = 3000 cm^3

(i) Density of spirit, $\rho = \frac{M}{V} = \frac{6000\text{ g}}{3000\text{ cm}^3}$

$= 2$ g cm^{-3}

(ii) Density of spirit in kg m^{-3} = 2×1000

$= 2000$ kg m^{-3}

Example 6 : A rectangular block of glass is 30 cm long, 25 cm wide and has a thickness of 2 cm. Find its density if it weighs $7{\cdot}5$ kg.

Solution :

Volume of glass block

= Length × Breadth × Thickness

= 30 cm × 25 cm × 2 cm

= 1500 cm^3

Mass of block = $7{\cdot}5$ kg = 7500 g

Since $\rho = \frac{M}{V}$

$$\therefore \quad \rho = \frac{7500\text{ g}}{1500\text{ cm}^3} = 5\text{ g cm}^{-3}$$

Intext Questions

Fill in the blanks :

(a) Weight is dependent on .... and ....

(b) The mass of a body can never be ....

(c) A beam balance must have both arms of .... length.

(d) One .... is defined as the mass of 1 litre of water at 4°C.

RELATIVE DENSITY

Take equal volumes of iron and aluminium and weigh them. You will find that iron is heavier than aluminium. Again, take equal volumes of aluminium and wood, now you will find that aluminium is heavier than wood. Does this not create a confusion as to which is heavier than what ? To avoid this confusion, the density of most substances is compared to the density of water, since the density of water at 4°C is 1 g cm^{-3}. If an object, like a piece of wood, floats on water, it is less dense than water. If a piece of rock sinks in water, it is more dense than water. As a result, the density of every substance is expressed relative to the density of water at 4°C.

The **relative density** (R.D.) of a substance is defined as *the ratio of the density of the substance to the density of water at 4°C*. Relative density is also known as **specific gravity** of the substance.

$$\therefore \text{ R.D.} = \frac{\text{Density of substance}}{\text{Density of water at 4°C}}$$

Since, density $= \frac{\text{mass}}{\text{volume}}$, therefore if we take equal volumes (V) of the substance and water, we have

$$\text{R.D.} = \frac{\text{density of substance}}{\text{density of water at 4°C}}$$

$$= \frac{(\text{Mass of substance}) \div \text{volume } (V)}{(\text{Mass of water at 4°C}) \div \text{volume } (V)}$$

$$= \frac{\text{Mass of a certain volume of substance}}{\text{Mass of the same volume of water at 4°C}}$$

Thus, relative density can also be defined as the **ratio of mass of a substance to the mass of the same volume of water at 4°C.**

Since relative density is the ratio of two densities, it has no unit.

Substance	Relative density
Alcohol	0·82
Mercury	13·6
Water (4°C)	1
Dry air	0·0013
Oxygen	0·00143
Petrol	0·72
Sea water	1·02

DETERMINATION OF RELATIVE DENSITY OF A LIQUID

The relative density (R.D.) of a liquid is determined using a special bottle called specific gravity (S.G.) bottle which is also called R.D. bottle.

We take an empty dry specific gravity bottle. We weigh it accurately, along with the stopper, on a physical balance. Suppose it weighs M_1 *i.e.*, its mass is M_1.

Fig. 1.9 Specific gravity bottle (R.D. bottle)

Now we fill the bottle completely with water and insert the stopper. The extra water overflows through the hole in the stopper. Dry the outer surface with a blotting paper and then measure the bottle again on a physical-balance. Suppose, the mass is M_2. Now empty the bottle and dry it with hot air. Fill the bottle again completely with the given liquid, say, mustard oil and insert the stopper. Again, the extra mustard oil, if any, will overflow through the hole in the stopper. Dry and weigh the bottle again. Suppose the mass recorded is now M_3.

Therefore, we write,

Mass of empty S.G. bottle $= M_1$

Mass of S.G. bottle + water $= M_2$

Mass of S.G. bottle + mustard oil $= M_3$

Now, mass of water $= M_2 - M_1$

Mass of mustard oil $= M_3 - M_1$

$\therefore$ R.D. of mustard oil

$$= \frac{\text{Mass of mustard oil}}{\text{Mass of equal volume of water}} = \frac{M_3 - M_1}{M_2 - M_1}$$

Example 1 : A specific gravity bottle weighs 25 g. When fully filled with water, it weighs 55 g. When filled with alcohol, it weighs 49 g. Find the relative density of alcohol.

Solution :

$$M_1 = 25 \text{ g}$$
$$M_2 = 55 \text{ g}$$
$$M_3 = 49 \text{ g}$$
$$\therefore \quad M_2 - M_1 = 55 \text{ g} - 25 \text{ g} = 30 \text{ g}$$
$$M_3 - M_1 = 49 \text{ g} - 25 \text{ g} = 24 \text{ g}$$
$$\text{R.D. of alcohol} = \frac{M_3 - M_1}{M_2 - M_1} = \frac{24\text{ g}}{30\text{ g}} = 0{\cdot}8$$

Example 2 : A stone of mass 60 g has a volume of 30 cm^3. What is its density ? Also find the relative density of the stone.

Solution : Given $M = 60$ g

$$V = 30 \text{ cm}^3$$

$$\text{Since, } \rho = \frac{M}{V} = \frac{60\text{ g}}{30\text{ cm}^3} = 2 \text{ g cm}^{-3}.$$

$$\text{R.D.} = \frac{\text{Density of stone}}{\text{Density of water at 4°C}}$$

$$= \frac{2\text{ g cm}^{-3}}{1\text{ g cm}^{-3}} = 2$$

ACTIVITY 6

Using a density-bottle and a beam-balance in your physics laboratory, determine the density of (i) Water (ii) Alcohol (iii) Kerosene Oil.

SINKING AND FLOATING

When a solid object is placed over a liquid whose density is less than the density of the object, the object will **sink**. If the same object is placed over a liquid of density higher than the density of the object, it will **float**.

A solid iron ball with a density of 7·86 g cm^{-3} will sink in water which has a density of 1·0g cm^{-3}. The same iron ball will float in mercury which has a density of 13·6 g cm^{-3}.

A small cork will float on water because the density of the cork is less than the density of water, whereas an iron nail will sink in water because the density of iron nail is more than the density of water.

Hence, we arrive at the conclusion that **a solid body will float on a liquid if its density is less than the density of the liquid, while it will sink in a liquid, if its density is more than the density of the liquid.**

Iron needle sinks in water but not an iron ship

Iron needle is compact and its density is 7·8 g/cm^3. Since the density of iron needle is more than the density of water (or 1 g/cm^3), it sinks in water. However, an iron ship is constructed in such a way that it is mostly hollow from within or there is sufficient amount of air inside the ship. Since the density of air is very small, thus the average density of ship becomes less than the density of water. The ship therefore floats on water.

Applications of Floatation

- It is easier for a man to swim in sea water than in fresh water because the density of sea water is greater than that of fresh water, due to dissolved salts.
- Since the density of ice is less than that of sea water, an iceberg floats in the sea water

with a small part outside. Its part hiding inside the water may be dangerous for any boat or ship sailing in water.

- A hydrometer is a device specially designed to float on a liquid. It is a device used for measuring the relative density of a liquid. Its lower bulb is weighted with lead shots or mercury which makes it float vertically in the liquid. It also has a graduated cylindrical stem to read the relative density of the liquid. It is used for testing the purity of milk, for testing concentration of acid in batteries, *etc*.

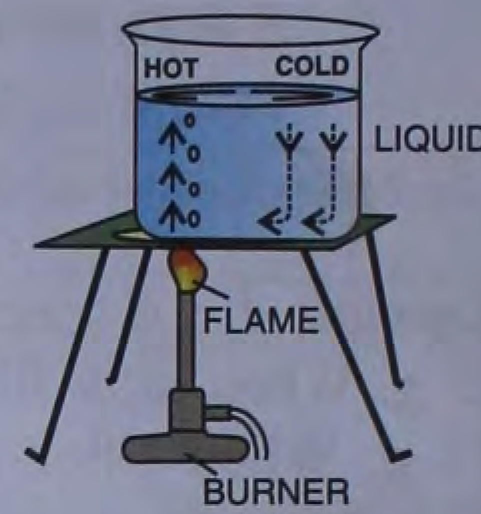
Fig. 1.10
A hydrometer

EFFECT OF TEMPERATURE ON DENSITY OF SOLIDS, LIQUIDS AND GASES

Generally, substances expand on heating and contract on cooling. But their mass remains unchanged. Therefore, density of most of the substances decreases with increase in temperature and increases with decrease in temperature.

Since liquids and gases expand on heating, the density of liquids and gases decreases with the rise in temperature. In a mixture of fluids, the hot fluid being lighter rises up and the cold fluid being denser descends down. This happens simply because the density of hot fluid decreases.

Water shows an abnormal behaviour between 0°C and 4°C, because of which its density decreases on freezing. You must have observed that ice floats on the surface of water. The density of water is maximum at 4°C, its value being 1000 kg m^{-3} (or 1 g cm^{-3}).



In practice, variation of density with temperature gives rise to **convectional currents** in liquids and gases.

Convection Current (in liquids or gases)

When a fluid (liquid or gas) is heated, it expands and becomes lighter (density decreases due to thermal expansion). This fluid being lighter rises upwards. The cold fluid being heavier moves downwards to take the place vacated by the hot fluid. The cold fluid then gets heated and again moves upwards. This cycle of upward and downward movement of the hot and cold fluid form currents in the medium which are known as **convection current**.

In the same way the transfer of heat in gases through convection process may be understood by the following experimental arrangement.

Take a rectangular box with wooden frame and base but with glass panes all around with two chimneys X and Y as shown in the figure.

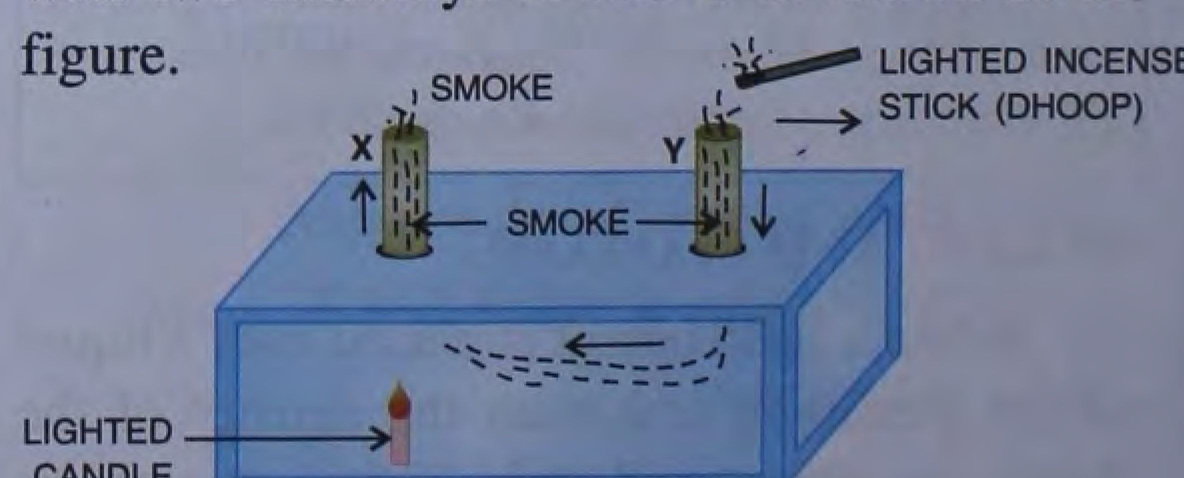


Fig. 1.11

If we bring a lighted incense stick just above the chimney Y, it is seen that smoke from the stick enters into the box through chimney Y and then goes out through the chimney X.

The candle inside the box heats up the air near the chimney X. This air becomes less dense and rises upwards through the chimney X and as a result a rational vacuum is created in the box. Therefore smoke through chimney Y rushes into the box thereby forming a convection current of smoke (as shown in Fig. 1.11).

Some practical application of convection current are given below :

1. We have ventilators near the ceiling and windows near the floor fixed in our rooms. The basic reason behind it is that when we breathe out in a room, the surrounding air becomes warm and impure. Since warm air is lighter, it rises up and moves out through the ventilators. Cold fresh air enters the room through windows and doors to take its place. Thus, convection current is formed in the room which keep the air in the room fresh and cool.
2. We normally install an air-conditioner in a room at some height, simply because the cold air coming out of the AC being heavier moves downwards and the hot air in the room being lighter moves upwards. This circulatory upward and downward motion of hot and cold air forms convection current and the entire room becomes cold.
3. A refrigerator has a cooling (or freezing) chest near its top. Now, the air near the top in contact with the freezing chest gets cooled. The cold air being heavier comes down and the hot air being lighter rises from the lower part. Thus, convection current is set up. The cold air from the cooling chest which is coming down cools the entire region of the refrigerator below the chest.

Intext Questions

1. Define relative density.
2. What is the unit of density ?
3. What is specific gravity ?

TEST YOURSELF

A. Fill in the blanks :

1. The quantity of matter present in a body regardless of its volume, size or any force acting on it, is called ....
2. The weight of a body is the force of .... acting upon it.
3. 1 atomic mass unit (u) = ... kg.
4. 1 kg is the mass of .... ml of water at 4°C.
5. The S.I. unit of density is ....
6. 1 g of iron will occupy .... volume as compared to 1 g of aluminium.
7. 1 kg m^{-3} = ... g cm^{-3}
8. The density of ice .... on melting.

Ans. (1) mass (2) gravity (3) $1{\cdot}66 \times 10^{-27}$ (4) 1000 (5) kgm^{-3} (6) less (7) $\frac{1}{1000}$ gcm^{-3} (8) increases

B. Short Answer Questions

1. Define density of a substance.
2. The density of mercury is 13·6 g cm^{-3}. What does this statement imply ?
3. Why is there a capillary bore in the stopper of the density bottle ?

4. Which of the following will sink or float in water ? (density of water = 1 g cm^{-3})
   (a) Body A having density 500 kg m^{-3}
   (b) Body B having density 2520 kg m^{-3}
   (c) Body C having density 1100 kg m^{-3}
   (d) Body D having density 0·85 g cm^{-3}

C. Long Answer Questions

1. Briefly explain the formation of convection current in a fluid.
2. Briefly explain, how you will measure the density of a liquid with the help of a density-bottle.
3. Why does ice float on the surface of water ?
4. State and define S.I. unit of weight.
5. State the characteristics of a true beam balance.
6. State two important differences between mass and weight.
7. Draw a neat and labelled diagram of a beam balance and a spring-balance.

D. Numerical Problems

1. The density of air is 1·28 g/litre. Express it in : (a) g cm^{-3} (b) kg m^{-3}
   Ans. (a) 0·00128 g cm^{-3} (b) 1·28 kg m^{-3}
2. 28 cm^3 of zinc having density 4200 kg m^{-3} is placed on one pan of a beam-balance. What known weight must be placed on the other pan to secure a balance ? **Ans.** 117.6 g
3. The dimensions of a hall are 10 m × 7 m × 5 m. If the density of air is 1·11 kg m^{-3}, find the mass of air in the hall. **Ans.** 388·5 kg
4. An empty density-bottle weighs 21·8 g. When fully filled with a liquid A, it weighs 40·6 g. If the volume of the density-bottle is 20 ml, what is the density of liquid A ? **Ans.** 0·94 g cm^{-3}
5. (a) Density of aluminium is 2·7 g/cm^3. Express it in kg/m^3. **Ans.** 2700 kg/m^3
   (b) Density of alcohol is 600 kg/m^3. Express it in g/cm^3. **Ans.** 0·60 g/cm^3
6. A piece of zinc of mass 438·6 g has a volume of 86 cm^3. Calculate the density of zinc.
   Ans. 5·1 g/cm^3
7. A piece of wood of mass 150 g has a volume of 200 cm^3. Find the density of wood in (a) CGS system and (b) S.I. system.
   Ans. (a) 0·75 g/cm^3, (b) 750 kg/m^3
8. 5 litres of kerosene oil is found to weigh 6·60 kg. Find the density of kerosene oil in (a) CGS system and (b) S.I. system.
   Ans. (a) 1·32 g/cm^3, (b) 1320 kg/m^3
9. Calculate the volume of wood of mass 6000 kg when the density of wood is 0·8 g/cm^3. **Ans.** 7·5 m^3
10. Volume of a metal cube is 200 cm^3. If the density of the metal is 7·5 g/cm^3, find the mass of the metal in kilogram. **Ans.** 1·5 kg
11. Calculate the density of solid from the following data :
    (a) Mass of solid = 72 g
    (b) Initial volume of water in measuring cylinder = 24 cm^3
    (c) Final volume of water when solid is immersed in water = 42 cm^3
    Ans. 4·0 g cm^{-3}
12. An empty density bottle weighs 22 g. When completely filled with water, it weighs 50 g and when completely filled with brine solution, it weighs 54 g. Calculate the density of brine solution. **Ans.** 1·14 g/cm^3
13. An empty density bottle weighs 30 g. When completely filled with water, it weighs 75 g and when completely filled with a liquid x, it weighs 65 g. Calculate (a) volume of density bottle, (b) density of liquid x.
    Ans. (a) 45 cm^3, (b) 0·77 g/cm^3
14. A boy in your class has a mass of 40 kg. What is his weight in Newton on
    (a) the surface of the earth
    (b) the surface of the moon. (Take $g = 9{\cdot}8$ ms^{-2} on earth and $g = 1{\cdot}568$ ms^{-2} on moon)
    Ans. (a) 392 N (b) 62·72 N

RECAPITULATION

- Mass is the total amount of matter contained in a body. The position of the body does not change the mass of the body.
- Weight is the pull or gravitational force of the earth by which it attracts body towards its centre.
- The weight of the body changes with the acceleration due to gravity.
- Weight of a body is zero at the centre of the earth.
- Mass per unit volume of a substance is called density of the substance.
- The unit of density in S.I. system is kg m^{-3} and g cm^{-3} in CGS system.
- The density of body in S.I. system is 1000 × density of the body in CGS system.
- The density of liquids and gases decreases with the rise in temperature.
- If the density of a liquid is more than the density of the body, then the body floats on the liquid. This is the reason why a ship made of iron floats and a small iron needle sinks in water.