3. Force and Pressure

Can you recall? What is a force?

A stationary object on which no force is acting, remains stationary. An object in motion continues to move with the same speed and direction when no force is acting on the object. This is Newton's first law of motion.

Observe Observe the pictures in figures 3.1 and 3.2.

3.1 Various Actions

Contact and Non contact forces : In fig. 3.1 a car moves in forward direction when a man applies force from behind. A reluctant dog is being pulled by his master and a boy playing football is kicking the ball away. What do you observe from these? A force acts on two bodies through an interaction between them.

As seen in fig 3.2, iron nails get attracted to the pole of a magnet due to magnetic force.

3.2 Some events

A coconut is falling from the coconut tree. Objects are attracted to the earth due to the force of gravity. When a comb gets rubbed against hair, small pieces of paper kept on a table get attracted to the comb. The comb has an electrostatic charge and there is an induced opposite charge on the pieces of paper and the pieces stick to the comb.

In fig 3.1 a force is seen to act through a direct contact of the objects or via one more object. Such a force is called 'Contact force'. In fig 3.2, a force is applied between two objects even if the two objects are not in contact, such a force is called a 'Non contact force'.

Muscular force is an example of contact force and is applied to objects with the help of our muscles. It is applied in several cases such as lifting, pushing, pulling. On the contrary, forces like magnetic force, gravitational force, electrostatic force act without a contact. Therefore, these are the examples of non contact forces.

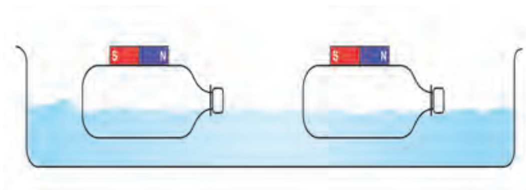
When a ball is kept on a table and pushed a little, it moves ahead and gets slow and stops. A car running on a plane road travels some distance and stops after the engine is switched off. This is because of the force of friction between the ground surface and the object in motion. In the absence of frictional force, the object would have remained in motion. Frictional force is very useful in daily life. While walking, we push the ground behind with our feet. In the absense of friction, we will slip and will not be able to walk. All the objects in motion have a frictional force acting on them which is acting in the direction opposite to the direction of motion. You must have seen that one tends to slip over banana peel on the street. Similarly one can slip due to mud. Both these examples occur due to reduced friction.

Use your brain power

Make a list of some more examples in which contact and non contact forces are applied. Write the types of force.

Try this

Take two plastic bottles with rectangular shape. Close their openings by fitting the lids tightly. Keep two small bar magnets on them and fix them neatly using a sticking tape. (fig 3.3)



3.3 Non contact force

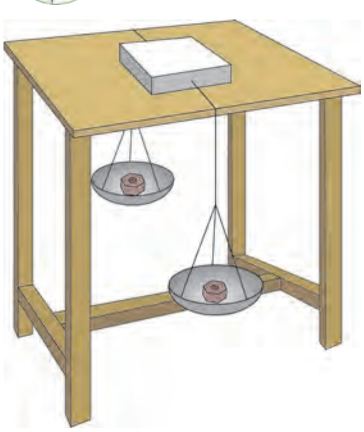
Fill a big plastic tray with water and leave the two bottles floating with magnets at the top. Take one bottle near the other. If the north pole of the magnet is near the south pole of the other magnet, the bottles will head towards each other, because unlike poles attract each other. Observe what will happen when the directions of the bottles are changed. We can observe change in the motion of the bottles without any direct contact. This means that there exists a non contact force between the two magnets.

Use your brain power

You have learnt about static electricity in the previous standard. Electrostatic force is a non contact force. To verify this, which experiment will you perform?

Balanced and unbalanced force

Try this


3.4 Balanced and unbalanced force

Take a cardboard box, tie thick string to its two sides and keep it on a smooth table as shown in fig. 3.4. Take the strings on both sides of the table. Tie weighing pans of equal masses to the two ends. Keep equal masses in both the pans. The box does not move on the table. If more mass is kept in one of the pans than in the other, the box starts moving in the direction of that pan. Equal gravitational force acts on both the pans when equal masses are kept in them. This means balanced forces act on the box, with effective force equal to zero as these are acting in opposite directions. On the contrary, if more mass is kept in one pan than in the other, the box starts moving in the direction of the pan with more mass. When unequal forces are applied to the box on the two sides, an unbalanced force acts on the box resulting in imparting motion to the box.

Children playing tug of war pull the rope in their respective directions. If the pull of the force is equal on the two sides, the rope does not move. If the force is more on one side, the rope moves in that direction. This means that initially, the two forces are balanced; the rope moves in the direction of higher force when the forces become unbalanced.

Let us see one more example. When big grain storage container is required to slide on the ground, it becomes easier if two persons push it rather than one person. When the force is applied by both in the same direction, the movement is easy. You may have experienced this. What do we understand from this example?

a. If several forces are applied on an object in the same direction, a force equal to their addition acts on that object.

b. If two forces are applied on one object in directions opposite to each other, a force equal to their difference acts on the object.

c. A force is expressed in magnitude and direction. Force is a vector quantity.

If more than one force are acting on a body, then the effect on the body is due to the net force.

When a force is applied on a stationary object it moves, its speed and direction change. Similarly, a force is required to stop an object in motion. An object can change its shape due to force. While kneading a dough made from flour, the dough changes its shape when a force is applied. A potter applies a force in a specific direction while shaping the pot. Rubber band, when stretched, expands. There are many such examples.

Inertia : We have seen that an object changes its state of motion due to force. In the absence of a force, objects exhibit a tendency to remain in the existing state of motion. Let us see the following examples.

Try this

Activity 1 : Take a postcard and keep it on a glass. Keep a 5 Rupee coin on it. Now skillfully push the card. The coin straight away falls in the glass. Have you ever done this?

Activity 2 : Hang a half a kg mass to a stand, with a string 1. Tie another string 2 to the mass and keep it hanging. Now pull the string 2 with a jerk. The string 2 breaks but the mass does not fall. Heavy mass does not move. Now pull the string 2 slowly. The string 1 breaks and the mass falls down. This is because of the tension developed in the string 2 due to the mass.

Pressure : You must have observed the tyres of two wheelers and four wheelers getting 'Pressurized'. The air filling machine has a 'pressure' indicating dial or a digital meter showing the digital reading of 'pressure'. The machine fills the 'pressure' to a certain value. You are aware that a force has to be applied for filling air in the bicycle tyre with a hand pump. By applying force, air 'pressure' is increased and then the air is pushed into the tyre. Are 'force' and 'pressure'related?

Activity 3 : Take some sharp pointed nails and push them into a wooden plank by hammering on their heads. Now take a nail and hold it with its head on the plank and hammer it down from the pointed end. When pressing the drawing pins into a drawing board, they get into the board easily. By applying a force using the thumb one can push the pins into the board. On the contrary, while pressing ordinary pins into the board with a thumb, the thumb may get hurt.

Always remember

The tendency of an object to remain in its existing state is called its inertia. This is why an object in stationary state remains in the same state and an obect in motion remain in the state of motion in the absence of an external force.

Types of inertia : 1. Inertia of the state of rest : An object in the state of rest can not change its state of rest due to its inherent property. This property is called the inertia of the state of rest. **2. Inertia of motion :** The inherent property of an object due to which its state of motion can not change, is called its inertia of motion. For exmaple a revolving electric fan continues to revolve even after it is switched off, passengers sitting in the running bus get a jerk in the forward direction if the bus suddenly stops. **3. Directional inertia :** The inherent property of an object due to which the object can not change the direction of its motion, is called directional intertia. For example, if a vehicle in motion along a straight line suddenly turns, the passengers sitting in it are thrown opposite to the direction of turning.

What does this simple experiment tell? The nail easily penetrates into wood from its pointed end. From this you will notice that when a force is applied on the head of the nail, it is easy to hammer it into the plank.

Use your brain power

It is easy to cut vegetables, fruits with a sharp knife. A blunt knife does not work here. Why does this happen?

The force exerted perpendicularly on a unit area is called 'pressure'

$$\text{Pressure} = \frac{\text{Force}}{\text{Area on which the force in applied}}$$

> Presently we are considering only the force acting on an area in a direction perpendicular to it.

Unit of pressure : The SI unit of force is Newton (N). Area is measured in m^2. Therefore, the SI unit of pressure is N/m^2. It is known as Pascal (Pa). In atmospheric science, the unit for pressure is bar
$1 \text{ bar} = 10^5 \text{ Pa}$. Pressure is a scalar quantity.

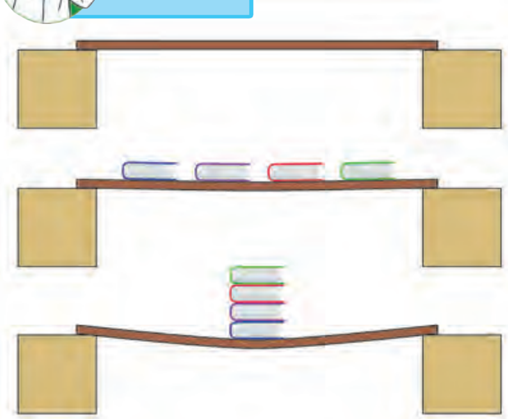
If area increases, pressure reduces for the same force, and if the area decreases, the pressure increases for the same force.

For example, due to natural adaptation the bottom surfaces of camel's feet are broad. Hence the camel's weight is exerted on a large area and the pressure on the sand is reduced. This is why camel's feet do not penetrate into the sand and it becomes easy to walk.

Pressure on solids : Air pressure is exerted on all the objects kept in air. When a weight is kept on a solid, pressure is exerted on it. This pressure depends on the value of the weight and the contact area between the two.

Try this

Do the activity as depicted in fig 3.5. What is seen?



3.5 Force and Pressure

Use your brain power

You must have seen a vegetable vendor carrying a basket on her head. She keeps a twisted piece of cloth on the head, below the basket. How does it help?

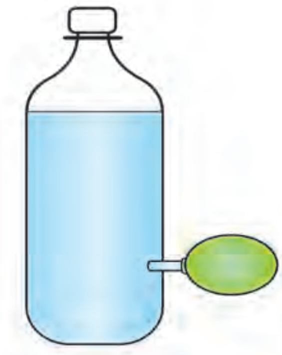
We can not stand at one place for a long time. How then can we sleep on a place for 8 and odd hours?

For skiing on ice, why are long flat ski used?

Try this

Pressure of liquid

Activity 1 : Take a plastic bottle. Take a 10 cm long piece of a glass tube on which a rubber balloon can be fitted. Warm up one end of the glass tube and gently push in the bottle at about 5 cm from the bottom (fig 3.6). To avoid water leakage, apply molten wax on the side of the glass tube. Now fill water slowly in the bottle and see how the balloon inflates. What is observed? The pressure of water acts on the side of the bottle as well.



3.6 Pressure of Liquid

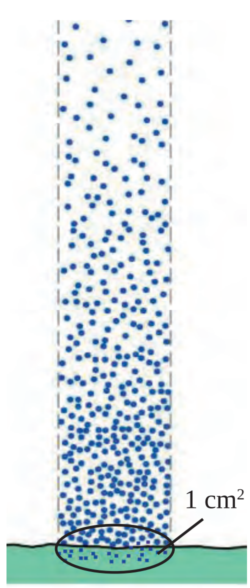
Activity 2 : Take a plastic bottle. Pierce it with a thick needle at the points 1,2,3 as shown in the fig. 3.7. Fill water in the bottle upto full height. As shown in the figure, water jets will be seen emerging and projecting out. The water jet emerging from the hole at the top will fall closest to the bottle. The jet from the lowest hole falls farthest from the bottle. Also, jets coming out from the two holes at the same level fall at the same distance from the bottle. What is understood from this? At any one level, the liquid pressure is the same. Also, the pressure increases as the depth of the liquid increases.

3.7 Level and Pressure of Liquid

Gas pressure : If a balloon is inflated by filling air by mouth, it inflates on all sides. If a pin hole is created in the balloon, air leaks out and the balloon does not inflate fully. It is realized that like a liquid, gas also exerts pressure on the wall of the container in which it is enclosed. All gases and liquids have a common name 'fluid'. Fluids in a container exert pressure from within, on the walls and the bottom of the container. A fluid enclosed in a containers exerts its pressure equally in all directions at a point within the fluid.

Atmospheric Pressure : Air surrounds the earth from all sides. This layer of air is called atmosphere. The atomosphere exists to about 16 km height. It further extends up to about 400 km in a very dilute form. The pressure created due to air is called the atmospheric pressure. Imagine that a very long hollow cylinder of unit cross-sectional area is standing on the surface of the earth, and it contains air (fig.3.8). Weight of this air is the force applied in the direction of the centre of the earth. This means that atmospheric pressure is the ratio of this weight divided by the area of the surface.

The air pressure at the sea level is called 1 Atomosphere pressure. Air pressure decreases as one goes up in height from the sea level.



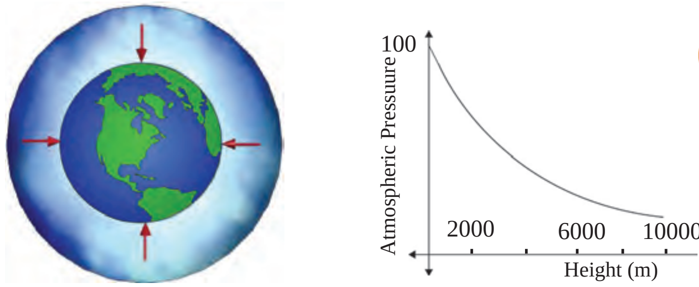
3.8 Atmospheric Pressure

1 Atomosphere = 101×10^3 Pa = 1 bar = 10^3 mbar

1 mbar $\approx 10^2$ Pa (hecto pascal)

Atmospheric pressure is specified in the units mbar or hectopascal (hPa). The atmospheric pressure at a point in air is equal from all sides. How is this pressure created? If air exists in a closed container, the air molecules in random motion continuously hit the walls of the container. In this interaction a force is exerted on the walls of the container. Pressure is created due to this force.

We constantly bear the atmospheric pressure on our heads. However the cavities in our body are also filled with air and arteries and veins are filled with blood. Therefore we do not get crushed under water and due to atmospheric pressure, as the pressure is balanced. The earth's atmospheric pressure decreases with height from the sea level as shown in fig 3.9.



3.9 Atomospheric Pressure

Use your brain power

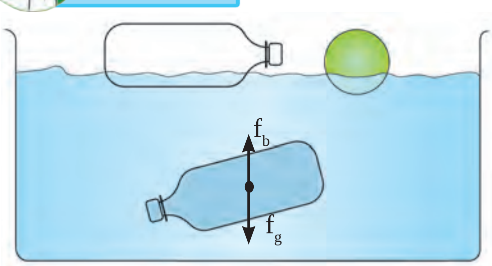
At the sea level the atmospheric pressure 101 x 10^3 Pa is acting on a table top of size $1m^2$. Under such a heavy pressure, why doesn't the table top crumble down?

Buoyant Force :

Try this

Take a plastic bottle and fix the lid tightly. Now place it in water and see. It will float on water. Try and push it into the water. Even when pushed, it continues to float. This experiment can also be done with a plastic hollow ball (fig 3.10)

Now fill the bottle with water to the fullest capacity and close the lid, and release in water. The bottle will float inside the water. Why does this happen?



3.10 Balanced and unbalanced Buoyant force

The empty plastic bottle floats on the surface of water. On the contrary, the bottle full of water floats inside water but does not go to the bottom. The weight of the empty bottle is negligible as compared with the weight of the water inside. Such a bottle with water neither floats on the surface, nor does it go to the bottom. This means the force due to gravity acting downwards (f_g), must have been balanced by an opposing force in the upward direction (f_b) on the bottle filled with water. This force must have originated from the water surrounding the bottle. The upward force acting on the object in water or other fluid or gas is called Buoyant force (f_b).

Use your brain power

While pulling a bucket from a well, the bucket full of water immersed fully in water appears to weigh less than when it has been pulled out of water. Why?

Try this

Take a piece of thin aluminium sheet and dip it in water in a bucket. What do you observe? Now shape the same piece of aluminium into a small boat and place it on the surface of water. If floats, isn't it?

An iron nail sinks in water, but why does the massive steel ship float on it? When an object is dipped in a liquid, a buoyant force acts on it and hence it appears that the weight of the object is reduced.

It becomes easier to swim in sea water than in fresh water. This is because the density of sea water is higher than the density of fresh water, due to salts dissoved in sea water. In this book you have seen that lemon sinks in a glass filled with water but it floats when we stir in two spoons of salt in the water. In salty water the buoyant force exceeds the gravitational force. What is understood from these examples? Buoyant force depends on two factors

1. Volume of the object - The buoyant force is more if the volume of the dipping object is more.
2. Density of liquid - More the density of liquid, more is the force of buoyancy.

Do you know?

How is it decided that in object left in liquid will get sink in the liquid, will float on the surface, or will float inside the liquid?

1. The object floats if the buoyant force is larger than its weight.
2. The object sinks if the buoyant force is smaller than its weight.
3. The object floats inside the liquid if the buoyant force is equal to its weight.

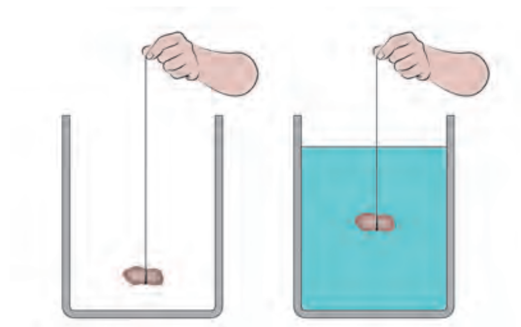
Which forces are unbalanced in the above cases ?

Archimedes Principle :

Try this

Take a long rubberband and cut it at one point. At one of its ends tie a clean washed stone or a 50 g weight as shown in figure 3.11.

Now hold the other end of the rubberband and make a mark there. Keep the stone hanging in air and measure the length of the rubberband from the stone to the mark made earlier. Now take water in a pot and hold the rubberband at such a height that the stone sinks in it. Again measure the length of the rubberband up to the mark. What is observed? This length in shorter than the earlier length. While dipping the stone in water, length of the stretched rubber gets slowly reduced and is minimum when it sinks completely. What could be the reason for a shorter length of the rubberband in water?



3.11 Buoyant Force

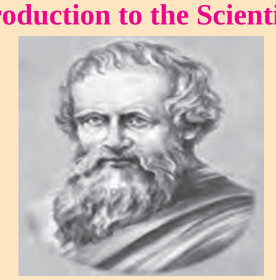
When the stone is sunk in water, a buoyant force acts on it in the upward direction. The weight of the stone acts downwards. Therefore, the force which acts on it in the downward direction is effectively reduced.

How much is the magnitude of the buoyant force? Is it the same for all the liquids? Is the buoyant force of equal magnitude for all objects? The answers to these questions are embodied in Archimedes Principle. This principle states that : **When an object is partially or fully immersed in a fluid, a force of buoyancy acts on it in the upward direction. This force is equal to the weight of the fluid displaced by the object.**

Use your brain power

Explain the obsevations in the earlier experiments according to the Archimedes Principle.

Introduction to the Scientist :



Archimedes
(287 B.C - 212 B.C)

Archimedes was a Greek Scientist and a mathematician with sharp intelligence. He found out the value of π by numerical calculations. His knowledge of levers, pulleys, wheels in physics was useful to the Greek army in fighting against the Roman army. He became famous due to his work in geometry and mechanics. When he entered a bath tub for taking bath, he discovered the above principle by observing the overflowing water. He came out in the same state shouting ‘eureka’, ‘eureka’, meaning ‘I found it’, ‘I found it.’

The use of Archimedes Principle is very wide. This principle has been used in the construction of ships and submarines. The instruments such as lactometer, hygrometer are based on this principle.

Density of substance and Relative density

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

The SI unit of density is kg/m^3. The property density is very useful in deciding the purity of the substance. The relative density of a substance is expressed w.r.t. the density of water.

$$\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of water}}$$

this being a ratio of two equal physical quantities it has no unit. Relative density of a substance is called its 'specific gravity.'

Solved examples

Example 1. The area of the bottom of a tiffin box is 0.25 m^2 and weight is 50 N, Calculate the pressure exerted by the box on the shelf.

Given : Area = 0.25 m^2, weight of the box = 50 N, Pressure = ?

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{50 \text{ N}}{0.25 \text{ m}^2} = 200 \text{ N/m}^2$$

Example 2. Calculate the relative density of iron if the density of water is 10^3 kg/m^3 and the density of iron is $7.85 \times 10^3 \text{ kg/m}^3$.

Given : density of water = 10^3 kg/m^3, density of iron = $7.85 \times 10^3 \text{ kg/m}^3$

Relative density of iron = ?

Relative density of iron

$$= \frac{\text{(density of iron)}}{\text{(density of water)}}$$

$$= \frac{7.85 \times 10^3 \text{ kg/m}_3}{10^3 \text{ kg/m}^3} = 7.85$$

Example 3. The area of the tip of a screw is 0.5 mm^2 and its weight is 0.5 N. Calculate the pressure (in Pa) exerted by the screw on a wooden plank.

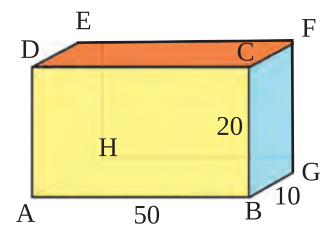
Given : Area = $0.5 \times 10^{-6} \text{ m}^2$

Weight of the screw = 0.5 N, Pressure =?

$$\text{Pressure} = \frac{\text{weight}}{\text{area}} = \frac{0.5\text{N}}{(0.5\times10^{-6}\text{m}^2)} = 10^6 \text{ N/m}^2$$

$= 10^6$ Pa

Example 4. Mass of a block of metal is 10 kg and its dimensions are length 50 cm, breadth 10 cm, height 20 cm. (See fig.) If the metal block is placed on the following suface on the table, find out on which of the surface ABCD, CDEF and BCFG will the pressure exerted on the table be maximum.



Given : Weight of the block = mg =10 x 9.8N =98 N

For the surface ABCD, length = 50 cm, height = 20 cm.

Area = 50 cm x 20 cm

$= 1000 \text{ cm}^2 = 0.1\text{m}^2$

$$\text{Pressure} = \frac{\text{weight}}{\text{area}} = \frac{98}{(0.1)} = 980 \text{ Pa}$$

For the surface CDEF, length = 50 cm breadth = 10 cm

Area = 50 cm x 10 cm = 500 cm^2 = 0.05 m^2

$$\text{Pressure} = \frac{\text{weight}}{\text{area}} = \frac{9800}{5} = 1960 \text{ Pa}$$

For the surface BCFG, height = 20 cm breadth = 10 cm

Area = 20 cm x 10 cm

$= 200 \text{ cm}^2$

$= 0.02 \text{ m}^2$

$$\text{Pressure} = \frac{\text{weight}}{\text{area}} = \frac{98 \text{ N}}{0.02 \text{ m}^2}$$

= 4900 Pa : Maximum Pressure. Hence, smaller the area of contact, larger is the pressure.

Example 5. A piece of marble tile weighs 100 g in air. If its density is 2.5 g/cc, what will be its weight in water ?

Given : Weight in air = 100 g
Density = 2.5 g/cc $\therefore$ Volume = 100g /(2.5 g/cc) = 40 cc
Therefore, according to Archemedes principle, when the piece is dipped in water, water of volume equal to the volume of the piece i.e. 40 cc will be displaced. The loss in the weight of the piece will be equal to the weight of displaced water 40g.
$\therefore$ Weight in water = 100 g - 40 g = 60 g

Exercises

1. Write proper word in the blank space.

a. The SI unit of force is ....
(Dyne, Newton, Joule)

b. The air pressure on our body is equal to........... pressure.
(Atmospheric, Sea bottom, Space)

c. For a given object, the buoyant force in liquids of different.... is............... .
(the same, density, different, area)

d. The SI unit of pressure is ....
(N/m^3, N/m^2, kg/m^2, Pa/m^2)

2. Make a match.

A group	B group
1. Fluid	a. Higher pressure
2. Blunt knife	b. Atmospheric Pressure
3. Sharp needle	c. Specific gravity
4. Relative density	d. Lower pressure
5. Hecto Pascal	e. Same pressure in all directions

3. Answer the following questions in brief.

a. A plastic cube is released in water. Will it sink or come to the surface of water?

b. Why do the load carrying heavy vehicles have large number of wheels?

c. How much pressure do we carry on our heads? Why don't we feel it?

4. Why does it happen?

a. A ship dips to a larger depth in fresh water as compared to marine water.

b. Fruits can easily be cut with a sharp knife.

c. The wall of a dam is broad at its base.

d. If a stationary bus suddenly speeds up, passengers are thrown in the backward direction.

5. Complete the following tables.

Mass (kg)	Volume (m^3)	Density (kg/m^3)
350	175	-
-	190	4

Density of Metal (kg/m^3)	Density of water (kg/m^3)	Relative Density
	10^3	5
8.5×10^3	10^3	-

Weight (N)	Area (m^2)	Pressure (Nm^{-2})
-	0.04	20,000
1500	500	-

6. The density of a metal is 10.8×10^3 kg/m^3. Find the relative density of the metal.

(Ans. 10.8)

7. Volume of an object is 20 cm^3 and the mass in 50 g. Density of water is 1 gcm^{-3}. Will the object float on water or sink in water?

(Ans : Sink)

8. The volume of a plastic covered sealed box is 350 cm^3 and the box has a mass 500 g. Will the box float on water or sink in water? What will be the mass of water displaced by the box?

(Ans : Sink, 350 g)

Project :

Video record all the experiments (Try it) in this chapter with the help of mobile phone and send to others.

JU1ATD