More about Solids, Liquids, and Gases

4

LEARNING OUTCOMES

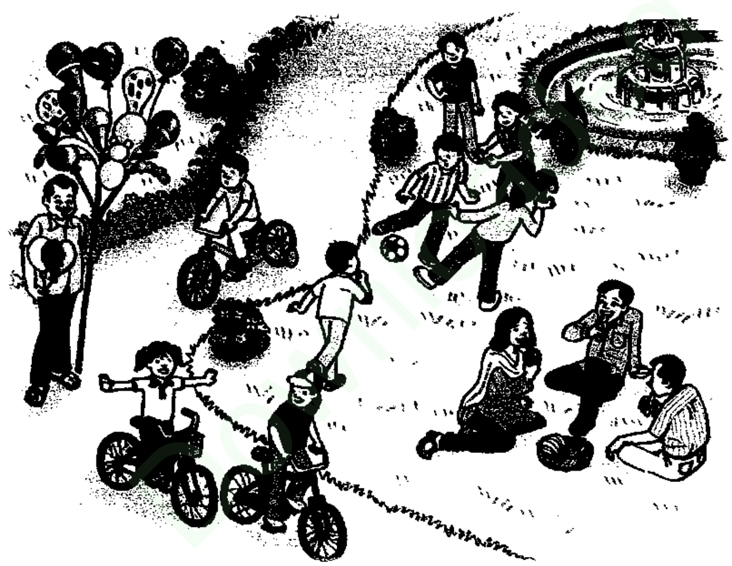
- Kinetic theory of matter
- States of matter
- Cohesion and adhesion
- Surface tension
- Pressure: atmospheric pressure
- Liquid pressure
- Archimedes' principle
- Law of flotation

FACT FILE

The Greeks in 500 BC believed that all matter is composed of atoms. But **Aristotle**, the famous philosopher, in 350 BC stated that all matter is composed of four elements earth, air, fire, and water. This view lasted for 2000 years until **John Dalton** (shown below) revived the idea of atoms around 1800 AD. He explained chemical reactions by proposing that all matter is made up of atoms. Although he did not know about their structure, he knew that the evidence pointed to something fundamental.

Look at your surroundings. What do you see? You see so many things like books, stones, bus, petrol, water, lunchboxes, trees, people, etc., of different textures and nature. All these things constitute matter. *Anything that has mass and occupies space is called* ***matter***. When we talk of matter we mean every substance in the universe, from the tiniest speck of dust to the largest star.

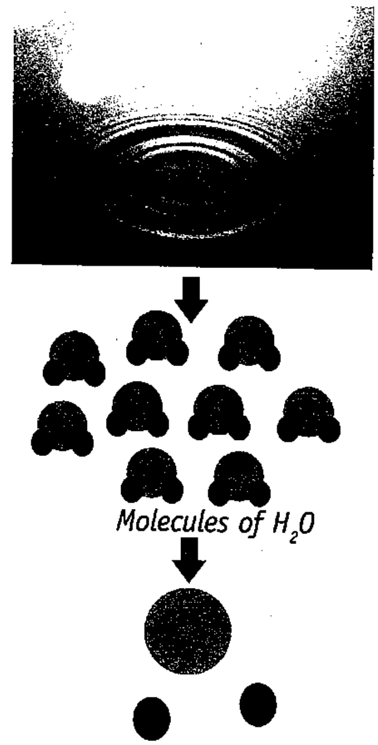
Look at the figure below. Can you name some things from the figure that have mass and occupy space? Does the air in the balloon also form part of matter? Yes! since it has mass and occupies space.



So, we know that everything around us is made up of matter. Have you ever wondered what is matter made up of? Matter is made up of numerous tiny particles called *molecules* that, in turn, are made up of *atoms*. For example, a drop of water is made up of millions of molecules of H_2O. A molecule of water, in turn, is made up of two atoms of hydrogen and one atom of oxygen. Thus, water is made up of numerous atoms of hydrogen and oxygen. This means that all things that make up matter, like bus, books, water, air, etc. are made up of atoms. This serves as the foundation of all science. Can you believe that the whole lot of different things which you see around are made from just about 100 elements, in different proportions?

Do you know that even you are made of atoms? You might have studied that our body is made up of cells. If a cell is broken down, you will find that it is made of many chemicals which are a combination of elements, such as carbon, hydrogen, oxygen, sulphur, phosphorous which are again made up of atoms. Infact, all living things are an incredible organization of atoms.

In order to understand the nature of these atoms and molecules, their arrangement in a substance, their movement, etc., scientists gave the *kinetic theory of matter*.



One molecule of H_2O contains 1 atom of oxygen and 2 atoms of hydrogen

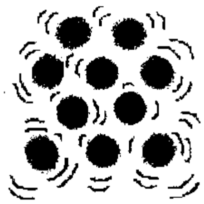
KINETIC THEORY OF MATTER

The kinetic theory of matter was published in around 1860. This is the most-widely accepted theory about the behaviour of matter. This theory states that all matter is made up of atoms (often molecules), but with an enormous variety of arrangements and different motions. The main points that the kinetic theory of matter states are as follows:

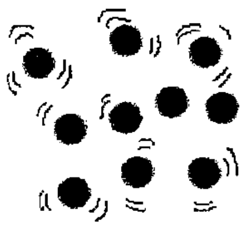
1. All matter is made up of atoms or molecules.
2. The smallest molecules are of the order 10^{-10} m in size.
3. These molecules are always in *constant, random, zig-zag motion* and possess kinetic energy due to their motion.
4. The kinetic energy of the molecules of a substance is directly proportional to the temperature of the substance.
5. There is a *force of attraction* between the molecules of matter. This force between similar kinds of molecules is called *force of cohesion*, while the force of attraction between different kinds of molecules is called *force of adhesion*.
6. The space between the molecules of a substance is called the *inter-molecular space*.

FACT FILE

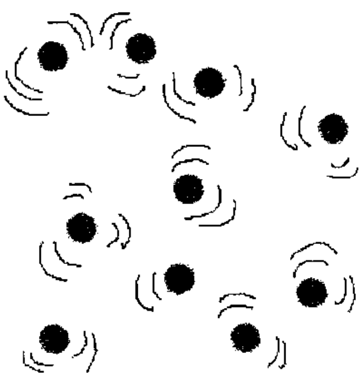
Do increase in population and other materials every year increase the total mass on the earth? No! the atoms that make up our body and other materials are probably the same atoms that were here before we were born. They are believed to be recycled among the living and the non-living forms on this earth. It is quite possible that the atoms in your body were once part of Galileo's brain or of a dinosaur's legs! Amazing, is'nt it?



(a)



(b)



(c)

Fig. 4.1 Molecules in a (a) solid; (b) liquid; and (c) gas

THINK QUEST

If we burn an incense stick (*agarbatti*) or open a bottle of perfume at one corner of a room, its smell spreads in the room within a short while. Can you tell why? (*Hint: think of the inter-molecular spaces in a gas.*)

7. The inter-molecular force of attraction is less when the inter-molecular space between the molecules is large.

Depending upon the arrangement of molecules in matter, the force of attraction between the molecules, and the inter-molecular spaces between them, all matter is divided into three categories: *Solids*, *Liquids*, and *Gases*. Let's study about them in detail.

Solids: Look at your pencil box. It is a solid. Solids have a definite volume and shape. In solids, molecules are very tightly packed because they have a very strong force of attraction between them.

Since the force of attraction is very strong, the molecules have least inter-molecular spaces between them. See Figure 4.1 (a). Since the inter-molecular space is almost negligible, the molecules cannot move easily from their positions. Because of this reason, solids are not easily compressible and expand very little on heating.

Liquids: Take a glass of water. Now take an empty pan and pour water in the pan from the glass. What do you observe? You will see that water, which was previously in the shape of the glass has now taken the shape of the pan. Thus, we say that liquids have a definite volume but not a definite shape. They take the shape of the container in which they are kept.

If you throw water on the floor you will see that it spreads on the floor. What does this show? This shows that the inter-molecular attraction between the molecules of a liquid is not as strong as in the case of solids. Because of this, the inter-molecular space in liquids is more in comparison to solids. See Figure 4.1 (b). Hence, on heating they expand more than solids. Since liquids have a definite volume, they cannot be compressed easily.

Gases: In gases the molecules are very loosely packed. The forces of attraction between the molecules are the least in gases in comparison to solids and liquids. See Figure 4.1 (c).

Hence, their expansion is very high when heated. They can also flow in any direction unlike liquids, which can flow only from a higher level to a lower level.

Since inter-molecular forces are very less in gases, they can change their shape and volume easily and can be compressed to fill any container, e.g., petroleum gas is compressed and filled in the cooking gas cylinders that we use in our kitchen to cook food.

ACTIVITY

Aim: To study the nature of solids, liquids, and gases.

Materials required: Tray with wooden partition and marbles.

Procedure: 1. Take a tray with three wooden partitions. Fill one region with lot of marbles such that there is no room for the marbles to move.

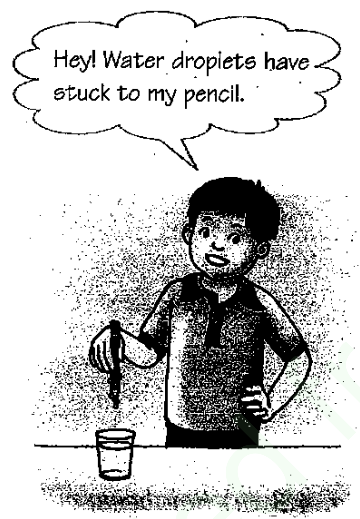
2. Fill the second region with marbles such that there is little room for the marbles to move and the third region with less number of marbles such that there is lot of space for the marbles to move.

3. Now shake the tray slowly. See how marbles are moving in each section.

Conclusion: The first section will tell you how atoms or molecules move in a solid, second section will tell you how liquid molecules move, and the third section will tell you how gas molecules move around.

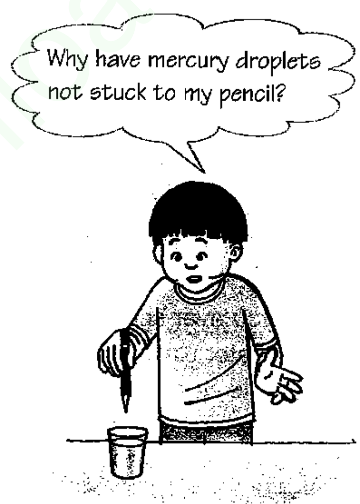
Force of cohesion and adhesion

Have you ever dipped your wooden pencil in a glass of water? Try it out yourself and see what happens. When you take your pencil out after dipping it in water, you will see drops of water sticking to the pencil. We say that the pencil is wet. Now when another pencil is dipped in a glass of mercury, does it appear to be wet? No! It doesn't look as if you had dipped it in mercury.



Why does this difference between the two liquids occur? When we dip our pencil in water, the water molecules get attracted to the pencil molecules and stick to it. *The attractive force acting between different types of molecules (of different substances) is called the* ***force of adhesion***. The strength of this force depends on the kind of molecules that are present and the distance between them. There is an adhesive force between the water molecules and wood (pencil) and that is why water wets the wood.

On the other hand, *the force of attraction acting between similar kinds of molecules (within a substance) is called the* ***force of cohesion***. The force of cohesion acts between the molecules of water, oil, etc., and holds them together as drops. Force of cohesion also acts between the molecules of wood, paper, etc.



In case of water molecules the adhesive force between water and wood is much greater than the cohesive force between water molecules itself, that is why the molecules stick to the pencil. However, in mercury the cohesive forces are much greater than the adhesive force, that is why the molecules of mercury do not stick to the pencil.

We have just studied that molecules of a substance are attracted to one another due to the cohesive forces between the molecules. In a jar full of a liquid, say water, a molecule in the middle has other molecules all around. So, it experiences cohesive forces from all

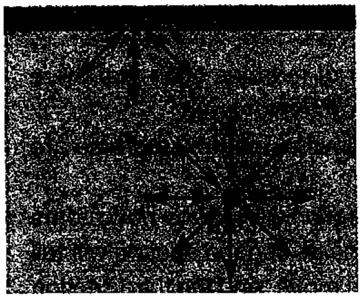
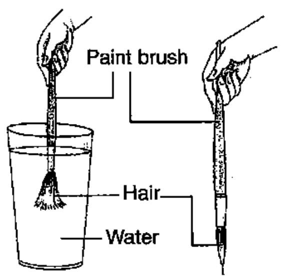


Fig. 4.2 Cohesive forces acting on molecules in a liquid



(a)

(b)

Fig. 4.3 *(a) Hair being pulled together; and (b) Spherical shape of the water droplet*

FACT FILE

Have you ever seen a pond skater walking on water? Its weight is supported by the surface tension on the surface of water.

the sides. See Figure 4.2. Think of the molecule which is at the surface of the liquid. At the surface, the molecule has no molecule above it. How does the cohesive force act on such molecules? This is explained by a term called *surface tension*.

SURFACE TENSION

Have you ever tried placing a razor or a needle gently on the water surface? Does it float or sink? It floats due to a property of the liquid surface called *surface tension*, which is caused by the molecular attractions in the liquid.

In Figure 4.2, the molecules that are down in the liquid experience cohesive forces from the neighbouring molecules on all sides. Thus, the forces balance out. However, at the surface the molecules have no liquid molecules above them. Hence, the net cohesive force that acts on the molecules is sideways and downwards. Because of this, the molecules on the surface experience an overall force pulling them inwards, keeping the molecules and the surface together. Due to this pull, the surface tends to occupy a minimum surface area and the surface contracts and behaves like a stretched elastic membrane.

*The property of a liquid to contract its surface area due to the inter-molecular attractions is called **surface tension**.*

Let us study an example to make the concept clear. Take your paint brush and dip it in a glass of water. Look at its hair. Now slowly take the brush out of water and now look at its hair. Do you see any difference? When the brush is under water, the hair are fluffed. But, when the brush is lifted out, the surface film of water contracts due to surface tension and pulls the hair together [Fig. 4.3 (a)].

Look at Figure 4.3 (b). Do you see the water droplet spherical? Can you tell why this happens? Molecules on the inside are pulled in all directions. But, we know that the molecules on the surface are pulled in only one direction—inwards. Thus, the molecules on the outside tend to move inward to form a shape, which has the least surface area possible. The geometrical figure that has the least surface area, for a given volume, is a sphere. Hence, the water droplet is spherical.

Another effect seen in liquids due to cohesion and adhesion is the shape of the meniscus in the capillary tube.

When any liquid is taken in a container, a curve is formed at the surface of the liquid due to the surface tension. This curve is called a *meniscus*. Why does water meniscus curve upwards, while mercury meniscus curve downwards?

When water is poured in a glass jar, the adhesion of the water molecules to the glass molecules is greater than their inter-molecular cohesion. Consequently, the meniscus curves upwards, and the liquid rises in the capillary tube forming a *concave meniscus* [Fig. 4.4 (a)].

On the other hand, the inter-molecular cohesion of mercury molecules is greater than their adhesion to the glass molecules. Hence, the liquid curves downwards forming a *convex meniscus* accompanied by capillary depression. [Fig. 4.4 (b)].

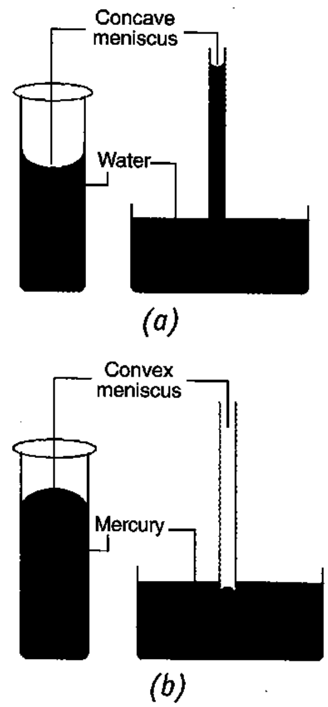


Fig. 4.4 *(a) Concave meniscus; and (b) Convex meniscus*

Can you weaken the surface tension of water?

What happens when you add soap to water? You weaken the surface tension of water by adding certain kinds of impurities, like soap. The molecules of soap get between the water molecules. Because of this, the strong cohesive forces between the water molecules are broken and the surface tension is reduced. Hence, water can go through the clothes easily and clean them. Also, since hot water has less surface tension than cold water, it cleans clothes better.

When studying about surface tension, we must note that the surface tension is more noticeable in water than in any other liquid. Surface tension also helps us in many ways.

The surface tension of our urine is decreased if the amount of bile in it increases. This forms the basis of the Hay test, a test for jaundice. In the Hay test, sulphur is sprayed on the urine surface. If the amount of bile in urine is normal, sulphur floats on it; otherwise, it sinks if the surface tension of urine is lowered by bile.

Disinfectants that we use to kill microbes are usually solutions of low surface tension. This allows them to spread out on the cell walls of bacteria and disrupt them.

Till now you have studied how the kinetic theory of matter applies to solids, liquids, and gases. Let us now study how the kinetic theory of matter is useful in explaining the heat transfer in a substance.

Have you ever wondered why hot and cold soup taste different? Hot water has less surface tension than cold water. This allows the grease or oil in hot soups to float in little bubbles on the surface of the soup. When the soup cools and the surface tension of water increases, the grease or oil is dragged out over the surface of soup and the soup becomes greasy. Hence, hot soups taste different from cold soups.

FACT FILE

Can heat be transferred only if the molecules vibrate or move? No! How do we get heat energy from the sun? Heat from the sun travels through space which is vacuum, where there are no molecules of air to vibrate or move to transfer energy! The transfer of heat energy where a medium or molecules are not required is called **radiation.**

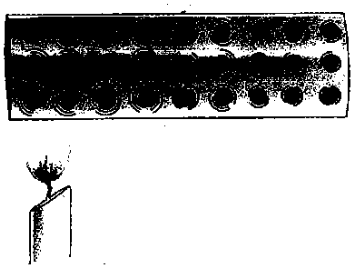
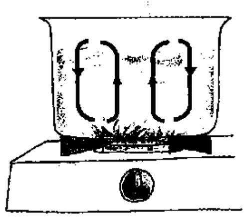


Fig. 4.5 Conduction of heat



Hot water (red) rises up, cold water (blue) falls to the bottom

THINK QUEST

1. Why do we have ventilators and windows near the ceilings of our rooms?
2. You might have seen big chimneys in factories from where smoke comes out. Why are they made so high? (*Hint: think of the difference in hot and cold air.*)

Heat transfer in solids, liquids, and gases

You have done heat transfer in solids, liquids, and gases in class 7. What do you observe if you hold a metal rod from one end and heat the other end over a flame. You will observe that after some time the other end of the rod, which you are holding starts getting hot. We say that when one end of the metal rod is heated, the heat gets transferred to the other end slowly. The heat from the flame moves through the rod by a process called *conduction*.

According to the kinetic theory of matter, we know that the molecules in the metal rod are in a *constant, random, zig-zag motion* and have kinetic energies even before heating. When we heat the rod at one end, the molecules gain energy from the flame and vibrate more. As a result, they collide with the neighbouring molecules and transfer energy to them because of which even the neighbouring molecules start vibrating. Like this the vibrations reach the last molecule on the other end (Fig. 4.5). This effect of the increased motion of all the molecules results in an increase in the kinetic energy of the molecules, and thus, increase in the temperature of the body. This is why the other end of the rod, though not directly in contact with the flame, gets hot.

We now know that *heat flows in solids by **conduction***. But how does heat flow in liquids and gases? *Liquids and gases are together called fluids*. According to the kinetic theory of matter, the molecules in fluids are not arranged very close as in solids and there are less inter-molecular forces of attraction. In the case of fluids, the molecules themselves carry heat energy from the hotter region to the cooler region (unlike in solids where the molecules transfer the vibrations and do not themselves move). This kind of heat transfer is called *convection*.

If a vessel containing water is kept on a flame, the water at the bottom of the vessel gets hot, and since hot water is lighter than cold water, it rises up, carrying the heat energy with it. The colder and denser water on the top falls to the bottom of the vessel and gets heated in its turn. This process continues till the whole liquid becomes hot. Sea and land breezes are an excellent example of convection currents in the atmosphere.

According to the kinetic theory of matter, the molecules in liquids and gases are in constant random motion. During their motion, they collide with each other and with the walls of the container and thus, exert *pressure*.

You have studied about pressure in class 6. Can you define it?

Let us understand what pressure is with a simple example. If you press your thumb against a piece of paper, and in the other case press the pointed end of a drawing pin against that same piece of paper, do you notice any difference? You will notice that with the drawing pin, you will be able to make a hole in the paper, while no effect is produced with your thumb.

This is because although the force applied in both the cases is the same, in case of the needle the area over which that force acts is smaller in comparison to your thumb. Thus, its effect on the paper is much greater and it makes a hole in the paper. This effect is called *pressure*.

Pressure is defined as the force acting normally (thrust) on unit area of a surface. Its SI unit is pascal (Pa).

$$\text{Pressure (in Pa)} = \frac{\text{Force (in newton)}}{\text{Area (in m}^2\text{)}} \text{ or } \frac{\text{Thrust}}{\text{Area}}$$

Given alongside are some very simple examples based on this formula. Can you calculate the pressure in each case? From figures (a) and (b) alongside, we can say that

Same force
- more area ⟶ less pressure
- less area ⟶ more pressure

Some everyday examples based on this relation are as follows:

1. The foundations for the high-rise buildings are kept very wide so that they do not sink into the ground.
2. Camel is provided with specially-designed broad feet which increase the area so that the feet do not sink in sand.
3. The rear side of trucks and buses is provided with double wheels so that the tyres do not sink into the ground.

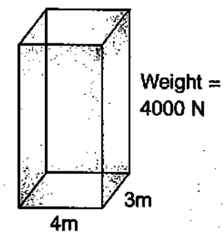
After having understood what pressure means and its everyday applications, let us understand how liquids and gases (together called *fluids*) exert pressure.

PRESSURE IN FLUIDS

Unlike in solids (where pressure is always exerted downwards), the pressure in fluids acts in all directions. Fluids exert pressure on all bodies immersed in them and also on the walls of the container that holds them.

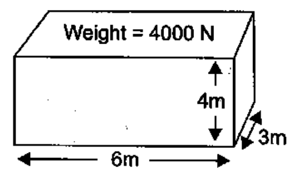
Let us first see the pressure exerted by gases.

Calculate the pressure in each case



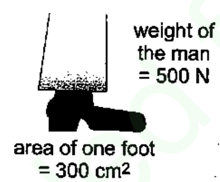
Pressure =

(a)



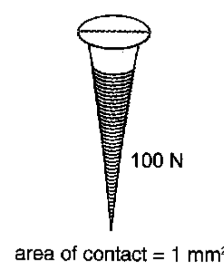
Pressure =

(b)



Pressure =

(c)



Pressure =

(d)

Pressure exerted by a gas

Put a light-weight book on a plastic bag and blow air into the bag. You will see that the air pressure increases inside the bag and lifts the book. This shows that air pushes out in all directions. The pressure exerted by a gas in a closed container is due to the collision of gas molecules with the walls of the container as according to the kinetic theory of gases, molecules are in a state of random motion.

Do you know that all of us are immersed in a sea of air and are experiencing its pressure all the time? This pressure is called *atmospheric pressure*.

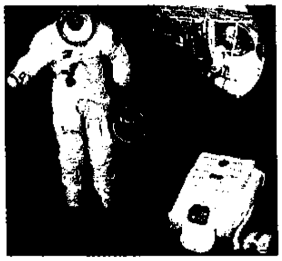
***Atmospheric pressure** is defined as the force exerted on unit area of a surface by the weight of the air above it.*

Since air molecules are in constant random motion, atmospheric pressure can also be said to be the result of the collision of air molecules with any surface.

The atmospheric pressure on the earth's surface at sea level is about one hundred thousand pascal, i.e., 100 kPa (10^5 Pa). But the question is when such an enormous amount of pressure is acting on us, why do we not feel it? This is because the pressure of the blood and the other fluids present in our body balances out the atmospheric pressure.

Is the atmospheric pressure the same at all places on the earth? No! The *atmospheric pressure at a place depends on its altitude* (the altitude of a place is its height above sea level). As we go higher, air thins out and hence pressure decreases.

FACT FILE



What will happen if the pressure of the air around us is suddenly taken away? If this happens, our body will explode due to the pressure of the blood and other fluids inside. This is why spacemen have to wear special pressurized suits as in space there is no air and hence, no air pressure.

ACTIVITY

Aim: To determine the presence of atmospheric pressure.

Materials required: An empty, dry can with an airtight stopper and water.

Procedure: 1. Take an empty, dry can and pour some quantity of water in it. Boil this water for few minutes until the steam has driven out the air.

2. Close the can with the stopper tightly and allow the can to cool by pouring cold water over it. What do you observe? You will see that the can gets crushed from all directions.

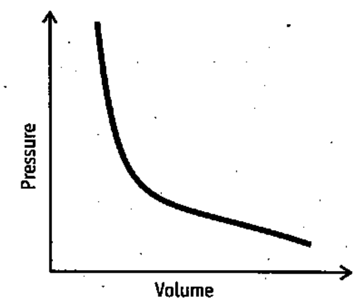
Conclusion: When cold water is poured over the can, the steam inside the can condenses and gets transformed to water. Since air is driven out from the can, low pressure is created inside. As a result, the excess atmospheric pressure outside the can exerted in all directions crushes it inwards.

Effect of volume on pressure

Try to gradually squeeze an inflated balloon to reduce its volume. What happens to the balloon? It finally bursts. Can you tell why? This happens because, with reduction in volume, the pressure of the air inside the balloon gradually increases and reaches a limit where the strength of the balloon can no longer hold it. As a result, the balloon bursts. So, we can say that for a given mass of gas, by reducing its volume, the pressure rises correspondingly.

If the mass and temperature of a gas are kept constant, then the volume of a given mass of a gas is inversely proportional to its pressure (see the graph alongside). *This relation is called **Boyle's law***, which you will study in detail in higher classes.

At the top of a mountain, some people can feel their ears 'popping' due to decrease in the air pressure. The ears pop in order to balance the difference in pressure between the outside and the inside of the body.



Applications of atmospheric pressure

Drinking straw and dropper: You must have used a drinking straw to suck up fruit juice. When air is sucked in, it causes a decrease in the air pressure inside the straw. As a result, the atmospheric pressure on the outside (being higher) forces the liquid inside the straw. This is called suction mechanism. The dropper also works on the same principle.

Syringe: When we pull the piston of a syringe out, we increase the volume inside the syringe. This correspondingly decreases the pressure inside than the outside and forces the fluid into the syringe.

Rubber sucker: When the concave surface of the rubber sucker is pressed against a wall or any flat surface, the air between the two surfaces is squeezed out, leaving the pressure in the enclosed space much reduced. The external atmospheric pressure acting on the sucker (being higher) forces the sucker against the flat surface.

Having understood what atmospheric pressure means, can you tell why you cannot drink fruit juice with a straw on the moon? It is because there is no atmosphere on the moon to force the juice up.

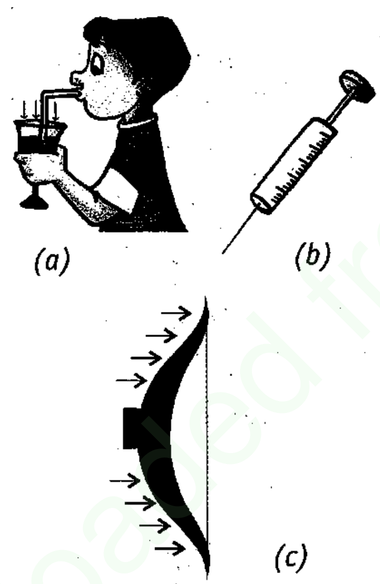


***Fig. 4.6** (a) Drinking straw; (b) Syringe; and (c) Rubber sucker*

Why do the helium or hot air balloons burst after flying up in the air for some time?

Imagine that the balloon is sealed so that no air can escape from the balloon. As the altitude of the balloon increases, the air pressure outside the balloon decreases. The amount of air in the balloon stays the same and so does the pressure that it exerts outwards. When the balloon reaches a height where the pressure outside the balloon becomes less than the pressure inside, the balloon bursts.

Measurement of atmospheric pressure

We have studied that the atmospheric pressure decreases as we go up. This means that the atmospheric pressure is not the same at all places. *The instrument used to measure the atmospheric pressure is called a barometer.*

ACTIVITY

Aim: To construct a simple mercury barometer.
Materials required: A metre-long glass tube, a dish, mercury, scale, and a stand.
Procedure: 1. Take a metre-long glass tube closed at one end. Fill it completely with mercury.
2. Fill a dish with mercury and invert the tube over this dish of mercury by closing the open end of the tube with your finger. Remove your finger when the open end of the tube is well immersed in the dish.
3. Fix the tube to a stand so that it stays in the vertical position. What do you notice when you remove your finger from the tube? You will see that when you remove your finger, some mercury from the tube flows into the dish. If we measure the height of the mercury column in the tube, it is found to be 76 cm above the mercury surface in the dish.

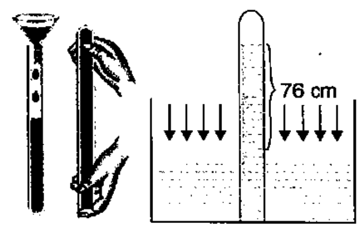


Fig. 4.7 A barometer

In 1643, an Italian scientist named Torricelli set up the first barometer. He found that the pressure of the air bearing down on the mercury in the dish forces it to rise in the glass tube to a height of 76 cm at sea level. If the height of the mercury column is less than 76 cm, we say that the air pressure has fallen, and if the height is more than 76 cm, we say that the air pressure has increased. Have you ever wondered why water is not used as a barometric liquid, in place of mercury, in a barometer?

Water is 13.6 times less dense than mercury. Hence, if water is taken as a barometric liquid, atmospheric pressure should support a water column, which is 13.6 times that of the mercury column, i.e., $76 \times 13.6 = 10.33$ m. Since it is impractical to have such a long tube, water is not used as a barometric liquid.

The mercury barometer that we have studied above has some drawbacks also, like (i) the dish is open and there are chances of mixing of the impurities with the pure mercury in the dish; and (ii) it is not portable and compact. Because of these, a compact barometer was designed, named the *aneroid barometer*.

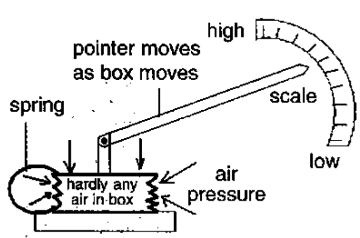


Fig. 4.8 Working of an aneroid barometer

Figure 4.8 shows the working of an aneroid barometer. The aneroid barometer uses a flexible metal box with hardly any air in it, with a special spring to prevent the box from collapsing. When the air pressure rises, the box is squeezed in slightly—when the pressure drops, the box expands. As the box moves in or out, it pushes a pointer next to a scale, which tells us the atmospheric pressure.

LIFT PUMPS (COMMON WATER PUMPS)

It consists of a cylindrical metal barrel with a side tube near the top to act as a spout. At the bottom of the barrel, where it joins a pipe leading to the well, there is a clack valve V_1. A piston carrying a leather cup and fitted with a second clack valve V_2 is moved up and down inside the barrel by a handle. Both the valves can only be moved upwards. When the valve V_2 is closed, the pressure of the air inside the cylinder is the same as the atmospheric pressure on the water; and hence, water does not rise in the cylinder.

When the piston is pushed up with the help of a handle, valve V_2 is moved up, and the air pressure inside the cylinder becomes less than the atmospheric pressure. So, water rises in from the well by opening the valve V_1 [Fig. 4.9 (a)]. Now, when the piston is pushed down, the pressure inside the cylinder increases and water rushes above the piston, opening valve V_2. Due to the weight of the water above, valve V_1 closes [Fig. 4.9 (b)].

When the piston is again pushed up, the pressure inside the cylinder decreases and the valve V_1 opens up. The valve V_2 gets closed due to the weight of the water above it. Now, the water which rushed above the piston rises up along with the piston and comes out from the spout [Fig. 4.9 (c)]. Again, when the piston is pushed down, the valve V_1 gets closed and the valve V_2 opens up and water rushes above the piston. This process is repeated, and there is a continuous flow of water from the spout.

After studying about atmospheric pressure and how pressure acts in gases, let us now see how liquids exert pressure.

Liquid pressure

You might have noticed liquid pressure on you when you go for swimming. Just like in the case of atmospheric pressure, the pressure at any point under a liquid is due to the weight of the liquid column above that point. Try pushing down an inverted glass bottle into a bucket full of water. You will notice that the bottle resists being pushed down into the water. This happens because of the pressure exerted by water on the bottle upwards. Just like in gases, the pressure in liquids also acts in all directions. Let's perform an activity to understand this.

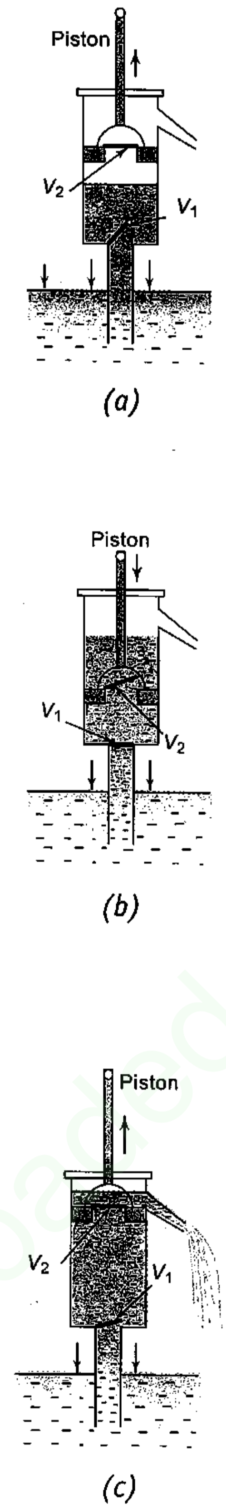


Fig. 4.9 Working of a lift pump

ACTIVITY

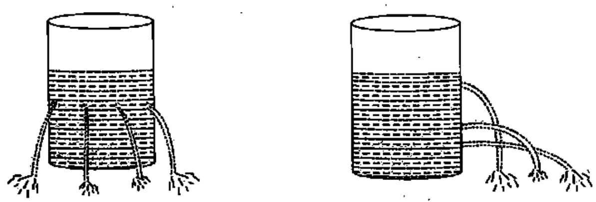
Aim: To study how liquid pressure works.

Materials required: Three tins or plastic bottles of different diameters and sizes, water, and tape.

Procedure: 1. Take three tins of different diameters and sizes and mark them as I, II, and III. On tin I, make four holes at the same height. On tins II and III make three holes each at different heights and close all the holes of all the tins with tape.

2. Fill the tins with water and remove the tapes from tin I and observe the flow of water from the holes. Now remove the tapes from tins II and III simultaneously and observe the flow of water from the holes. Do you notice any difference?

Conclusion: In tin I, the water stream comes out evenly, irrespective of the direction of the hole. In tins II and III, the water stream coming out of the lowest hole reaches the farthest. Also, although the size of tins II and III is different, there is no difference in the water stream. If you repeat the entire procedure with another liquid (other than water), you will notice a change in the lengths of the stream coming out of the holes.



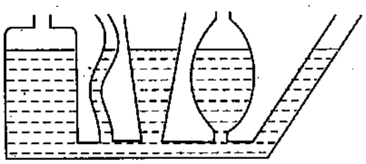


Fig. 4.10 A liquid seeks its own level

From the activity above, we can state that the pressure in a liquid

1. is exerted on all sides of the container (this is called *lateral pressure*) and remains the same in all directions at a given depth;
2. increases with depth;
3. depends on the density of the liquid; and
4. is independent of the size or the shape of the container, but depends only on the height or the depth of the liquid. The pressure at any point in the containers shown in Figure 4.10 will be the same. Hence, we say that *a liquid seeks its own level.*

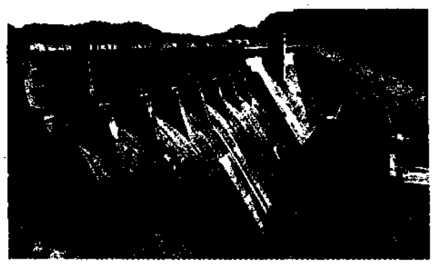
The above statements state why

1. deep-sea divers have to wear specially designed suits to protect them from the huge pressure of the water underneath.
2. bodies of fishes burst if they are brought from deep seas as they are brought from a region of high pressure to a region of low pressure. The huge pressure difference causes the fishes' body to burst.

Fig. 4.11 Deep-sea divers

Hydraulic machines are powered by liquid pressure. When you press one part of the liquid, the pressure increases throughout the liquid. As liquids cannot be compressed and since it has to move somewhere, it forces the piston or the wheel to move.

Have you ever wondered why the walls of the dams are made stronger and thicker at the bottom than at the top? They are made thicker from the base to withstand the huge lateral pressure of water at greater depths.



We know that pressure = force/area. Hence, force or weight of the liquid = $v \times d \times g$, where v = volume; d = density; and g = acceleration due to gravity.

so, $p = \dfrac{a \times h \times d \times g}{a}$,

since volume (v) = $a \times h$, Hence, $p = hdg$. You will study more about this formula in higher classes.

Measurement of liquid pressure

Pressure in a liquid can be measured by a simple device called a *manometer*. A manometer consists of a U-shaped tube containing a liquid (sometimes water) (Fig. 4.12). One arm of the tube is open to air and the other arm is connected to a funnel with a rubber membrane stretched across its mouth. The difference in the liquid levels in the two arms represents the pressure exerted on the rubber membrane.

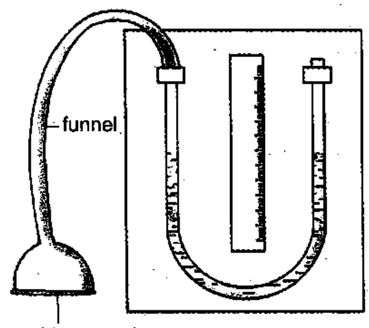


Fig. 4.12 *A manometer*

Buoyant force

Try lifting or moving a brick in water. It seems to weigh less under water. Have you ever drawn water from a well? You would have noticed that the bucket of water appears lighter under water, but heavier as it comes out of water. Do you know why?

We have learned that when an object is immersed in a liquid, the liquid exerts pressure on the object on all sides. The pressures acting on the opposite sides of the object are equal and opposite and so, they cancel each other. The pressure exerting downwards on the upper face is less than the pressure exerted upwards on the lower face of the object, because of the depth (Fig. 4.13).

This difference between the two pressures on the two faces of the object causes a resultant upward force, which is called the ***upthrust*** or the ***buoyant force.*** Because of the upthrust, a submerged object appears to lose weight in a liquid.

The property of a liquid to exert an upward force on an object immersed in it is called buoyancy and the upward force is called the *upthrust* or the *buoyant force*. For example, if the weight of a body is 50 N in air and if it is 45 N in a liquid, the upthrust exerted on the body will be 5 N (50–45). This upthrust is very useful in determining whether an object floats or sinks in a liquid. Let us see how?

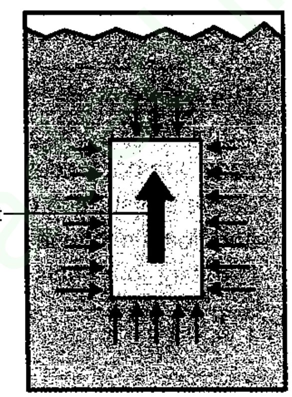


Fig. 4.13 *Upthrust acting on an immersed body*

FACT FILE

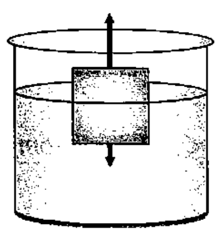
Can you tell why a tin lid floats in a bowl of water, but when it is crushed into a ball, it sinks?
When we crush the tin lid, its volume decreases. When volume of an object decreases, the upthrust acting on it also decreases, so it sinks. If you put this crushed tin into a bowl of mercury, you will see that it now floats because the density of mercury is much greater than water; hence the upthrust on the lid is greater in case of mercury.

Sinking and floating

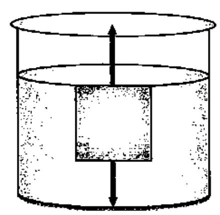
Take an iron nail and a toothpaste cap and put them in water. What do you see? You will see that the iron nail sinks in water, while the toothpaste cap floats on the water surface. Can you tell why this happens? What makes an object float in a liquid and another object sink in the same liquid?

The *upthrust* determines whether an object will float or sink in a liquid. If the upthrust exceeds the weight of the object, the object floats; if the weight of the object exceeds the upthrust, the object sinks. If the upthrust is equal to the weight of the object, then it floats anywhere inside the liquid. Is the upthrust same on all objects and in all liquids? No! the upthrust acting on an object in a liquid depends upon:

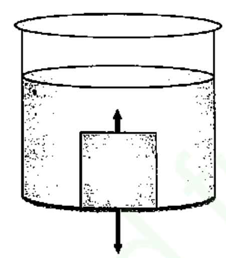
1. the volume of the object – larger the volume of the object submerged in the liquid, greater is the upthrust – and;
2. the density of the liquid – greater the density of the liquid, greater is the upthrust.



The weight of the body is less than the buoyant force. In this case, the body rises partly above the surface of the liquid and floats because the resultant force acts upwards.



The weight of the body is equal to the buoyant force. In this case the body just floats within the liquid. This is because the resultant of the two equal and opposite forces is zero.



The weight of the body is greater than the buoyant force. Here, the body will sink in the liquid due to the resultant force acting downwards.

Archimedes' principle

Over 2000 years ago a Greek mathematician and physicist called Archimedes discovered an important law about upthrust. He studied that *whenever an object is immersed in a liquid, it displaces a certain amount of that liquid. The weight of the liquid displaced by the immersed part of the object is equal to the apparent loss in weight of the object due to the upthrust.* This principle is called Archimedes' principle. Let us understand this principle with an activity.

ACTIVITY

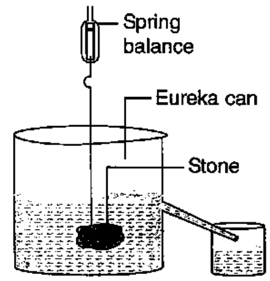
Aim: To verify Archimedes' principle.

Materials required: A stone, spring balance, a Eureka can, water, and a beaker.

Procedure: 1. Take a Eureka can and fill it with water. Suspend the stone from a spring balance. Note its weight. Let it be 200 N.

2. Now immerse the stone completely in water. You will see that the level of water rises and the water starts flowing through the spout. Collect this water in a beaker. Note the weight of the stone when it is fully immersed in water. Let it be 160 N.

3. The difference in the weight of the stone is 40 N. Now weigh the water collected in the beaker. You will see that the weight of the water displaced by the stone is also 40 N. What do you conclude from this?



Conclusion: We conclude that when an object is immersed in a liquid, the loss in weight of the object is equal to the weight of the liquid displaced. This is **Archimedes' principle.**

Law of flotation

We have studied that when the weight of an object is equal to the buoyant force or the upthrust, the object floats. The ***law of flotation** states that an object floats in a liquid if the weight of the object is equal to the weight of the liquid displaced by the submerged part of the object*. In such a case, the apparent loss in the weight of the object is zero. For example, a piece of wood floats in water because the weight of water displaced by it is equal to its own weight. Some common applications of the law of flotation are as follows.

***Fig. 4.14** A ship floats in water*

***Fig. 4.15** An iceberg*

Applications of the law of flotation

1. Have you ever wondered why an iron nail sinks in water but a huge ship made of iron floats in water? This is because of the hollow shape of the ship, which increases its volume and decreases its density with respect to that of water. An increase in the volume results in an increased upthrust and a large amount of water displaced. So, a ship floats in water.
2. Law of flotation explains why an iceberg floats with 3/4th part under sea water. ***Icebergs are large masses of ice floating in seas and oceans***. With a major part below the water surface, an iceberg can displace water equal to its own weight and hence, floats. This can cause much danger to the ships as from outside icebergs just seem to be a lump of ice.
3. Swimming in sea water is easier than in fresh water because sea water provides a greater upthrust as compared to fresh water. This is because the density of sea water is higher than the density of fresh water. For the same reason, when a ship

FACT FILE

Hydrogen-filled balloons tend to rise upwards. This is because the weight of the air displaced by the balloon is much more than the weight of the balloon with hydrogen, as density of hydrogen is only 1/4th of the density of air. Hence, upthrust acts on the balloon and it rises upwards. Thus, Archimedes' principle holds true for gases also.

enters sea water from fresh water it sinks less as it does not have to displace more water as sea water is dense.

The buoyant force, Archimedes' principle, and law of flotation can be applied to gases as well.

KEYWORDS

Matter Anything that has mass and occupies space
Surface tension Property of a liquid to contract its surface area due to inter-molecular attraction
Atmospheric pressure Force exerted on unit area of a surface by the weight of the air above it
Buoyant force The upward force exerted by a liquid
Archimedes' principle When an object is completely or partly immersed in a liquid, it experiences an apparent loss in weight, which is equal to the weight of the liquid displaced by the immersed part of the object
Law of flotation When a body floats in a liquid, the weight of the body becomes equal to the weight of the liquid displaced, which is the upthrust

SUMMARY

- The kinetic theory of matter states that all matter is made up of atoms, but with an enormous variety of arrangements and different motions.
- In solids the atoms are tightly packed, in liquids they are loosely packed, and in gases they are very loosely packed as compared to solids and liquids.
- The attractive force between similar kinds of molecules is called force of cohesion, and the attractive force between different kinds of molecules is called force of adhesion.
- The surface tension of water can be decreased by adding soap or by heating it.
- In a closed container, the pressure of the gas can be increased by reducing the volume.
- The instrument used to measure the atmospheric pressure is called a barometer.
- A mercury barometer can support 76 cm of mercury, at sea level.
- Liquid pressure depends only on the depth and the density of the liquid and acts in all directions.
- A manometer is used to measure liquid pressure.
- The upward force acting on an object when it is immersed in a liquid is called the buoyant force or upthrust.
- The buoyant force or upthrust depends on the volume of the body and the density of the liquid.

EXERCISES

I. Review questions

A. Choose the correct answer

1. .... is easily compressible.
   (a) Solid (b) Liquid (c) Gas (d) Water
2. The surface tension of water can be weakened by adding ....
   (a) salt (b) sugar (c) detergent (d) sand

3. The atmospheric pressure is due to the .... of the air acting on unit area of any surface.
   (a) mass (b) weight (c) volume (d) area
4. Upthrust = ... of the liquid displaced.
   (a) volume (b) density (c) mass (d) weight
5. When a body floats, the apparent loss in weight of the body will be ....
   (a) more (b) less (c) zero (d) can't say

B. Fill in the blanks

1. Liquids have a definite volume, whereas .... (solids/gases) don't have.
2. The force of attraction between similar kinds of molecules is called the force of .... (cohesion/adhesion).
3. Pressure is defined as ..../................ (force, area/normal force, area).
4. For a given force, increasing the area .... (increases/decreases) the pressure.
5. Unlike in solids, pressure in fluids acts in .... (only one/all) direction/s.
6. The pressure of a gas enclosed in a container can be increased by .... (decreasing/increasing) the volume.
7. The atmospheric pressure .... (decreases/increases) with altitude.
8. The pressure in a liquid is .... (independent/dependent) on/of the size of the container.
9. The volume of an immersed body is equal to the .... (weight/volume) of the liquid displaced.
10. When the weight of the body is less than the upthrust, the body .... (sinks/floats).

C. Correct the statements that are false

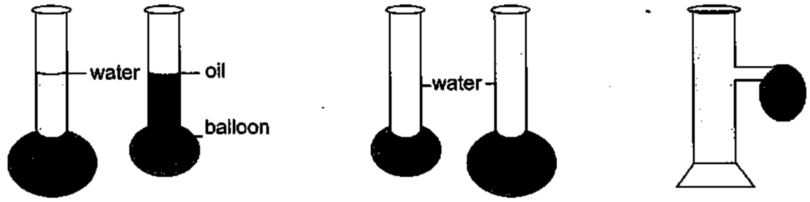
1. Since the force of adhesion between mercury and glass is greater than the force of cohesion between the mercury molecules, the meniscus of mercury curves downwards.
2. The atmospheric pressure can support 76 cm of water.
3. The aneroid barometer does not have any liquid in it.
4. The liquid pressure remains the same in all directions at a given depth.
5. When the volume of a body increases, the buoyant force on it also increases.

D. Answer the following questions

1. State any three points of the kinetic theory of matter.
2. Differentiate between solids, liquids, and gases on the basis of the kinetic theory.
3. Why does water wet glass, whereas mercury does not?
4. Define surface tension. Give its two applications.
5. The cutting edges of tools like knives, blades, etc. are provided with sharp edges. Give reasons.
6. On what factors does the liquid pressure depend?
7. Why are the walls of the dam made thicker at the bottom?
8. Explain the working of a syringe.
9. State Archimedes' principle.
10. How can you increase the buoyant force acting on a body when it is immersed in a liquid?
11. Why do ships entering fresh water from sea water sink more?
12. Why do bodies of fishes burst if they are brought from deep seas?
13. Define the law of flotation? Explain why an iron nail sinks in water while a ship floats in water.
14. Why do objects weigh more in vacuum than in air?

II. Skill-based questions

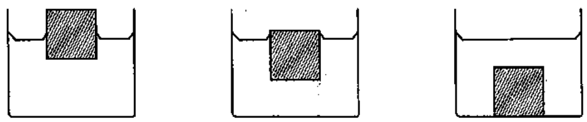
E. Look at the figures and answer the following questions



(a) (b) (c)

1. What can you say about the pressure exerted by oil in comparison to that by water in (a)?
2. Why is the bulging of rubber in both the cases in (b) different although we use water in both the cases?
3. Why has the balloon on the side in (c) bulged out?

F. Look at the figures and answer the following questions



A B C

The diagram shows three blocks, of different materials, in water. What can you say about the density of each material? Comment, with reasons, on the weight of the water displaced in each case.

III. Fun time

Use the clues given to find the words that fit in the following blanks.

1. The attractive force between similar kinds of molecules.

   ◯ _ _ _ _ ◯ _ _

2. The curve formed at the surface of a liquid.

   _ _ _ _ ◯ _ _ _

3. The atmospheric pressure at a place depends on its ....

   _ ◯ _ _ _ _ ◯ _

4. A brick seems to weigh less in water due to ....

   _ ◯ _ _ _ _ ◯ _

5. Swimming is easier in this kind of water.

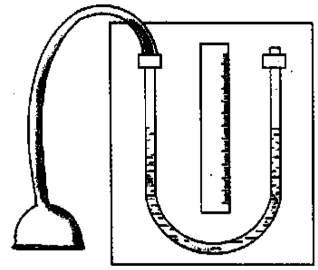
   _ _ _ _ ◯ _ ◯ _

Now unjumble the words in the circles to form a word so as to complete the given sentence.

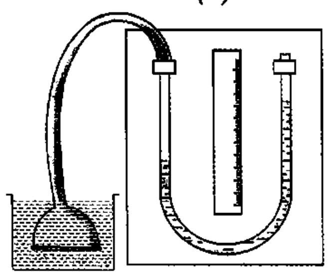
If an object floats freely in a liquid, the weight of the liquid it .... is equal to its own weight.

PROJECT IDEA

- **Aim:** To make your own improvised manometer.
  Materials required: A plastic tube, wooden board, funnel, balloon membrane, and water.
  Procedure: 1. Take a plastic tube and bend it in the form of a U-tube.
  2. Mount it onto a wooden board. Connect one arm to a funnel, which has a stretched balloon membrane at its mouth.
  3. Fill the U-tube with coloured water. You will find that the level in both the limbs of the tube is the same [Fig. (a)].
  4. Place a scale in between the two limbs of the tube. Now put the funnel in a beaker of water and record the variation in the height of the coloured water in the limbs [Fig. (b)].
  5. Turn the face of the funnel in the beaker in different directions, while keeping it at the same depth. Note the pressure now. Now increase the depth to which the funnel is placed in the beaker and note the pressure. Record your observations at different positions and depths of the funnel in the beaker and give reasons for the difference in pressure that you observe.
  Record your findings and observations on a chart paper.



(a)



(b)

TEACHER'S NOTES

- The activities on liquid pressure could be done in the laboratory to get the concept across.
- Buoyant force and Archimedes' principle could be explained with a demonstration in the laboratory. Since the two cause confusion, they could be broken down into two or three concepts.

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