1 FORCE AND PRESSURE

THEORY

1.1 INTRODUCTION (FORCE)

We use force all the time. We use force to open a door. We use force to pick up the school bag. We use force to brush our teeth. We use force to squeeze out toothpaste from a tube and so on.

Force is not an object which can be seen, force can be experienced or measured. We can experience the force of pull of earth on us and can measure it by a weight machine.

Now we are in position to define the force

"Force is a push or pull acting on an object"

1.2 FORCE

"Force is a push or pull which changes or tends to change the state of rest or of uniform motion, direction of motion, or the shape and size of a body".

Unit: A unit of force on SI is **Newton** (represented by N).

It is a vector quantity.

One Newton force is that much force which produces an acceleration of 1 ms^{-2} in a body of mass 1 kg.

Unit of force on **c.g.s.** system is **dyne**.

One dyne force is that much force which produces an acceleration of 1 cms^{-2} in a body of mass one gram.

Relation between newton and dyne

1 N = 10^5 dyne

Remember

A force produces or tries to produce motion in a body at rest, stops or tries to stop a moving body, changes or tries to change the direction of motion of a body and produces and tries to produce a change in the shape of a body.

1.3 EFFECTS OF FORCE

(A) FORCE ACTING ON A BODY CAN CHANGE ITS STATE OF MOTION OR OF REST

- A force can make a stationary body move. When you kick a stationary football it moves.
- A force can stop a moving body. A fielder catches a moving cricket ball to stop its motion.
- A force can increase the speed of a moving object when a force is applied on a moving object in the direction of motion, its speed increases.
- A force can decrease the speed of a moving object when a force is applied on a moving object in the direction opposite to the direction of motion its speed decreases.

Fig.: A force can make a body move

(B) FORCE CAN CHANGE THE DIRECTION OF MOTION OF A MOVING OBJECT

There are many activities that show that a force can change the direction of motion of a moving object. During the game of cricket, the batsman changes the direction of the moving ball by touching or striking it with the bat at a suitable angle.

When you pass alongside a bus or truck emitting smoke, you wave the smoke away by moving your hand. Your moving hand exerts force on the smoke and pushes it away.

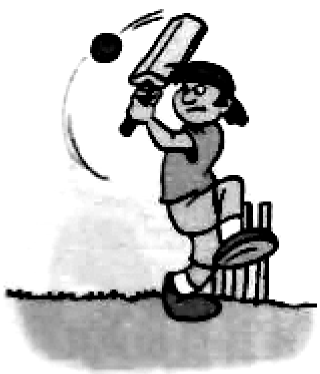


Fig.: Force can change the direction of a moving body

(C) FORCE CAN CHANGE THE SHAPE AND SIZE OF AN OBJECT

When a force is applied on a soft object, it changes the size and shape of the object. For example,

(a) When a inflated balloon is pressed between the two hands, its shape and size change.

(b) When a ball of wheat flour is pressed its shape changes. In fact, it can be given any shape.

(c) When a spring is pulled, its shape and size change.

(d) Foam or sponge can be compressed by applying force on it.

(e) The shape of tooth paste tube changes on squeezing.

Thus we see that force acting on a body is push, pull or a squeeze.

Fig.: Force can change the shape and size of object

1.4 BALANCED AND UNBALANCED FORCES

A number of forces acting on an object may either be balanced or unbalanced.

(A) **Balanced Forces :** If a number of forces acting on an object does not produce any change in its state of rest or uniform motion or direction of motion then, they are called as balanced forces.

For example

(i) A person holding a briefcase in hand.

(ii) A book resting on table.

(iii) Squeezing a lemon etc.

(B) **Unbalanced Forces :** If a number of forces acting on an object produce a change in its state of rest or uniform motion or direction of motion, then they are termed as unbalanced forces.

For example

(i) A briefcase released from a persons hand.

(ii) A stone dropped etc.

1.5 FORCE CAN BE CLASSIFIED INTO TWO CLASSES

Type of Forces :

(A) **Contact forces** **(B)** **Non-contact forces**

(A) **CONTACT FORCE**

- In all the above cases we observed that force acts on an object only when the force is in contact with the object. Such forces are called Contact force

- Contact forces represent the result of physical contact between two objects, one by which force is exerted and the other on which force is exerted.
- Pulling (stretching) of a coiled spring, pulling of a cart/and kicking of a football are some examples of contact forces. The force exerted on us by the wind is also a contact force.
- Contact forces are the following types :

(i) **Muscular Force :** If a school bag is lifted or a football is kicked, force is applied. Whatever you do, you do it with the force of your muscles. Your body has to be in contact with the object to apply a force. **This force exerted by the muscles is called a muscular force.** All animals and human beings use their muscles to do work. The muscles exert a force on the object that brings it in motion. Muscular force can also change the speed of moving bodies [fig. (a) & (b)].

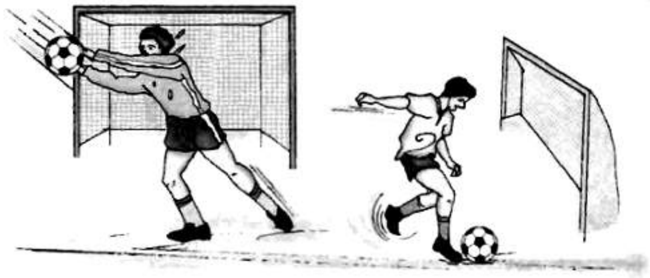


Fig.: Muscular Force

(ii) **Mechanical Force :** The force exerted by a machine is called **mechanical force**. Machine do not produce force by themselves. In order to produce force they need energy from other sources. Mechanical force produced by a car engine, and mechanical force produced by the turbines in a hydroelectric power station (figure) are examples of contact forces. A crane lifting heavy objects with the help of a mechanical force is also an example of contact force. Here the heavy object and the crane come in contact with each other. Therefore the mechanical force that makes the crane lift the object is a **contact force**.

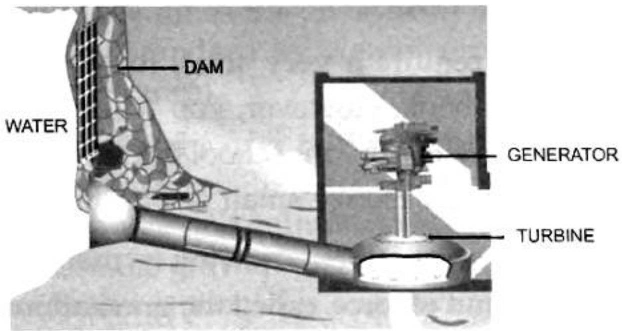


Fig.: Muscular Force

(iii) **Applied Forces :** The forces that we use with our hands, leg, figures, etc. are collectively called **applied forces**. When we tie a stone to a string and suspend it, the tension in the string opposes the force of gravity of the Earth and keeps the stone from falling down. When we do work with our hands, like lifting a weight, or pulling an object, the force required is provided by the tension of our muscles. When we need to apply a force, the brain sends a signal to the muscle (in the form of electrical signals via the nerve cells), which makes the muscle contract. This is how we can apply a force with our hands, legs, etc.

(iv) **Frictional Force :** The resistance into the motion experienced when two surfaces in contact move with respect to each other is called **friction**. Whenever the surface of one body slides over that of another, each exerts a force on the other which opposes the motion of the body. This is called frictional force. Frictional force comes into play only when two surfaces are in physical contact and is, therefore, a contact force.

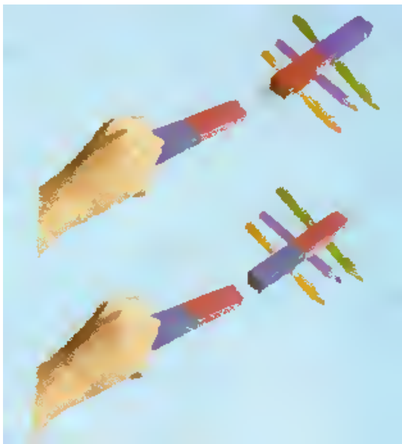
Friction is a very complex phenomenon, and there is a lot about it that still needs to be explained. Two simple explanations for why friction is caused are as follows:

- Any surface, however smooth, has a lot of irregularities when seen under a microscope. These irregularities are like hills and valleys. When two such surface slide over each other, there will be a resistance to motion (friction).
- Another theory that explains friction says that when two surfaces come in contact, their atoms and molecules pull each other due to electrostatic forces. They 'stick' to each other at a microscopic level. When we try to slide the surfaces with respect to each other, these offer a resistance to motion. Frictional force depends on two main factors : the nature of the surfaces in contact and the mass of the object.

(v) **Tension Force :** Tension is a force exerted by string, ropes, fibres and cables when they are pulled.

(vi) **Normal Force :** The force perpendicular to the surfaces of the objects in contact is called normal force.

(B) NON CONTACT FORCE OR (ACTION AT A DISTANCE FORCES)



- These forces do not need any physical contact with the object on which they are acting and they can also act through empty space.
- The action at a distance force are the forces which do not involve physical contact between the two objects but act through the space between the two.
- There are three types of non-contact force

Non-contact force
- Gravitational Force
- Electrostatic Force
- Magnetic Force

- The gravitational force, electrical force, and magnetic force are very common property that they act from a distance.

(i) **Gravitational Force :** *The force with which objects pull each other is called **gravitational force**.* This force is very small and we can feel it only if an object is very massive, like the Earth. It is the gravitational force of the Earth that keeps us bound to the Earth. Gravitational force makes the Earth move around the sun and also makes the moon go around the Earth. In fact, our weight is the gravitational force of the Earth acting on us. Different objects exert different magnitudes of gravitational force. For example, the gravitational force of the moon is about one-sixth that of the Earth. This means that the weight of any object on the moon will be one-sixth of its weight on the Earth.

(ii) **Electrostatic Force :** The force between electric charges is called electrostatic force. If we rub a plastic object like a pen, comb, or CD with hair and bring it close to tiny bits of paper, the bits of paper get attracted to the plastic object (Fig.). This is due to electrostatic force. Tiny particles of dust and smoke can also be attracted by electrostatic force. This method is used in electric air purifiers and in factories to purify air in chimneys before letting it escape into the atmosphere.

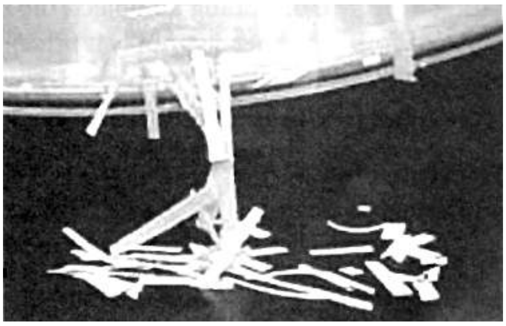


Fig.: A charged CD attracting pieces of paper

(iii) **Magnetic Force :** The force exerted by magnets on each other and on metals like iron and nickel is called magnetic force. Since magnets attract iron (Fig.), they are used to separate waste iron objects from garbage dumps so that they can be recycled.

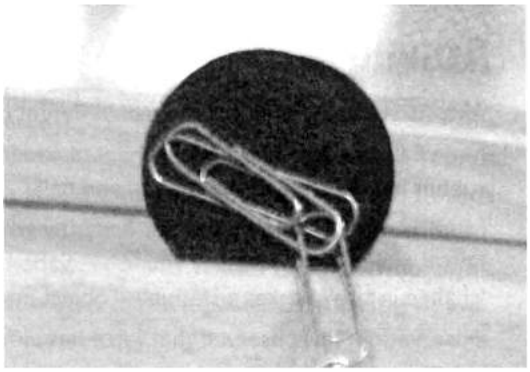


Fig.: A magnet attracting iron pins

Gravitational force: Objects or things fall towards the earth because it pulls them. This force is called force of gravity.

Note: Gravity is not a property of earth alone. In fact, every object in the universe, whether small or large exerts a force on every other object. This force is known as the gravity force.

Electrostatic force: Force exerted by any charged body on another charged or uncharged body is known as electrostatic force.

Illustration 1

What is force?

Solution

Force acting on a body is push, pull or squeeze. It can not be seen, we can feel the force through its effects.

Illustration 2

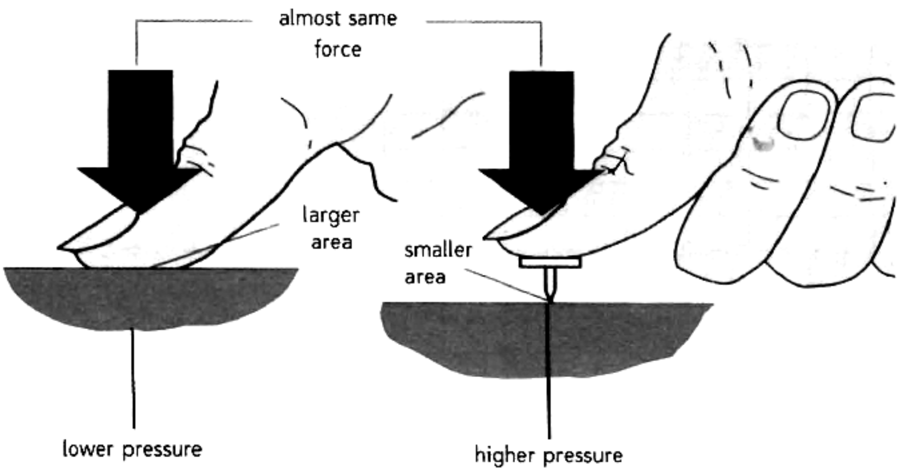
Write True or False for the statements given below.

1. A force can make a moving object move faster. **[True]**
2. A moving object can be slowed down by applying a force. **[True]**
3. Forces that do not need physical contact with the object on which they are acting are called contact forces. **[False]**
4. An electrostatic force is a contact force. **[False]**
5. A magnetic force is a non-contact force. **[True]**

1.6 INTRODUCTION (PRESSURE)

Press your thumb against a piece of paper without using your nails. What do you see? Now take a needle or a drawing pin and push its pointed end against the paper. What do you see this time? You will see that if you use a needle or a drawing pin, you will be able to make a hole in the paper, while you can't do the same with your thumb. Can you explain why this happens?

Although the force applied on the paper is almost the same in both the cases, the needle has a much smaller area of contact as compared to our thumb. This means that in the case of the needle the area over which the force acts is smaller, and therefore, its effect on the paper is much greater (it makes a hole in the paper). This is because of a physical quantity called **pressure**.



Pressure is defined as the force per unit area. The SI unit of pressure is **pascal** (Pa), which is newton per square metre.

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

The effect of force on a body depends on the pressure produced. Some very important and useful devices such as syringes, dropper, straw, etc. work on the principles of pressure.

The normal force acting on a unit area of a surface is called pressure.
So porters place a round piece of cloth on their heads, when they have to carry heavy loads. By doing this they increase the area of contact of the load with their head.
So, the pressure on their head is reduced and they find it easier to carry the load. In mathematical form.

$$\text{Pressure} = \frac{\text{Normal Force (Thrust)}}{\text{Area on which it acts}}$$

Remember

Blaise Pascal (1623-1662)

Have you ever wondered why the unit of pressure is called pascal? It is named after the French mathematician and physicist Blaise Pascal. He was a child prodigy. He has made important contributions to the study of fluids and pressure, among many others.

Remember

Factors on which applied Pressure depends = $P \propto F$,

i.e. Pressure directly proportional to force and $P \propto \frac{1}{A}$ i.e. Pressure is inversely proportional to Area.
A camel has flat, broad feet that reduce the pressure exerted on the sand. As a result, the camel's feet sink very little in the sand, allowing it to move fast.

Illustrations

Illustration 2

If a force of 2 N is applied over an area of 2 cm^2, calculate the pressure produced.

Note: To get the pressure in Pa, we have to make sure that the force is in newton and the area in m^2.

Solution

Here, the area is in cm^2. To convert this to m^2, we have to divide the given area by 10,000.

Thus, $\text{Area} = \frac{2}{10{,}000} = 0.0002\ \text{m}^2$

Now, $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$

$$= \frac{2\text{N}}{0.0002\ \text{m}^2} = 10{,}000\ \text{Pa}$$

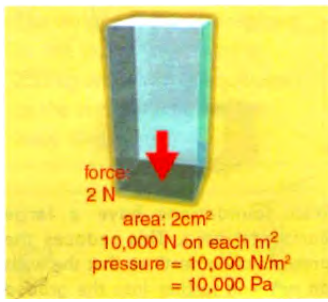


Illustration 3

Calculate the pressure if a force of 2 N is applied on an area of 2 mm^2.

Solution

Here, again the area is not in m^2. To change it into m^2, we divide the area by 1,000,000.

Thus, $\text{Area} = \dfrac{2}{1{,}000{,}000} = 0.000002 \text{ m}^2$

Now, $\text{Pressure} = \dfrac{\text{Force}}{\text{Area}}$

$$= \frac{2 \text{ N}}{0.000002 \text{ m}^2} = 1{,}000{,}000 \text{ Pa}$$

Have you noticed that in the above two examples we have taken the same force and calculated the pressure when this force acts over two different areas? You will see that the same force, when acts on a smaller area produces a greater pressure.

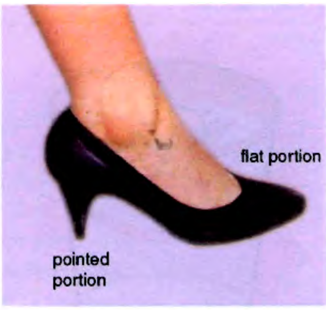
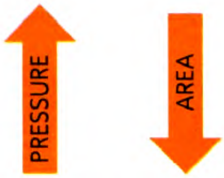


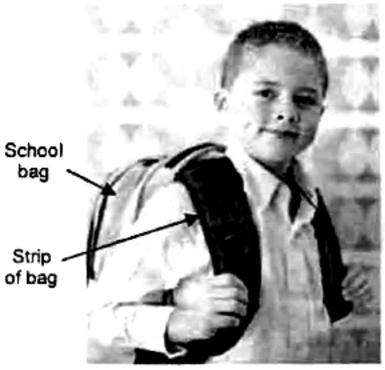
Fig. *The pointed end of a high-heeled shoe exerts a greater pressure than the flat end*



This picture is conveying a message. Can you figure out what it is? ....

1.6.1 Examples of Pressure in Everyday Life

1. The drawing pin is broad-based towards the thumb side and pointed towards the other end. This decreases the area of contact and the pressure exerted by the thumb increases. Thus, piercing becomes easier.
2. Desert animals like camels can walk easily on sand as compared to other animals because they have broad feet which exert less pressure on the ground.
3. Foundations of high-rise buildings are kept broad and wide so that they exert less pressure on the ground and do not sink in due to extremely high pressure of the building.
4. Porters wear turbans when they have to carry heavy loads on their heads, to increase the area of contact. This reduces pressure on their heads.
5. School bags and shopping bags have broad straps or belts so that the area of contact increases and pressure on the hand or shoulder is reduced.



6. A heavy truck or a lorry carrying heavy loads has eight tyres instead of four and the tyres are broader. This increases the area of contact with the ground, thus reducing the pressure exerted on the ground.

7. Have you ever noticed that the rails on a railway track are fixed to large wide wooden or steel sleepers? The heavy thrust of the train on the rail is spread over the large surface area of the sleepers. It reduces the pressure on the ground and prevents the rails from sinking into the Earth under heavy pressure

Remember

Variation of pressure with area

We have learnt just now that, for the same force, increasing the area over which it acts decreases the pressure applied. The converse is also true: decreasing the area of application increases the pressure produced, for the same force. This property is made use of many appliances that we use, to increase or decrease pressure.

The studs on a football boot have only a small area of contact with the ground. The pressure under the studs is high enough for them to sink into the ground, which gives extra grip.

Skis have a large area to reduce the pressure on the snow so that they do not sink in too far.

The area under the edge of a knife's blade is extremely small. Beneath it, the pressure is high enough for the blade to push easily through the material that needs to be cut.

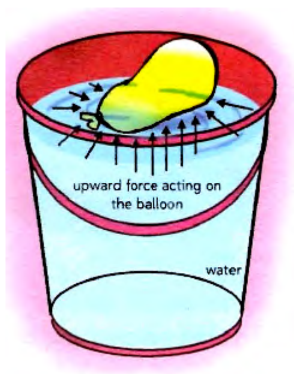
Wall foundations have a large horizontal area. This reduces the pressure underneath so that the walls do not sink further into the ground under the weight of the building.

1.6.2 Pressure exerted by Liquids and Gases

If a liquid is filled in a container then it exerts a pressure on the walls of the container, similarly gases too exerts pressure on the walls of their container.

(i) Pressure in fluids

Have you tried to push an inflated balloon into a bucket of water? Try it. You will find that as you try to push down the balloon, the water seems to be pushing it right back, upward! In fact, if you stop pushing the balloon, the balloon will be pushed back to the surface. This is because the water in the bucket exerts a pressure on the balloon (Fig).



Fluids exert pressure

Liquids and gases are together called fluids. Fluids exert pressure on all bodies immersed in them and on the walls of the container that holds them. This is why a balloon expands when we blow air into it. The air inside the balloon exerts a pressure on the inner wall of the balloon. If we blow in too much air, and the material of the balloon is not capable of expanding further, increasing the pressure inside can cause the wall of the balloon to break at one or more points. This is why a balloon bursts when too much air is blown into it.

Did you know that all of us are immersed in a sea of air and are experiencing its pressure all the time? This is called atmospheric pressure. We will learn about atmospheric pressure in the following section)

In case of solids the force can be applied in any direction with respect to the surface but in liquids, the force must be applied at right angles to the liquid surface. This is because fluids (liquids and gases) at rest cannot sustain a tangential force. Therefore, we state the pressure acting on the fluid instead of force.

The pressure (P) is defined as the magnitude of the normal force acting on a unit surface area of the fluid.

If a constant force of magnitudes F acts normally on a surface area A, then pressure acting on the surface is given by P = F/A.

The pressure is a scalar quantity this is because hydrostatic pressure is transmitted equally in all directions when force is applied which shows that a definite direction is not associated with pressure.

(ii) Units of pressure

(a) CGS and SI unit: In CGS, system unit of pressure is dyne cm^{-2}. In SI unit of pressure is Nm^{-2} or Pascal (Pa)

$$1 \text{ Pa} = 1 \text{ N m}^{-2}$$

Scientists discovered atmospheric pressure in the seventeenth century. This discovery uncovered an interesting fact-that air actually has weight! The weight of the atmosphere presses down on the earth's surface and creates a pressure on it. The pressure at any point exerted by the weight of the air above it is called atmospheric pressure.

The pressure of the air inside makes the balloon expand

Atmospheric pressure is defined as the pressure exerted on an object by the weight of the air above it.

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

Fact: The weight of the atmosphere on the top of your head is 250 kg wt, which is equivalent to the weight of about two baby elephants.

(iii) Variation of atmospheric pressure with altitude

The altitude of a place is its height above sea level. The atmospheric pressure at a place depends on its altitude. The atmospheric pressure decreases as we go up. Can you tell why this happens? We know that atmospheric pressure at a place is the force exerted by the weight of the air column above that place. As we go up, the length of the air column above us decreases. This means its weight, and therefore the atmospheric pressure is smaller at higher places (than at sea level).

What do you think will happen if air pressure is suddenly taken away? If the pressure of atmosphere is removed suddenly, our blood vessels and tissues will rupture 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.

(iv) Pressure in Liquids

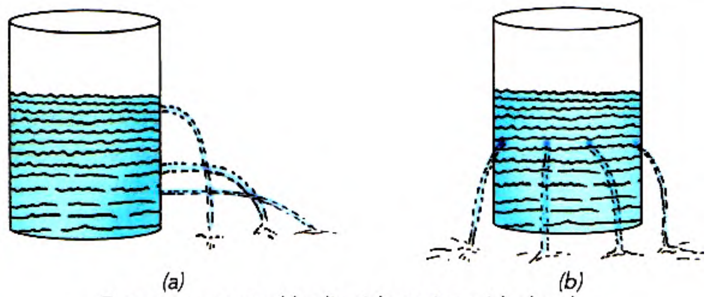
As we mentioned earlier, both liquids and gases exert pressure. We just now learnt about the pressure exerted by air. Let us now learn about the pressure exerted by liquids.

Try pushing down an inverted glass bottle into a bucket full of water. You will notice that the bottle resists being pushed down into water. This happens because of the force exerted by water on the bottle. 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 the point.

When an object is immersed in a liquid, the liquid exerts a net upward force on the object. This upward force determines whether an object will float or sink in a liquid. If the upward force exceeds the weight of the object, the object floats; if the weight of the object exceeds the upward force, the object sinks.

(v) Variation of pressure with depth

As we go deeper beneath the surface of a liquid, the pressure increases. Pressure increases with depth. Deep under the sea the pressure exerted by water is much greater than at the sea level. See Figure.



Pressure exerted by liquids varies with depth

The pressure experienced by deep-sea divers is so great that they have to wear specially designed suits to protect themselves. They use special suits called diving suits and buoyancy compensators to combat the weight of their diving equipment and the water pressure at great depths [Fig. (a)].

Dams are made stronger and thicker at the bottom than at the top to withstand the high pressures at greater depths [Fig. (b)].

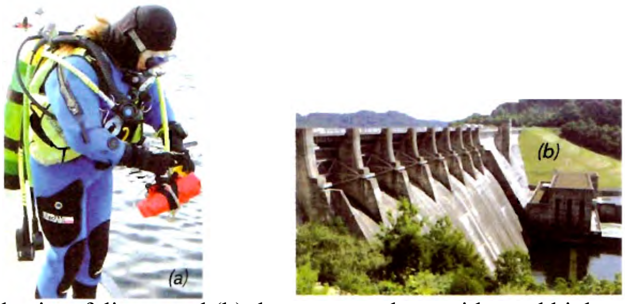


Fig.: (a) Special suits of divers and (b) dams are made to withstand high pressures at greater depths

Remember

- **Decompression sickness :** Decompression sickness, one of the dangers of diving, is a common symptom noticed in most deep-sea divers. Because deep sea divers have to breathe air at high pressure under water, more air dissolves in their blood and tissues than at atmospheric pressure. Now if the diver were to swim to the surface quickly, it's like uncorking a soda bottle-the air is released. This leads to a painful condition called decompression sickness, also called bends, which is characterized by severe pains in joints and chest, skin irritation, cramps, and paralysis. In severe cases, the condition may prove to be fatal too. To avoid the effects of quick decompression, it is advisable that the diver rises slowly and/or makes intermittent stops on the way up (called "decompression stops") so that the air can escape slowly.

- **Reason behind the release of nitrogen gas :** Deep under water the solubility of gases increases because a greater amount of gas dissolves under high pressure. When the diver rises to the surface suddenly, there is a sudden drop in the surrounding pressure, which causes the air (containing mainly nitrogen gas) to escape or decompress This results in the formation of nitrogen bubbles in the blood and tissues, consequently causing severe pains to the diver.

Remember

Atmospheric Pressures on Other Planets :


Have you ever wondered if there is an atmospheric pressure on other planets? Well, if a planet has an atmosphere, it will have an atmospheric pressure too! For example, the atmospheric pressure on Jupiter is so high that scientists believe that on Jupiter, hydrogen exists as a super hot liquid metal. The planet Venus too has a thick atmosphere and has an atmospheric pressure of about 90 times that on the surface of the earth.

Atmospheric pressure :

The envelope of gases surrounding the earth is called atmosphere. At the earth's surface the composition of dry air is 78% nitrogen, 21% oxygen, 0.94% argon, 0.03% carbon-dioxide, 0.01% hydrogen and the remainder includes small amounts of neon and helium. As we go higher, the density of atmospheric air goes on decreasing. Thus it becomes difficult to breath at high altitude above sea level. The ocean of air (i.e. atmosphere) exerts pressure on the earth's surface. The pressure is called atmospheric pressure.

Standard or normal atmospheric pressure is equal to the pressure due to a column of 76 cm (= 0.76 m) of mercury at 0°C at sea level, density of mercury = 13.6×10^3 kg × m^{-3} and at sea level, g = 9.8 ms^{-2}.

Now, $P = h\rho g$

$\therefore$ 1 atmospheric pressure $= 76 \times 13.6 \times 10^3 \times 9.8 \text{ N m}^{-2}$

$= 1.013 \times 10^5 \text{ N m}^{-2}$ (or Pa)

Practical units of atmospheric pressure:

1 Atmosphere (atm) = 76 cm of mercury column at 0°C and at sea level
$= 1.013 \times 10^6$ dyne cm^{-2}
$= 1.013 \times 10^5$ Nm^{-2}
$= 1.013 \times 10^5$ Pa

1 bar $= 10^6$ dyne cm^{-2}
$= 10^5$ Nm^{-2}
$= 10^5$ Pa

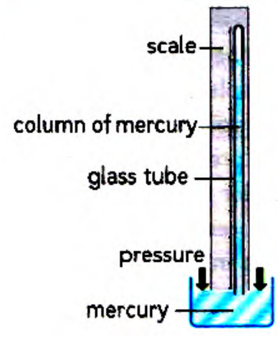
1 millibar $= 10^{-3}$ bar
$= 10^{-3} \times 10^6$ dyne cm^{-2}
$= 10^3$ dyne cm^{-2}
$= 10^2$ Nm^{-2}
$= 10^2$ Pa

1 torr = 1 mm of mercury column
= 133.3 Pa

Remember

Barometer :

An instrument used to measure atmospheric pressure is a barometer. It consists of a long glass tube, which is sealed at one end. It is filled with mercury, a silvery liquid metal. The open end of the tube (filled with mercury) is placed in a small trough full of mercury. The air exerts pressure on the mercury in the trough and is able to hold certain height of mercury column. When the air pressure reduces, the column of the mercury moves down, and when the air pressure increases, the height of the mercury column increases. This way, the pressure is measured by the height of the mercury column, in mm of Hg, i.e., the height of the mercury column in millimeters. At sea level it is 760 mm of Hg.



Water Barometer

Let us suppose water is used in the barometer instead of mercury

We know, atmospheric pressure = 1.013×10^5 N m^{-2}. Let h be the height of the water column supported by earth's atmosphere.

Therefore, pressure corresponding to height h of water column = $h\rho g$

Now $h\rho g = 1.013 \times 10^5$ or $h = \dfrac{1.013 \times 10^5}{\rho g}$

For water, $\rho = 10^3$ kg m^{-2} $\therefore$ $h = \dfrac{1.013 \times 10^5}{10^3 \times 9.8} = 10.3$ m

Thus, the height of the water column in the tube of a barometer will be 10.3 m. Such a long tube cannot be managed easily and hence water can not be the replacement of the mercury in the barometer. In other words, water barometer is not feasible.

1.7 OTHER APPLICATIONS OF PRESSURE

(a) Drinking straw

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

(b) Syringe

In the case of a syringe, the pressure of the liquid (blood) forces the liquid to move into the syringe when its plunger is withdrawn.

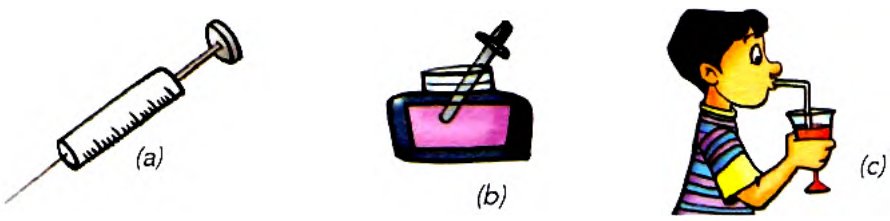


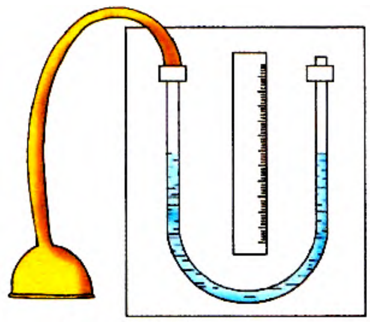
Fig.:(a) Syringe, (b) Dropper and (c) Drinking straw work on the principle of pressure

(c) Vacuum Cleaner

A vacuum cleaner, as you might be aware, helps clean up the debris from carpets and the remotest corners of a house. Have you ever wondered how it works? A vacuum cleaner is an electrical appliance that cleans surfaces by suction. A fan inside the vacuum cleaner lowers the air pressure and creates a low pressure inside the device. Consequently, the air and dirt particles on and near the surface are sucked into the device. This is what helps in cleaning the surface.

(d) Measuring Pressure

The instrument used to measure pressure is called a pressure gauge. The simplest type of pressure gauge is the open-tube manometer which measures pressure difference. A manometer consists of a U-shaped tube containing a liquid (sometimes water). One arm of the tube is open to air and the other arm is connected to the vessel in which we want to measure the pressure (Figure). The difference in liquid level represents the applied pressure.

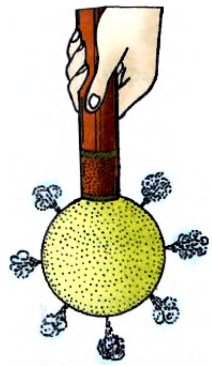


An open-tube manometer

(e) Pascal's Law : The pressure applied to an enclosed liquid gets transmitted equally to every part of the liquid. This property was first demonstrated by Pascal and is called Pascal's law. According to Pascal's law, when some pressure is applied to any part of the enclosed liquid, an equal and uniform pressure gets transmitted over the whole liquid.

Hydraulic devices like hydraulic press and car brakes work on the above principle.

The pressure applied to an enclosed liquid gets transmitted equally to every part of the liquid. It can be demonstrated using a glass vessel with holes at different places as shown in Figure. When a force is applied to the piston, the pressure exerted on the water is transmitted equally throughout the water so that water comes out of all the holes with equal force.



Transmission of pressure in a liquid

Illustrations

Illustration 4

Define Pressure.

Solution

The force per unit area of a surface and normal to it is called pressure.

Illustration 5

A man of weight 500 N (i.e. 50 kg) is standing on a platform of area 1/10 m^2. Find pressure on the ground due to the platform assume platform as massless.

Solution

$$P = \frac{\text{Force}}{\text{Area}} = \frac{500\text{ N}}{1/10\text{ m}^2} = 5000\text{ N/m}^2 = 5000\text{ Pa}$$

Note that force is taken in newton and area is taken in m^2 to get the pressure in N/m^2 or Pa.

Illustration 6

Find pressure due to water at a depth 2m inside it (Given density of water = 1 g/cm^3 = 1000 kg/m^3)

Solution

$P = \rho g h$

Here to find pressure in N/m^2 (SI unit)

We have to take density (ρ) in kg/m^3

g in m/s^2 which is 10 m/s^2

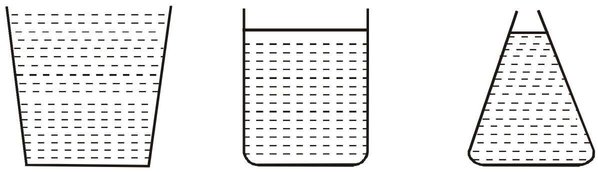
h in metre which is 2m

So, $P = 1000 \times 10 \times 2 = 20000$ N/m^2

Advance Learning

HYDROSTATIC PARADOX

Consider three vessels A, B and C of different shapes as shown in figure.



All these vessels have the same area of base and all of them are filled with water to the same depth. The pressure at the base of each vessel is same, regardless of the shapes of the vessels. Pressure is directly proportional to the depth and by applying Pascals law it can be seen that pressure is independent of the size and shape of the containing vessel.

LET US RECAPITULATE

- Force is a push or pull or squeeze that can change the speed, direction or shape of a body. It may also be defined as an external agency that displaces or tends to displace a body from its position of rest.
- Contact forces are those forces which act only when objects are in physical contact with each other and bring about necessary changes.
- The effect of a contact force depends on the magnitude of the force and the area over which it acts. The smaller the area of contact, the greater is the effect of the force.
- The force exerted by the muscles is called muscular force. It can also change the shape of the bodies.
- Some forces do not involve physical contact between the bodies on which they act. These forces are called 'Non-contact Forces.'
- The force which a magnet exerts on the iron nails is called magnetic force .
- The force which results due to repulsion of similar charges or attraction of opposite charges is called electrostatic force.
- When two surfaces slide over each other, the force which opposes their relative motion is called friction or force of friction.
- Mass is the quantity of matter contained in a body. Weight is the force with which the Earth pulls a body towards its centre.
- The force acting per unit area of a surface is called pressure .
- SI unit of pressure is Nm^{-2}. Pascal is another unit of pressure $1\ Pa = 1Nm^{-2}$
- The total force acting perpendicularly on a surface is known as thrust. Pressure = $\frac{\text{Thrust}}{\text{Area}}$
- According to Pascal's law, when pressure is applied to any part of the liquid, an equal and uniform pressure gets transmitted over the whole liquid.
- The atmosphere is the layer of air around the Earth. It extends up to 1000 km above the surface of the Earth and has a total weight of about 4.5×10^{18} kg. This weight exerts a pressure on the surface of the Earth which is called atmospheric pressure.
- At high altitudes the air pressure is less, therefore, breathing is difficult and nose bleeding may occur.
- The single force which acts on the body to produce the same effect in it as done by all the forces collectively is called resultant force. When two forces act in the same direction along the same line, the resultant force is equal to the sum of the two forces.
- When two forces act along the same line but in opposite directions, the resultant force is equal to the difference of the two forces.
- In case the resultant of all the forces acting on an object is zero, the forces are said to be balanced forces. For a given force, smaller the area of contact, higher is the pressure exerted by it.
- For a given force, larger is the area of contact, lesser is the pressure exerted by it.
- For a fixed area of contact, the pressure exerted increases with an increase in force or other way round.
- A pressure exerted by a liquid increases with depth, pressure at the bottom of the sea is much greater than its surface. At a depth of 1000 m, pressure due to water is about 100 times greater than the atmospheric pressure.
- Pressure exerted by a liquid does not depend on shape or size of the container.