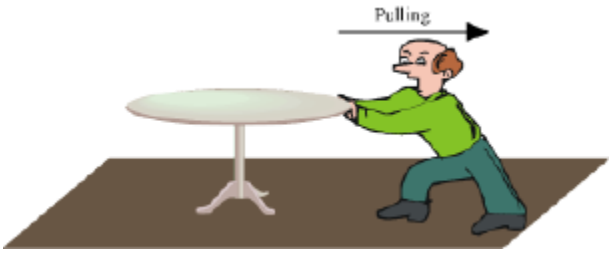
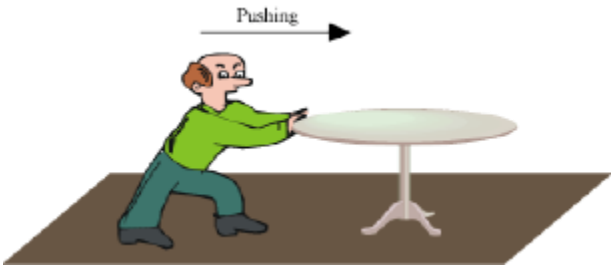
Force and Pressure

Force: Push or Pull



A table can be moved from one place to another by either pushing it or pulling it. Similarly, you can open a door by either pushing or pulling it. When a ball is thrown with more force, it travels a longer distance. The shape of a bottle can change when it is squeezed. Also, the direction of a moving ball can change by striking it.



Have you wondered how the shape of a bottle changes when squeezed? Or how can the direction of a moving ball change by kicking it in different ways?

All the above activities can be associated with **pushing** or **pulling**. Therefore, whenever an object is moved, we can say that it has either been pushed or pulled.

This push or pull is known as force. In other words, a body moves whenever a force is applied to it. Therefore, a body cannot move unless a force is applied.

Apart from push or pull, force is any action that has the tendency to change the position, shape, or size of an object. Everyday actions such as pushing, pulling, stretching, lifting, squeezing, and twisting are also examples of force.

Let us try to list some examples of everyday force and see if we can classify them as push or pull. A few examples have already been classified for you. Try to classify the rest.

Description	**Push or Pull**
Hitting a cricket ball with a bat	Push
Opening a door	Push and Pull
Plucking a flower	Pull
Flying a kite	
Moving a wheel barrow	

Hitting a tennis ball with a racquet	
Taking a carrot out of the ground	
Playing on a swing	
Picking up a shopping bag	
Squeezing a toothpaste tube	

Interaction of Forces

Unit of Force

Do you require equal amount of force to lift your physics book and a bucket full of water? Definitely not! You require greater force to lift the bucket. Can you tell how much more force is required to lift the bucket?

For that, we have to measure the forces. Thus, we require some unit to describe the amount of force.

The SI (International System of Units) unit of force is Newton, which is denoted by N.

You must have heard the term **kilogram force (kgf)**. It is the commonly used unit of force and is defined as the **force that is required to lift a mass of 1 kg vertically upward**.

Do you know what the relation between the two units of force is?

1 kgf = 10 N

Therefore, you can easily define 1 N. Just try it.

Interactions of Forces

Have you ever seen an arm wrestling match? In an arm wrestling match, both the players try to push each other's hand towards the table. Hands move along the direction of the player who applies a greater force. The player who is able to apply more force wins the match.

A table in your room or a vehicle parked outside your house cannot move unless it is either pushed or pulled. To move a table, you have to either push or pull it. In cricket, a bat exerts force on the ball. Thus, the ball is able to gain speed and can reach the boundary line.

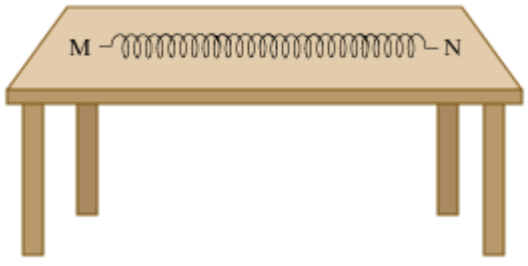
Thus, we can observe that force comes into play when at least two bodies interact with each other. **Can you list the two interacting bodies in the cases that we have discussed?**

Scenario	Interacting bodies
Arm wrestling	Arms of the players
Pushing or pulling a table	You and the table
A moving vehicle	Vehicle and the road (or the ground)
Bat hitting a ball	Bat and ball

What will happen if more than one force acts on a body?

In a game of tug of war, two teams try to pull each other towards themselves. This game is won by the team, which applies more force in their direction. Thus, the net resultant force is in their direction.

Balanced and unbalanced forces in a body



A metal spring having two ends M and N are placed on a table.

When you pull the end M of the spring, it will move towards the l
end N of the spring, it will move towards the right. **What will ha**
simultaneously pull both ends of the spring with the same fo

The spring will stretch and its shape and size will change, but it will not move because the net force acting on it is zero.

What will happen if two unequal forces are applied at the two ends of the spring?

When unbalanced forces are applied at the ends of the spring, it will start moving in the direction of the greater force. Hence, the net force is not zero in this case.

A toy car is pushed on a rough floor and is allowed to move. It moves some distance and comes to rest. **Why does the toy car come to rest?**

The toy car comes to rest after some time because of the frictional force between the moving wheels of the car and the rough floor. This force acts in the direction opposite to the direction of motion of the car. This means that an unbalanced force acts on the car in the direction opposite to the direction of motion of the car. As a result, it will come to rest after some time. Hence, in order to keep the toy car moving, one should push it again before it comes to rest.

An unbalanced force can stop a moving object.

An object moves with a uniform velocity when no net external force is acting on it i.e., the forces acting on it are balanced.

What will happen if you try to push a table on a rough floor?

The result of the applied force will depend on the magnitude of the force applied on the table.

The figure given above shows the various forces acting on the table.

Where,

F_1 → Magnitude of the applied force

F_2 → Frictional force caused by the rough surfaces in contact

It is clear from the figure that the frictional force F_2 opposes the applied force whereas force F_1 tends to overcome the frictional force. The table will not move, if you apply a small force. However, if you apply a force that is greater than the frictional force, then the table will move in the direction of the applied force.

Thus, from the above observations, we can conclude as follows

- If many forces act on a body in the same direction, the net force on the body is equal to the sum of all the forces.
- If two forces are acting on a body on opposite direction, the net force on the body is equal to the difference of the two forces. For the above example of table being pushed on a rough floor, the net force on the table = $F_1 - -F_2$, when table is moving. If the table is not moving, the net force on the table = $F_2 - - F_1$.

Effects of Force

Force cannot be seen, heard, or tasted. Only its effects can be felt or seen. It is correctly defined as a push or pull upon an object resulting from the object's interaction with another object. The various effects of force are:

It can move a body initially at rest.

It can bring a moving body to rest.

It can change the direction of a moving body.

It can change the speed of a moving body.

It can change the shape of a body.

It can change the size of a body.

Let us take an example of a football lying in a field. When a player hits the ball, it starts moving, i.e., it starts moving only when we apply force. Thus, force can move a body initially at rest.

Now, if the goalkeeper catches the moving ball, then it comes to rest. The goalkeeper applies a force to stop the moving ball. Hence, we can say that force can bring a moving body to rest.

If another player kicks the moving ball in the opposite direction, then it starts moving in the direction towards which it is kicked i.e. the direction of the football changes. The player applies force on the football to change its direction. Hence, force can change the direction of a moving body. Also, if the player hits the ball hard, then the net speed of the ball will also change. Hence, the speed of a moving body can be changed by applying force.

The shape of a deflated football can be changed by inflating it. When you inflate a football, you apply force on the pump. Hence, force can change the shape of an object. Also, if you keep inflating the football, then its size will keep on increasing. Hence, force can change the size of an object.

A deflated football

Force can change the shape of an object

Force can change the size of an object

Contact Forces

Contact Forces

Anuj is cycling on the road. He observes that as he stops pedalling, the cycle stops moving after travelling for some distance. **Let us see why this happens?**

Forces acting between two bodies can be classified into two broad categories: **Contact force** and **non-contact force**. Let us learn about contact forces in detail.

Contact forces are those that act between two objects, which are in direct contact with each other. The two common examples of contact forces are ***muscular*** and ***frictional***.

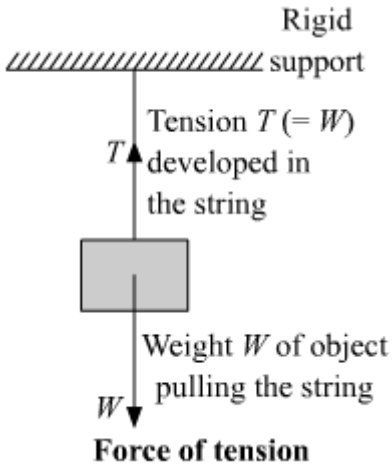
Frictional Force

Earlier you had seen that as Anuj stops pedalling the bicycle, it stops after some time. This happens due to the external force acting between the road and tyres of the bicycle. This force is known as the **frictional force**. The force of friction acts between all moving bodies, which are in contact with one another. The force of friction always acts opposite to the direction of motion. The magnitude of this force depends on the nature of the surface in contact.

Frictional force is a contact force.
Frictional force always acts between two moving objects, which are in contact with one another.
Frictional force always acts opposite to the direction of motion.
Frictional force depends on the nature of the surface in contact.

Tension Force

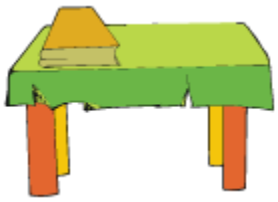
This force appears in a string, attached to a rigid support, when an object is suspended by it. In such case, the object pulls the string vertically downwards due to it weight and the string in its stretched condition pulls the object upwards by a force which balances the weight of the object. This force developed in the string is called tension *T*.



Muscular Force

The force applied by the action of muscles in our body is termed as a ***muscular force***.

For example, when you pick up a book placed on the table using your hands, you apply muscular force.



For lifting the book from the table using your hands, you had to touch the book. You cannot lift the book without making contact with it. Hence, ***muscular force is a contact force***.

Like humans, animals also use muscular force to perform various activities. For example, birds fly in the air by flapping their wings.

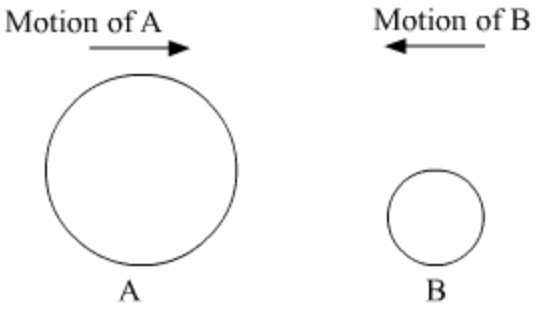
Mechanical Force

One more common example of contact forces is a **mechanical force** which is defined as the force generated by a machine. All the mechanical works are done by the mechanical force.

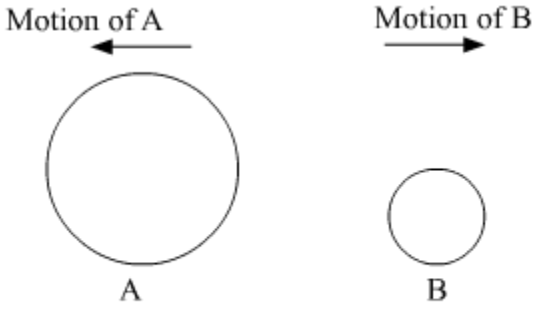
For example, when the car gets started the car's engine creates a mechanical force on the tyres that helps the car to accelerate. So here, the movement of car occurs due to the force generated by the machine on the tyres.

Force Exerted During Collision

Two objects push each other with an equal but opposite forces if collision occurs between them. These forces are known as the force of action and force of reaction. Let us consider a situation in which an object B in motion collides with a moving object A and applies a force F_{AB} on the object A i.e. an action force. At the same instant, the object A also applies an equal but opposite force of reaction F_{BA} on the object B. Because of this, they move apart from each other after collision.



Two objects moving towards each other



Objects moving away from each other after collision

Do you know the force(s) involved in the movement of trolley bags?

When we pull the trolley we are applying muscular force on it and at the same time, there is a frictional force acting between the tyres of the trolley and floor. These two forces are together responsible for the movement of the trolley.
So we can say that, **Combined forces** are nothing but varieties of forces acting on an object at the same time.

Non-Contact Forces

Does force act only when two objects are in contact?

To understand, let us perform a small activity. Take a bar magnet and an iron nail. Bring the magnet close to the iron nail, but do not bring them in contact.

What do you observe?

The iron nail moves towards the magnet. This means that there must be a force that is acting between the magnet and the iron nail.

Since the iron piece moves towards the magnet (even when they are not in contact), we can say that the force exerted by the magnet on the iron piece is a **non-contact force**.

Non-contact forces are those forces that act between two objects, but are not in direct contact with each another. Examples of non-contact forces include magnetic force, electrostatic force, and gravitational force.

Magnetic force

What will happen if you bring the South Pole of a bar magnet close to the North Pole of another bar magnet? The magnets will attract each other. They attract each other with ***magnetic force***.

What will happen if you bring the North Pole of both bar magnets close to each other? The bar magnets will repel each other. The force with which they repel each other is known as **magnetic force**.

Magnetic force can be attractive as well as repulsive.

Magnetic force is a non-contact force.

Magnetic force acts between two magnets, or between a magnet and a magnetic material (such as iron).

Magnetic force depends on the strength of the magnet used.

Magnetic force also depends on the distance between the interacting bodies.

Electrostatic force

Take a paper and tear it into pieces. Now, rub a plastic scale against dry hair and bring this scale close to the paper pieces. **What do you observe?**

You will observe that the pieces of paper are attracted towards the scale. This happens because rubbing of the scale against dry hair produces an electrostatic charge. Thus, the scale attracts the pieces of paper by a non-contact force known as **electrostatic force**.

Electrostatic force is a non-contact force.

Electrostatic force can be attractive as well as repulsive.

Electrostatic force is the force that exists either between two charged bodies, or between a charged and uncharged body.

Electrostatic force depends on the magnitude of charge present in the bodies.

Electrostatic force also depends on the distance between the interacting bodies.

Gravitational force

Do you know why apples fall towards the ground from trees? Why does water from a tap flow down?

The Earth attracts everything (that is near or on its surface) towards its centre by a non-contact force known as **gravitational force**. It is this force that makes an apple fall towards the ground from the tree and makes the water from a tap flow down.

Gravitational force is a non-contact force.

Gravitational force is an attractive force.

Gravitational force is the force that is exerted by the earth on every object, which is near or on its surface.

Gravitational force depends on the mass of the body.

Gravitational force also depends on the distance between the Earth and body.

Pressure

Press your thumb against a drawing board. Your thumb does not go inside the drawing board. Now, take a drawing pin and press it against the drawing board. The pin goes inside. **Why does the pin penetrate the drawing board?**

We know that it is easier to push a nail into a wooden plank by its pointed edge. **Why is it difficult to push a nail into a wooden plank by its blunt end?**

Why do your feet sink when you walk on loose sand?

When we walk on loose sand, our feet go inside the sand. However, this is not the case when we lie on loose sand. The force that is acting on the sand is our weight. Our feet have smaller surface areas than our entire body. This is the reason why our feet go deep inside the sand, but our bodies do not.

From these observations, we can conclude that the same force can produce different effects. The pressure exerted on a body depends upon the following two factors:

1. Force Applied

2. Area over which the force acts

The same force can produce different pressures, depending on the area over which it acts. For example, when a force acts over a large area, it produces a small pressure. However, if the same force acts over a small area, it produces a large pressure.

Pressure is the force that acts perpendicularly on a unit surface area. To obtain the value of pressure, we should divide the force acting on an object by the area on which it acts. Thus, the value of pressure is:

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

The unit of pressure is Newton per square meter (N/m^2), which is also known as Pascal.

$$1 \text{ Pascal} = 1 \text{ N/m}^2$$

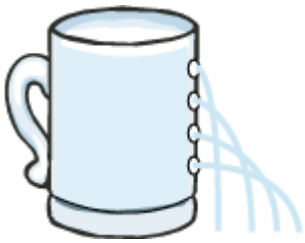
The force acting on a smaller area exerts a larger pressure as compared to the pressure it exerts on a larger area. This is the reason why drawing pins have pointed tips, knives have sharp edges, and dams have wide foundations.

Now, can you explain why it is difficult to carry a bag having thin straps?

Liquids Exert Pressure

Does liquid also exert pressure?

Therefore, it can be concluded that ***liquids also exert pressure***.



Take an empty plastic mug. Make four holes in the mug at different heights (as shown in the given figure). Now, fill the mug with water. **Does the water coming out of the holes fall at the same distance from the mug?**

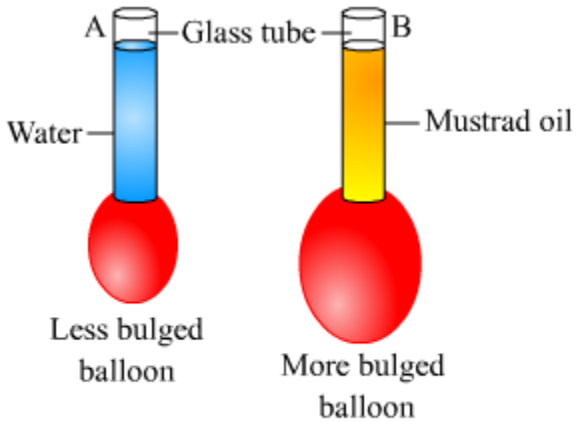
You will observe that water coming out of the holes fall at different distances. The pressure at which water comes out of the holes is directly proportional to its depth.

What happens when you make holes at the same height?

Water falls at the same distance. Thus, this proves that liquids exert equal pressure at the same depth.

Fluids exert pressure on the walls of the container.
Pressure exerted by fluids increases with depth.
Fluids exert equal pressure at the same depth.

- The liquid pressure at a point is independent of the quantity of liquid, but depends upon the depth of the point below the liquid surface. This is known as hydrostatic paradox.
- The liquid pressure increases with the increase in density of the liquid: As the density of mustard oil is more than water, so the balloon tied to tube bulges more than that tied to tube A. This proves that the liquid pressure increases with the increase in density of the liquid.



Liquid pressure increases with increase in density of liquid

- The atmospheric pressure at any point is equal to the weight of a column of air of unit cross-sectional area, extending from that point to the top of the earth's atmosphere.

- Atmospheric pressure at sea level is 1.013×10^5 Pa (1 atm).

- Two pressure-measuring devices are mercury barometer and open-tube manometer.

Consequences of liquid pressure

- The pressure at a certain depth in river water is less than that at the same depth in sea water. This is because the density of river water is less than that of the sea water.
- The wall of a dam is made thicker at the bottom as compared to its top. This is because the pressure exerted by the water (liquid) increases with depth. So to withstand such great pressure, thicker walls are required. Thus, the wall of a dam is made such that its thickness increases towards the base.
- The sea divers need to wear special protective suit while diving in deep sea. This is because in deep sea, the total pressure exerted on the diver's body is more than his/her blood pressure. To withstand such high pressure, the diver has to wear a special protective suit, made from glass reinforced plastic or cast aluminium. The pressure inside the suit is maintained at one atmosphere.

Atmospheric Pressure

You know that solids as well as liquids exert pressure. **Do you know that gases also exert pressure?** Let us see how gases exert pressure.

Air in an inflated tyre exerts pressure on the tyre from inside.

Air in an inflated balloon exerts pressure on its skin.

Atmosphere exerts pressure on the surface of the Earth.

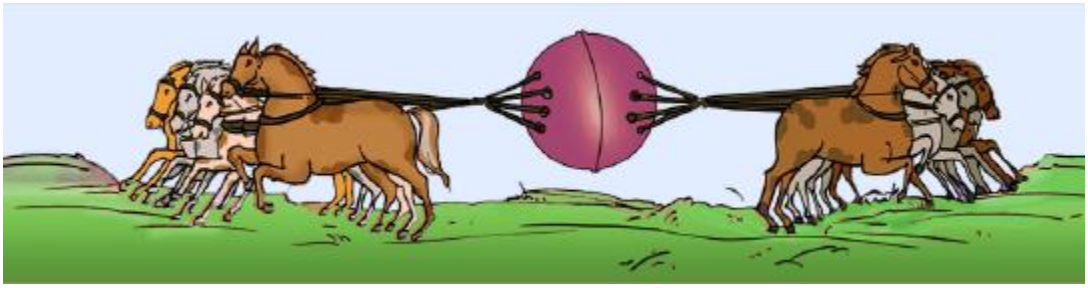
The Earth is surrounded by an envelope of different gases. This envelope of different gases is known as the **atmosphere**. It extends up to a few thousand kilometres. These gases exert pressure known as ***atmospheric pressure***. This pressure results from the weight of the gas molecules present in air.

The weight of air in a column of height of the atmosphere and area 10 cm × 10 cm is as large as 1000 kg.

Take an empty soft drink can. Pump all the air out of it, till practically there is no air left inside the can. This can be done using a vacuum pump. Due to the absence of air inside the can, it can be squeezed and crumbled under the effect of atmospheric pressure acting on the outer surface of the can.

Interesting Fact:

Otto von Guericke, a German scientist, in 1654 at Magdeburg took two hollow metallic hemispheres of 51 cm each. He joined the two hemispheres together. When there was air inside them, they could be easily separated from each other. However, when all the air was pumped out, the force due to the atmospheric pressure on the outer surface of the two hemispheres became so large, that even horses on each side could not separate the two hemispheres.



The Earth is surrounded by a lot of gases. This envelope of gases around our planet is called atmosphere. Atmosphere is vital for the survival of all life forms on the Earth. As gases have mass, they exert pressure on their surroundings. Atmosphere is made up of gases; hence, it also exerts pressure on the Earth' surface as well as on all its life forms. This pressure exerted by the atmosphere is called atmospheric pressure.

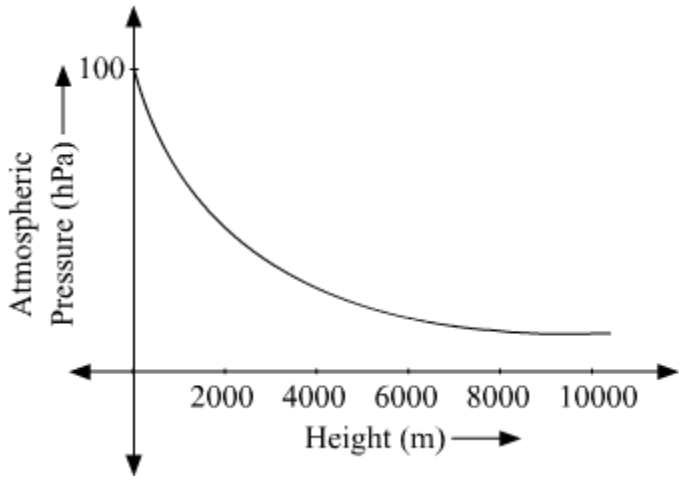
We can now define atmospheric pressure as follows:

The force exerted on a unit area by a column of air above the Earth's surface is called atmospheric pressure.

The value of atmospheric pressure in the SI system is 100000 N/m^2 or 100000 Pa.

Measurement of Atmospheric Pressure

The value of atmospheric pressure is not the same at all places. It is higher at sea level than on mountains. At sea level, the atmospheric pressure is about 100000 Pa or 102102 hPa. The below graph shows the variation of Earth's atmospheric pressure with height from the sea level.



To measure atmospheric pressure, we use an instrument called Barometer.

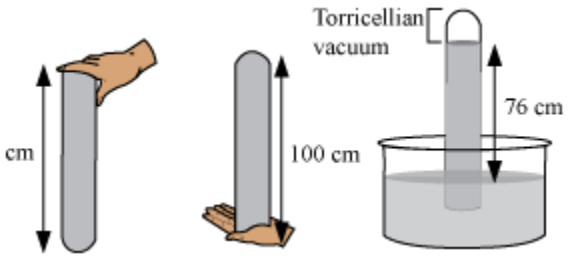
Barometer

Construction—

- A hard glass tube is taken and filled with mercury.
- The open end of the tube is closed with a finger.
- The tube is inverted over a trough filled with mercury.
- The finger is removed only when the open end of the tube is completely immersed in the mercury of the trough.
- On removing the finger, some mercury from the tube flows into the trough; the mercury column shows the height of 76 cm.

Mercury is used in a barometer because—

- It is the heaviest liquid. Hence, only 76 cm of mercury column is needed.
- Mercury gives more accurate readings because it does not stick to the glass tube.
- It can be easily seen while taking the reading because it is shiny and opaque.



Drawbacks of a Barometer—

- Trough is open; hence, there is always a chance of impurities getting mixed with pure mercury.
- It is not portable.
- It is not compact.

Effects of Atmospheric Pressure

If such a big force is acting all around us, then how is it that it is not felt by us? It is not felt by us because the oxygen in our blood also has pressure, which acts in the direction opposite to atmospheric pressure. This pressure of oxygen balances the pressure of the atmosphere. Hence, atmospheric pressure is not felt by us.

If we travel in an airplane and it is not pressurised properly, then our nose would start bleeding at high altitudes. This would happen because pressure at high altitudes is lesser than the pressure of the oxygen in our blood. This difference of pressure would burst the capillaries within our nose, thereby making our nose bleed. So, a passenger aircraft is pressurised properly so that the pressure in the aircraft is the same as at the ground level. Even astronauts wear space suits to counter the low pressure that exists in outer space. Fishes in deep sea water experience more pressure than we do on land; hence, their internal body pressure is more than ours. If these fishes are brought out of water, their body bursts because of the excess outward pressure that exists in the blood.

Similarly, if you take a fountain pen to a higher altitude, you will see that it leaks. This happens because the pressure outside gets reduced in comparison to the pressure inside. The pressure inside the pen squeezes the ink out.

When you use a straw to suck in a soft drink, the same principle is at work. When you suck air out of a straw, the pressure inside it falls. This fall in pressure is compensated by the liquid that is forced up by atmospheric pressure.