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10

FORCE AND MOTION

In the previous lesson you have learnt about the motion of a body along a straight line. You also know that motion can be uniform or non-uniform. You might have seen that a body at rest can be brought to motion and a moving body can be brought to rest. Do you know what makes bodies at rest to move or stop if they are in motion? What changes the speed or direction of a moving object? Why do the dust particles get detached from a carpet when it is beaten with a stick? Why does a ball rolling along the ground stops after moving through some distance? Why cutting tools always have sharp edges?

In this lesson we shall try to find the answer of all such questions.

OBJECTIVES

After completing this lesson, you will be able to:

- *explain the cause of motion - concept of force;*
- *distinguish between balanced and unbalanced forces;*
- *define the terms inertia, mass and momentum;*
- *state and explain the three laws of motion and explain their significance in daily life and nature;*
- *derive a relationship between force, mass and acceleration;*
- *explain the force of friction and analyze the factors on which it depends;*
- *illustrate and appreciate that rolling friction is less than sliding friction;*
- *cite examples from everyday life where importance of friction can be appreciated and*
- *explain the terms thrust and pressure, citing example from daily life situations.*

10.1 FORCE AND MOTION

If we place a ball on a flat surface, it will remain there until unless we disturb it. It will move only when either we push it or pull it. This push or pull acting on an object is known as a **force**. What else happens when we apply force on an object? Think! Let us do an activity to understand it.

ACTIVITY 10.1

Hold an inflated balloon between your palms. Now, apply a force on it by pressing your palms (Fig. 10.1). What do you observe?

You will observe that on pressing the balloon, its shape changes. Thus, we can say that on applying force, the shape of a body can be changed. Can you now think of some other effect of force?

Fig. 10.1 *Shape of balloon changes on applying force on it*

While playing football if you want to change the direction of the moving ball you will have to kick the ball in a particular direction. When you kick the ball, you apply certain force to change the direction of the moving ball. Similarly, you can also change the speed of a moving object by applying force on it. For example the speed of a moving bicycle can be changed by applying brakes on it.

Thus, on the basis of above examples and activities we can say that the force applied on an object can

- make the object move from rest.
- change the speed of a moving object.
- change the direction of motion of the object
- change the shape of the object.

Now, it is time to assess how much have you learnt?

INTEXT QUESTIONS 10.1

1. Is there any force applied when a cricket player changes the direction of ball by using his/her bat?

2. Give an example from your daily life in which the shape of an object changes by applying a force.

10.2 BALANCED AND UNBALANCED FORCES

Have you even seen a game of tug-of-war (Fig. 10.2)? In this game when the two teams pull with equal force they apply balanced forces on the rope. The rope thus remains stationary. When one of the teams applies greater force, it is able to pull the other team and the rope towards their side. In this case forces are unbalanced.

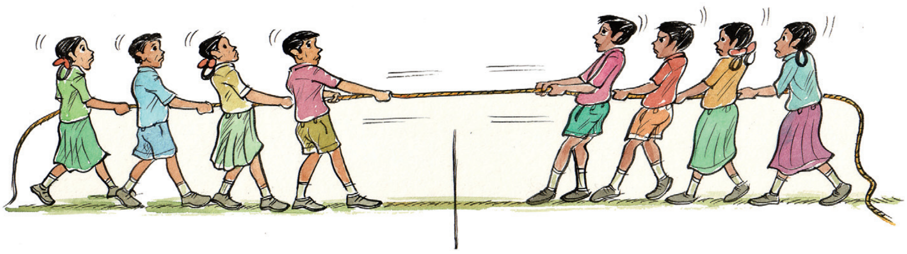
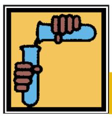


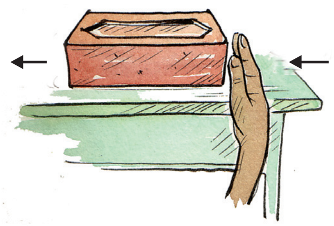
Fig. 10.2 *Tug of war*

For understanding the concepts of balanced and unbalanced forces, let us perform the following activity.

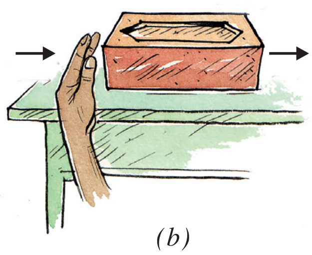


ACTIVITY 10.2

Place a brick on a table. Push the brick towards left with your right hand. What do you observe? The brick begins to move to the left direction [Fig. 10.3 (a)]. Now push the brick towards right with your left hand. In which direction the brick moves this time [Fig. 10.3 (b)]?



(a)



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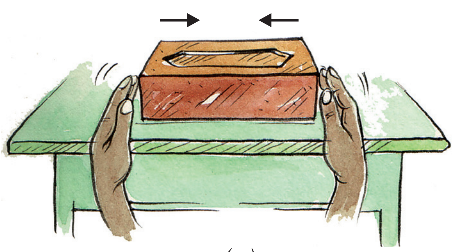


(c)

Fig. 10.3 *Unbalanced and balanced forces*

Now push the brick from both the sides with equal forces [Fig. 10.2 (c)]. What do you observe? In this case you will observe that the brick does not move in any direction. Can you think why the brick does not move this time? In fact, in this case the two forces balance each other. Such forces are called **balanced forces**.

What type of changes can be produced by balanced forces? As seen above, balanced forces do not change the state of rest or motion of the object on which they are applied. Now recall the activity 10.1 and think whether it was balanced or unbalanced force on the balloon? Yes, you are right, it was the balanced force applied by your palms that changed the shape of balloon.

What happen when the two opposite forces acting on the brick are of different magnitudes? In this case the brick would begin to move in the direction of greater force. Such forces are called **unbalanced forces**. Unbalanced forces acting on an object may change its state of rest or motion.

Try to find out some more examples of balanced and unbalanced forces.

INTEXT QUESTIONS 10.2

1. What are balanced forces?
2. Can a balanced force produces any acceleration in a body?
3. What type of change can be produced by an unbalanced force in a body?

10.3 NEWTON'S LAWS OF MOTION

10.3.1 Inertia

You would have seen that whenever we shake the branches of a tree vigorously, the leaves and fruits get detached. Similarly, when you beat a carpet with a stick, you will see that the dust particles get detached from the carpet. Do you know why?

The answer to all such questions is inertia. What is inertia? We can understand the property of inertia by doing a simple activity.

ACTIVITY 10.3

Take a smooth sheet of paper (30 cm × 8 cm) and place it on a table with some part of it coming out of the edge of the table. Now place a glass half filled with water on the paper. Remove the paper with a jerk (Fig. 10.4). What do you observe? You will find that the glass remains in its position. The inertia of the glass prevents it from moving with the paper.

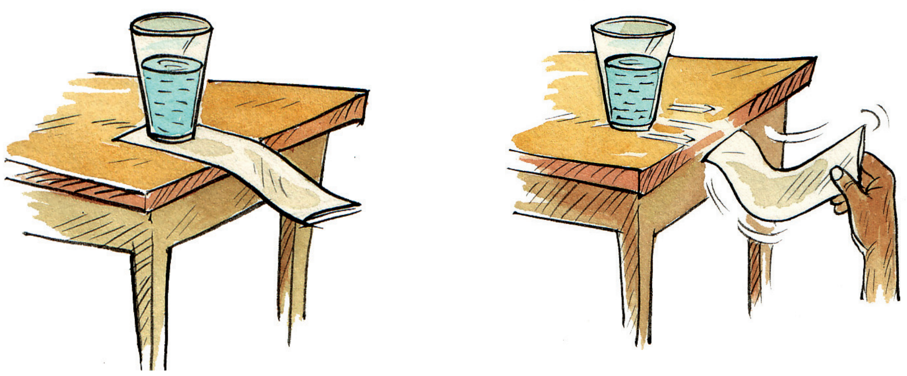


Fig. 10.4 *Glass remains in its position due to inertia*

Thus we can say that the inertia is the tendency of objects to stay at rest or to keep moving with the same velocity. You can find out some more examples of inertia from your daily life. In fact it is the inertia due to which a sprinter keeps running for some time even after crossing the finish line. Similarly, you would have noticed that it is difficult to take out the tomato sauce from a bottle by just inverting it. However, it is easy to take out the sauce from the bottle by giving a sudden jerk to it. By moving the bottle in the downward direction the sauce comes in motion. When the bottle stops suddenly, the sauce remains in motion due to inertia of motion and comes out of the bottle.

10.3.2 Inertia and Mass

By now you have learnt that due to inertia an object offer resistance to change its state of motion. Do all objects have the same inertia? Let us find out.

Push an empty box on a smooth surface. Now try to push a similar box full of books on the same surface. What do you find? Why is it easier to push an empty box than a box full of books?

Now suppose you are asked to stop a table tennis ball and a cricket ball moving with the same velocity. On which ball you are supposed to apply more force to stop it. You will find that cricket ball require more force to stop as compared to table tennis ball.

Thus all objects do not resist a change in their state of rest or motion equally. Massive objects resist more than lighter ones. What do you conclude from these observations? We can say that mass is a measure of inertia.

10.3.3 Newton's First Law of Motion

You have learnt that an object offer resistance to change in its state of motion. This was studied by Newton in detail and he presented his findings in the form of three fundamental laws that govern the motion of objects. Newton's first law of motion is stated as follows:

"Every body continues in its state of rest or of uniform motion in a straight line until unless it is compelled by some unbalanced force to change that state."

Newton's first law of motion tells us that all bodies resist a change in their state of motion. We know that this property of bodies is called inertia. That is why, Newton's first law of motion is also known as the law of inertia.

First law of motion has many applications in our daily life. Why do the passengers standing in a bus fall in the backward direction when the stationary bus begins to move suddenly (Fig. 10.5)?

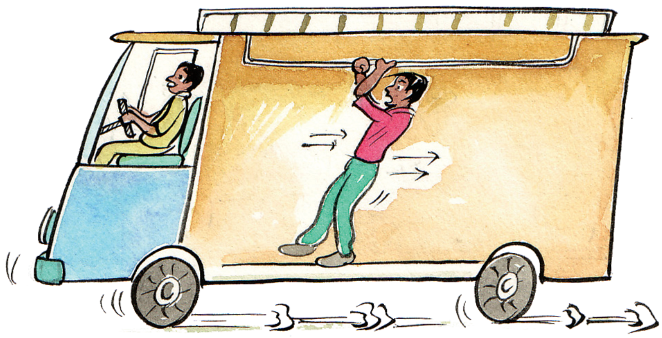


Fig. 10.5 *Passengers falling in the backward direction when the bus starts suddenly*

This observation can be explained on the basis of first law of motion. The feet of passengers are in contact with the bus. When the bus starts suddenly, the feet start moving with the bus. But the upper part of the passengers tries to remain at rest due to inertia and tends to fall in the backward direction.

What happen when the moving bus stops suddenly? In this case the passengers standing in the bus fall in the forward direction. Can you think the reason of it on the basis of the explanation of the above example?

Fig. 10.6 *Passengers falling forward as the moving bus stops suddenly*

Now you should be able to explain why do the dust particles get detached from a carpet when it is beaten with a stick? Try to explain it on the basis of first law of motion.

10.3.4 Momentum

You have learnt in the earlier section that the force required to stop a moving body depends upon its mass. Now suppose two balls of same mass are moving with different velocities. Which ball will need more force to stop? You will find that the faster moving ball require more force to stop it. Thus, the force required to stop a body also depends upon its velocity.

You must have noticed that a small bullet when fired from a gun can kill a person. But the same bullet if thrown with hand can hardly do any harm. Similarly a truck parked along a road side does not require any attention. But a moving truck may kill a person standing in its path. Is it only the velocity of the truck which makes us frightened? If it is so, then a toy car moving with the same velocity as the truck would have equally frightened to us.

From these observations it appears that the impact produced by the objects depends on their mass and velocity. These two quantities help us to define a new quantity called **momentum**.

The momentum, p of a moving body is defined as the product of its mass, m and velocity, v. That is

$$p = mv \qquad (10.1)$$

SI unit of momentum is kilogram-metre per second (kg m s^{-1}). Momentum has both magnitude and direction. Its direction is same as that of velocity.

10.3.5 Newton's second law of motion

According to Newton's first law of motion the application of an unbalanced force brings a change in the velocity of an object. Thus, the force can produce a change of momentum. Newton's second law of motion establishes a relationship between force and change in momentum.

Second law of motion states that the **rate of change of momentum of a body is directly proportional to the force acting on it and takes place in the same direction as the force.**

Sir Isaac Newton
(1642-1727)

Newton's second law of motion also gives a relation between force and acceleration. Let us derive this relationship.

Suppose the velocity of an object of mass m changes from u to v in time t by the application of a constant force F.

The magnitude of initial and final momentum of the object will be p_1 = mu and $p_2 = mv$ respectively. The change in momentum in time $t = p_2 - p_1$.

The rate of change of momentum = $\dfrac{(p_2 - p_1)}{t}$

According to second law of motion, the magnitude of the force F, is

$$F \propto \frac{p_2 - p_1}{t}$$

or
$$F = \frac{k(p_2 - p_1)}{t} \qquad ...(10.2)$$

where k is constant of proportionality.

Substituting the value of p_1 = mu and p_2 = mv, we get

$$F = \frac{k(mv - mu)}{t}$$

$$= \frac{km(v - u)}{t}$$

Now, $\dfrac{v - u}{t}$ is the rate of change of velocity, which is the acceleration 'a'. Therefore, we have

$$F = \text{kma} \qquad (10.3)$$

We choose the unit of force in such a manner that the value of k becomes one. For this we can define one unit of force as that amount which produces an acceleration of 1 m/s^2 in an object of 1kg mass. So that:

$$1 \text{ unit of force} = k\ (1\ \text{kg}) \times (1\ \text{ms}^{-2})$$

Thus, the value of constant k becomes 1. Therefore, from equation (10.3)

$$F = ma \qquad (10.4)$$

The unit of force is called newton and its symbol is N.

So a force of 1 newton will produce an acceleration of 1 m/s^2 on an object of mass 1 kg.

Can you estimate, how much is 1 N force?

For this, let us experience it. Keep a mass of 100 g on your palm. How much force you feel on your palm? Calculate this force.

From equation 10.4,

$$F = ma$$

Here, $m = \frac{1}{10}$ kg and $a = 10\ \text{ms}^{-2}$ (approximately)

Therefore, $F = \frac{1}{10}\text{kg} \times 10\ \text{ms}^{-2} = 1\ \text{N}$

Thus the force exerted by a mass of 100 g on your palm is approximately equal to 1 newton.

10.3.6 Some Example of Second Law of Motion from Daily Life

In our everyday life we see many applications of second law of motion. In many situations we try to decrease or increase the rate of change of momentum by changing the time in which the change of momentum takes place. Let us consider some examples.

(a) While catching a fast moving cricket ball, why does a fielder moves his hands backward?

By doing so the fielder increases the time duration in which the momentum of the ball becomes zero (Fig. 10.7). As the rate of change of momentum decreases, a small force is required for holding the catch. So the hands of the fielder do not get hurt.

Fig. 10.7 *A fielder moves his hands backward while holding a catch*

(b) Why does a person get hurt when he falls on a cemented floor?

Just before touching the floor, the person has some initial velocity, say u, which becomes zero when he comes to rest. Thus the momentum of the person becomes zero within a very short time. As the rate of change of momentum is very high, so very large force is exerted on the person, thereby hurting him. On the other hand, if he falls on sand or husk or on a foam mattresses, he does not get hurt due to longer period of time in making momentum zero and hence reduction of force.

(c) How does a karate player breaks a pile of tiles or a slab of ice with a single blow?

The karate player hits the pile of tiles or a slab of ice as fast as possible with her hand. In doing so the entire momentum of the hand is reduced to zero in a very short time. As a result, the force delivered on the tiles or slab of ice is large enough to break it.

(d) You would have noticed that when a bundle tied with a string is lifted quickly by holding it, the string breaks (Fig. 10.8). Can you now explain why the string breaks in this case?

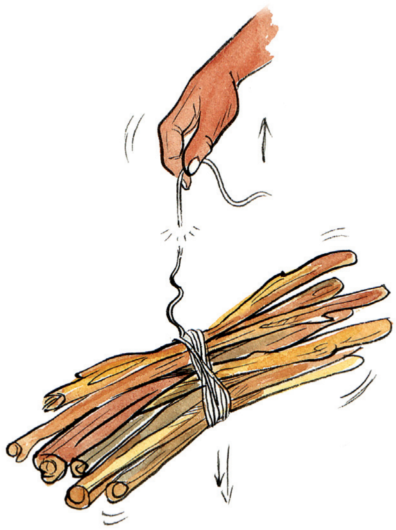


Fig. 10.8 *The string breaks when the bundle is lifted quickly.*

Example 10.1: What is the acceleration produced by a force of 15 N exerted on an object of mass 3 kg?

Solution: According to second law of motion

$$F = ma$$

Here $m = 3$ kg and $F = 15$ N

Therefore, $15 \text{ N} = 3 \text{ kg} \times a$

or $$a = \frac{15 \text{ N}}{3 \text{ kg}} = 5 \text{ ms}^{-2}$$

Example 10.2: What force accelerates a 50 kg mass at 5 ms^{-2}?

Solution: Newton's second law gives

$$F = ma$$

Here, $m = 50$ kg and $a = 5$ ms^{-2}

Therefore, $F = 50 \text{ kg} \times 5 \text{ ms}^{-2}$

$= 250$ N

10.3.7 Newton's Third Law of Motion

You must have noticed that when a rubber balloon filled with air is released, the balloon moves opposite to the direction of the air coming out of it (Fig. 10.9). Why does the balloon move in a direction opposite to the direction in which the air escapes? Let us find out.

You must have also noticed that when you jump from a boat to the river bank, the boat moves in the backward direction (Fig. 10.10). Why does this happen?

While jumping out of the boat, your foot exerts a backward force on the boat. This force is called **action**. At the same time a force is exerted by the boat on your foot, which makes you move forward. This force is known as **reaction**. Remember that two bodies and two forces are involved in this problem. You pushed the boat backward and the boat pushes you forward. These two forces are equal in magnitude but opposite in direction.

Fig. 10.9 *A balloon moves opposite to the direction in which air escapes*

Fig. 10.10 *A girl jumping out of a boat*

Let us consider the balloon problem again. In this case the air coming out of the balloon (action) exerts a force of reaction on the balloon and this force pushes the balloon backwards (reaction).

Newton in his third law of motion stated a relation between action and reaction. According to this law, **to every action there is an equal and opposite reaction.** The action and reaction act on two different bodies if action and reaction are on same body they will constitute a balanced force and body will not move.

Look at the Fig. 10.11 and find out the action and reaction forces and try to analyse wheather the truck will move or not.

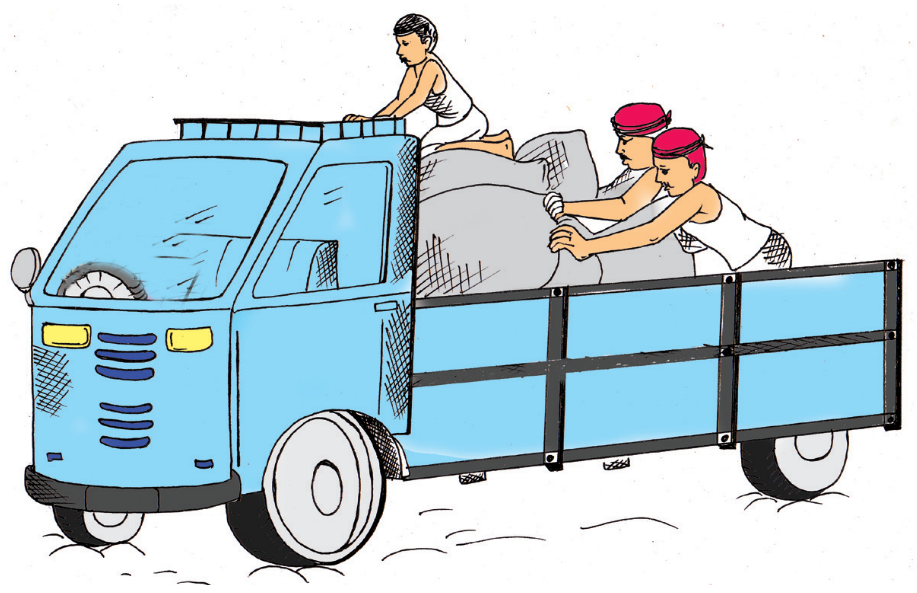


Fig. 10.11

There are three significant features of third law of motion:

(i) We cannot say which force out of the two forces is the force of action and which one is the force of reaction. They are interchangeable.

(ii) Action and reaction always act on two different bodies.

(iii) The force of reaction appears so long as the force of action acts. Therefore, these two forces are simultaneous.

Remember, it is not necessary that the two bodies, amongst which the forces of action and reaction act are in contact. They may be quite far from each other. For example, attraction or repulsion between two magnets can take place even without being in contact (Fig. 10.12).

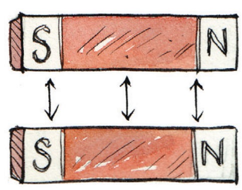


Fig. 10.12 *Repulsion between two magnets*

Do you know that action and reaction forces enable us to walk on the surface of the earth? Let us see how? While walking on the ground we push the ground with our foot in the backward direction. This is the force of action.

In return the ground exerts an equal force of reaction on our foot in the forward direction. The force that actually makes us walk in the forward direction is this reaction force.

Similarly, during swimming we push the water in the backward direction, with our hands and feet, to move in forward direction. It is the reaction to this force that pushes us forward (Fig. 10.13).

Fig. 10.13 *A swimmer pushes the water backwards with hands to move in forward direction.*

It may be interesting for you to know that rockets and jet-planes also work on the principle of action and reaction. In each of these, when the fuel burns, hot burning gases are ejected from the tail. The hot gases come out in the backward direction and the rocket or the jet plane moves in the forward direction (Fig. 10.14).

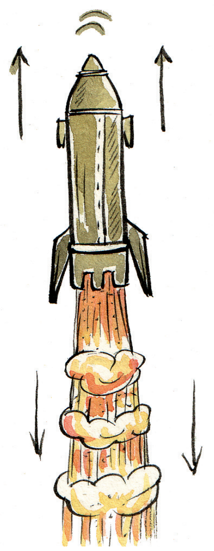


Fig. 10.14 *Working of jet planes and rockets*

Now think, why a rifle kicks backward when we fire a bullet?

10.3.8 Conservation of Momentum

Law of conservation of momentum is a very important law of science. According to this law, if two or more objects collide with each other, their total momentum remains conserved before and after the collision provided there is no external force acting on them.

From the Newton's laws of motion, we know that the rate of change of momentum is equal to the force.

If p_1 = initial momentum and p_2 = final momentum after time t, then

$$F = \frac{p_2 - p_1}{t}$$

Now, if $F = 0$, then we have $p_1 = p_2$. Which shows that the momentum of a system remains unchanged (or conserved) if no force is acting on it?

You can verify the law of conservation of momentum with the help of a simple activity.

ACTIVITY 10.4

Take a plastic channel of about 40 cm length and seven marbles of same size. Place the channel on a horizontal table and put the marbles on the channel touching each other as shown in figure 10.15. Remove one marble and keep it at a distance of about 15 cm from the rest. Hit this marble with your fore finger gently so that it collides with other marbles. What do you observed?

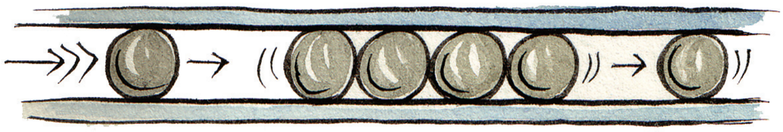


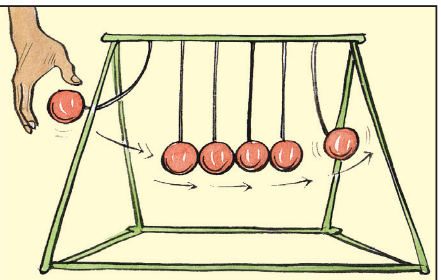
Fig. 10.15 *Arrangement to show the law of conservation of momentum*

You will find that after the collision, the moving marble comes to rest and the last marble out of the rest moves ahead. Try to guess the speed of this marble after the collision and compare it with the speed of marble you had thrown before the collision. Do the two speeds appear to be equal? What does it indicate? If the speeds are equal then the total momentum of the marble is same before and after the collision.

Repeat this activity by removing two marbles and striking them with the five marbles at rest. What do you observe this time? What conclusion do you derive from this activity? You will find that in each case, total momentum of marbles before collision is same as after collision.

? Do you know

Have you ever seen a toy as shown here? If not, try to find this toy in a toy shop or a science museum. Can you tell the principle on which this toy works?



Example 10.3: A bullet of mass 0.03 kg is fired with a velocity of 100 ms^{-1} from a rifle of mass 3 kg. Calculate the recoil velocity of the rifle.

Solution:

Here, mass of the rifle $m_1 = 3$ kg

mass of the bullet $m_2 = 0.03$ kg

Initial velocity of the riffle $u_1 = 0$

Initial velocity of the bullet $u_2 = 0$

Final velocity of the rifle = v_1 (say)

Final velocity of the bullet $v_2 = 100$ ms^{-1}

According to the law of conservation of momentum,

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

On substituting the given values,

$$0 + 0 = 3 \times v_1 + (0.03) \times 100$$

$$v_1 = \frac{-100 \times 0.03}{3} = -1.0 \text{ ms}^{-1}$$

$\therefore$ Recoil velocity of the rifle = –1.0 ms^{-1}

Negative sign indicates that the rifle would move in the direction opposite to that bullet.

Example 10.4: A rifle having a mass of 5 kg fires a bullet at a speed of 250 ms^{-1}. If the rifle recoil with a velocity of 1 ms^{-1} then find the mass of the bullet.

Solution:

Here, $M = 5$ kg; $m = ?$

$V = -1$ ms^{-1}; $v = 250$ ms^{-1}

$U = 0$ $u = 0$

According to the law of conservation of momentum

$$MU + mu = MV + mv$$

$$0 = MV + mv$$

$$m = \frac{-MV}{v} = \frac{-5 \times (-1)}{250} = \frac{1}{50} = 0.02 \text{ kg}$$

So, Mass of the bullet = 0.02 kg or 20 g

Negative sign indicates that the rifle would move in the direction opposite to that obullet.

INTEXT QUESTIONS 10.3

1. Why does water comes out from a wet piece of cloth when you shake it?
2. Why do we fall forward, when a moving bus stops suddenly?
3. Two similar trucks are moving on a road with the same velocity. One of them is empty while the other one is loaded. Which of the two has more momentum?
4. If a body of mass 5 kg moves with a velocity of 10 ms^{-1}, then what is the momentum of the body?
5. Why does a boxer move his head backward while taking an oncoming punch?

10.4 FRICTION

You might have noticed that a ball rolling along the ground stops after moving through some distance. Similarly a moving car begins to slow down the instant its engine is switched off and finally it stops. Why does it happen? Let us find out.

10.4.1 Force of Friction

According to Newton's first law of motion, a moving body continues to move along a straight line until unless an external force is applied on it. Is this external force slows down the motion of the ball or the car? Think! Infact the ball or car is slowed down by a force called **friction**. Friction exists between the surfaces of all materials which are in contact with each other. The direction of the frictional force is always in a direction opposite to the motion.

Now, try to analyze the forces acting on an object moving with a constant velocity. If an object is to move with a constant velocity, a force equal to the opposing force of friction must be applied. In that condition the two forces are balanced forces. They exactly cancel one another and the net force on the body is zero. Hence the acceleration produced in the body is zero and the body maintains its velocity. It neither speeds up nor slows down.

The resistive force, before the body starts moving on a surface is called **static friction**. Once a body starts moving on a surface the friction between them is called **sliding or kinetic friction**. You should remember that the sliding friction is slightly less than the static friction.

10.4.2 Factors affecting friction

You must have seen that it is easier to move a bicycle on a concrete road than on a rough road. Why is it so? Does friction depend upon the smoothen or the roughness of the surfaces? Let us find out.

ACTIVITY 10.5

Set up an inclined plane on a table as shown in Fig. 10.16. Mark a line near the top edge of the inclined plane. Now hold a pencil cell on this line. Release the pencil cell. What do you observe? The cell moves down the inclined plane and continues to move for some distance on the table. Note down the distance upto which the cell move on the table.

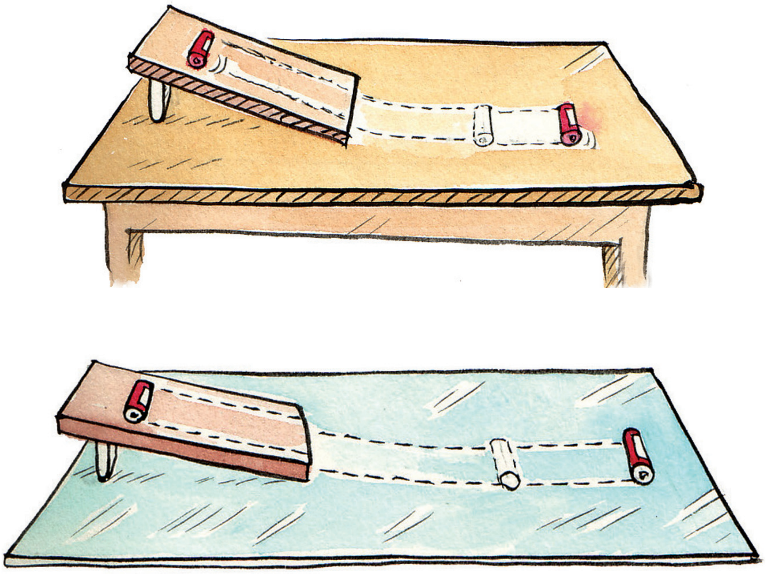


Fig. 10.16 *Pencil cell covers different distances on different type of surfaces*

Now place a glass sheet on the table. Again release the pencil cell from the line on the inclined plane and note the distance up to which the cell moves on the glass plate. Repeat this activity by spreading a uniform layer of sand on the table.

In which case the distance covered by the pencil cell is maximum? In which case it is minimum? What do you conclude from this activity?

You will find that the distance moved by the cell is maximum on the glass surface and minimum over the sand. This difference is due to the friction offered by different type of surfaces. Smooth glass surface offers less friction compared to a rough sand bed. Thus **smoothness of the surfaces is one of the factor on which friction depends**.

You might have observed that more force is needed to move a heavy box than to move a lighter box on the same surface. It is so because the heavy box has grater normal reaction (reaction of the surface on the box against the action of its weight) and hence greater frictional force. Thus **friction also depends upon the normal reaction**.

10.4.3 Advantages and disadvantages of friction

The friction plays a very important role in our day to day life. It has several advantages as well as disadvantages.

(a) Advantages of friction

Have you ever walked on ice or a wet marble floor? You might have found that it difficult to balance your body. The force of friction developed between the soles of your shoes and the ground helps us to move. Had there been no friction, walking or running would have been impossible.

You can write with a pen on page or with a chalk on the blackboard due to friction. Buildings may be constructed only due to force of friction between different building materials. Without friction, you could not fix a nail on the wall.

Tyres of automobiles are treaded to increase the friction between tyres and surface of the road. Thus the tyres get better grip with the ground. The breaks applied in automobiles also work only due to friction.

Can you think of some more examples from your daily life where friction is useful?

(b) Disadvantages of friction

Due to friction, a lot of energy is wasted in the form of heat that causes wear and tear of the moving parts of a machine. Friction also reduces efficiency of the machines as considerable amount of energy is wasted in overcoming friction. However, the efficiency of a machine can be increased by putting a suitable lubricant between its moving parts.

In most of the machines, to reduce friction ball bearings are used between the moving parts. By using the ball bearing the sliding friction is replaced by **rolling friction**. As the rolling friction is less than the sliding friction, therefore, the friction between the moving parts is reduced.

Friction also wears out the soles of shoes. You would have seen that the steps of foot over-bridge at railway stations also wear out due to friction.

Vandana and Navneet are racing on rock ice with the specially designed shoes shown in the Fig. *A* and *B* respectively. Who will win?

(A) Shoes for Vandana

(B) Shoes for Navneet

Cite some more example from you daily life where friction is undesirable.

INTEXT QUESTIONS 10.4

1. Why does a fast moving car slow down when its engine is switched off?
2. Why do we slip when we step on a banana peel?
3. Why are tyres of automobiles treaded?

10.5 THRUST AND PRESSURE

Observe some bodies around you like table, desk, bucket full of water, etc. They press the floor with a force equal to their own weight. You know that weight is the force acting vertically downwards. As the surface of the floor can be taken as horizontal, therefore, the force with which each of the above mentioned bodies presses the floor is directed perpendicular to the surface of the floor. The force acting upon the surface of a body perpendicular to it is called **thrust**.

Let us find out the effect of thrust acting on a surface.

ACTIVITY 10.6

Take a small wooden board (10 cm × 10 cm × 1.0 cm) with four nail fixed at each corner as shown in Fig. 10.17 (a). Fill a tray with sand to a depth of about 6 cm. Place the wooden board on sand with the nail-heads downwards [Fig. 10.17 (b)] Also put about 500 g weight on the board. Observe the depth of the nails upto which they penetrate into the sand.

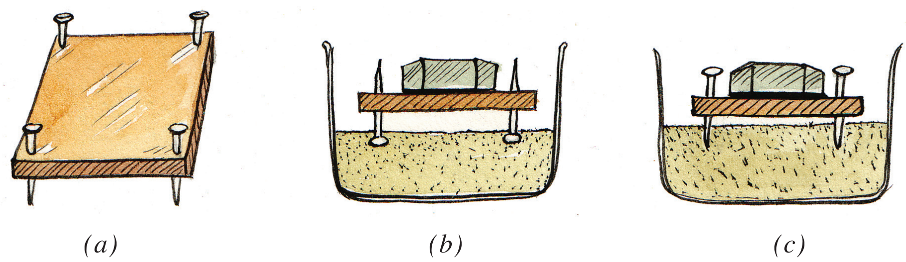


Fig. 10.17 (a), (b), (c) *Arrangement to show that pressure depends upon the area on which force is exerted*

Now place the wooden board on the sand with pointed side of the nails facing downwards and put the same weight on the board as in the previous case [Fig. 10.17 (c)]. Again observe the depth of the nails upto which they penetrate upto the sand.

In which of the above two cases the penetration is more? You will find that the penetration is more in the second case.

Thus the action of the given thrust depends on the area of the surface it acts upon. The smaller the area on which the thrust acts, the more evident is the result of its action. The thrust on unit area is called pressure. Thus

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} \qquad ...(10.5)$$

The SI unit of pressure is Nm^{-2}. This unit has also been given a specific name pascal (Pa) in honour of the scientist named Blaise Pascal.

Do you know

Pascal was a French philosopher and mathematician. He formulated the famous Pascal's law of hydraulics regarding transmission of pressure through fluids. He also invented one of the earliest calculating machines. The unit of pressure pascal (Pa) was named in his honour.


Blaise Pascal (1623-1662)

Equation (10.5) shows that the same force acting on a smaller area exerts a larger pressure and a smaller pressure on a larger area. This is the reason why cutting tools like knives and axes always have sharp edges.

In many cases it is desirable to decrease pressure. In such cases the area on which the thrust is acting should be increased. For example, foundation of buildings and dams are made on larger area. Similarly trucks and vehicles used to carry heavy loads have much wider tyres. Also army tank weighing more than a thousand tonne rests upon a continuous chain.

INTEXT QUESTIONS 10.5

1. Why does a porter carrying a heavy load place a round piece of cloth on his head?
2. Why a nail has a pointed tip?
3. Why shoulder bags are provided with broad straps?
4. State the SI unit of pressure.

WHAT YOU HAVE LEARNT

- Unbalanced forces acting on an object may change its state of rest or motion.
- Balanced forces do not change the state of rest or motion of an object. Balanced forces can change the shape of the object on which they are applied.
- Inertia is the tendency of objects to stay at rest or to resist a change in their state of motion.

- The mass of an object is a measure of its inertia.
- Newton's first law of motion states that, everybody continues in its state of rest or of uniform motion in a straight line until unless it is compelled by some unbalanced force to change that state.
- The momentum of a body is the product of its mass and velocity. The SI unit of momentum is kg ms^{-1}.
- Second law of motion states that the rate of change of momentum of a body is directly proportional to the force acting on it and takes place in the same direction as the force.
- The unit of force is newton and its symbol is N. A force of 1 newton will proceed on acceleration of 1 ms^{-2} on an object of mass 1 kg.
- Newton's third law of motion states that, to every action there is always an equal and opposite reaction. Action and reaction always act on two different bodies.
- According to the law of conservation of momentum, in an isolated system the total momentum remains conserved.
- Force of friction always opposes motion of bodies. Friction depends on the smoothness of surfaces in contact. It also depends upon the normal reaction.
- Rolling friction is less than the sliding friction.
- Force acting perpendicular to the surface of a body is called thrust.
- Thrust per unit area is called pressure. The SI unit of pressure is Nm^{-2}. This unit is known as pascal (Pa).

TERMINAL EXERCISE

1. Why does a sprinter keep running for sometime even after crossing the finish line?
2. Why is it advised to tie the luggage with a rope on the roof of busses?
3. Why do the dust particles from the hanging blanket fall off when it is beaten with a stick?
4. State Newton's first law of motion. Why do the passengers standing in a stationary bus fall in the backward direction when the bus begins to move suddenly.
5. Define momentum. How the rate of change of momentum is related to force?
6. If a body of mass 10 kg moves with a velocity of 7 ms^{-1}, then what is the momentum of the body?
7. If a force of 50 N acts on a body of mass 10 kg then what is the acceleration produced in the body?

8. State Newton's third law of motion. Why it is difficult for a fireman to hold a hose pipe which ejects larger amount of water at a high speed?
9. "Action and reaction forces are equal in magnitude and opposite in direction". Then, why do they not balance each other?
10. A motorcycle is moving with a velocity of 72 km/h and it takes 6 s to stop after the breaks are applied. Calculate the force exerted by the breaks on the motorcycle, if its mass along with the rider is 175 kg.
11. An object of mass 2 kg travelling in a straight line with a velocity of 10 ms^{-1} collides with and sticks to a stationary object of mass 6 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact.
12. What is the force of friction? State two methods to reduce friction.
13. What is the relation between thrust and pressure? State the SI units of thrust and pressure. Why a camel can run in a desert easily?
14. A block of wood kept on a table applies a thrust of 49 N on the table top. The dimensions of the wooden block are 40 cm × 20 cm × 10 cm. Calculate the pressure exerted by the wooden block if it is made to lie on the table top with its sides of dimensions (a) 20 cm × 10 cm and (b) 40 cm × 20 cm.

ANSWER TO INTEXT QUESTIONS

10.1

1. Yes
2. Pressing a lump of dough with your hands.

10.2

1. When two or more forces acting on an object in opposite direction balances each other then the forces are known as balanced forces.
2. No. Balanced forces do not change the state of motion of an object.
3. Unbalanced forces acting on an object may change its state of rest or motion.

10.3

1. Due to inertia of rest. When we shake the cloth, the water remains in its position and comes out.
2. Lower part of our body come to rest but due to inertia of motion our upper part tends to move in the forward direction and we fall in the forward direction.

3. As momentum is equal to mass × velocity. So the momentum of loaded truck (more mass) has more momentum.
4. Momentum = $m \times v$ = 5 kg × 10 ms^{-1} = 50 kg ms^{-1}.
5. To decrease the rate of change of momentum boxer moves his head backward so that the impact of punch is reduced.

10.4

1. Due to force of friction acting between wheel of car and ground.
2. Because the friction between banana peel and ground is very small.
3. Treaded tyres provide better grip with the ground because in such tyres the friction between the tyres and ground is very large.

10.5

1. Round piece of cloth increases the area of contact between load and head of porter, thereby decreasing the pressure on his head.
2. To increase the pressure.
3. To decrease the pressure.
4. Nm^{-2} or pascal (Pa)