2

Force

SYLLABUS

1. **Force :** The effects of a force (starting or stopping motion, changing its direction, changing speed, changing the shape/size of a body) – simple everyday examples of these.
2. **Types of forces :** Contact forces, friction, forces that act at a distance – gravitational, magnetic - examples of these in action.
3. Force is measured in newtons (N). The resultant of forces acting along the same line, in similar or opposite directions.

STATE OF REST

When we look around, we observe that many objects do not appear to move, rather they are considered to be *at rest*. A book lying on the table will not change its position if it is not disturbed by anyone and will be considered to be in the state of rest. Similarly, a bench fixed in a garden is at rest as there is no change in the position of the bench with respect to its surroundings, such as trees, houses *etc*.

A body is said to be at rest if it does not change its position with time with respect to its surroundings.

STATE OF MOTION

We see many things around us moving from one place to another like a flying bird, a moving bus, a boy playing football, the oscillating pendulum of a wall clock, *etc*. All these things are said to be *in motion*.

A moving car changes its position with time with respect to a tree by the side of a road. So, the car is said to be in motion.

Similarly, a flying bird is also said to be in motion as it changes its position with time with respect to a tree.

Even when we are at rest, blood is moving through our arteries and veins, air is flowing in and out of our nostrils and our heart is beating.

We must note here that rest and motion are relative terms. Imagine yourself sitting inside a moving bus. On looking outside the bus, you will observe that you are moving. Now look towards the roof of the bus, you will feel that you are in a position of rest with respect to the roof.

Therefore, an object is in the state of motion with respect to a set of objects, but may be in the state of rest with respect to the other set of objects (moving with the same speed and in the same direction). It is the observer and the surroundings that decide whether a given object is *at rest* or *in the state of motion*. Thus, we can say :

A body is said to be in the state of ***motion*** *if it changes its position with time with respect to its surroundings.*

To change the state of rest to motion or the state of motion to rest, a physical cause is needed. The cause which can change these states is called force.

FORCE

In our everyday life, we push or pull objects. To open a door, we either push or pull it. To draw a bucket from a well, we pull the rope. We kick, throw or hit a ball, *i.e.*, we are pushing it. We pull or push chairs, tables, etc. This pull or push is known as *force*. The direction in which we apply the force is called the *direction of force*. It is true that a pull or push may or may not produce a fruitful result but it definitely tries to produce a change in the state of the body. *For example*, an almirah when pushed may not move by a single person but the same almirah can be pushed by two or three persons.

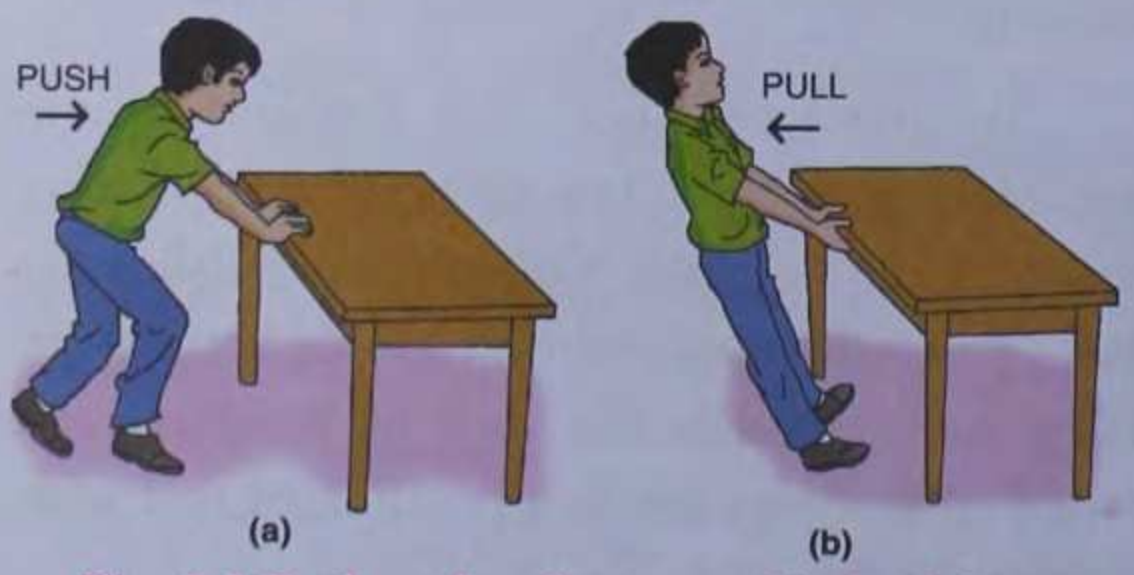


Fig. 2.1 Push and pull are two kinds of force

Therefore, we can say that *force is a physical cause that changes or tries to change the state of rest or the state of motion of an object.*

ACTIVITY 1

Try to recollect and make a list of some of the forces that you have exerted in the last few minutes.

Force as a push

A body is considered to be *pushed* when we apply a force on it and the direction of motion is away from us.

Examples :

(i) To open a door, we push it.

(ii) To switch On or Off a T.V., we press (push) its switch.

(iii) To remove a pile of rubbles (*i.e.*, rough broken pieces of stone), it is pushed by a bulldozer.

(iv) To move a baby cart, it is pushed as shown in Fig. 2.2 (a).

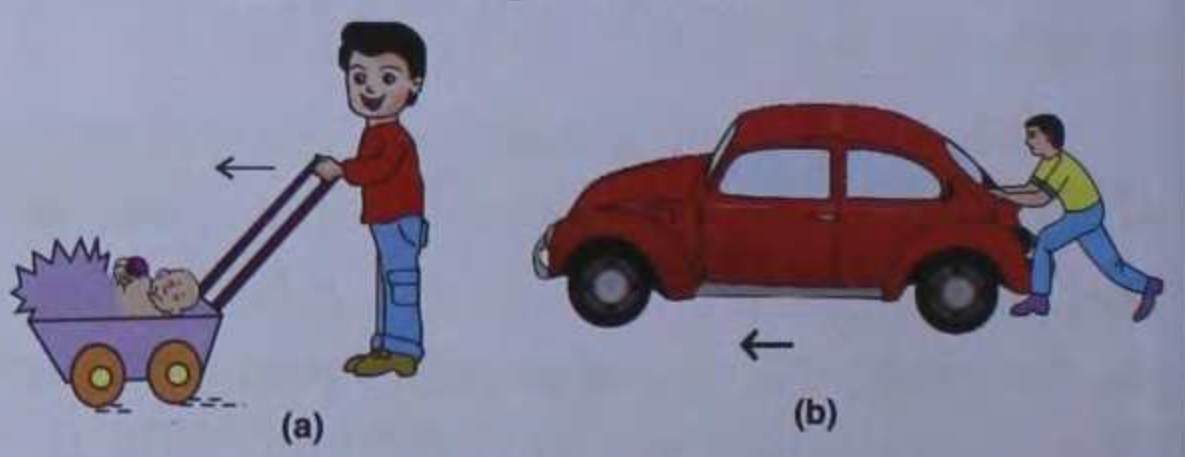


Fig. 2.2 Examples of force as a push in our daily life

(v) If a car does not start, we push it to move as shown in Fig. 2.2 (b).

Force as a pull

A body is considered to be *pulled* when we apply a force and the body moves towards us.

Examples :

(i) We pull a door to open it.

(ii) To level the soil in a lawn, a roller is pulled by the gardener [Fig. 2.3 (a)].

(iii) To move a cart, pull is exerted by a horse or a bull [Fig. 2.3 (b)].

(iv) To move a luggage trolley, pull is exerted by the coolie [Fig. 2.3 (c)].

(v) A rickshaw puller exerts pull on the rickshaw to move it [Fig. 2.3 (d)].

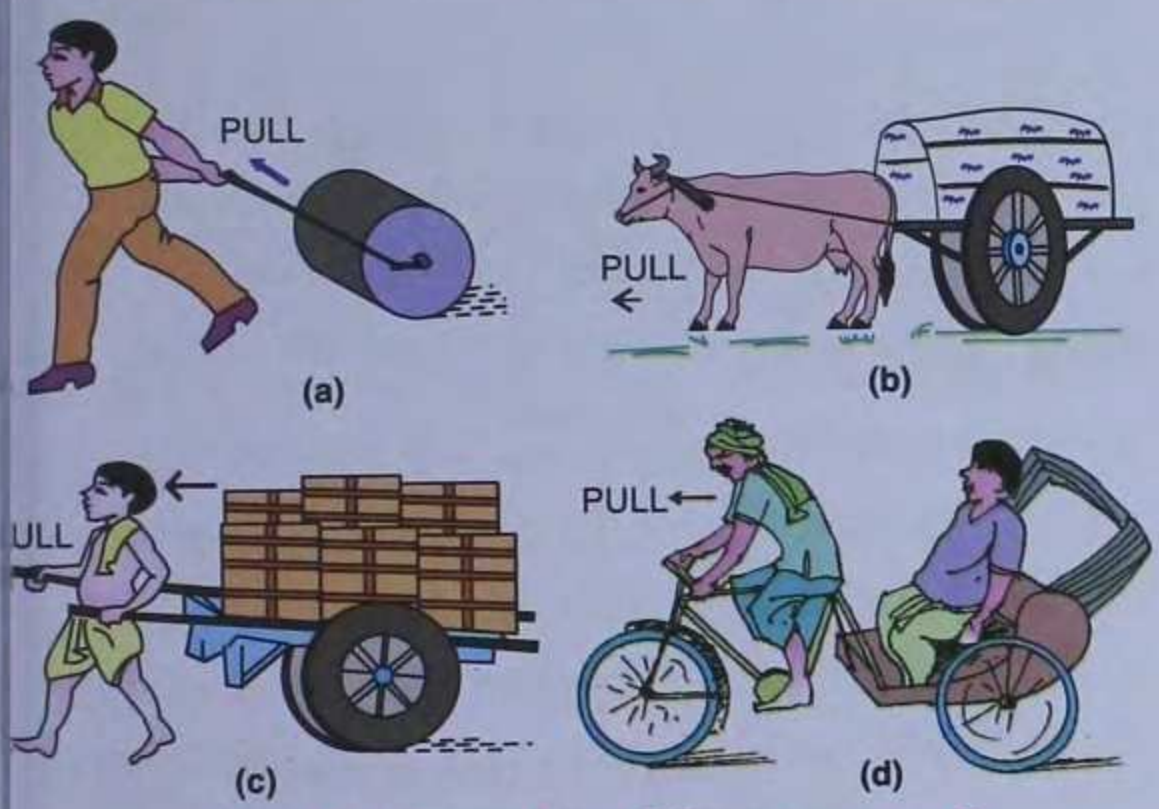


Fig. 2.3 Examples of force as a pull

From the above discussed examples, we can infer that at least two objects must interact for a force to come into play. Thus, an interaction of one object with another object results in a force between the two objects.

Intext Questions

Identify action as push or pull.

Sl. No.	Description of the situation	Action can be grouped as Push/Pull
1.	Moving a book placed on a table.	.....
2.	Opening or shutting a door.	.....
3.	Drawing a bucket of water from a well.	.....
4.	A football player taking a penalty kick.	.....
5.	A cricket ball hit by a batsman.	.....
6.	Moving a loaded cart.	.....
7.	Opening a drawer.	.....
8.	Attraction between a magnet and a piece of iron.	.....
9.	Repulsion between similar poles of two magnets.	.....
10.	Game of tug of war.	.....

Stretch and Squeeze

The terms **stretch** and **squeeze** also means force. Let us define these terms.

A body is considered to be *stretched* if a force applied on it increases its length, *i.e.*, the increase in length is in the direction of the applied force. *For example*, when we apply a force on a rubber band or a spring, its length increases. The force and increase in length are in the same direction.

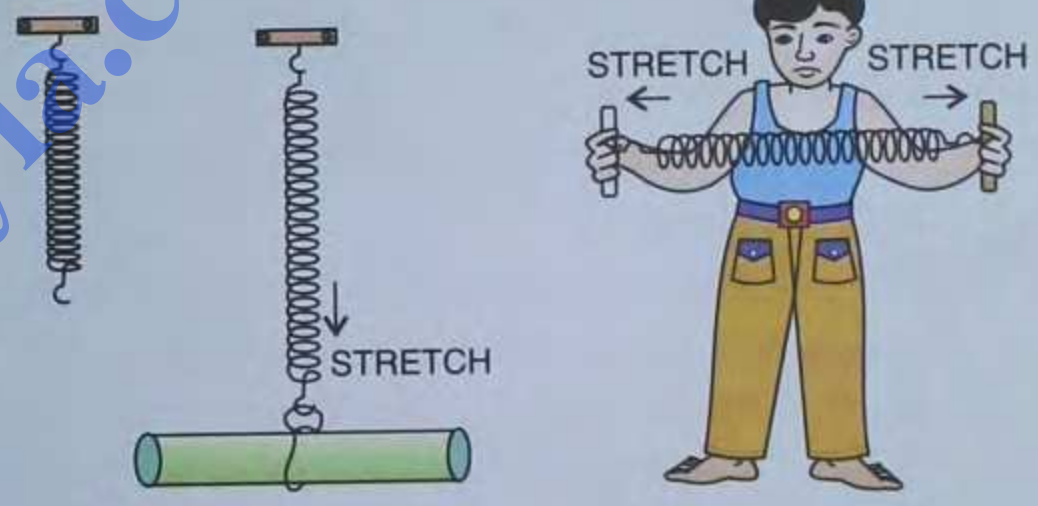


Fig. 2.4 Spring balance under stretch

A body is considered to be *squeezed*, if a force applied on it decreases its length or changes its dimension. *For example*, when we squeeze a tube to take cream out of it, its shape changes.

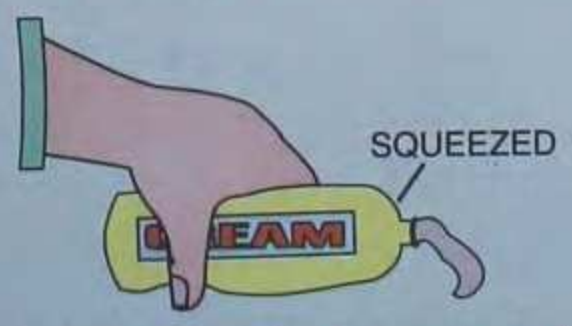


Fig. 2.5 A shaving cream tube in squeezed position

Thus, force is a cause (a push, pull, stretch or squeeze) which changes or tends to change the state of rest or the state of uniform motion, or direction of motion, or the shape and size of a body.

Effects of Force

We cannot see a force. However, we can see the effects of force, *i.e.*, what a force does.

ACTIVITY 2

1. Apply a force to a block of rubber by pulling or pushing or twisting it. What happens when the force is withdrawn ?
2. What happens when a force is applied to a piece of modelling clay ? What happens when the force is removed ?

ACTIVITY 3

Place a table tennis ball on a bench and blow it using a drinking straw.

1. What happens to the ball when it is at rest and you blow it ?
2. How does the ball change its motion when the ball comes towards you after blowing ?
3. How does the ball move when it moves across the table, if you blow it from the side ?
4. Everytime, when you blow on the table tennis ball, you are exerting a force on it. State three things that can happen to the ball when a force is exerted on it.

ACTIVITY 4

A boy tries to drink juice with the help of a straw.

The boy pulls the air present in the straw. A vaccum is created and as a result the juice rises up and he is able to drink the juice.

Normal Reaction Force : When a body is kept on a table top, the body's weight acts vertically downwards. As a reaction of the table, a force is exerted by the surface of the table on the body in vertically upward direction. This force is called normal reaction force.

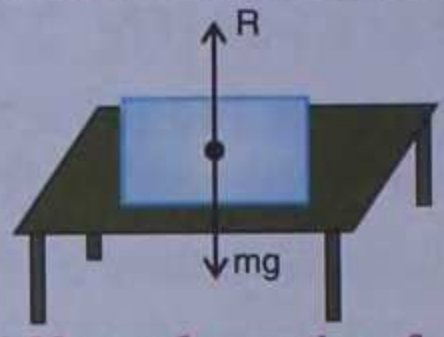


Fig. 2.6 Normal reaction force.

Tension force applied on string : When an object is suspended by a string, the weight of the body acts downwards. As a result a force acts vertically upwards on the body by the string. This is known as the tension force.

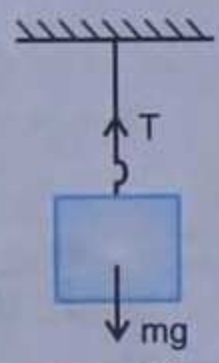


Fig. 2.7 Tension (A type of force on a suspended spring).

1. *A force can change the shape or size of an object. For example*, the shape of a sponge changes on pressing, the size of a spring changes on pulling and the shape and size of an iron strip can change on hammering.

Examples :

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

(b) The shape and size of a ball of dough changes when it is rolled to make a chapati.

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

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

2. *A force can make a stationary object move.* When you push a stationary car or when you kick a stationary football, you apply force to make them move.

3. *A force can change the speed of a moving object.* When we give a push to a moving swing, it moves faster. When we want to slow it down, we apply force in the opposite direction of motion. Such a push or pull is called **force**.

4. *A force can change the direction of a moving object.* When a player kicks a moving football, he changes the direction of the ball. Similarly, a batsman changes the direction of the ball by hitting it towards all sides of the field. In this process, the speed of the ball also changes.

Example : 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.

5. *A force can stop a moving object.* By applying force on a moving body, it can be made to stop. *For example*, if a person is riding slowly on a bicycle and we pull the bicycle from behind, it stops. Similarly, a moving bicycle, bus or train is stopped by applying the brakes. The brakes provide the stopping force to the vehicle.

ACTIVITY 5

A force can change the direction of a moving object. Take a small piece of cardboard and hold it in between your two fingers. Release it gently so that it falls down. While it is falling, strike the cardboard with another finger. You will notice that the board does not fall along the same path but it falls somewhere else. This happens because the push of the finger changes its direction.

ACTIVITY 6

Press the table with your hand. Does the shape of the table change ? Does the table move ? Does a force always have the effects listed in the previous page ?

Intext Questions

1. What is the term used for push and pull ?
2. Why do we say, stretch and squeeze are force ?
3. Give an example to show that force can change the shape or size of an object.

TYPES OF FORCES

Force can be divided into *two* types — **contact force** and **non-contact force** (force at a distance).

(a) Contact Force :

When the force applied on an object is in direct contact *i.e.*, the object with which we apply the force and the object on which the force is applied are in direct contact, then we call it a *contact force*. Pulling a chair or pushing a chair is an example of contact force and is also known as **muscular force**.

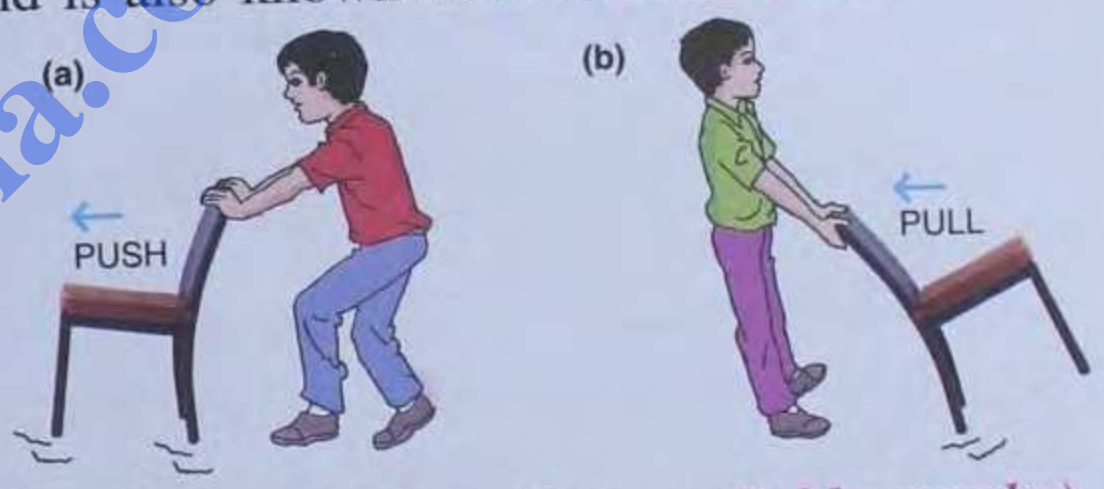


Fig. 2.8 Muscular force (force applied by muscles)

Muscular force : The force applied by the muscles of a human or animal body is called muscular force.

We use our muscular force during walking, running, kicking and lifting certain objects.

Fig. 2.9 Muscular force

Animals exert muscular force to do heavy works such as pulling a cart, ploughing, carrying heavy loads etc.

When two objects collide with each other like a bus and a car, it is a contact force and we also call it a *collision force.*

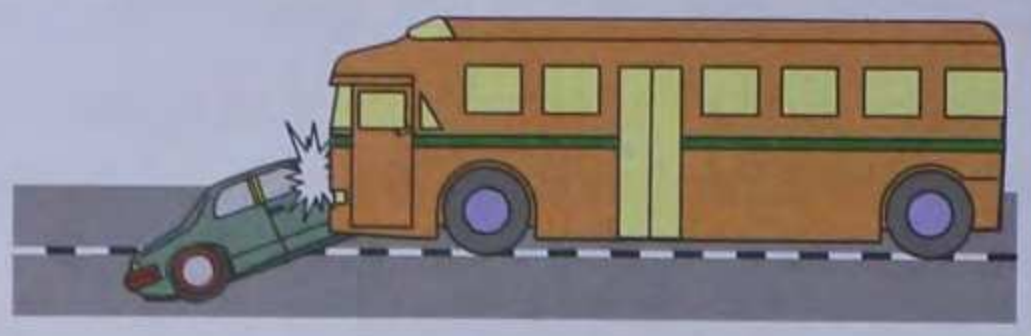


Fig. 2.10 Collision force

Mechanical force and *frictional force* are *two* other examples of contact force.

Mechanical force : When a body moves with the help of a machine, the force exerted by the machine is called the mechanical force. Actually, a machine does not exert force by itself, but it needs energy from other sources to exert a force. *For example*, the engine of a car exerts a mechanical force to move it. A railway engine exerts a mechanical force to pull the train. Similarly, the force exerted by wind to move a sailboat and to rotate the windmill is the mechanical force.

Frictional force : It is our common experience that when we stop pedalling a cycle, it gradually slows down and ultimately stops after travelling a certain distance. Friction between water and the boat also stops the boat, once you stop rowing. Similarly, if we roll a ball on a plain ground, it moves some distance and then stops. Since force can stop a moving body, so we can say that there must be a force acting on the cycle or the ball which stops them.

The force which slows down the motion of a moving body in contact with the other body, is called the frictional force or the force of friction.

This force always opposes the motion. Figure 2.10 shows that while pushing a sofa, the force of friction opposes the motion and it becomes difficult for us to push it.

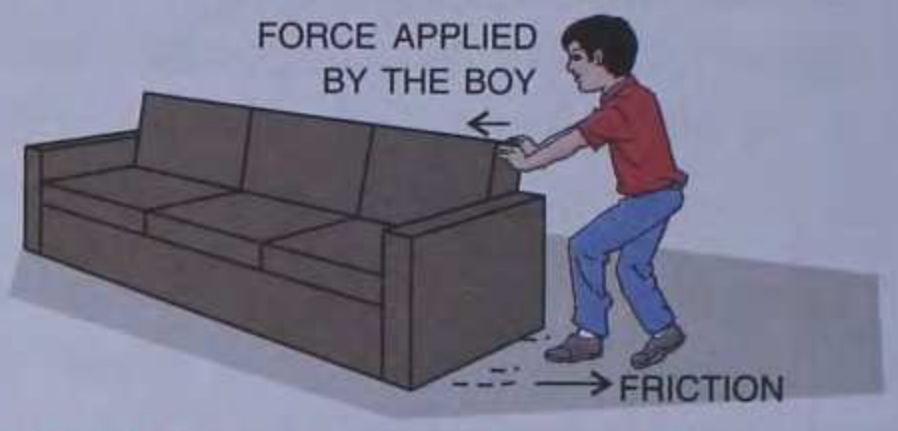


Fig. 2.11 Friction opposes the motion

ACTIVITY 7

1. List out five situations where you think friction is an advantage.
2. List out three situations where you think friction is a disadvantage.

Reducing or increasing friction : We need to oil our bicycle regularly. Oiling reduces the frictional force between its parts and makes it easier to ride the bicycle. Bicycles and other machines have ball bearings. Their function is to reduce the frictional force and thus to reduce the wear and tear of the machines.

When a car gets stuck in mud, its wheels turn without moving forward. At such times,

Fig. 2.12

a wooden plank is placed under the wheels so that friction increases. This helps the wheels to come out of the mud. In short, frictional force can be increased or reduced to suit a purpose.

TRY THIS

1. Place a ball on a smooth floor. Give it a gentle push. It moves some distance and then stops. Do the same thing on a rough surface. What difference do you see?
   * Why do tyres of motor vehicles have patterns of grooves or 'treads'? What would happen if tyres were smooth?
   * Why are chisel marks made on grinding stones?
2. Play a game of carrom. Find out where you must flick the striker and with what force in order to put the coins in the corner pockets.
3. While cycling, what do you do to stop the bicycle?

(b) Non-contact Force :

Non-contact force is also called the force acting at a distance. When we apply a force on an object without actual contact, it is the force acting at a distance. Magnetic force, electrostatic force and gravitational force are the examples of non-contact forces.

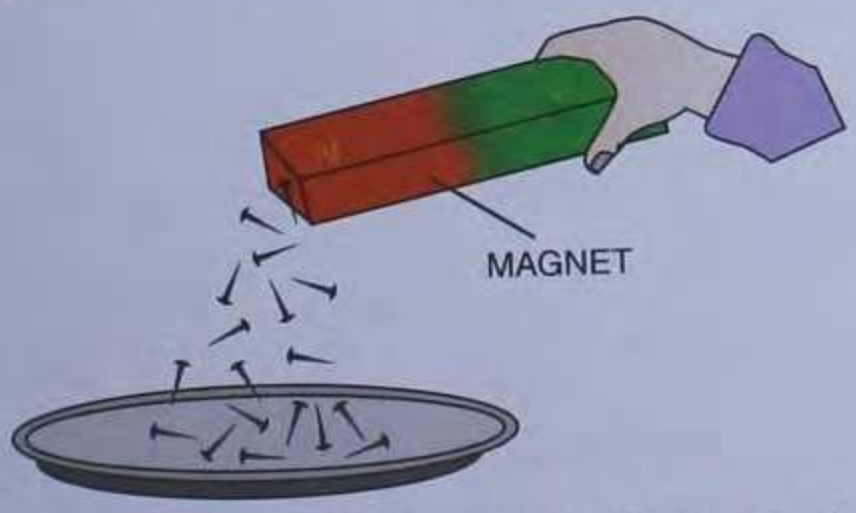


Fig. 2.13 Pins are pulled towards the magnet due to the magnetic force

Magnetic force : When we bring a magnet close to iron nails, they get attracted towards the magnet. Clearly, the magnet has applied a force on the nails, although there is no direct contact between them.

This force exerted by the magnet is called the *magnetic force*.

A magnet also exerts a force on another magnet. This can be a force of attraction or repulsion. It depends on the ends (poles) of a magnet that are facing each other. All magnets have a north-seeking pole (N) on one end and a south-seeking pole (S) on the other end. When like poles face each other, the magnets repel (push) each other (Fig. 2.14). When unlike poles face each other, the magnets attract (pull) each other (Fig. 2.15).

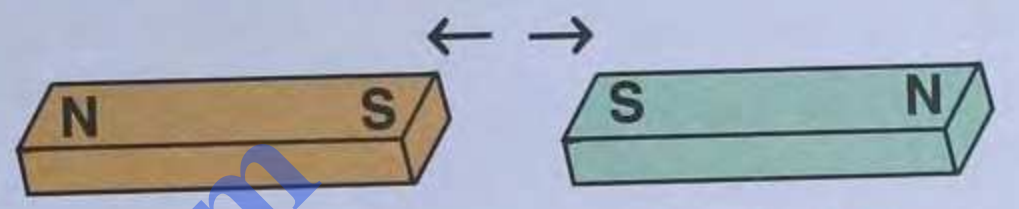


Fig. 2.14 Like poles repel each other

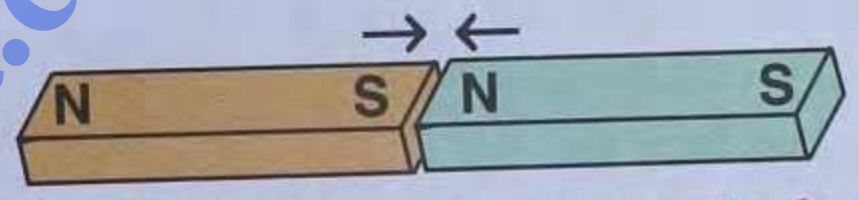


Fig. 2.15 Unlike poles attract each other

The forces of attraction and repulsion can be shown by bringing two magnets closer together.

Scientists have designed a train which gets lifted up above the track and travels with great speed in air. The maglev train is a recent application of the magnet. Its speed is 500-580 kmph. It makes use of the principle of magnetic repulsion between like poles of a magnet. Magnetic repulsion

Maglev train

between the track or the guideway and the bottom of the train lifts the train off the ground. Thus the train actually floats in air. A linear motor is used to propel the train forward.

Maglev stands for magnetic levitation.

The maglev train floats in air !

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

If you rub a plastic comb on your dry hair and bring small pieces of paper close to it, the comb will attract the pieces of paper. This is because when we rub the comb with dry hair, an electric charge is produced on the surface of the comb which is responsible for applying a force on the pieces of paper (Fig. 2.16).

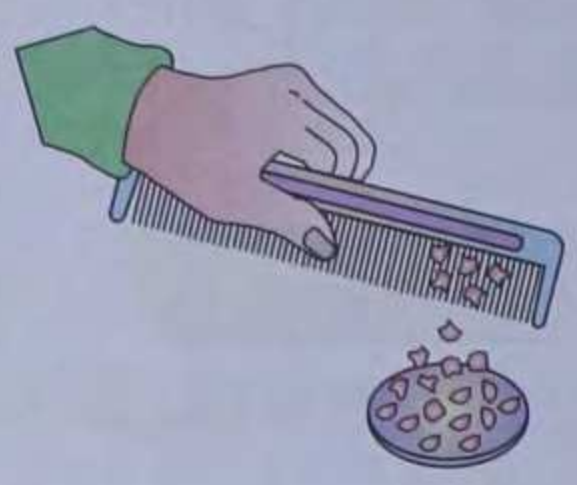


Fig. 2.16 : Charged comb attracts small pieces of paper

This force exerted on the pieces of paper is known as *electrostatic force*.

Gravitational force : The force of attraction between any two objects possessing mass is called gravitational force which exists everywhere in the universe. The magnitude of gravitational force between any two bodies depends upon their masses and the distance between them.

For example, the force acting between any two books, between a book and a table, between earth and the moon etc., is gravitational force.

Leaves and fruits fall towards the ground, water begins to flow towards the ground as soon as we open a tap, water in rivers flows downstream due to the force of gravity.

Leave a stone from your hand. It goes towards the surface of the earth. When we throw a ball, it attains certain height, and then comes back to the surface of the earth (Fig. 2.17). Why does this happen ? The earth has a characteristic property of its own to pull every object towards it. This pull is known as the *force of gravity* or *gravitational force*.

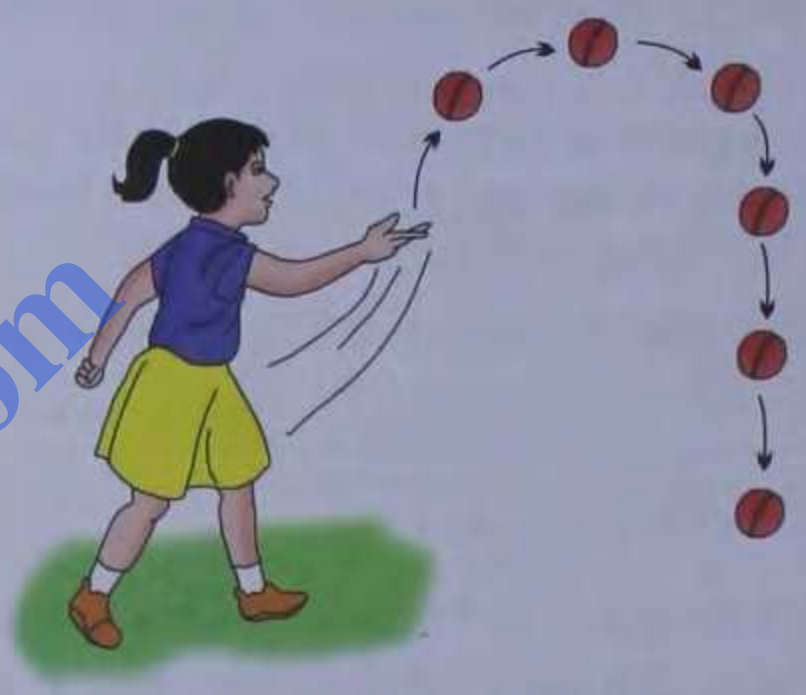


Fig. 2.17 Gravitational force

Here, it is to be noted that the force of gravity (unlike magnetic force) attracts but does not repel.

When we discuss gravitational force, we must discuss the term *weight*. The force of gravity on an object is actually the weight of that object. *Weight is the force with which a body gets attracted towards the centre of the earth.*

In the previous chapter, we have learnt that the mass of an object is measured by the physical balance and its S.I. unit is kg.

You should remember that the weight of an object is measured by a spring balance and its S.I. unit is newton.

Mass is measured in kg while weight is measured in newton.

Unit of Force

The S.I. unit of force is ***newton***. The symbol for newton is N. This unit is named after the English scientist Sir Isaac Newton who did a lot of research work on force.

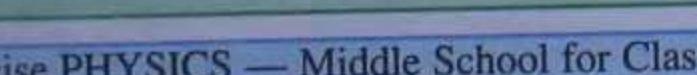
1 newton is that much force which produces an acceleration of 1 m/s^2 in a body of mass 1 kg.

One kgf is equal to nearly 10 newton,

i.e., 1 kgf $\approx$ 10 N

Thus, we can say, a force of 10 newton is needed to lift a mass of 1 kg.

A force is represented by an arrow. The length of the arrow represents the magnitude and the head of the arrow represents the direction of the force.



less force bigger force

Knowledge bank

Non-S.I. units of force

1. Kilogram force – It is denoted by kgf.
2. Gram force – It is denoted by gf.

1 kgf = 1000 gf

It has been determined experimentally that,

1 kilogram force = 9·8 newton

1 kgf = 9·8 N

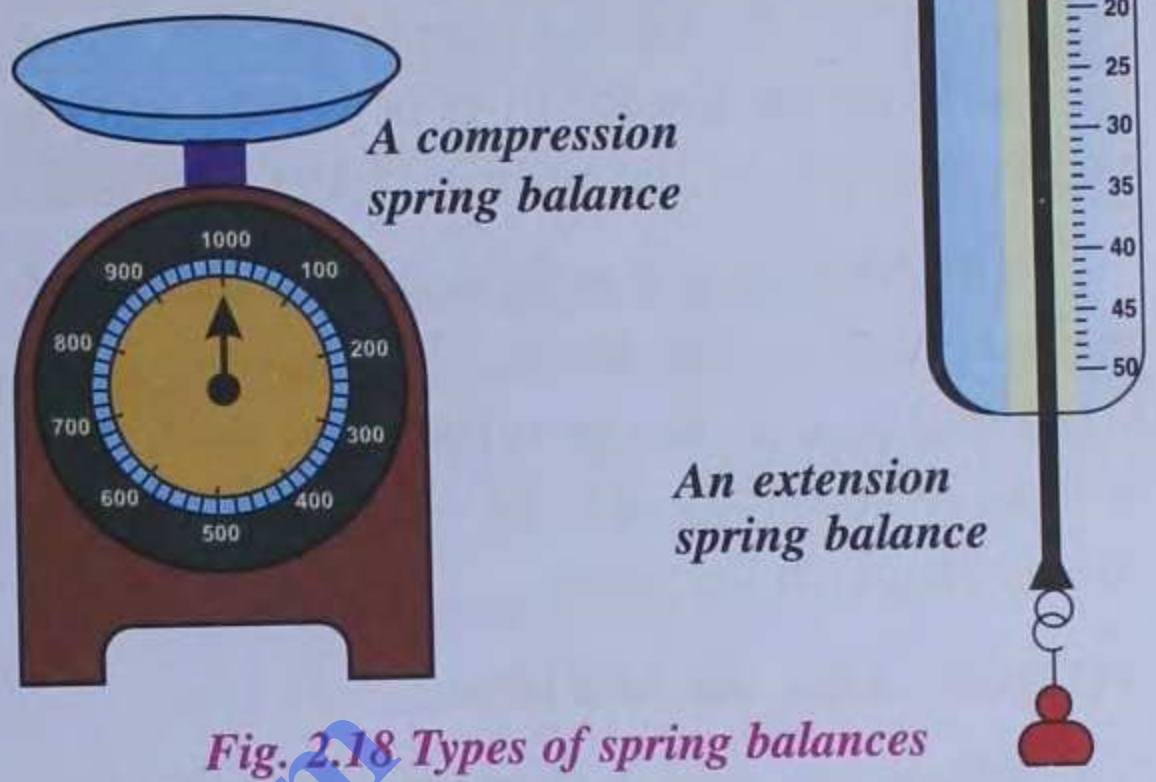
or

For the sake of convenience of calculations, we generally take,

1 kgf = 10 N = 1000 gf

Measurement of Force (weight)

Force can be measured with the help of a spring balance. There are *two* types of spring balances—extension spring balance and compression spring balance (Fig. 2.18). In an extension spring balance, the spring stretches when a force acts on it. The greater the force, the more the spring stretches. In a compression spring balance, the spring gets compressed when a force acts on it.



A compression spring balance

An extension spring balance

Fig. 2.18 Types of spring balances

Working of an extension spring balance : The spring balance consists of a special spring which is enclosed in a metal case

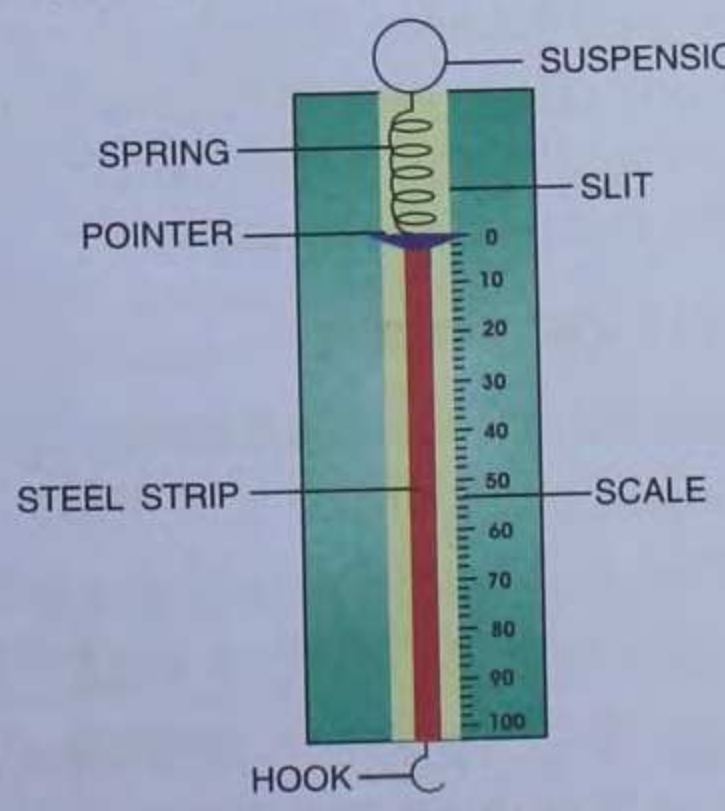


Fig. 2.19 Internal metre of a spring balance

with a slit cut at its centre along its length. The top end of the spring is attached to the body of the case and the lower end of the spring is attached to a steel strip where a hook is fixed at its end. A small pointer is attached at the junction of the steel strip and the spring which passes out of slit. On the side of the slit, there are markings on a scale in *gf* or *kgf* depending on the strength of spring (Fig. 2.19).

The body whose weight is to be measured is attached to the hook. The spring gets stretched due to the gravitational pull. The weight of the body is read where the pointer finally stops on the scale.

ACTION AND REACTION

When you kick a football, does it exert a force on your boot ? If you throw a cricket ball against a wall, does the ball exert a force on the wall or the wall exerts a force on the ball ? Such experiments indicate that the forces do not appear alone, but they come in pairs. If you hit your head against a brick wall (action), the wall will retaliate (reaction). Sir Isaac Newton discovered this fact hundreds of years ago and said that the two forces, action and reaction, are always equal in magnitude, but opposite in direction. If body (A) applies a force on body (B) in one direction, body (B) will apply exactly the same force on the body (A) but in opposite direction.

NET EFFECT OF FORCE

To know the net result of forces applied, we must know the magnitude and direction of the force. The magnitude of a force tells us how large or small a force is whereas the direction gives the negative or positive effects of the force as follows :

1. *If two or more forces act in the same direction, they add up to give a resultant force in the same direction.*

For example, in Fig 2.20, two horses pull the cart in the same direction, each by a force of 50 N. The net force on the cart is 50 N + 50 N = 100 N.

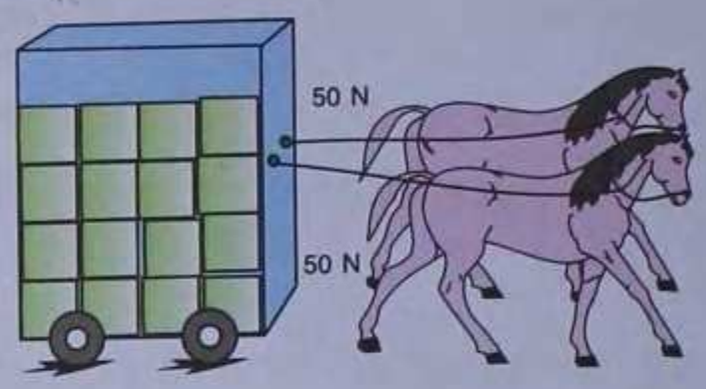


Fig. 2.20 Two forces acting in the same direction

2. *If two forces act in opposite directions, the net force is equal to the difference of the two forces, in the direction of the greater force.*

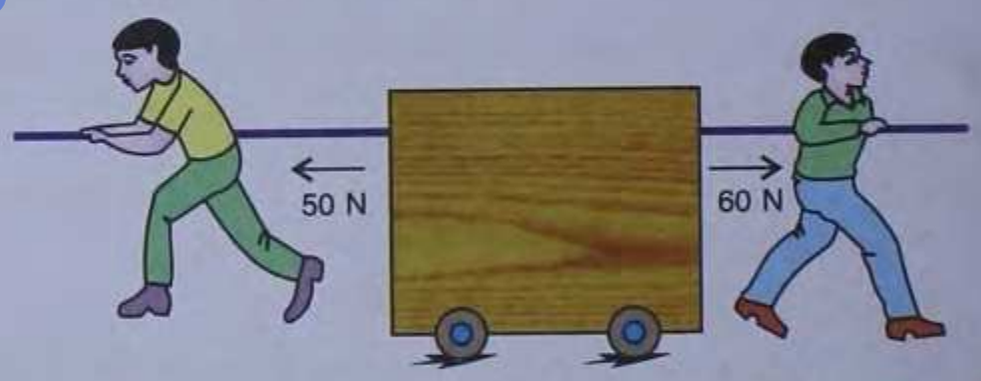


Fig. 2.21 Two forces acting in the opposite directions

For example, in Fig. 2.21, one person pulls the cart by a force of 50 N towards left and the other person pulls the cart by a force of 60 N towards right. The net force on the cart is 60 N – 50 N = 10 N towards the right.

Thus, *if the two forces acting on a body are equal in magnitude, but opposite in direction, the net force on the body is zero (Fig. 2.22).*

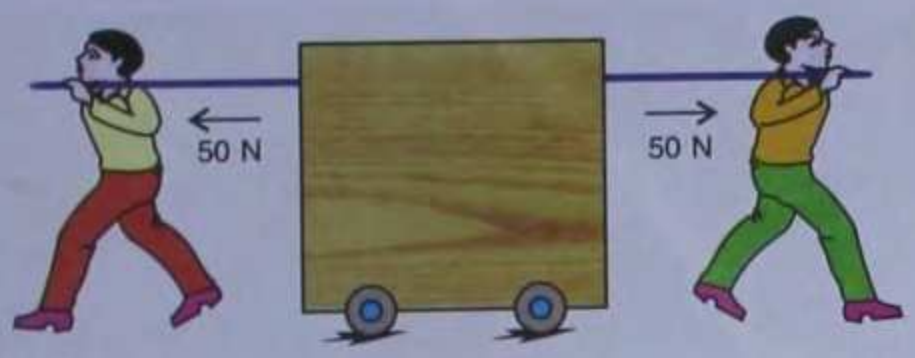


Fig. 2.22 Two equal and opposite forces – the net force is zero

Intext Questions

1. Name the different types of forces ?
2. How can you generate an electrostatic force ?
3. Name the measuring devices of force.

TEST YOURSELF

Short Answer Questions

1. State whether the following statements are *true* or *false* :
   (a) Deciding the state of rest or motion depends on the observer or surroundings.
   (b) A force changes the direction of an object.
   (c) Non-contact force acts at a distance.
   (d) The S.I. unit of force is kgf.
   (e) The pull and push actions are known as force.
2. Fill in the blanks :
   (a) A ..... is a push or a pull.
   (b) ..... force opposes motion.
   (c) A ..... is used to measure the force exerted by an object.
   (d) The direction in which a body is pushed or pulled is called the .....
   (e) The earth is in a state of .....
   (f) A tree in a park is in a state of .....
   (g) Force acting on a body can change its ..... and .....
   (h) The force of gravity is a ..... force.
   (i) The standard unit of force is .....
3. Match the following columns :

Column A	*Column B*
(a) Non-contact force	(i) repel
(b) Like poles	(ii) kg
(c) Contact force	(iii) Gravitational force
(d) Mass	(iv) kgf
(e) Weight	(v) muscular force

4. Answer the following questions :
   (a) Define the following terms :
   (i) State of rest (ii) State of motion
   (iii) Stretch (iv) Squeeze
   (v) Gravitational force
   (vi) Electrostatic force
   (b) While sitting in a moving car, are you in motion or at rest ? Explain your answer.
   (c) Define the term force. Give its S.I. unit.
   (d) Name *two* pairs of such substances which when rubbed together produce electric charge.
   (e) What is the effect of force on a rubber or spring?
   (f) Define contact and non-contact forces.
   (g) Name the force applied in each of the following actions:

Action	Force applied
1. A bullock pulling a cart	.....
2. A crane lifting a heavy iron load	.....
3. Weighing something on a spring balance.	.....
4. Applying the brakes on a bicycle.	.....
5. Picking up paper scraps with a plastic ruler.	.....

   (h) What is the difference between muscular force and mechanical force ?

(i) Name :
   (i) The force applied when a potter turns his wheel.
   (ii) A substance that develops static-electricity on rubbing.
   (iii) A force that always acts against motion.

(j) What happens to the speed of your bicycle when you :
   (i) pedal it faster
   (ii) apply brakes to it ?

B. Long Answer Questions :

1. Explain how a frictional force is used to stop a moving bicycle.
2. A ball rolling along the ground stops after sometime. Why ?
3. What are the effects of force ?
4. What are the different types of forces? Give *one* example of each.
5. (a) Why does a satellite move without needing a force to push it ?
   (b) Is any work done when you push a wall with your hands ? Why ?
6. Give *three* characteristics of force.
7. Draw a neat and labelled diagram of a spring balance.
8. What are the various units of force ?
9. What is the relationship between
   (a) newton and gram-force
   (b) newton and kilogram-force.
10. Which surface exerts lesser force of friction — a smooth polished surface or a rough surface ?

RECAPITULATION

- A body not moving with time with respect to a nearby fixed object is said to be at rest.
- A body moving with time with respect to a nearby object is said to be in motion.
- Rest and motion are relative terms.
- Force is a pull, push, squeeze or stretch which can start, stop, change the shape or size of a body.
- Force is necessary to move an object from its state of rest.
- Force applied on an object can change its shape, size, motion and direction of motion.
- There are two types of forces – contact force and non-contact force.
- The various types of force are muscular, mechanical, gravitational, magnetic, frictional and static electric force.
- The force against the relative motion betwen two objects which acts between two surfaces in contact is called friction.
- Force which only acts when the objects are in physical contact and brings about changes is called contact force.
- Forces which are not in physical contact between two objects but act through the space between the two and bring changes are called forces at a distance.
- The pull of the earth on a body is known as force of gravity or the weight of the body.
- Mass is measured by the physical balance while weight is measured by the spring balance.
- The S.I. unit of force is newton (N).