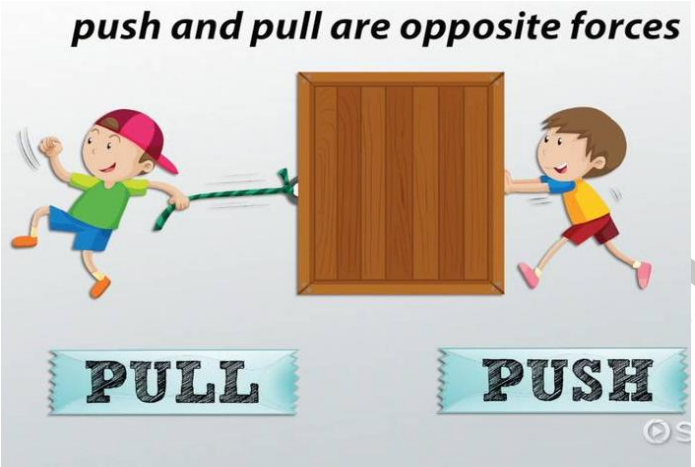
# Chapter -9 Force & Laws of Motion

*Force may be defined as a pull or push which changes or tends to changes the state of rest or state of motion of a body.*

- If force is applied directly on a body then force is called contact force and if force is applied without actual contact from a distance then it is called action at a distance.




## Effect Produced By Force:

***i. Force can change speed of an object:-***

e.g.:- A ball thrown with a larger force will have larger speed and force applied on breaks of a car makes car speed slow down.

***ii. Force can change direction of motion of an object:-***

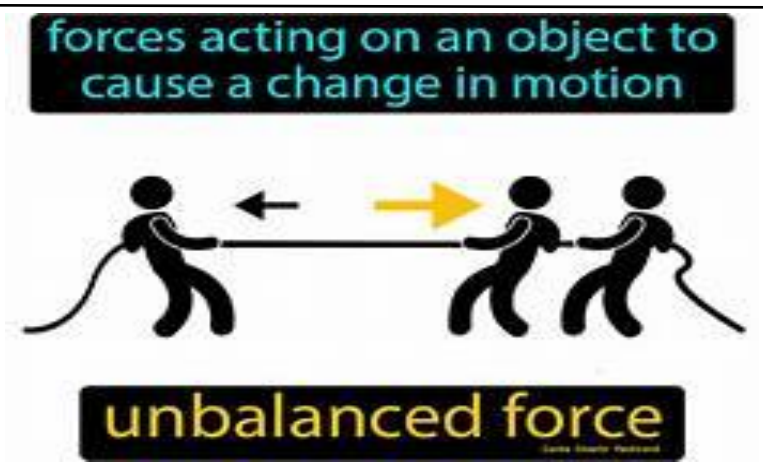
e.g.:- Force applied on the steering wheel of a car changes the direction of motion of car.

***iii. Force can change the shape of an object:-***

e.g.:- By pushing the rubber ball we can change its shape.

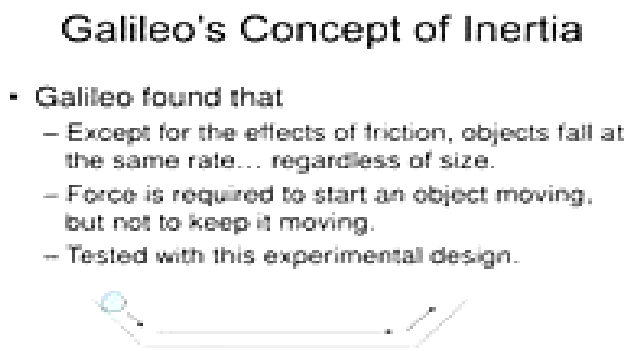
## Balanced forces & unbalanced forces

- **Balanced forces:** Forces are said to be balanced forces if they cancel one another and their resultant force is zero.
- **Unbalanced forces:** When two opposite forces acting on a body, move a body in the direction of the greater force or forces which brings motion in a body are called as unbalanced forces.




**Galileo's Law of Inertia:**

According to this law, it is inability of a body to change the state of rest or uniform motion of a body without the help of any external force.




**Inertia:**

The inability of a material body by virtue of which it cannot change its state of rest or uniform motion is called inertia. Inertia means resistance to change.

- **Question Which of the following has more inertia:**
  **(a) a rubber ball and a stone of the same size?**
  **(b) a bicycle and a train?**
  **(c) a five-rupees coin and a one-rupee coin?**
  **Answer:**
  (a) A stone of the same size
  (b) a train
  (c) a five-rupees coin
  As the mass of an object is a measure of its inertia, objects with more mass have more inertia.

**Different Types of Inertia:**

1. **Inertia of rest**
2. **Inertia of motion**
3. **Inertia of direction**

## 1. Inertia of rest:

The inability of a body changes its state of rest called inertia of rest:-

Why a person falls backward when bus suddenly starts moving forward?

when bus starts moving forward then the lower part of the body starts moving forward while the upper part is in rest due to this the person falls backward.

- **Question. Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.**
  **Answer:** When the tree's branch is shaken vigorously the branch attains motion but the leaves stay at rest. Due to the inertia of rest, the leaves tend to remain in its position and hence detaches from the tree to fall down.

## 2. Inertia of motion

The inability of a body changes its state of rest motion is called inertia of motion:-

- **Why a person falls backward when bus suddenly stops.**

This is due reason that when bus, suddenly stops then lower part of the body comes into rest while the upper part is still in the motion due to this person falls forward.

**Question 4. Explain why it is dangerous to jump out of a moving bus.**

**Answer:** While moving in a bus our body is in motion. On jumping out of a moving bus our feet touches the ground and come to rest. While the upper part of our body stays in motion and moves forward due to inertia of motion and hence we can fall in forward direction.
Hence, to avoid this we need to run forward in the direction of bus.

## 3.Inertia of direction

*The inability of a body changes itself its direction of motion is called inertia of direction*

**Q. Why a person sitting inside the bus experience force acting away from the center of curved path when a bus takes a sharp turn?**

Ans. This is due to reason that the body of person does not like to change its direction of motion.

**Question: how is the inertia of a body measured?**

*Inertia of a body is measured by the mass of the body; greater is the amount of mass greater is the inertia of the body.*

e.g.:- It is easy to change the position of football than a stone of same size because the mass of football is smaller than the mass of the stone. It does not depend on the shape of the body.

**Momentum**

The quantity of motion possessed by the body is called the momentum. It is equal to product of mass and velocity of the body.

Momentum =mass x velocity

Or P=mv

Momentum is vector quantity. Its direction is same as that of velocity.

The *S.I.* unit of momentum = kgm/s .

- **How much momentum will a dumb-bell of mass 10 kg transfer to the floor if it falls from a height of 80 cm? Take its downward acceleration to be 10 $ms^{-2}$.**

**Mass of dumb-bell = 10 kg**

**Height, $h$ = 80 cm = 0.8 m**

$a$ = 10 m/s²

$u$ = 0

$v^2 - u^2 = 2as$

$$v^2 - (0)^2 = 2 \times 10 \times 0.8$$
$$v^2 = 16$$
$$\therefore \quad v = 4 \text{ m/s}$$
$$\text{Momentum } \rho = mv$$
$$= 10 \times 4$$
$$= 40 \text{ kgm/s}$$

## Newton's Laws of Motion

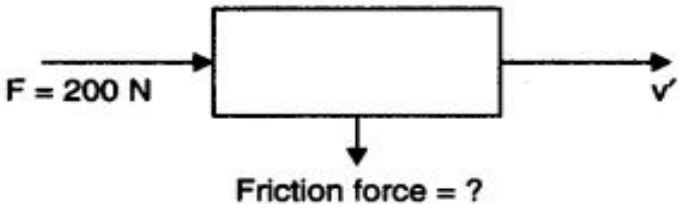
### Newton's First Law of Motion

*A body in rest will remain in rest or a body is in motion will remain in motion till any external force is applied on the body.*

*How Newton's first law defines force?*

- According to Newton's first law, force is external agency which changes the state of rest or uniform motion of the body. Hence this law gives the qualitative definition of force.
- Newton's first law sometimes called law of inertia.

**Question**: **Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet?**




As the wooden cabinet moves across the floor at a constant velocity and the force applied is 200 N. Hence the frictional force that will be exerted on the cabinet will be less than 200 N.

## Newton's Second Law of Motion:

*According to Newton's second law of motion, the rate of change of linear momentum is directly proportional to applied force.*

*Mathematically*

$$\vec{F} \alpha \frac{\overrightarrow{dp}}{dt}$$

or $$\vec{F} \alpha \frac{d(m\vec{v})}{dt} \qquad (\because \vec{P} = m\vec{v})$$

Or $$\vec{F} \alpha m\frac{d\vec{v}}{dt}$$

Or $$\vec{F} \alpha m\vec{a}$$

Or $$\vec{F} = km\vec{a}$$

Where $$k = 1$$

$\Rightarrow$ $$\vec{F} = m\vec{a}$$

Force is a vector quantity.

SI unit of force is one Newton

If a force displace a body of mass one kg through a distance of one metre then the force acting on the body is called one Newton.

c.g.s. unit of force is dyne

**Question. An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of $1.7 ms^2$?**

mass = 1500 kg
$a = -1.7\ m/s^2$
$F = ?$
$F = m \times a$
$= 1500 \times (-1.7)$
$= -2550\ N$

The force between the vehicle and road is – 2550 N.

**Question. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 tones (Hint: 1 tone = 1000 kg).**

$u = 0\ m/s$
$s = 400\ m$
$t = 20\ s$
$a = ?$
$F = ?$

$m = 7$ tonnes
$= 7 \times 1000\ kg$
$= 7000\ kg$

$$s = ut + \frac{1}{2}at^2$$

$$400 = (0 \times 20) + \frac{1}{2}a\,(20)^2$$

$$= \frac{400 \times 2}{(20)^2} = a \qquad \therefore a = 2\ m/s^2$$

Force→ $F = ma$
$= 7000 \times 2 = 14000\ N$

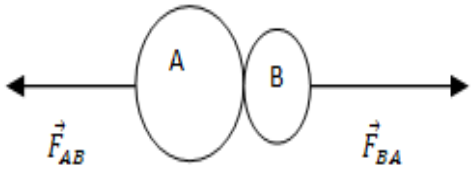
**Question. A stone of 1kg is thrown with a velocity of 20 ms~1 across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?**

$m = 1\ kg$
$u = 20\ m/s$
$s = 50\ m$
$v = 0$
$F = ?$
$a = ?$

$v^2 - u^2 = 2as$
$(0)^2 - (20)^2 = 2a(50)$
$\therefore -400 = 100\,a$
$\therefore a = \frac{-400}{100} = -4\ m/s^2$

Force of friction, $F = m \times a$
$= 1\ kg \times -4\ m/s^2$
$= -4\ N$

**(iii) Newton's Third Law of Motion:**



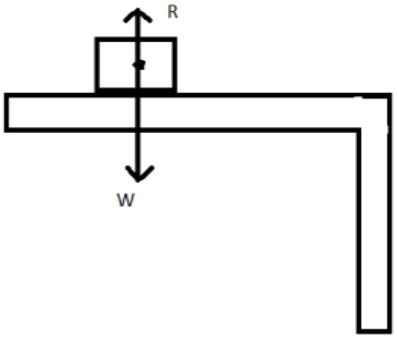

It states that to every action, there is always an equal and opposite reaction.

Suppose $\vec{F}_{AB}$ is the amount of force exerted by body $B$ on body $A$ and $\vec{F}_{BA}$ Is the amount of force on $B$ due to $A$. then from Newton's Third law of motion $\vec{F}_{AB} = -\vec{F}_{BA}$

I.e. Force on $A$ by $B = -Force\ on\ B\ by\ A$

**Illustrations of Newton's Third Law of Motion**

1. A book kept on table exert a force due to weight on the table in down ward direction, due to which a equal and opposite force is Act on book due to table in upward direction. Hence both remain in equilibrium.
2. While walking, we press the ground in backward direction, them the ground exerts an equal and



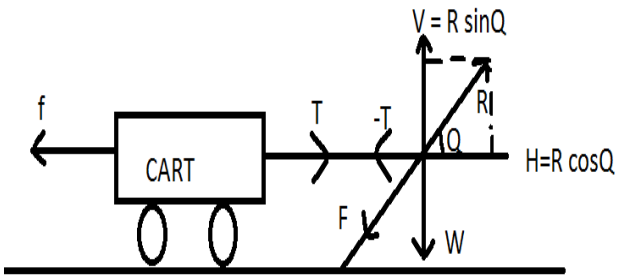
opposite force on us due to which we walks.

3. It is difficult to walk on slippery ground or sand because we are unable to exert force due to which reaction is not sufficient to walk.

**Question . If action is always equal to the reaction, explain how a horse can pull a cart?**

**Answer:** The third law of motion states that action is always equal to the reaction but they act on two different bodies.

In this case the horse exerts a force on the ground with its feet while walking, the ground exerts an equal and opposite force on the feet of the horse, which enables the horse to move forward and the cart is pulled by the horse.




**Law of Conservation of Linear Momentum**

If $\vec{F}$ is the external force acting on the system then $\vec{F} = \frac{d\vec{p}}{dt}$

For isolated system $F = 0 \Rightarrow \frac{d\vec{p}}{dt} = 0 \quad \vec{p} = constant$

Thus in absence of external force the linear momentum of isolated system remains constant.

**Application of Law of Conservation of Linear Momentum:**

- While firing a bullet, the gun should be hold tight to the shoulder because as we know the recoiling gun can hit the shoulder. If the gun is hold tight to the body then gun and body becomes a isolated system of large mass and recoil velocity becomes small.

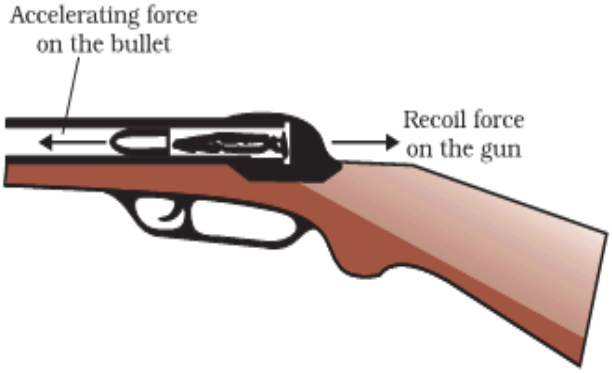
- Rocket and Jet planes work on the principle of conservation of linear momentum:-In rockets and Jet planes the fuels impart momentum in downward direction due to which rocket get a momentum in upward direction.
- When a men jumps out of a boat to the shore, the boat moves slightly away from the shore becomes initially total momentum of both is zero, but during jumping man acquire a momentum in forward direction due to which boat acquire momentum in backward direction so it happens.

- Recoil of gun: suppose a bullet of mass m is fired from a gun of mass M. initially both are in rest but after firing suppose v is the velocity of bullet and V is the velocity of gun. Then from conservation of linear momentum.

$$0 = m\vec{v} + M\vec{v}$$

$$\text{Or} \qquad M\vec{v} + m\vec{v}$$

$$\text{Or} \qquad \vec{V} = \frac{-m}{M} v$$




**Question . From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 m/s. Calculate the initial recoil velocity of the rifle.**

$(m_1)$ Mass of rifle = 4 kg

$(m_2)$ Mass of bullet = 50 g = 0.05 kg

$(v_2)$ Velocity of bullet = 35 m/s

$(v_1)$ Recoil velocity of rifle = ?

According to the law of conservation of momentum

Momentum of rifle = momentum of bullet

$$m_1 v_1 = m_2 v_2$$

$$4\text{ kg} \times v_1 = 0.05 \times 35\text{ m/s}$$

$$\therefore \quad v_1 = \frac{0.05 \times 35}{4} = \frac{1.75}{4}$$

$$v_1 = 0.4375\text{ m/s}$$

$\therefore$ Recoil velocity of rifle = 0.4375 m/s

**Question . An object of mass 100 kg is accelerated uniformly from a velocity of 5 $ms^{-1}$ to 8 $ms^{-1}$ in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.**

$m = 100\text{ kg}$

$u = 5\text{ m/s}$

$v = 8\text{ m/s}$

$t = 6\text{ s}$

$\rho_1 = ?$

$\rho_2 = ?$

$F = ?$

$\therefore$ Initial momentum $\rho_1 = mu$

$= 100 \times 5 = 500\text{ kg m/s}$

Final momentum $\rho_2 = mv$

$= 100 \times 8 = 800\text{ kg m/s}$

Force exerted on the object $F = ma$

$$= 100\left(\frac{u-v}{t}\right)$$

$$= 100\left(\frac{8-5}{6}\right) = 100 \times \frac{3}{6}$$

$F = 50\text{ N}$

- **Question . Class V students were playing cricket with the cork hall in the school campus. Charu a senior student told them about the accidents that can occur due**

**to cork ball in the campus and also advised them to bring soft cosco ball to play the game.**

**(a) Why it was safe to play with soft ball and not with hard cork ball?**

**(b) A player pulls his hands backwards after holding the ball shot at high speed. Why?**

**(c) What value of Charu is seen in this act?**

**Answer:**

(a) The soft ball will have less inertia as compared to the heavy ball and it would not hurt the players.

(b) By pulling the hand backwards it reduces the force exerted by the ball on hands.

(c) Charu showed the value of being responsible and helpful by nature.