St. Andrews Scots Sr. Sec. School

9th Avenue, I.P. Extension, Patparganj, Delhi – 110092.
Session: 2022-2023
Subject: Physics
Class: IX **Ch-9:Force & Laws Of Motion** **Topic: Notes**

FORCE

<u>Force</u> may be defined as an agency (a push or pull) which changes or tends to change the state of rest or of uniform motion or the direction of motion of a body.

EFFECTS OF FORCE

A force applied on an object can produce the following changes:

1. **A force can change a state of rest**.

<u>For Example</u> – If we kick a football kept on the ground, then the football starts moving; If we push a resting table, then the table will start moving. In both the cases, the force applied has changed the state of rest.

2. **A force can stop a moving body**.

<u>For Example</u> – A football moving on ground stops after sometime, because of the force of friction of ground.

3. **A force can change the speed of an object**.

<u>For Example</u> – A speed of a moving car can be increased by accelerating the car or can be decreased or stopped by applying the brakes.

4. **A force can change the direction of motion of an object**.

<u>For Example</u> – A force exerted on the steering wheel of a car changes the direction of motion; A force exerted by the cricket player's bat changes the direction of moving cricket ball.

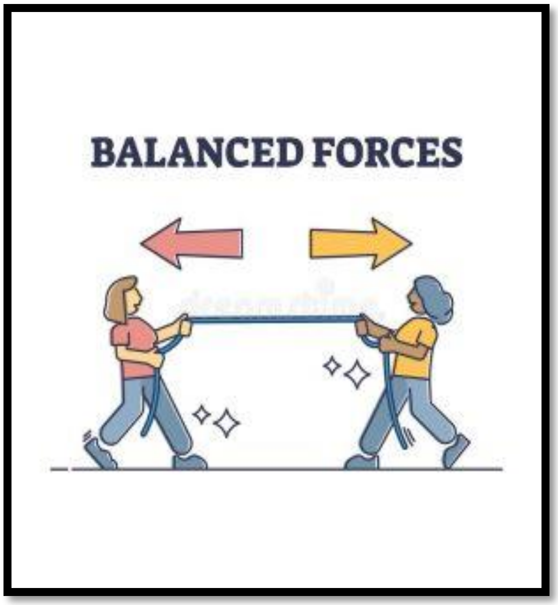
5. **A force can change the shape of an object**.

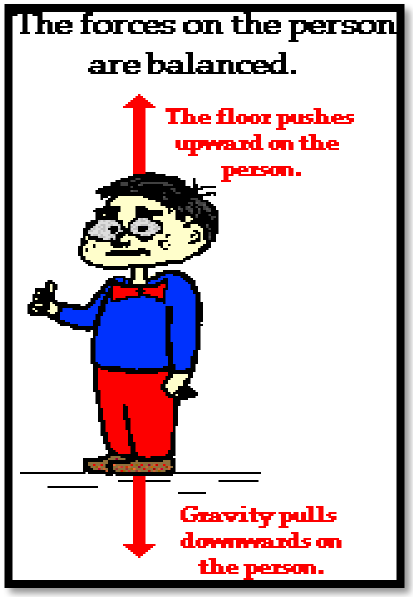
<u>For Example</u> – If we pull a spring from both the ends, then the shape of spring changes.

BALANCED FORCES

If the resultant of all the forces acting on a body is zero, the forces are called **<u>balanced forces</u>**.

<u>For Example</u> - A game of tug of war with equally matched opponents is an example of balanced force; When the man pushes against the wall, the forces at play balance each other, and as a result, the wall does not move.

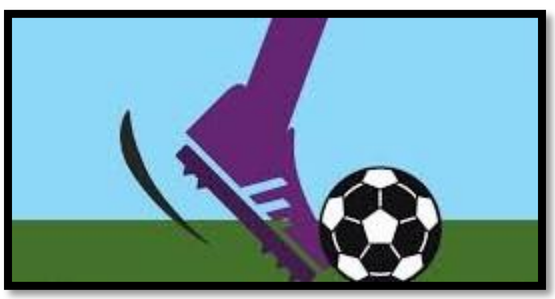




UNBALANCED FORCES

If the resultant of all the forces acting on a body is not zero, the forces are called **<u>unbalanced forces</u>**.

<u>For Example</u> - The ball moves from one place to another after it's kicked.



INERTIA

The inherent property or tendency of an object by virtue of which it cannot change its state of rest or uniform motion in a straight line is called **<u>inertia</u>**.

TYPES OF INERTIA

a) Inertia of rest – The tendency of a body to remain in its state of rest is called inertia of rest.

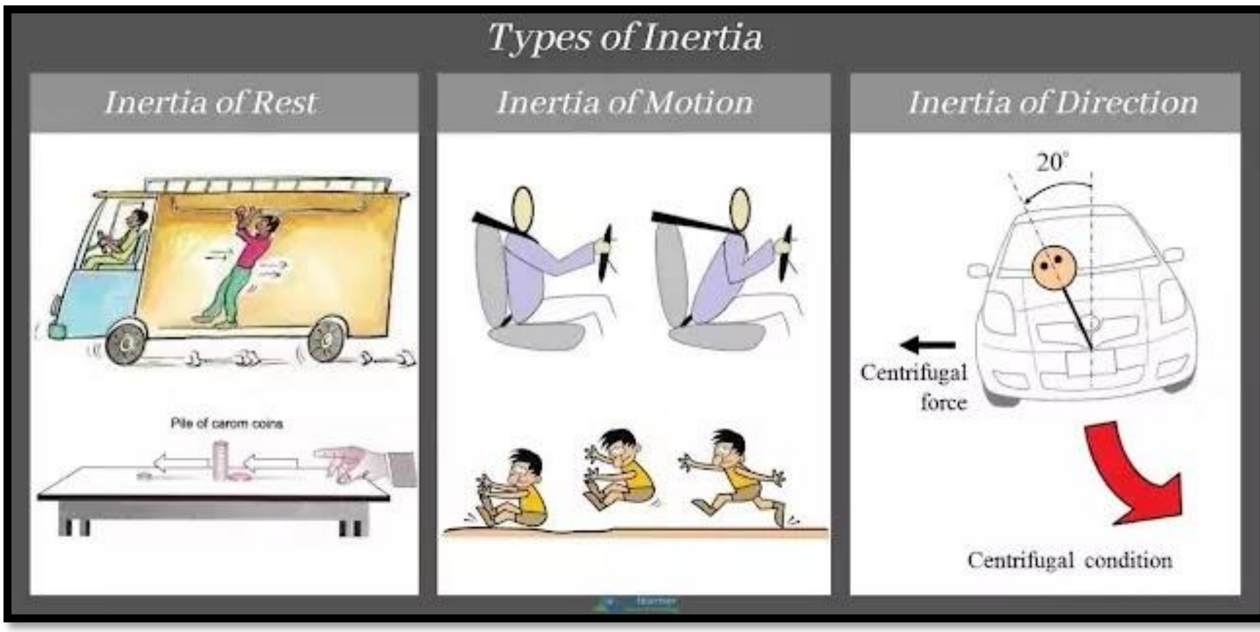
Example – *A person standing in a bus falls backward when the bus suddenly starts moving forward*. When the bus moves, the lower part of his body begins to move along with the bus while the upper part of his body continues to remain at rest due to inertia. That is why, a person falls backward when the bus starts.

b) Inertia of motion – The tendency of a body to remain in its state of uniform motion in a straight line is called inertia of motion.

Example – *When a moving bus suddenly stops, a person sitting in it falls forward.* As the bus stops, the lower part of the body comes to rest along with the bus while the upper part of body continues to remain in motion due to inertia and falls forward.

c) Inertia of direction – *The inability of a body to change its direction of motion is called inertia of direction.*

Example – When a bus takes a sharp turn, a person sitting in the bus experiences a force acting away from the centre of the curved path due to his tendency to move in the original direction.



- **Mass as the measure of inertia** – *Mass is the measure of its inertia.* If a body has more mass, it has more inertia. And if a body has less mass, it has less inertia.

  Example – A stone has more inertia than a football; A truck has more inertia than a bicycle; etc.

NEWTON’S LAWS OF MOTION

Sir Isaac Newton (1642-1727) made a systematic study of motion and gave three laws which describe the motion of bodies. These three laws are known as Newton’s Laws of Motion.

1. Newton’s First Law Of Motion

According to Newton’s first law of motion, a body at rest will remain at rest, and a body in motion will continue its uniform motion in a straight line until and unless some external force is applied to change its state of rest or of uniform motion. This law consists of two parts:

(i) **First part** says that a body at rest continues its state of rest. An external force has to be applied on it to make it move. A chair lying on the floor will continue to remain there unless we displace it.

(ii) **Second part** says that a body in motion continues moving in a straight path with a uniform speed. This part seems to be contrary to our everyday experience. A rolling ball comes to rest on a rough ground. This is because of force of friction. The ball moves through a larger distance on smooth floor. If the friction were zero, the ball would continue its motion forever. This part also indicates that to increase or decrease the speed of a body moving in a straight line, a force has to be applied on it in the direction of motion or opposite to the direction of motion.

- **Hence, Newton's first law of motion defines Force and Inertia:**

(a) **Force –** According to Newton's first law of motion, force is the only reason, which can change the state of rest or of uniform motion of a body along a straight line. This gives the definition of force i.e. Force is the external agency, which changes or tends to change the state of rest or of uniform motion along straight line of a body.

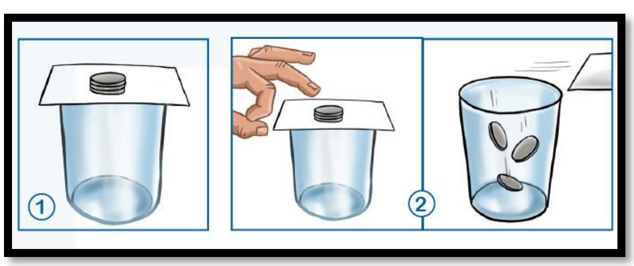
(b) **Inertia –** Newton's first law of motion shows the property of a body at rest or in uniform motion along straight line, to continue to be at rest or in uniform motion respectively unless no external force is acted on it. The inherent property or tendency of an object by virtue of which it cannot change its state of rest or uniform motion in a straight line is called inertia.

Some more examples of Inertia:-

(A) Inertia of Rest

(i) **Dust is removed from a hanging carpet by beating it with a stick**. As the carpet is beaten, it suddenly moves forward while the dust particles tend to remain at rest due to inertia of rest and so fall off.

(ii) **Coin falls into the tumbler when the card is given a sudden jerk.** Place a coin on a playing card covering a glass tumbler. Give a sudden jerk to the card, the card flies off and the coin drops into the tumbler. This is because the coin tends to remain at rest due to inertia.



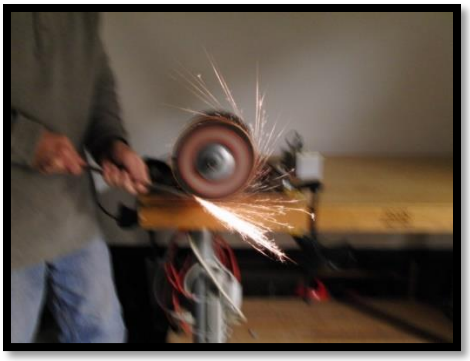
(B) Inertia of Motion

(i) **An athlete runs for a certain distance before taking a long jump.** The inertia of motion gained by him at the time of jumping adds to his muscular effort and helps him in taking a lower jump.

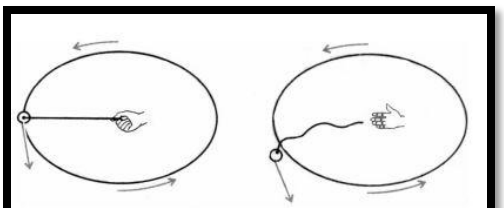
(ii) **A ball thrown upward in a moving train comes back into the thrower's hands.** The ball acquires a horizontal velocity of the train and maintains it inertia of motion during its upward and downward motion. In this period the ball covers the same horizontal distance as the train, so it comes back to thrower's hands.

(C) Inertia of Direction

(i) During the sharpening of a knife, **the sparks coming from the grind stone fly off tangentially.** This is due to inertia of direction.



(ii) When a stone is tied to one end of a string is whirled and if the string or thread suddenly breaks then the stone flies off along the tangent to the circle. This is due to inertia of direction.



When left free, the stone flies off tangentially

LINEAR MOMENTUM

When a small piece of stone is dropped from a small height on a glass pane placed on a table, it does not break the glass pane. But when a heavy stone is dropped from the same height, the glass pane breaks. Here the small and a heavy stone is having same velocity when they fall on a glass pane. On the other hand, a greater effort is required to stop a bullet fired from the gun than to stop a bullet of the same mass when just thrown by the hand.

The above examples show that the effect of motion of a body depends both on its mass and velocity.

Therefore, **Momentum** of a body is the quantity of motion possessed by the body. It is equal to the product of mass and velocity of a body.

Momentum = Mass x Velocity

p = m x v,

where, p = Momentum

m = Mass of the body

v = Velocity of body

- Momentum is a vector quantity.
- Its direction is same as the direction of the velocity of the body.
- S.I unit of momentum is kg m/s.
- Every moving body possesses momentum.
- Change in momentum = Final momentum – Initial momentum

= mv - mu

2. Newton's Second Law Of Motion

Suppose a fixed force is applied on two bodies of different masses for the same direction. The lighter body gains a higher speed than the heavier one. However, the change in momentum in both cases is found to be the same. This shows that the same force for the same time causes the same change in momentum for bodies of different masses. This fact was recognized by Newton who expressed it as his second law of motion.

According to Newton's second law of motion, the rate of change of momentum of a body is directly proportional to the external force applied on the body and the change takes place in the direction of the applied force.

$$\textbf{Force} \propto \frac{\textbf{Change in momentum}}{\textbf{Time Taken}}$$

Newton's second law of motion gives the measurement of force.

Consider a body of mass 'm' having an initial velocity 'u'. The initial momentum of this body will be '*mu*'. Suppose a force 'F' acts on a body for time 't' and cause the final velocity to become 'v'. The final momentum of this body will be *'mv'*. Now, the change in momentum of this body is 'mv – mu' and the time taken for this change is 't'. So, according to Newton's second law of motion:

$$\mathbf{F} \propto \frac{\mathbf{mv-mu}}{\mathbf{t}}$$

Or, $$\mathbf{F} \propto \frac{\mathbf{m(v-u)}}{\mathbf{t}}$$

Or, $\mathbf{F} \propto \mathbf{m \times a}$ **(**[v – u] / t = a).

Thus, the force acting on a body is directly proportional to the product of 'mass' of the body and 'acceleration' produced in the body by the action of force, and it acts in the direction of acceleration.

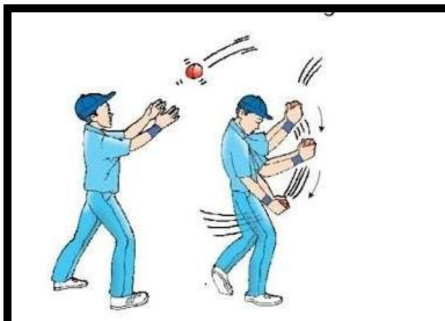
Force = Mass x Acceleration

Thus, Newton's second law of motion gives us a relationship between 'force' and 'acceleration'.

- Force is a vector quantity.
- S.I unit of force is Newton(N) or kg m/s^2.

Applications Of Newton 's Second Law Of Motion:-

(i) **A cricket player moves his hands backward while catching a fast cricket ball.** A cricket player moves his hands backward while catching a fast cricket ball so that the momentum of the ball reduces to zero as the momentum of the fast-moving ball is large. By moving his hand, he is increasing the time taken thereby reducing the momentum.



A fielder pulls his hands gradually with
e moving ball while holding a catch.

(ii) **The use of seat belts in cars.** The cars are provided with seat belts for passengers to prevent injuries in case of an accident. In an accident, the fast running car stops suddenly. Due to this the momentum of the car reduces to zero in a very short time. The stretchable seat belts worn by the passengers increase the time taken by the passengers to fall forward. Due to longer time, the rate of change of momentum is reduced, and hence less stopping force acts on them. So, the passengers are saved from fatal injuries.

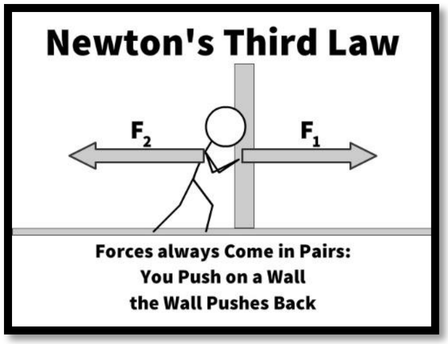
3. Newton's Third Law Of Motion

According to Newton's third law of motion, To each and every action, there is an equal and opposite reaction.

In simple terms, third law can be stated as follows:

Forces in nature always occur between pair of bodies. Force on body A by body B is equal and opposite to the force on the body B by A.

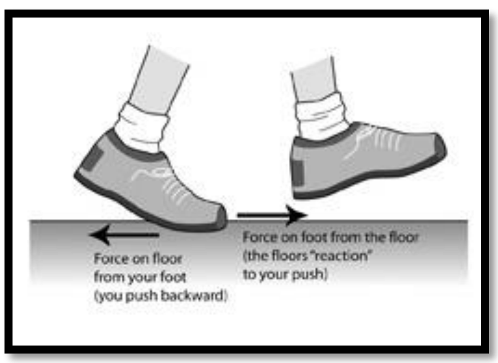
i.e. $F_{AB} = - F_{BA}$



- **Action and reaction always act on different bodies.** If they acted on the same body, the resultant force would be zero and there could never be accelerated motion.
- **The forces of action and reaction cannot cancel each other.** This is because action and reaction, though equal and opposite, always act on different bodies and so cannot balance each other.

<u>Applications Of Newton 's Third Law Of Motion</u>:-

(i) **Walking of a person.** A person is able to walk because of the Newton's Third Law of Motion. During walking, a person pushes the ground in backward direction and in the reaction the ground also pushes the person with equal magnitude of force but in opposite direction. This enables him to move in forward direction against the push.



(ii) **Recoil of gun:** When bullet is fired from a gun, the bullet also pushes the gun in opposite direction, with equal magnitude of force. This results in gunman feeling a backward push from the butt of gun.