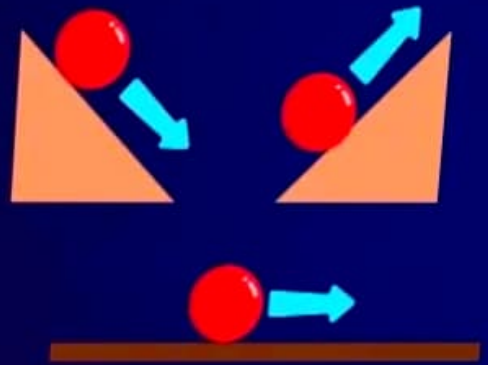
Balanced Force	Unbalanced Force
1. When two or more forces act on a body and produce a net force equal to zero, the forces are called balanced forces.	1. When two or more forces act on a body and produce a net force not equal to zero, the forces are called unbalanced forces.
2. A balanced force does not produce any change in the state of uniform motion or rest of the body.	2. An unbalanced force can produce a change in the state of uniform motion or rest of the body.
3. A balanced force does not cause a body to accelerate.	3. An unbalanced force can accelerate a body.
4. In balanced forces, the forces are equal in magnitude and opposite in direction, canceling each other out.	4. In unbalanced forces, the forces are unequal in magnitude, causing the object to move in the direction of the greater force.

Galileo's Analysis on Motion:

- ***Aristotle's Belief:*** Natural state of bodies is rest.
- ***Galileo's Opposition:*** Challenged Aristotle's view.

Galileo's Observation:

- Ball rolling down an inclined plane: Speed increases.
- Ball rolling up an inclined plane: Speed decreases.



Experiment on Horizontal Plane:

- On smooth surface, ball continues to move.
- Speed remains constant with no external force or friction.

Conclusion: Bodies naturally oppose changes in their state of rest or motion.

Inertia:

- *Inertia is defined as a property of matter by which it tries to maintain its state of rest or of uniform motion along a straight line*

- Inertia of an object is measured by its mass. Inertia is directly proportional to the mass. This means inertia increases with increase in mass and decreases with decrease in mass.

Inertia of Rest:

An object stays at rest, and it remains at rest until an external force affects it. Example: When a car accelerates, passengers may feel as though their bodies are moving backwards. In reality, inertia is making their bodies stay in place as the car moves forward.

Inertia of Motion:

An object will continue to be in motion until a force acts on it. Example: A hockey puck will continue to slide across the ice until acted upon by an outside force.

IMPORTANT

Q. Why does a person standing in a bus fall backward when the bus suddenly starts moving?

- Initially, both the bus and the person are at rest. When the bus suddenly starts moving, the legs of the person move with the bus, but the upper part of their body tends to remain at rest due to inertia, causing them to fall backward if they are not alert.

Q. Why does a person standing in a moving bus fall forward when the driver suddenly applies the brakes?

- When the bus is moving, the person is also in motion along with it. When the brakes are suddenly applied, the bus slows down or stops abruptly, but the upper part of the person's body tends to remain in motion due to inertia, causing them to fall forward.

IMPORTANT

Q. Why are seat belts used in cars and other vehicles?

- Seat belts are used to prevent passengers from being thrown forward in case of sudden braking or an accident. When the vehicle stops suddenly, passengers tend to continue moving forward due to inertia, and the seat belt restrains them and prevents injuries.

Q. Why do we give many jerks to wet clothes before hanging them to dry?

- Jerks cause the water droplets in the clothes to separate from the fabric. When the clothes are suddenly moved, the water droplets tend to remain at rest due to inertia and fall out, reducing the water content in the clothes and helping them dry faster.

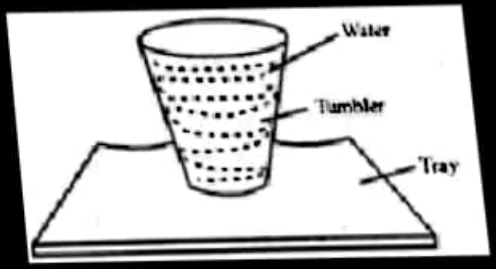
IMPORTANT

Q. Why does the coin fall into the glass tumbler when the card is flicked away quickly?

- The coin remains in its state of rest due to inertia. When the card is flicked away quickly, the coin's inertia causes it to stay in place while the card moves, so the coin falls straight down into the tumbler.

Q. Why does water spill when you turn around quickly holding a tray with a water-filled tumbler?

- The water tends to stay in its state of rest due to inertia. When the tray is turned quickly, the water does not follow the motion of the tray immediately, causing it to spill out.



Q. Why is the head of a hammer tightened by banging the handle against a hard surface?

- When the handle is struck against a surface, the handle comes to rest, but the head of the hammer, due to inertia, continues moving downward and tightens onto the handle after repeated strikes.

Q. Why does only the bottom coin move when a pile of coins on a carom board is hit with a striker?

- When the striker hits the pile of coins, only the bottom coin moves due to the force applied, while the rest of the coins in the pile tend to remain at rest due to inertia, causing them to drop vertically and stay in place.

Newton's First Law of Motion

Newton's first law of motion states that:

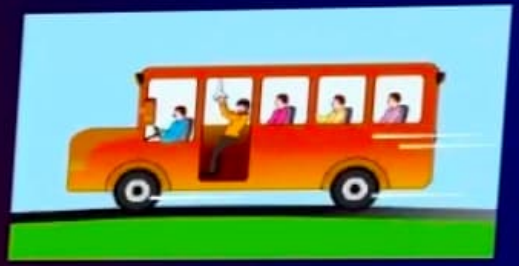
A body remains in the state of rest or uniform motion in a straight line unless and until an external force acts on it.

There are two conditions on which the 1st law of motion is dependent:

- **Objects at rest:** When an object is at rest, velocity ($v = 0$) and acceleration ($a = 0$) are zero. Therefore, the object continues to be at rest.
- **Objects in motion:** When an object is in motion, velocity is not equal to zero ($v \neq 0$), while acceleration ($a = 0$) is equal to zero. Therefore, the object will continue to be in motion with constant velocity and in the same direction.

Newton's First Law of Motion: Examples

- A person standing in a bus falls backward when bus starts moving suddenly.
- A person standing in a moving bus falls forward if driver applies brakes suddenly.
- Before hanging the wet clothes over laundry line, usually many jerks are given to the clothes to get them dried quickly.



MOMENTUM

Momentum is the quantity of motion an object has

The product of velocity and mass is called the momentum. Momentum is denoted by 'p'.

$$p = m \times v$$

where, p = momentum, m = mass of the object and v = velocity of the object.

Impulse = (Force × time)

Momentum: Examples

- Even a small bullet is able to kill a person when it is fired from a gun because of its momentum due to great velocity.

- A person get injured severely when hit by a moving vehicle because of momentum of vehicle due to mass and velocity.

- A person get injured in the case of hitting by a moving object, such as stone, pebbles or anything because of momentum of the object.

Newton's Second Law of Motion

The rate of change of momentum of an object is directly proportional to the applied unbalanced force in the direction of the force.

Newton's second law of motion states that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

If any object is in the state of rest, then it will remain in rest until a external force is applied to change its state. Similarly, an object will remain in motion until any external force is applied over it to change its state.
This means all objects resist to in changing their state.

The state of any object can be changed by applying external forces only.

Q: A person is prone to more serious injuries when falling from a certain height on a hard concrete floor than on a sandy surface. Explain why.

[CBSE 2011, 2012, 2015]

Ans: When a person falls from a height on a hard concrete floor, he immediately comes in rest position. It means change in momentum is taking place in an extremely short time and consequently, force exerted by the floor on the person to destroy its momentum is extremely large. Hence, chances of more injuries.

When a person falls on a sandy surface, the surface gets compressed downward and it increases the time of fall. As a result for same change in momentum force exerted by sandy surface on the person is less and chances of his being hurt are less.

Q. Why does a continuous push over time help to accelerate a car with a dead battery more effectively than a sudden push?

- Continuous pushing applies a steady force over time, gradually changing the car's momentum, which is more effective than a sudden push that does not provide enough time for momentum change.

Q. Why does a fast-moving cricket ball hurt a spectator more than a table tennis ball hitting a player?

- A fast-moving cricket ball has greater momentum due to its higher mass and velocity, which results in a more forceful impact compared to a table tennis ball.

Mathematical Expression:

Newton's second law of motion states that the force exerted by a body is directly proportional to the rate of change of its momentum.

$$F \propto \frac{Change\ in\ momentum}{time}$$

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

$$F \propto m\left(\frac{v-u}{t}\right)$$

$$F \propto ma \rightarrow F = kma\left(\therefore \frac{v-u}{t}\right)$$

$$F = ma(\therefore k = constant = 1)$$

mass = 'm'

velocity changes from u to v

time = 't',

force = 'F'

Newton's Second Law of Motion

$$F = ma$$

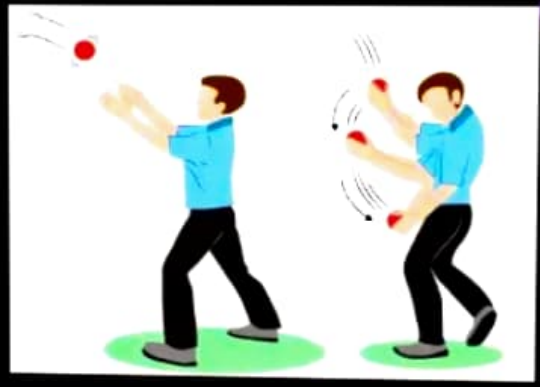
S.I. Unit of Force is kg m/^{2} or Newton.

1 Newton: When an acceleration of 1 m/s^2 is seen in a body of mass 1 kg, then the force applied on the body is said to be 1 Newton.

Force	Momentum
Force = mass * acceleration (F = ma)	Momentum = mass * velocity (p = mv)
Forces can exist even when the object is stationary.	Momentum for stationary objects is always zero.
The direction of the force depends on the acceleration.	The direction of momentum depends on the direction of velocity.
Force is inversely proportional to time ($F \propto 1/t$).	Momentum is directly proportional to time ($p \propto t$).
Force remains constant for constant acceleration.	Momentum changes with constant acceleration, but remains constant if velocity is constant.

Q. Why does a fielder pull his hands backwards while catching a fast-moving cricket ball?

- Answer: The fielder pulls his hands backward to increase the time over which the ball's momentum decreases to zero. This reduces the acceleration of the ball and thus the force of impact, which helps in reducing the chance of injury.



Q. Why are athletes in high jump events made to fall on cushioned or sand beds?

- Answer: Athletes fall on cushioned or sand beds to increase the time over which their momentum decreases to zero. This reduces the rate of change of momentum and thus the force of impact, minimizing the risk of injury.

Q. Why does a karate player use a quick, powerful strike to break a slab of ice?

- Answer: A karate player uses a quick, powerful strike to achieve a high acceleration of the fist, which generates a large force over a very short period. This force is sufficient to break the slab of ice despite its resistance.

Newton's Third Law of Motion

Newton's 3rd law states that every action has an equal and opposite reaction. Action and reaction forces are equal, opposite and acting on different bodies.

"When one body exerts a force on the other body, the first body experiences a force which is equal in magnitude in the opposite direction of the force which is exerted".

The mathematical representation of Newton's third law of motion is let A be the body exerting force F_1 on the body B, then body B too exerts a force F_2 on body A, which is given as:

$$F_1 = -F_2$$

Q. Why do both players get hurt when they collide while playing football?

- Answer: Both players get hurt because, according to Newton's third law, each player exerts an equal and opposite force on the other. These action and reaction forces are equal in magnitude but opposite in direction, resulting in both players feeling the impact.

Q. Why do you push the ground backward when trying to walk forward?

- Answer: When you try to walk forward, you push the ground backward. According to Newton's third law, the ground exerts an equal and opposite reaction force on your feet, which propels you forward.

Q. Why does a gun recoil when a bullet is fired?

- Answer: When a gun is fired, it exerts a forward force on the bullet, and the bullet exerts an equal and opposite reaction force on the gun. This reaction force causes the gun to recoil backward. The difference in mass between the gun and the bullet results in different accelerations.

Q. Why does a rowing boat move backward when a sailor jumps out of it?

- Answer: When a sailor jumps forward from a rowing boat, the force exerted by the sailor on the boat has an equal and opposite reaction force on the boat, causing it to move backward. This demonstrates Newton's third law of motion.

Q. Why does a swimmer push water backward to move forward in the water?

- Answer: A swimmer pushes water backward using their arms and legs. According to Newton's third law, the water exerts an equal and opposite force on the swimmer, propelling them forward. The reaction force from the water helps the swimmer move forward in the water.

Q. Why does a rocket move upwards when it is launched?

- Answer: A rocket moves upwards because it expels gases downward. According to Newton's third law, the gases push back on the rocket with an equal and opposite force, causing the rocket to accelerate upward.

Q. Why is it difficult to walk on ice compared to a rough surface?

- Answer: Walking on ice is difficult because there is less friction between the ice and your shoes. According to Newton's third law, the reaction force you exert on the ice is the same in magnitude but opposite in direction to the friction force, which is much lower on ice than on a rough surface.

Q. Give a reason of the following:
(a) A footballer kicks a ball, which rolls on the ground and after covering some distance comes to rest.
(b) Only the carrom coin at the bottom of a pile is removed when a fast moving striker hits it.
[CBSE 2015, 2018, 2022]

Ans:(a) When a football is rolling on the ground, a force of friction acts on it due to ground in a direction opposite to its motion. As a result, the motion of football gets slowed down and after covering some distance it comes to rest.

(b) The carrom coin at the bottom of a pile comes in a state of motion due to force exerted by the striker on it. However, other coins of pile remain intact due to their inertia of rest.