FORCE AND LAWS OF MOTION

NEWTON'S FIRST LAW OF MOTION

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 act on it.

Putting Newton's 1st law of motion in simple words, a body will not start moving until and unless an external force acts on it. Once it is set in motion, it will not stop or change its velocity until and unless some force acts upon it once more. The first law of motion is sometimes also known as the law of inertia.

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.

Interested to learn how to derive the first law of motion? Below is the link:

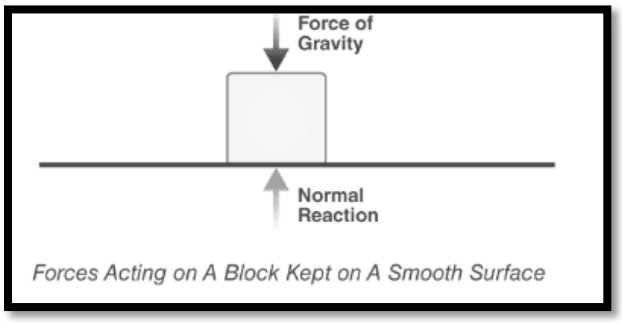
External Force

An external force is defined as the change in the mechanical energy that is either the kinetic energy or the potential energy in an object. These forces are caused by external agents. Examples of external forces are friction, normal force and air resistance.

Example

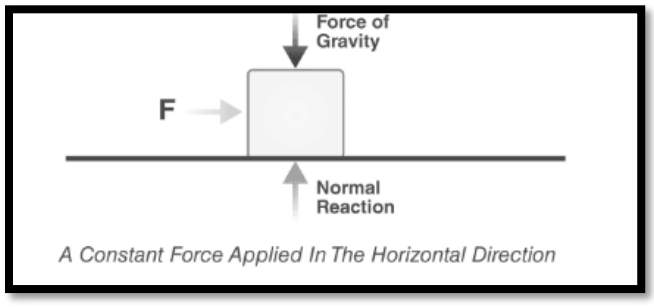
Let us take a block on a smooth surface. By smooth, we mean that there is no friction acting on the surface. The block is at rest, that is, it is not moving.

Now, let us examine the forces acting on the block. The only forces acting on the block are the force of gravity and the normal reaction by the surface. There is no force acting on it in the horizontal direction. Since the forces in the vertical direction are equal to each other in magnitude, they cancel each other out, and hence there is no external force on the block. Since this block is at rest, we can say that it confirms Newton's first law of motion.



Forces Acting on A Block Kept on A Smooth Surface

Now, if we apply a constant force F on the block in a horizontal direction, it will start moving with some constant acceleration in the direction of the applied force.



A Constant Force Applied In The Horizontal Direction

Thus, the first law of motion is confirmed again.

Note:

Newton's laws are valid only in inertial frames of reference.

Newton's First Law of Motion Example in Daily Life

Wearing a seat belt in a car while driving is an example of Newton's 1st law of motion. If an accident occurs or brakes are applied to the car suddenly, the body will tend to continue its inertia and move forward, probably proving fatal. To prevent such accidents, seat belts are used, stopping your body from moving forward in inertia and avoiding danger.

Concept of inertia

Inertia:

It is inherent property of all bodies, by virtue of which it resists or opposes any change to its present state (of rest or of uniform motion). It varies directly as mass of the body.

Inertia of a body is of three Types:

(a) Inertia of rest:

It is inability of a body to change by itself, its state of rest. This means a body at rest remains at rest and cannot start moving on its own.

Examples:

1. A passenger in a bus tends to fall backward when the bus starts suddenly.
2. On shaking or giving jerks to the branches of a tree, the fruits fall down.
3. Dust can be removed from a hanging carpet by shaking it or beating it with a stick.
4. A bullet fired against a glass windowpane makes a hole in it but the glass pane is not cracked.
5. If a piece of paper placed under a pile of books is suddenly pulled, it does not disturb the pile of books

(b) Inertia of motion:

It is inability of a body to change by itself, its state of uniform motion. i.e. a body in uniform motion can neither accelerate nor retard on its own and come to rest.

Examples:

1. A passenger in a moving bus tends to lean forward when the bus stops suddenly.

2. A person jumping out of a speeding bus may fall forward.

3. An athlete runs a certain distance before taking a long jump. 4. A cyclist does not come to rest immediately after he stops paddling

(c) Inertia of Direction:

It is inability of a body to change by itself its direction of motion.

Example:

1. The passengers tend to fall sideways, when speeding bus takes a sharp turn.

Momentum:

Suppose we throw a cricket ball and a tennis ball, both with the same speed or velocity. It will be found that more force is required to stop the cricket ball which has more mass and less force is required to stop the tennis ball (which has less mass). And if we throw two cricket balls of same mass but with different speed or velocity. It will be found that more force is required to stop the ball having more velocity as compared to the ball with less velocity. We conclude that there must be a physical quantity which depends on the mass of the body as well as on velocity of the body. That physical quantity which depends upon mass and velocity is momentum. Thus, momentum is a measure of the quantity of motion of a body.

Thus, momentum = mass × velocity

$\vec{P} = m\vec{v}$

Where P ρ = momentum m = mass of the body

$\vec{v}$ = velocity of the body

Momentum is a vector quantity, and its direction is same as the direction of velocity. Its S.I. unit is kilogram - meter per second or kg - m/s.