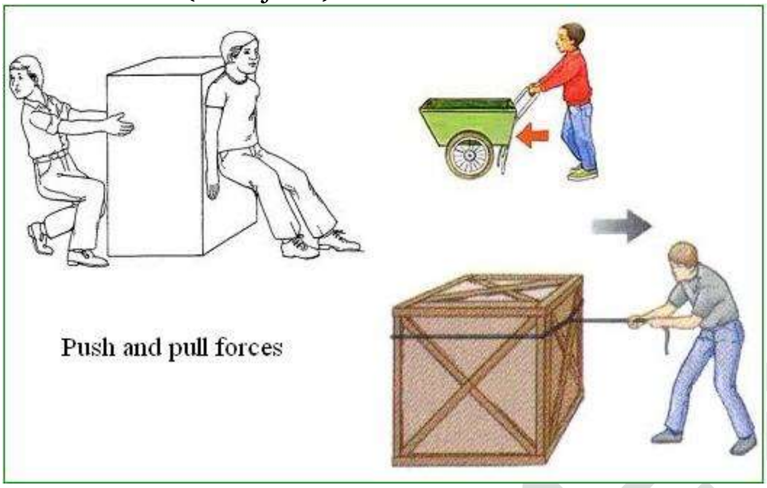
Force and Newtons Laws of Motion

Force and Newton's Laws of Motion

A push or pull on a body is called force. Forces are used in our everyday actions like pushing, lifting, pulling, stretching, twisting and pressing. A force cannot be seen. A force can be judged only by the effects which it can produce in several bodies (or objects) around us.



Force has both magnitude and direction, making it a vector quantity. It is measured in the SI unit of Newton and represented by the symbol F.

In the below shown images we can see how forces are being applied in our everyday life:

(a) The trolley moves along the direction we push it.
(b) The drawer is pulled.
(c) The hockey stick hits the ball forward

Effects of Force

- Force can make a stationary body in motion. For example a football can be set to move by kicking it, i.e. by applying a force.
- Force can stop a moving body – For example by applying brakes, a running cycle or a running vehicle can be stopped.
- Force can change the direction of a moving object. For example; by applying force, i.e. by moving handle the direction of a running bicycle can be changed. Similarly by moving steering the direction of a running vehicle is changed.
- Force can change the speed of a moving body – By accelerating, the speed of a running vehicle can be increased or by applying brakes the speed of a running vehicle can be decreased.
- Force can change the shape and size of an object. For example; by hammering, a block of metal can be turned into a thin sheet. By hammering a stone can be broken into pieces.

Balanced and Unbalanced Forces

a. Balanced Forces

If the resultant of applied forces is equal to zero, it is called balanced forces. Balanced forces do not cause any change of state of an object. Balanced forces are equal in magnitude and opposite in direction. Balanced forces can change the shape and size of an object. For example – When forces are applied from both sides over a balloon, the size and shape of balloon is changed.

b. Unbalanced Forces

If the resultant of applied forces are greater than zero the forces are called unbalanced forces. An object in rest can be moved because of applying balanced forces.

Unbalanced forces can do the following:

1. Move a stationary object.
2. Increase the speed of a moving object.
3. Decrease the speed of a moving object.
4. Stop a moving object.
5. Change the shape and size of an object.

Some Common Forces

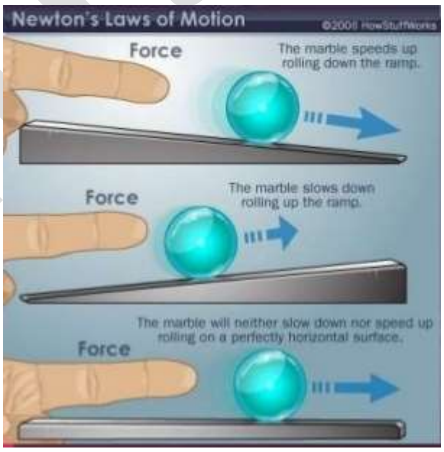
1. **Muscular Force:** The force obtained by the working of human body muscles is called muscular force. Ex: Lifting objects, doing exercise etc.
2. **Gravitational Force:** The force applied by earth on an object in downward direction is called gravitational force.
3. **Frictional Force:** The force which opposes motion is known as frictional force. It acts in the direction opposite to the velocity of body.
4. **Air Resistance:** When an object moves through air, air applies a small force in direction opposite to velocity. This force is called air resistance.

Newton's Laws of Motion

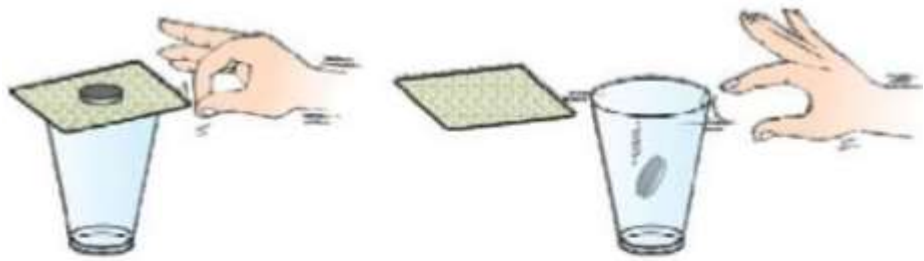
Newton has given three laws to define the motion of bodies. These laws are known as Newton's laws of motion.

Newton's 1st Law

A body at rest will remain in rest, and a body in motion will continue in motion in a straight line with uniform speed, unless it is compelled by an external force to change its state of rest or of uniform motion.



Inertia and Mass: Inertia is that property of body due to which it resists a change in its state of rest or of uniform motion.



In this above shown picture the inertia of the coin tries to maintain its state of rest even when the card flows off. The mass of an object is a measure of its inertia. Its SI unit is kilogram (kg).

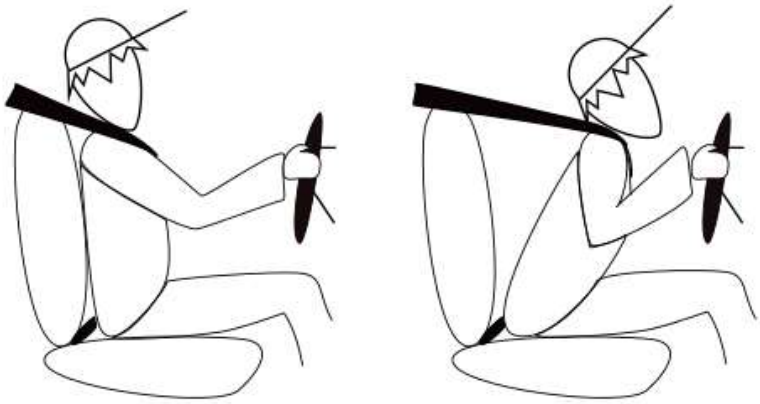
Application of Newton's 1st Law

(1) A passenger in bus has a tendency to keep moving in a straight line inside a bus due to inertia. When the bus takes turn, body of passenger wants to continue moving in straight line. Due to this, it appears that his body bends outwards.

(2) When we hit a carpet it loses inertia of rest and moves. But the dust in it retains inertia of rest and is left behind. Thus dust and carpet are separated.

(3) When a tree is shaken, it moves to and fro. But fruit remains at rest due to its inertia of rest. Due to this fruit breaks off the tree.

(4) When a car is braked suddenly, the man bends forward violently due to inertia of motion. The man may collide with parts of car hurting himself. Seatbelt will not let the man bend forward. And thus save them from accident.



(5) Due to inertia of motion even when the car stops, the luggage on the top of car has the tendency to move forward. Therefore luggage is tied.

Momentum: The momentum of a body is defined as the product of its mass and velocity.

Thus, momentum = mass x velocity

Or, p = m x v

Where, p = momentum

m = mass of the body

v = velocity of the body

The SI unit of momentum is kilograms meters per second (kg.m/s)

Note: The force required to stop a moving body is directly proportional to its mass and velocity.

Change in momentum: It is defined as the difference between final momentum and initial momentum. Suppose initial momentum is mu, and final momentum is mv, then

Change in momentum = mv – mu

Rate of change of momentum: The rate at which momentum is changing is known as rate of change of momentum.

$$\text{Rate of change of momentum} = \frac{mv - mu}{t}$$

$$\text{Or,} \quad = \frac{m(v-u)}{t}$$

Newton's 2nd Law

The rate of change of momentum of a body is directly proportional to the applied force, and takes place in the direction in which the force acts.

$$\text{Force} = \frac{\text{change in momentum}}{\text{time taken}}$$

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

$$= \frac{m(v-u)}{t} \qquad \text{But we know that } \frac{(v-u)}{t} = a$$

=> F = m x a

Or Force = Mass × Acceleration

Its SI unit is Newton (N).

Thus, one unit of force is defined as the amount that produces an acceleration of 1 m s^{-2} in an object of mass 1 kg.

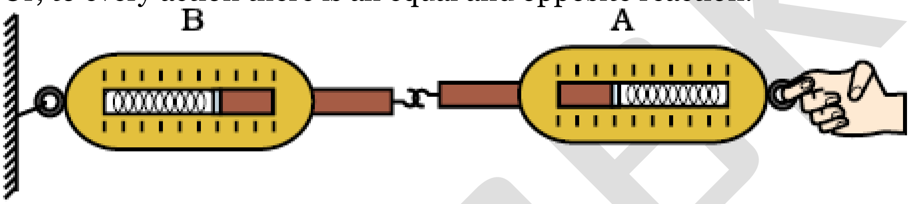
Application of Newton's 2nd Law:

(1) When we stop the ball gradually, we need to apply less force. This is easy and safe. If we stop the ball suddenly, we need to apply larger force which is difficult and can also injure our hand.

(2) In high jump if surface is hard, athlete's body changes velocity in very less time. Large force acts on his body due to which he may get injured. If the surfaces are soft, athlete's body changes velocity in more time. And less force acts on his body which is safe.

Newton's 3rd Law

Whenever one body exerts a force on another body, the second body exerts an equal and opposite force to the first body. Or, to every action there is an equal and opposite reaction.



Action and reaction forces are equal and opposite.

Application of Newton's 3rd Law:

(1) Gun applies force on bullet due to which it moves ahead. By Newton's 3rd Law, bullet will also apply same force on gun in backward direction. Due to this force, gun moves back. This is called recoil of gun. Gun moves back only by small amount due to its heavy mass.

(2) Hose pipe applies large force on water due to which water moves ahead. By Newton's 3rd Law water applies the same force on pipe backwards. Due to this force, pipe can move backwards. To stop it, many people need to hold it.

(3) Man pushes the boat backwards and by newton's 3rd law, boat pushes man forward.

(4) Man pushes water back by applying force. By Newton's 3rd Law, water applied equal and opposite force on swimmer. Due to this force man moves ahead.

(5) Cheetah applies forces on ground in backward direction. By 3rd law, ground applies force equal and opposite on cheetah in forward direction. It is due to this force that cheetah moves ahead. For running faster cheetah needs to apply more force on ground in forward direction.

Conservation of Momentum

If two or more objects apply force on each other with no external force, their final momentum remains same as initial momentum.

Total momentum before collision = Total momentum after collision

Practical examples of conservation of momentum:

(1) In rocket, fuel is burnt due to which gases are ejected downwards. For conservation of momentum, rocket moves up.

(2) Fuel in jet plane burns and ejects gases in backward direction. Then by conservation of momentum, plane moves ahead.