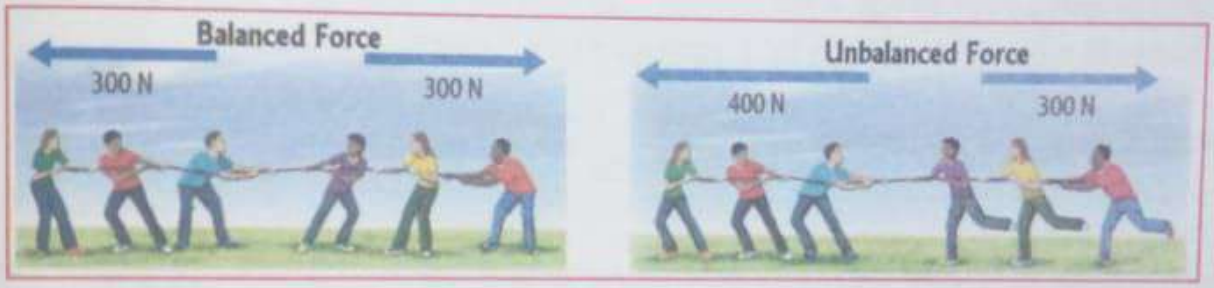
2 FORCE AND LAWS OF MOTION

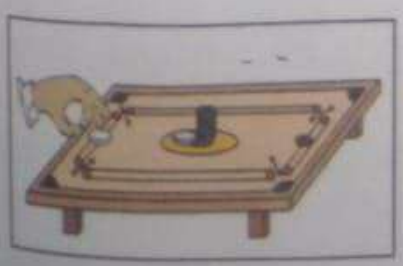
SYNOPSIS :

- **Force :** It is an external agent or push or pull which changes or tends to change the state of rest or the state of uniform motion of a body.

- A force can produce the following effects
  - A force or set of forces can change the speed of a body
  - A force or set of forces can change the direction of motion of a body
  - A set of forces can change the shape of a body
- **Balanced and unbalanced forces :**
  - If a set of forces acting on a body produce no acceleration in it, the forces are said to be balanced.
  - If a set of forces produces a nonzero acceleration the forces are said to be unbalanced.



- Newton has given three laws to describe the motion of bodies. These laws are known as Newton's laws of motion.
- **Newton's first law of motion :** Every body continues to remain in its state of rest or of uniform motion unless it is compelled to change its state of rest or of uniform motion, by some external force.
  - Newton's first law of motion is also called law of inertia.
  - Newton's first law of motion defines force qualitatively It does not tell the quantity of force.
- **Inertia :** The natural tendency of an objects to resist a change in their state of rest or of uniform motion is called inertia.
  - The mass of an object is a measure of its inertia
  - Its SI unit is kilogram (kg).
- **Types of Inertia :**
  - **Inertia of rest :** It is the tendency of the body at rest to remain at rest.
  - **Inertia of motion :** It is the tendency of the body in motion to continue moving with same velocity.
  - **Inertia of direction :** It is the tendency of the body in motion to continue moving in the same direction.



Inertia of rest

Inertia of motion

Inertia of direction

➢ **Momentum :** The product of the mass of a body and its velocity is called linear momentum momentum.

- It is a vector quantity. It is represented by symbol $\vec{p}$.
- Momentum = mass × velocity

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

- SI unit of momentum is kg ms^{-1}, C.G.S unit of momentum is g cms^{-1}
- Every moving body possesses momentum, thus the quantity of motion in a body depend the mass and velocity of the body.

➢ **Newton's second law of motion :** The rate of change of momentum is directly proportional to f applied on it and change takes place along the direction of force.

➢ **Mathematical formulation of second law of motion :**

Let a force 'F' acts on a body of mass m for time 't' and changes its velocity from 'u' to 'v'.
Initial momentum of a body = mu
Final momentum of a body = mv
Change in momentum of body in 't' seconds = (mv – mu)

$$\text{Rate of change of momentum} = \left(\frac{change\ in\ momentum}{time}\right)$$

$$= \frac{m(v-u)}{t} = (m \times a) \qquad \left[\because a = \frac{v-u}{t}\right]$$

Rate of change of momentum = mass × acceleration.
Rate of change of momentum of a body is directly proportional to the applied force and takes pla the direction of force.

$$\boxed{F = \frac{\Delta p}{\Delta t} = \frac{m(v-u)}{t}}$$

- The magnitude of net force acting on a body is proportional to the product of the mass body and its acceleration. The direction of force is the same as that of acceleration.

F = ma

- Newton's second law is quantitative measurement of force.
- SI unit of force is newton (N)
- One newton is the force which when applied on a body of mass 1kg, produce in it an accele of $1 m/s^2$. $\Rightarrow \boxed{1N = 1 kgms^{-2}}$
- C.G.S unit of force is dyne
- One dyne is that force which when applied on a body of mass 1g, produces in it an accele of $1 cm/s^2$. $\boxed{1\,dyne = 1\,gcms^{-2}}$

Impulse : The product of magnitude of force applied on a body within a short interval of time is called impulse.

- It is represented by symbol I or J

  Impulse = change in momentum

$$I = (F \times t) = (mv - mu) = (p_2 - p_1)$$

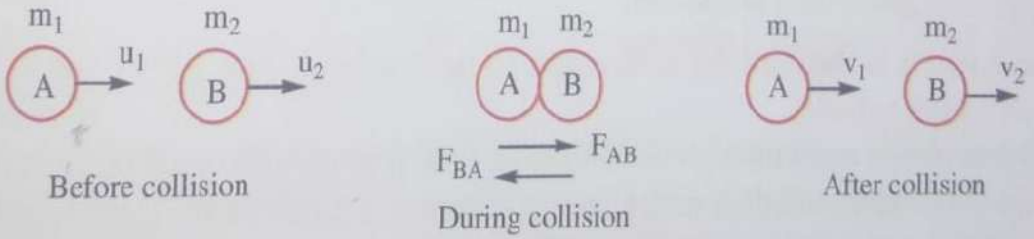
- Its SI unit is newton - second (Ns), C.G.S unit is dyne - second (dyne - s)

Newton's third law of motion : For every action there is an equal and opposite reaction.

- Action and reaction forces are equal in magnitude and opposite in direction.
- Action and reaction forces always occur in pairs.

Law of conservation of momentum :

When two (or more) bodies act upon one another, their total momentum remains constant (or conserved) provided no external force acts on them.



Suppose two balls A and B of masses m_1 and m_2 are travelling in the same direction with different velocities u_1 and u_2 ($u_1 > u_2$) before collision, v_1 and v_2 ($v_2 > v_1$) after collision.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Total momentum of system before collision = Total momentum of the system after collision.