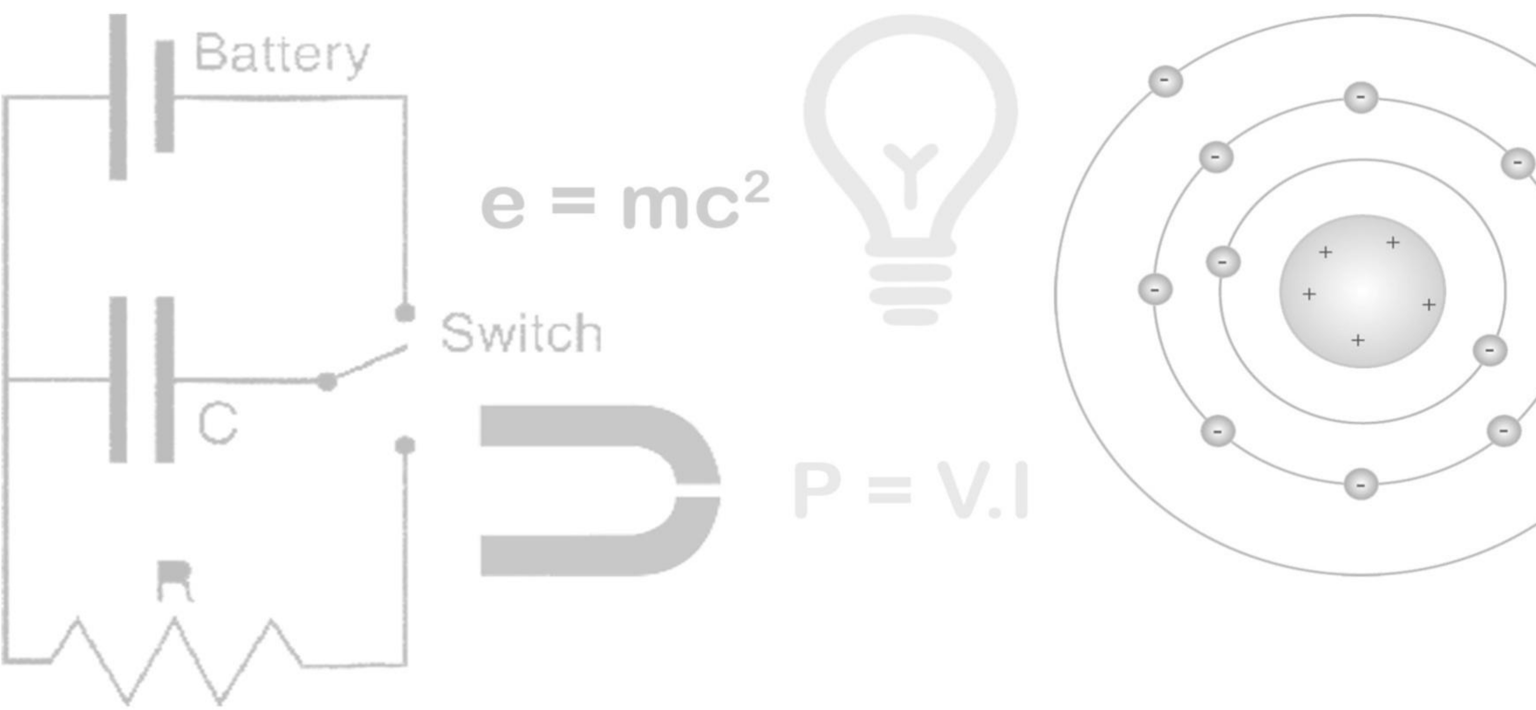
PHYSICS

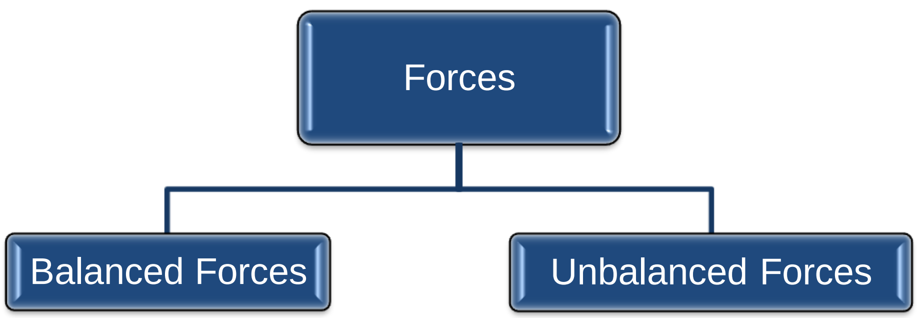


Force and Laws of Motion

Force

- Force is used in our everyday actions such as pushing, pulling, twisting, lifting, pressing and stretching.
- A force can produce the following **effects**:
    - **Move** a body at rest.
    - **Stop** a moving body.
    - **Change the speed** of a moving body.
    - **Change the direction** of a moving body.
    - **Change the shape and size** of a body.

Balanced and Unbalanced Forces



- If the resultant of all the forces acting on a body is zero, then the forces are called **balanced forces**.
- If the resultant of all the forces acting on a body is not zero, then the forces are called **unbalanced forces.**
- Balanced forces cannot change the state of rest or of uniform motion of a body. They can, however, change the shape and size of the body.
- Unbalanced forces can change the state of rest or of uniform motion of a body.

Newton's First Law of Motion

A body continues to be in a state of rest or in a state of uniform motion along a straight line unless acted upon by an external unbalanced force.

- The property of a body due to which it resists any change in its state of rest or of uniform motion along a straight line is called **inertia**.
- Mass is a measure of inertia of a body.
- Newton's first law provides a definition of **force**: Force is something which changes or tends to change the state of rest or uniform motion of a body. **Force** is a **vector** quantity.

Momentum

- The force required to stop a moving body is directly proportional to the mass and velocity of the body.
- The quantity of motion in a body depends on the mass and velocity of the body. This quantity is termed momentum.
- The **momentum (p)** of a body is defined as the **product of its mass (m) and velocity (v)** and has the same direction as that of the velocity. Its SI unit is kilogram metre per second (kg m s^{-1}).
  Momentum = mass × velocity
  p = m × v
- **Momentum** has both magnitude as well as direction; hence, it is a **vector** quantity.
- Momentum of a body at rest is zero.

Newton's Second Law of Motion

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.

- If a body of mass 'm' moving with an initial velocity 'u' is accelerated to a velocity 'v' by the application of a constant force 'F' in time 't', then according to Newton's second law of motion

$$\text{Force} \propto \frac{\text{Change of momentum}}{\text{Time taken}}$$

If mu is the initial momentum and mv is the final momentum:

Change in momentum = mv − mu

$$\text{or, } F \propto \frac{mv - mu}{t}$$

$$= \frac{m(v-u)}{t} \qquad \left[\text{we know that } \left(\frac{v-u}{t}\right) = a\right]$$

$$\text{or, } F \propto m \times a$$

$$F = kma$$

In SI units, k = 1

$$\therefore\ F = ma$$

The force 'F' is applied for time 't' so that the final velocity of the body becomes 'v'.

- **Force** acting on a body is the **product of mass of the body and its acceleration**. i.e. **F = m a**
- The SI unit of force is kg m s^{-2}. This is also known as Newton and represented by the symbol N. A force of one Newton produces an acceleration of 1 ms^{-2} in a body of mass 1 kg.
  1 Newton = 1 kg × 1 m/s^2

Newton's Third Law of Motion

To every action, there is an equal and opposite reaction.

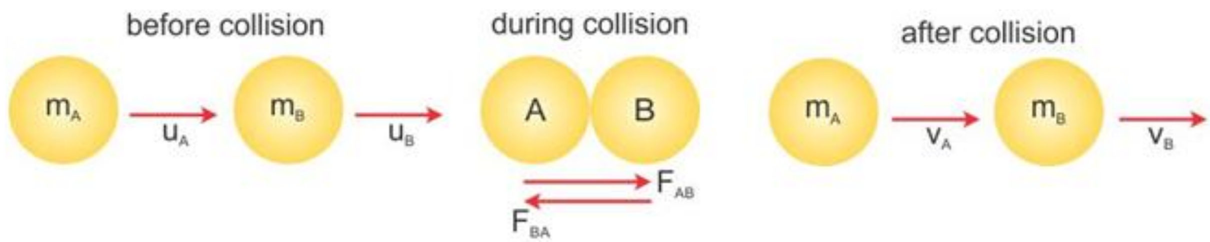
- The action and reaction forces act on two different bodies and never cancel each other.
- Although the action and reaction forces are always equal in magnitude, the forces may not produce acceleration of equal magnitude because they act on different bodies which may have different masses.

Law of Conservation of Momentum

- According to the law of conservation of momentum, **the sum of momenta of two objects before collision is equal to the sum of momenta after collision**, provided there is no external unbalanced force acting on the objects.

Total momentum before collision = Total momentum after collision

i.e.



$m_A u_A + m_B u_B = m_A u_A + m_B v_B$
where m_A and m_B are masses of the bodies
u_1 and u_2 are initial velocities of the bodies
v_1 and v_2 are final velocities of the bodies

- All applications of Newton's third law of motion can be explained in terms of the law of conservation of momentum.
- When a bullet is fired from a gun, the gun moves backwards. The **recoil velocity** v_2 of the gun $v_2 = -\frac{m_1 v_1}{m_2}$, where v_1 is the velocity of the bullet of mass m_1 and m_2 is the mass of the gun.