

## LAWS OF MOTION

### Concepts of Force and Inertia

- The property of an object by which it resists a change in its state of rest or of uniform motion in a straight line is called **Inertia**. Mass of a body is a measure of its inertia
- The change in velocity of an object can only be brought, if a net force acts on it.
- They may change the shape and the size of an object.
- Forces also influence the motion of an object.
- Forces can rotate a body about an axis.

### Force and Motion

- Force is a vector quantity.
- Motion of a body is characterised by its displacement, velocity etc.
- For a body in motion, the velocity will change depending on the direction of the force acting on it.
- velocity of a body changes as long as a net force is acting on it

### First Law of Motion (Law of Inertia)

- A body continues to be in a state of rest or of uniform motion in a straight line unless it is acted upon by a net external force

### Concept of Momentum

- The product of mass  $m$  of a body and its velocity  $v$  is called its linear momentum  $p$ . Mathematically

$$p = mv$$

- SI units is  $\text{kg ms}^{-1}$
- Momentum is a vector quantity

### Second Law of Motion

- The rate of change of momentum of a body is directly proportional to the net force acting on the body.
- Change in momentum of the body takes place in the direction of net external force acting on the body.

$$F = k \frac{\Delta p}{\Delta t}$$

$$F = k m a$$

$$\text{Where } a = \frac{\Delta v}{\Delta t}$$

- Unit of force  $\text{kg m s}^{-2}$
- The unit of force is Newton

### Third Law Of Motion

- To every action, there is an equal and opposite reaction.
- when two objects interact, the force exerted by one object on the other is equal in magnitude and opposite in direction to the force exerted by the latter object on the former

$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

### Impulse

- The effect of force applied for a short duration is called impulse.
- Impulse is defined as the product of force (F) and the time duration ( $\Delta t$ ) for which the force is applied.

$$\text{Impulse} = \mathbf{F} \cdot \Delta t$$

- That is, impulse is equal to change in linear momentum.
- Impulse is a vector quantity
- its SI unit is  $\text{kg m s}^{-1}$  (or N s)

### Conservation Of Momentum

- In an isolated system, the vector sum of the momentum of bodies remains constant.

### A Few Illustrations of Conservation of Momentum

Recoil of a gun

When a bullet is fired from a gun, the gun recoils.

$$mv_1 + Mv_2 = 0$$

$$v_2 = \frac{-m}{M} v_1$$

Where, m= mass of bullet, M mass of gun,  $v_1$  velocity of bullet,  $v_2$  velocity of gun.

- Collision
- Explosion of a bomb
- Rocket propulsion

### Equilibrium of Concurrent Forces

- A number of forces acting simultaneously at a point are called Concurrent Forces.

### Friction

- Force of friction is a contact force and always acts along the surfaces in a direction opposite to that of the motion of the body
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Static Friction	Kinetic Friction
$f_s \propto f_N$	$f_k \propto f_N$
$f_s = \mu_s f_N$	$f_k = \mu_k f_N$
$\mu_s$ , coefficient of static friction	$\mu_k$ Coefficient of kinetic friction

- Values of  $\mu_s$  and  $\mu_k$  for a given pair of materials depend on the roughness of

D.  $6 \text{ Kgms}^{-1}$

- surfaces, their cleanliness, temperature, humidity etc.

### Methods of Reducing Friction

- Use of lubricants such as grease or oil between the surfaces in contact reduces friction.
- Flow of compressed and purified air between the surfaces in contact

### CHECK YOURSELF

1. S.I. unit of linear momentum
  - A.  $\text{Kgms}^{-1}$
  - B.  $\text{Kgm}^{-1}\text{s}$
  - C.  $\text{Kgm}^{-1}\text{s}^{-1}$
  - D.  $\text{Kgms}^{-2}$
2. 1N is equivalent to
  - A.  $10^5$  dyne
  - B.  $10^{-5}$  dyne
  - C.  $10^6$  dyne
  - D.  $10^{-6}$  dyne
3. Dimension of Impulse is
  - A.  $[\text{MLT}^{-1}]$
  - B.  $[\text{MLT}^{-1}]$
  - C.  $[\text{ML}^2\text{T}^{-2}]$
  - D.  $[\text{M}^{-1}\text{L}^{-1}\text{T}^{-1}]$
4. Conservation of momentum in a collision particle can be understood from
  - A. Conservation of energy
  - B. Newton I<sup>st</sup> law
  - C. II<sup>nd</sup> law
  - D. II<sup>nd</sup> & III<sup>rd</sup>
5. A boy has a mass 60kg and travels with a velocity  $1.0 \text{ ms}^{-1}$ 
  1. Momentum of boy
    - A.  $60 \text{ Kgms}^{-1}$
    - B.  $6 \text{ Kgms}^{-2}$
    - C.  $60 \text{ Kgms}^2$

### STRETCH YOURSELF

1. What is the principle of working of a rocket?
2. A cricket player lowers his hand while catching a ball why?
3. Why are wheels of an automobile made circular?
4. State and explain Newton's second law of motion hence deduce the relation  $F=ma$
5. Explain the role of friction in the case of bicycle brake. What will happen if grease is put on the rim?

### Answer to Check Yourself

1(A) 2(A) 3(A) 4(D) 5(A)