Laws of Motion

Introduction

The **Laws of Motion** explain the relationship between the **motion of an object and the forces acting on it**. These laws were formulated by **Sir Isaac Newton** and form the foundation of classical mechanics. The three laws of motion help us understand why objects move, stop, accelerate, or change their direction.

Force

Definition

Force is an external influence that can change or try to change the state of rest or motion of an object.

It can:

- Change the speed of an object.
- Change its direction of motion.
- Change its shape or size.

SI Unit: **Newton (N)**

Force is a **vector quantity**.

Newton's First Law of Motion

Law of Inertia

Newton's First Law states that:

An object remains at rest or continues to move with uniform velocity in a straight line unless acted upon by an external unbalanced force.

This law is also called the **Law of Inertia**.

Inertia

Inertia is the tendency of an object to resist any change in its state of rest or motion.

Types of inertia:

- **Inertia of Rest**
- **Inertia of Motion**
- **Inertia of Direction**

The inertia of an object depends on its **mass**. Greater mass means greater inertia.

Newton's Second Law of Motion

Statement

Newton's Second Law states that the **rate of change of momentum of an object is directly proportional to the applied external force and occurs in the direction of the force**.

Mathematically:

F = dp/dt

For constant mass:

F = ma

where:

- **F** = Force
- **m** = Mass
- **a** = Acceleration

This is the most commonly used form of Newton's Second Law.

Newton's Third Law of Motion

Action and Reaction

Newton's Third Law states:

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

The action and reaction forces:

- Are equal in magnitude.
- Are opposite in direction.
- Act on different bodies.
- Occur simultaneously.

Examples

- A person walks by pushing the ground backward.
- A rocket moves upward by pushing gases downward.
- A swimmer pushes water backward and moves forward.

Momentum

Definition

Momentum is the product of the mass and velocity of an object.

Formula:

p = mv

where:

- **m** = Mass
- **v** = Velocity

Momentum is a **vector quantity**.

SI Unit: **kg m/s**

Conservation of Momentum

Law

The **Law of Conservation of Momentum** states that if no external force acts on a system, the total momentum of the system remains constant.

For two interacting bodies:

Total Momentum Before = Total Momentum After

This law is widely used in studying collisions and explosions.

Impulse

Definition

Impulse is the product of force and the time interval for which the force acts.

Formula:

Impulse = F × Δt

Impulse is also equal to the change in momentum:

J = Δp

SI Unit: **N s**

Example

When a cricket player moves their hands backward while catching a fast ball, the time of impact increases and the force experienced by the hands decreases.

Friction

Definition

Friction is the force that opposes the relative motion or tendency of motion between two surfaces in contact.

Types:

- Static Friction
- Limiting Friction
- Kinetic Friction

Friction is useful for walking, writing, and braking, but it can also cause energy loss and wear.

Circular Motion

Centripetal Force

When an object moves in a circular path, a force directed towards the centre of the circle is required. This force is called **centripetal force**.

Formula:

$Fc = mv^2/r$

where:

- **m** = Mass
- **v** = Speed
- **r** = Radius of circular path

Centripetal force changes the direction of velocity and keeps the object moving in a circular path.

Applications of Newton's Laws

Importance

Newton's laws are used to understand:

- Motion of vehicles

- Walking and running
- Rocket propulsion
- Sports
- Collision of objects
- Motion of planets and satellites
- Engineering and machines

Key Points

- Force can change the state of motion of an object.
- Newton's First Law is the **Law of Inertia**.
- Newton's Second Law gives **F = ma**.
- Newton's Third Law describes action and reaction forces.
- Momentum is given by **p = mv**.
- Momentum is conserved when no external force acts.
- Impulse equals the change in momentum.
- Friction opposes relative motion.
- Centripetal force acts towards the centre of circular motion.

Chapter Summary

This chapter explains the three laws of motion given by Newton. It introduces force, inertia, momentum, impulse, conservation of momentum, friction, and centripetal force. Newton's laws provide the basic framework for understanding how forces affect the motion of objects and are widely applied in everyday life, science, engineering, and technology.