UNIT 3

Laws of Motion

INERTIA

- It is an inherent property of all the bodies by virtue of which they cannot change their state of rest or uniform motion along a straight line on their own. Quantitatively, inertia of a body is measured by its mass. Thus, heavier the body greater is its inertia.

Types of Inertia

Inertia of a body is of three types :

- Inertia of rest
- Inertia of motion
- Inertia of direction

- **Inertia of rest :** It is the inability of a body to change its state of rest by itself. *e.g.*, a person standing in a stationary bus falls backward when the bus suddenly starts moving.
- **Inertia of motion :** It is the inability of a body to change its state of uniform motion by itself. *e.g.*, a person getting down a moving bus or train falls forward.
- **Inertia of direction :** It is the inability of a body to change its direction of motion by itself. *e.g.*, when a car suddenly takes a turn, the person sitting inside is thrown in the outward direction.

NEWTON S LAWS OF MOTION

Newton s First Law of Motion

- According to Newton's first law, every body continues to be in its state of rest or of uniform motion in a straight line, unless it is compelled by some external force to act otherwise.
- **Newton's first law of motion can be expressed as :** If the net external force on a body is zero, its acceleration is zero. Acceleration can be non-zero only if there is a net external force on the body.
- Newton's first law is also known as law of inertia.
- **Momentum :** Momentum of a body $(\vec{p})$ is defined as the product of its mass (m) and velocity $(\vec{v})$.

  i.e., $\vec{p} = m\vec{v}$

  The direction of momentum is same as that of the velocity.
- Momentum is a vector quantity. Its SI unit is kg m s^{-1}. Its dimensional formula is $[MLT^{-1}]$.

Newton s Second Law of Motion

- According to Newton's second law of motion, the rate of change of momentum is directly proportional to the applied force and takes place in the direction in which force acts.

  $\vec{F} = k\frac{d\vec{p}}{dt} = km\vec{a}$, as m is constant.

  where $\vec{F}$ is the net external force on the body and $\vec{a}$ its acceleration. In both SI and CGS systems constant of proportionality $k = 1$.
- Newton's second law of motion gives us a measure for force.
- Newton's second law is consistent with the first law ($\vec{F} = 0$ implies $\vec{a} = 0$).
- Newton's second law of motion is applicable to a particle, and also to a body or a system of particles provided $\vec{F}$ is the total external force on the system and $\vec{a}$ is the acceleration of system as a whole.
- **Units of force :** The units of force are of two types
  - Absolute unit
  - Gravitational unit
- **Absolute unit :** In SI system the absolute unit of force is newton. It is denoted by symbol N.
  1 N = 1 kg m s^{-2}
  In CGS system the absolute unit of force is dyne.
  1 dyne = 1 g cm s^{-2}
- Relationship between newton and dyne
  1 N = 10^5 dyne
- **Gravitational unit :** In SI system, the gravitational unit of force is kilogram weight (kg wt) or kilogram force (kg f).
  1 kg wt or 1 kg f = 9.8 N.
  In CGS system, the gravitational unit of force is gram weight (g wt) or gram force (g f).
  1 g wt or 1 g f = 980 dyne
- The gravitational unit of force is used to express the weight of a body. *e.g.*, weight of a body of a mass 2 kg is 2 kg f or 2 kg wt.
- Force is a vector quantity. Its dimensional formula is $[MLT^{-2}]$.
- The straight line along which a force is directed is called line of action of force.

Illustration 1

A force $\vec{F} = (6\hat{i} - 8\hat{j} + 10\hat{k})$ N produces acceleration of 1 m s^{-2} in a body. Calculate the mass of the body.

Soln. : $\because \quad a = \frac{|\vec{F}|}{m}$

$\therefore \quad m = \frac{|\vec{F}|}{a} = \frac{\sqrt{(6)^2 + (-8)^2 + (10)^2}}{1} = 10\sqrt{2}$ kg