

Physics Notes: Laws of Motion

Scalar Quantities: Physical quantities which have magnitude only and no direction are called scalar quantities.

Example: Mass, speed, volume, work, time, power, energy etc.

Vector Quantities: Physical quantities which have magnitude and direction both and which obey triangle law are called vector quantities.

Example: Displacement, velocity, acceleration, force, momentum, torque etc.

Electric current, though has a direction, is a scalar quantity because it does not obey triangle law.

Moment of inertia, pressure, refractive index, stress are **tensor** quantities.

Distance: Distance is the actual path traveled by a body in a given period of time.

Displacement:

- Displacement is the shortest distance.
- The change in the position of the object in a given period of time
- Distance is a scalar quantity whereas displacement is a vector quantity both having the same unit (**meter**)
- Displacement may be **positive, negative, or zero** whereas distance is always **positive**.

Speed:

- Distance travelled by the moving object in the unit time interval is called speed i.e. speed = Distance/ Time
- It is a scalar quantity and its SI unit is **meter/second (m/s)**.
- The speed of an object at any instant is called instantaneous speed.
- An object is said to be travelled with non-uniform speed if it covers the unequal distance in an equal interval of time.

Velocity:

- The velocity of a moving object is defined as the displacement of the object in unit time interval i.e., velocity =
- It is a vector quantity and its SI unit is **meter/second**.
- If a body goes equal displacement in equal interval of time then it is called uniform velocity.
- If a body undergoes unequal displacement in equal interval of time then it is called variable velocity.
- **Relative velocity**
 = $V_1 + V_2$ if two travels in the **opposite** direction
 = $V_1 - V_2$ if two travels in the **same** direction

Acceleration:

- Acceleration of an object is defined as the rate of change of velocity of the object.
- It is a **vector** quantity and its SI unit is **meter/second² (m/s²)**
- If velocity decreases with time then acceleration is negative and is called **retardation**.
- If acceleration does not change with time it is called **constant** acceleration.
- Some equation of acceleration;

$$V = u + at$$

$$S = ut + at^2/2$$

$$V^2 = u^2 + 2as$$

Here v = final velocity, u is initial velocity, t is a time interval, a is acceleration and s is the distance travel.

Circular Motion:

- The motion of an object along a circular path it is called circular motion.
- If the object moves with uniform speed, its motion is uniform circular motion.
- Uniform circular motion is an accelerated motion because the direction of the velocity changes continuously.

Angular Displacement and Velocity:

- The angle subtended at the centre of a circle by a body moving along the circumference of the circle is called angular displacement of the body.
- Its unit is radian.
- Angular displacement = length of arc / radius of the circle
- The time rate of change of angular displacement is called angular velocity. It is generally denoted by ω and

$$\omega = \frac{\theta}{t}$$

Force:

- Force is that external cause which when acts on a body change or tries to change the initial state of the body.
- Its SI unit is **Newton(N)**.
- A body is said to be in equilibrium if the sum of all the forces acts on the body is **Zero**.
- The nuclear force is the strongest force.

Momentum:

- Momentum is the property of a moving body and is defined as the product of mass and velocity of the body i.e.
- Momentum = mass x velocity.
- It is a vector quantity. Its SI unit is kg-m/s.

Newton's Law

Newton first law

If no external force acts on a body then it remains in the same state of rest or motion that is in its present state.

The inertia of Rest:

- **Inertia** is the property of a body by virtue of which it opposes any change in its state of rest or of uniform motion.
- When a bus or train at rest starts to move suddenly the passengers sitting in it feels a jerk in backward direction due to the inertia of rest.
- **Dust particle** comes out of a carpet if we beat it with the stick.
- A passenger jumping out of a train is advised to jump in the direction of the bus and ran for a short distance.

The inertia of Motion:

When a running bus or train stops suddenly, the passengers sitting in it jerk in the forward direction due to the inertia of motion.

Newton's second law of motion:

- The rate of change in momentum of a body is directly proportional to the applied force on the body and takes place in the direction of the force.
If F = force applied, a = acceleration produced and m = mass of body
then $F = ma$.

Newton's Third Law of Motion: To every action, there is an equal and opposite reaction.

Examples of third law –

- The recoil of a gun
- Motion of rocket
- While drawing water from the well, if the string breaks up the man drawing water falls back.

Centripetal Force:

- When a body is in a circular motion, a force always acts on the body towards the centre of the circular path, this force is called **centripetal force**.
- If a body of mass m is moving on a circular path of radius R with uniform speed v , then the required centripetal force
 $F = mv^2 / r$

Centrifugal Force:

- Centrifugal force is such a pseudo force.
- It is equal and opposite to centripetal force.

Application of centripetal and Centrifugal forces:

- Roads are banked at turns to provide the required centripetal force for taking a turn.
- The cream is separated from milk when it is rotated in a vessel about the same axis.
- The gravitational force of attraction between earth and sun acts as a centripetal force.
- The orbital motion of electrons around the nucleus
- Cyclist inclined itself from vertical to obtain the required centripetal force.

The principle of conservation of linear momentum:

- If no external force acts on a system of bodies, the total linear momentum of the system of bodies remains constant.
- As a consequence, the total momentum of bodies before and after collision remains the same.
- As in the case of the rocket, ejecting gas exerts a forward force which helps in accelerating the rocket in the forward direction.

Impulse:

- When a large force acts on a body for a very small time, then the force is called impulsive force.

- Impulse is defined as the product of force and time.
- Impulse = force x time = change in momentum.
- It is a vector quantity and its direction is the direction of the force. Its SI unit is newton second (Ns).

Friction:

It is the force that acts on a body when two bodies are in contact and one tries to move over another.

Types of Friction:

Static Friction: The opposing force acts on a body when it tries to move over the other but actual motion has yet not started.

Limiting friction: It is the force that comes to play when a body is on the verge of moving over the other body.

Kinetic Friction: This is the opposing force that comes to play when one body actually moves over the surface of another body is called kinetic friction. It is of two types which are as follows:

Sliding Friction: When a body slides over the surface of other

Rolling Friction: When a body rolls over the surface of another body

- It is easier to roll a body than to slide because the sliding friction is greater than the rolling friction.
- It is easy to drive a bicycle when its tyres are fully inflated because it decreases rolling friction.

Application of Friction:

- A ball bearing is used to reduce rotational friction.
- Friction is necessary for walking and to apply breaks in vehicles.
- When a pedal is applied to a bicycle, the force of friction on the rear wheel is in the forward direction, and on the front wheel, it is in the backward direction.
- Friction can be reduced by applying the polishing or applying any lubricants.
- The tyre is made up of synthetic rubber because its coefficient of friction with the road is larger and stops sliding the bicycle.

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