Chapter 3

Force and Newton's law of Motion

Newton's First Law of Motion

A body continues in its state of rest or of uniform motion in a straight line unless an external force acts on it. It is based on **law of inertia**. Inertia is the property of a body by virtue of which is opposes any change in its state of rest or of uniform motion in a straight line.

Inertia of Rest

When a bus or train at rest starts, to move suddenly, the passengers sitting in it jerk in backward direction due to their inertia of rest.

The dust particles come out from a carpet when it is beaten with a stick due to their inertia of rest.

A passenger jumping out from a rapidly moving bus or train is advised to jump in forward direction and run forward for a short mile due to inertia of rest.

Inertia of Motion

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

Momentum

The momentum of a moving body is equal to the product of its mass and its velocity.

Conservation of Linear Momentum

The linear momentum of a system of particles remains conserved if the external force acting on the system is zero.

Rocket propulsion and engine of jet aeroplane works on principle of conservation of linear momentum. In rocket, ejecting gas exerts a forward force which helps in accelerating the rocket upward.

Newton's Second Law

The rate of change of momentum of a body is directly proportional to the force applied on it and change in momentum takes place in the direction of applied force.

$$F = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} = ma$$

Newton's Third Law

For every action, there is an equal and opposite reaction and both act on two interacting objects. Rocket is propelled by the principle of Newton's third law of motion.

Impulse

- A large force which acts on a body for a very short interval of time and produces a large change in its momentum is called an impulsive force.
- Its unit is newton-second.
- A fielder lowers its hand when catching a cricket ball because by lowering his hands, he increases the time of contact for stopping the ball and therefore fielder has to apply lesser force to stop the ball. The ball will also exert lesser force on the hands of the fielder and the fielder will not get hurt.

- Wagons of a train are provided with the buffers to increase the time of impact during jerks and therefore, decreases the damage. The vehicles like scooter, car, bus, truck etc. are provided with shockers.

Friction

Friction is a force which opposes the relative motion of the two bodies when one body actually moves or tries to move over the surface of another body.

The cause of friction is the strong atomic or molecular forces of attraction acting on the two surfaces at the point of actual contact.

Uses of Friction

- A **ball bearing** is a type of rolling-element that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and to support loads (weight).
- Friction is necessary for walking, to apply brakes in vehicles, for holding nuts and bolts in a machinery etc.
- Friction can be decreases by polishing the surfaces by using lubricants or by using ball bearings.
- Tyres are made of synthetic rubber because its coefficient or friction with road is larger and therefore, large force of friction acts on it, which stops sliding at turns.
- The tyres are threading which also increases the friction between the tyres and the road.
- When pedal is applied to a bicycle, the force of friction on rear wheel is in forward direction and on front wheel is in the backward direction.

Loses due to Friction

Too much Loss of Energy in machines and then ultimately the machines are damaged.

Laws of Limiting Friction

(i) It depends on the nature of the surfaces in contact and their state of polish.

(ii) It acts tangential to the two surfaces in contact and in a direction opposite to the direction of motion of the body.

(iii) The value of limiting friction is independent of the area of the surface in contact so long as the normal reaction remains the same.

(iv) The limiting friction ($f_{s\,max}$) is directly proportional to the normal reaction R between the two surfaces.