SHARJAH INDIAN SCHOOL (BOYS WING) CLASS XI

NEWTON'S LAWS OF MOTION.

NEWTON'S FIRST LAW OF MOTION - LAW OF INERTIA.

According to this law, a body continues to be in its state of rest or of uniform motion along a straight line unless it is acted upon by an external force.

Inertia It is the inability of a body to change the state of rest or of uniform motion by itself. Inertia is a measure of mass. The three types of inertia are,

1. inertia of rest.
2. inertia of motion.
3. inertia of direction.

Examples - A passenger standing in a stationary bus falls backwards when the driver starts the bus suddenly.

- An athlete cannot stop running as soon as reaching the finishing point.

- It is dangerous to jump out of a running bus.

physical meaning - On a frictionless surface if an object is moving with a constant velocity, no force is acting on it.

NEWTON'S SECOND LAW OF MOTION.

According to this law, the rate of change of momentum of a body is directly proportional to the external force applied on the body and it takes place in the direction of applied force.

Momentum ($\vec{P}$)

It is the product of mass and velocity $P = mv$. Vector. S.I. unit is $kgms^{-1}$.

Consider an object of mass 'm'. Let 'F' be the force acting on it so that its momentum changes to 'dP' in 'dt' time. According to Newton's second law,

$$F \propto \text{rate of change of momentum}$$

$$F \propto \frac{dP}{dt}$$

$$F = k\frac{d(mv)}{dt} = k\,m\frac{dv}{dt} = k\,ma.$$

$\underline{F = ma}$, $k = 1$.

<u>Impulse (J)</u>

A large force acting for a short interval of time producing a change in momentum is called impulsive force.

$$\text{Impulse} = F \times \text{time} = ma \times t = m\frac{(v-u)}{t} \times t$$

$$= m(v-u)$$

ie, Impulse = change in momentum.

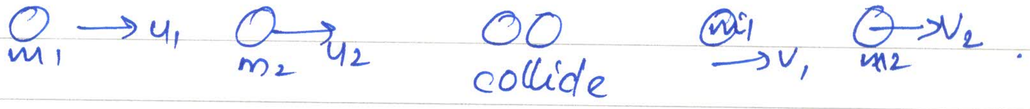
<u>Third law of motion.</u>

To every action, there is always an equal and opposite reaction.

Eg. walking - action on the ground, reaction on the foot., book kept on a table, bouncing of a ball, firing from the gun, flight of jet planes.

<u>Conservation of momentum</u>.

In an isolated system with no external forces, the total momentum is conserved.



Here during collision, total momentum before collision is equal to total momentum after collision.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2.$$

<u>Proof</u> From second law,

$$F = \frac{dP}{dt}.$$

$\frac{dP}{dt} = 0$, ie, P is a constant.

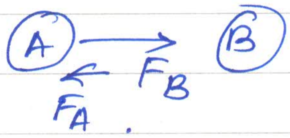
Total momentum is a constant.

<u>Proof of law of conservation of momentum from third law of motion.</u>

Consider two bodies of momentum P_A and P_B. They collide each other so that their momenta will change to P'_A and P'_B.

Force on body B,

$$F_B = \frac{P'_B - P_B}{\Delta t} \quad \text{and}$$



Force on body A, $F_A = \frac{P'_A - P_A}{\Delta t}$.

But from Newton's third law of motion,

$$F_A = -F_B.$$

$$\frac{P'_A - P_A}{\Delta t} = -\frac{(P'_B - P_B)}{\Delta t}$$

$$P'_A - P_A = -P'_B + P_B.$$

$$P_A + P_B = P'_A + P'_B$$

Total momentum of A and B before collision = Total momentum of A & B after collision.

<u>Prove that Newton's second law of motion is the real law of motion.</u>

From second law of motion,

$$F = ma = m\frac{(v-u)}{t}.$$

If $F = 0$,

$$0 = m\frac{(v-u)}{t}$$ 'm' cannot be zero.

ie, $\frac{(v-u)}{t} = 0$ or $v = u$.

which means if there is no external force, the vel. of the body will not change, which is First law of motion.

ii) To get third law from 2^{nd} law.

Consider two objects A and B. Let them collide. Let F_A and F_B be the force on A and B respectively.

$F_A = \frac{dP_A}{dt}$ — ① and $F_B = \frac{dP_B}{dt}$ — ② from Newtons second law of motion.

① + ② → $F_A + F_B = \frac{dP_A}{dt} + \frac{dP_B}{dt}$

$= \frac{d}{dt}(P_A + P_B)$.

But according to law of conservation of momentum, $P_A + P_B$ = a constant.

$\therefore \frac{d(P_A + P_B)}{dt} = 0$.

ie, $F_A + F_B = 0$

$F_A = -F_B$. ie, action is equal and opposite to reaction, which is the third law of motion.

<u>Applications of Impulse</u>.

Impulse $= F \times \Delta t = m(v-u)$

1. A cricket player lowers his hands while catching a cricket ball.
   Here change in momentum is a const. The force acting on the hands can be reduced if time of catch is more.
2. When a person falls from a height to a heap of sand, the person is not hurt.
   Here Impulse $= F \times \Delta t = P_f - P_i$
   Change in momentum is a const. which takes place for a greater duration of time so that the force exerted on the body is less.
3. Shock absorbers of vehicles also work on this concept.

Applications of law of conservation of momentum.

1. Recoiling of a gun.

When a bullet is fired from the gun, the gun recoils. The recoil vel. of the gun can be calculated using law of conservation of momentum.

Total momentum of the bullet and the gun before firing $= 0$

Total momentum of the bullet and the gun after firing $= m_g v_g + m_b v_b$

According to law of conservation of momentum,

Total momentum before firing = Total momentum after firing

$$0 = m_g v_g + m_b v_b$$

$$v_g \text{ (Recoil vel)} = \frac{-m_b v_b}{m_g}$$

Equilibrium of concurrent forces.

Many forces acting at a point is called concurrent forces.

Translational (linear) equilibrium of a particle refers to a situation when the external force on the particle is zero. ie, the body will not be accelerated. ie, either the body is at rest or moving with const. vel along a straight line.

If there are three forces acting on the body,

$$\vec{F_1} + \vec{F_2} + \vec{F_3} = 0.$$

ie, the resultant of F_1 and F_2 should be equal and opposite to F_3.

$$\vec{F_1} + \vec{F_2} = -\vec{F_3}$$

If there are 'n' forces, $\vec{F_1} + F_2 + \cdots + \vec{F_n} = 0$.