SHORT NOTES: CLASS 9

CHAPTER 8: FORCE AND LAWS OF MOTION

1. **Force:** Force is an external effort in the form of push or pull which…

(i) produces or tries to produce motion in a body at rest

(ii) Stops or tries to stop a moving body.

(iii) Changes or tries to change the direction of motion of the body.

Note: at least two objects must interact for a force to come into play.

2. **Magnitude and direction of force:** The strength of force is its magnitude.

(i) If forces are applied in the same direction, they add to one another.

(ii) If two forces act in opposite directions on an object, the net force acting on it is the difference between the two forces

3. **State of motion:** Rest and motion, both are the state of motion. it is described by the speed and direction of an object. The state of rest is considered to be the state of zero speed.

4. **Factors on which the effect produced by the force on an object depends on:**

(i) Magnitude of force.

(ii) Direction of applied force.

(iii) Point of application of force.

5. **Frictional force**: frictional force is defined as an opposing force that comes into play when one body moves or even tries to move over the surface of another body. The force of friction arises due to the irregularities between the surfaces at contact. Thus, the force of friction develops at the surfaces of contact of two bodies and opposes their relative motion.

6. **Balanced and unbalanced forces**:

(i) **Balanced forces**: when two forces of equal magnitude but acting in opposite directions on an object simultaneously, then the object continuous in the state of rest or of uniform motion in a straight line. Such forces are called balanced forces.

Effects of balanced forces:

a. Balanced forces can't change the state of rest or motion of a body.

b. Balanced forces can change the shape of a body.

The net force on the object is zero.

F=f so, F-f= 0

(ii) **Unbalanced forces**: When two forces of unequal magnitudes are acting in opposite directions of an object simultaneously. Then, the object moves in the direction of the larger force. These forces acting on the object are known as unbalanced forces.

Effects of unbalanced forces:

a. Unbalanced forces can change the state of rest or motion of the body.

b. They can also change the shape of the body.

The net force on the object is not zero. F≠ f so, F-f ≠0

7. **NEWTON'S LAWS OF MOTION:**

- **Principle of inertia:** *by Galileo Galilei*

According to this principle, when no unbalanced force acts on a body at rest, then, it continues in the state of rest. Moreover, when no unbalanced force acts on a body moving with constant velocity,

then, it is continuous in the state of motion.

- **Newton's first law of motion:** Everybody continuous in its state of rest or of uniform motion in a straight line unless compelled by some external unbalanced force to change that state.
  Newton's first law is also known as the law of inertia.
- **Inertia:** The tendency of a body to oppose any change in its state of rest or of uniform motion is called inertia of the body.

Types of Inertia:

(i) Inertia of rest: The tendency of a body to oppose any change in its state of rest.
Ex: when a bus starts suddenly in the forward direction, the passengers in the bus fall backward.

(ii) Inertia of motion: The tendency of a body to oppose any change in its state of uniform motion.
Ex: the passengers fall forward when a fast-moving bus stops suddenly.

(iii) Inertia of direction: The tendency of a body to oppose any change in its direction of motion.
Ex: when a fast-moving bus negotiates a curve on the road, passengers fall towards the center of the curved road.

- **Inertia and mass:** It's more difficult to move a heavier object as compared to a lighter object. Therefore, heavier or more massive objects offer large inertia.

⇨ The inertia of a body is measured by its mass.
⇨ Inertia is the natural tendency of an object to resist any change in its state of rest or motion.
⇨ The mass of the object is a measure of its inertia.

- **Newton's second law of motion:**

Momentum: The quantity of motion possessed by a moving body is known as the momentum of the body.
Mathematically, the momentum of a body is equal to the product of the mass and velocity of the body.
Momentum= Mass x velocity
P= m.v
Unit is kgm/s

Second law: The rate of change of momentum of an object is directly proportional to the force acting on the object and the change in the momentum takes place always in the direction of applied force on the object.
i.e., F α dP/dt where dP is the change in momentum and dt is the time taken for this change.

Mathematical formulation:
Consider an object of mass, **m** moving with initial velocity, **u**. let a force, **F** act on the body, and its velocity changes to **v** after time, **t**.
The initial momentum of the body, $p_1 = mu$
Final momentum of the body, $p_2 = mv$
Change in momentum= $p_2 - p_1 = m(v-u)$
Time taken for this change in momentum = t-0 = t

As, F α dp/dt
⇨ F α m(v-u)/t
⇨ F α ma
⇨ F = kma [where, k = constant of proportionality]
Here, k= 1
Therefore, F=ma
⇨ Force acting on an object is directly proportional to its mass and acceleration.
Unit of force – Newton, N or kgm/s^2
$1 N = 1 kgm/s^2$

1 Newton: 1 Newton is that much force that produces an acceleration of 1 m/s^2 in a body of mass 1 kg.

Application: A cricket player lowers his hand while catching the ball. Because, in doing so, the fielder increases the time during which the high velocity of the moving ball decreases to zero. Thus, the acceleration of the ball is decreased and therefore, the impact of catching the fast-moving ball is also reduced.

- **Newton's third law of motion: Action and Reaction Forces.**

"to every action, there is an equal and opposite reaction".

The third law of motion states that when one object exerts a force on another object, the second object instantaneously exerts an equal and opposite force back on the first.

Note:

a) Action and Reaction forces are always equal in magnitude but opposite in direction.
b) They act on two separate bodies.
c) As they act on two different bodies, therefore they don't cancel each other. i.e., they are not balanced forces.
d) Though action and reaction forces are equal in magnitude, they may not produce equal acceleration. This is because they act on bodies of different masses.

Examples:

a) An object resting on a table.
b) A ball rebounds after striking against a floor.
c) Walking of a person- we push the ground in the backward direction. Ground pushes us forward.
d) Swimming: The swimmer pushes water backward. The reaction offered by the water to the swimmer pushes him forward.
e) When a bullet is fired from a gun, the gun recoils i.e., it moves backward.
f) Motion of the rockets and jet airplanes.

- **Law of conservation of momentum:** According to this law, the total momentum of the system remains constant if no external force acts on the system.

i.e., P= constant if F=0.

Consider two objects of masses m_1 and m_2 moving in the same direction in the same straight line with velocities u_1 and u_2.

Let $u_1 > u_2$. After some time, the two balls collide.

Let F_{12} => force exerted on object 2 due to 1.

And F_{21} => force exerted on object 1 due to 2.

Suppose v_1 and v_2 are the velocities of the object after collision.

The momentum of object 1 before collision = m_1u_1

The momentum of object 2 before collision = m_2u_2

The momentum of object 1 after collision = m_1v_1

The momentum of object 2 after collision = m_2v_2

$F_{12} = m_2 (v_2 - u_2)/t$; $F_{21} = m_1(v_1 - u_1)/t$

According to the third law of motion:

$F_{12} = - F_{21}$

⇨ $m_2 (v_2 - u_2)/t = - m_1(v_1 - u_1)/t$

⇨ $m_2v_2 - m_2u_2 = - m_1v_1 + m_1u_1$

⇨ $m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

⇨ Total momentum after collision = Total momentum before collision

Type 1: Bullet and Gun:

a) The total initial momentum of the bullet and the gun is zero as they are at rest.

b) The total final momentum of the gun-bullet system must be zero. Therefore, the velocity of the gun and bullet must be in the opposite direction.

Final Momentum = Initial Momentum

$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

$\Rightarrow m_1v_1 + m_2v_2 = 0$

$\Rightarrow m_1v_1 = - m_2v_2$

$\Rightarrow v_1 = - m_2v_2 / m_1$

None of the quantities in the above equation is negative. Therefore, the negative sign implies that the velocity of the gun is in the direction opposite to the bullet.

Type 2: The colliding bodies join and get entangled after the collision.

Final Momentum = Initial Momentum

$(m_1 + m_2)\, v = m_1u_1 + m_2u_2$

Type 3: Two colliding bodies interact and then separate:

Final Momentum = Initial Momentum

$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$