Module 2: NEWTON'S LAWS OF MOTION

INTRODUCTION TO MECHANICS

MECHANICS

Is the study of motion or states of material bodies under the action of forces i.e mechanics is the branch of physics which deals with the study of force and motion and their relationship. The study of mechanics is divided into three parts:-

1. **STATICS** this deals with the study of objects at rest.
2. **KINEMATICS** this deals with the study of motion of the objects without considering the causes of motion. This word kinematics comes from a Greek word **kinema** which means motion.
3. **DYNAMICS** this deal with the study of motion of the objects taking into consideration the causes of motion. The word '**Dynamics**' comes from a Greek word **dynamics** which means power.

REST AND MOTION

REST an object is said to be at rest if it does not change its position with respect to its surrounding with the passage of time.

MOTION an object is said to be in motion if its changes its position w.r.t its surrounding with passage of time.

TYPES OF MOTION

1. Translatory motion
2. Rotational motion
3. Oscillatory motion

- **TRANSLATORY MOTION**
  Is the type of motion where by every particle of the body have the same displacement in the same time of interval. Example motion of the car on the straight line along the road.

- **ROTATIONAL MOTION**
  Is the type of motion of the body in which each particle of the body (except those on the axis of rotation) travel in a circle. Example circular motion.

- **OSCILLATORY MOTION**
  Is the type of motion of the body in which the body moves to and fro repeatedly about a mean position example oscillation of the simple pendulum.

TOPIC 1: NEWTON'S LAWS OF MOTION

There are three Newton's laws of motion.

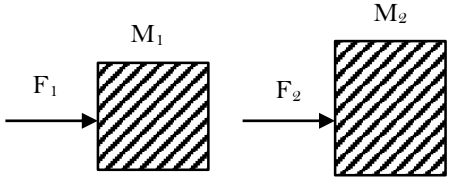
(i) Newton's first law of motion
(ii) Newton's second law of motion
(iii) Newton's third law of motion.

- **NEWTON'S FIRST LAW OF MOTION**
  State that 'everybody in its state of rest or uniform motion in a straight line unless some external force is applied on it to change that state some time newton's first law of motion is known as **law of inertia**.

Reasons:

According to the newton's first law in the absence of any net force act on a body the body is either at rest or it moves with a constant speed in a straight line in the other words in order to change the motion(i.e magnitude and direction) of the velocity , net external force is required this means that every body has a tendency to maintain its state of rest or uniform velocity for this reasons, newton's first law of motion is called law of inertia.

INERTIA is the tendency of a body to maintain its state of rest or uniform motion in the straight line i.e in the absence of external force , the inability of a body to change its state by itself is called **inertia**. This is the relactance of the body to be in state of rest or uniform motion. The quantitative measure of inertia is the mass of the body the more the mass of the body , the more its tendency to resist any change in its state of rest or uniform motion in a straight line i.e a change in its velocity.



If $M_2 > M_1$, then $F_2 > F_1$ newton's first law of motion gives a quantitative definition of force **A FORCE** is a push or pull exerted on a body which produces or tend to produce a change in its velocity.

TYPES OF INERTIA

There are three types of inertia of the body:

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

- INERTIA OF REST

  It is that property of virtue of which a body in a state of uniform motion tends to maintain its uniform motion. The ability of a body to change its state of uniform motion along a straight line , when no external force acts on it is called **inertia of motion**.

- INERTIA OF DIRECTION

  It is that property by virtue of which a body tends to maintain its direction.

APPLICATIONS OF LAW OF INERTIA

1. When a bus suddenly starts , a person sitting in the bus falls backwards.

   Reasons

   This is due to inertia of rest as the bus starts , the lower part of this body begins to move but the upper part of his body tends to remain at rest due to inertia.

2. When a man jump out of a bus he or she falls forward.

   Reasons

   This is due to inertia of motion this is because his fact comes to rest suddenly but the upper part of his body continues to move forward.

3. When a blanket (carpet) is given a sudden jerk , the dust particles fall off

   Reasons

   It is due to the reason that the blanket is suddenly set in motion but the dust particles tend to inertia of rest.

4. When a bullet is fired into a tightly – fitted glass plane from a reasonally close range , it makes a clear circular hole in the glass pane.

   Reasons

   This is due to the fact that particles of glass around the hole tend to remain at rest duet to inertia of rest so they are unable to share the fast motion of the bullet.

5. When the beat a carpet with a stick the carpet is suddenly set into motion but the dust particles tend to remain at the rest due to inertia therefore , dust particles get removed from carpet.

6. A passenger standing in a moving bus falls forward when the bus stops suddenly.

   Reasons

   This is due to the fact that the lower part of the body comes to rest along with the bus but the upper part of the body remains in the state of motion on account of inertia of motion the same argument can be applied to the case of a person jumping out of a moving train.

7. An athletes runs for some distance before taking a long jump.

   Reasons

   In this way , the athlete gains momentum and due to inertia of motion , he takes a longer jump.

8. During the sharpening of a knife using a grinding wheel sparks fly off tangentially.

   Reasons

   This is due to the inertia of direction on.

9. When we shake the branch of a mango tree , the mangoes fall down.

   Reasons

   Because due to shaking the branches comes into motion , but due to inertia the mangoes continue to remain at rest and get detached.

10. A ball thrown upwards in a train moving with uniform velocity , returns to the thrower.

Reasons

Because during the upward and the downward journey ; due to inertia the ball also moves along horizontal with the velocity of the train hence it covers the same horizontal distance as the train does and the ball returns to the thrower.

11. The mud from the wheels of a moving vehicle flies off tangentially.

Reasons

This is due to the inertia of direction in order that the flying mud does not spoil the clothes of the passer byes , the wheels are provided mud guards

12. If the cloth placed under a book is given a sudden pull , it goes out without disturbing the book because the book continues to best at rest due to inertia , when the cloth is suddenly pulled out.

13. Suppose a stone tied to one end of a string , is being whirled in a horizontal circle when the string breaks the stone tends to flies off tangentially along a straight line.

Reason

This is due to the inertia of the direction.

LINEAR MOMENTUM (P)

Newton introduced the concept of momentum to measure the quantitative effect of a force. The total quantity of motion possessed by a moving body is known as the linear momentum of body.

DEFINITION OF LINEAR MOMENTUM - is defined as the product of the mass and the velocity of the body.

$$P = MV \quad \text{or} \quad \vec{P} = M\vec{V}$$

Linear momentum is the vector quantity S.I unit of linear momentum is **Kgm/s**.

NEWTON'S SECOND LAW OF MOTION

State that 'The rate of change of linear momentum of a body is directly proportional to the applied force and takes place in the direction of the force'.

Net external force acting on a system or body is equal to the rate of change of linear momentum.

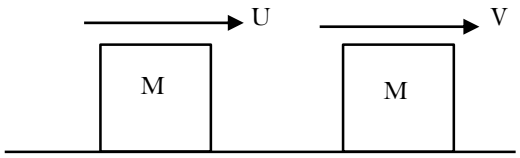
$$F = \frac{dp}{dt} = \frac{d}{dt}(mv)$$

$$F = M\frac{dv}{dt} = Ma$$

$$F = Ma$$

Derivation

Consider a body of mass, M starts to move with initial velocity , U and finally velocity , V.



The rate of change of linear momentum.

$$\frac{dp}{dt} = M\frac{(v-u)}{t} = ma$$

According to the newton's second law of motion

$$F \propto \frac{dp}{dt}, \quad F = K\frac{dp}{dt}$$

$$F = KMa$$

In S.I unit K = 1 , F = Ma

DIFFERENT FORMS OF EXPRESSION OF THE FORCE

1. $F = M\frac{(u-v)}{t}$
2. $F = Ma$
3. $F = \frac{dp}{dt}$
4. $F = M\frac{dv}{dt} + V\frac{dm}{dt}$
5. $F = M\left[\frac{V^2 - U^2}{2s}\right]$

IMPULSE OF A FORCE

Is defined as the product of the average force and force acts impulse of a force is the change in a linear momentum of the body. The total effect of force is called impulse. It may also be defined as a measure of the action of force it is vector quantity and is denoted by I.

******** END OF PREVIEW **********