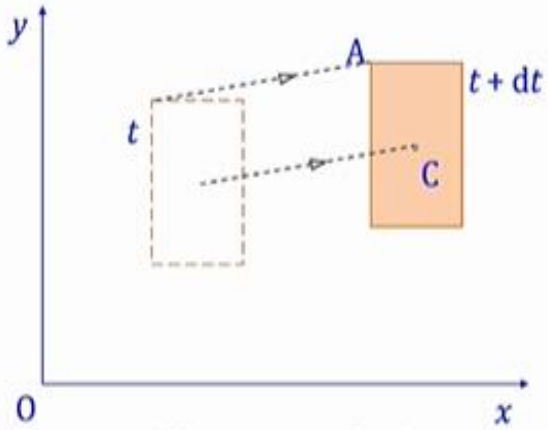
NLM
Lecture - 1

AUROUS ACADEMY

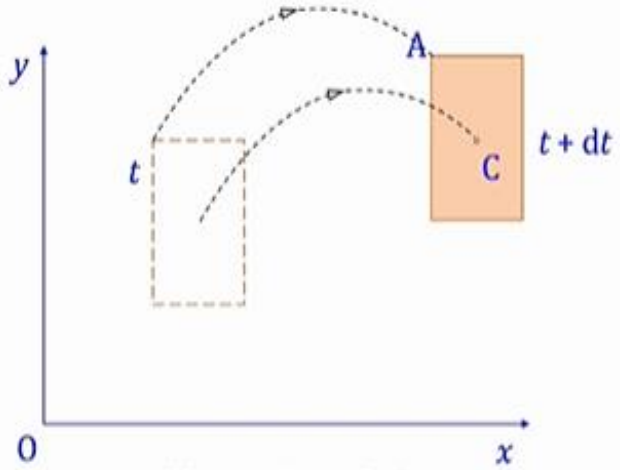
Translational Motion:

A body in translational motion, changes its location without rotation.

In translational motion, a body can move on a rectilinear or on a curvilinear path.



Rectilinear Translation



Curvilinear Translation

Characteristics of translational motion:

All the particles of the body and the mass center move on identical parallel trajectories.

All the particles and mass center of the body cover identical segments of their trajectories in a given time interval. Therefore, at any instant of time all of them have equal velocities and accelerations.

Particle:

Translational motion of a body can be represented by motion of any of its particle.

This is why; we can consider a body in translational motion as a particle, irrespective of its size.

In mechanics, a particle is either a material point or an extended body in translational motion.

Quantity of Motion:

If two bodies of unequal masses are moving with equal velocities, more effort is required to stop the body having greater mass.

If two bodies of equal masses are moving with different velocities, more effort is required to stop the body moving with greater velocity.

If any one, either mass or velocity vanishes, no effort is required to stop the body.

Thus, quantity of motion in a body depends on its velocity as well as its mass.

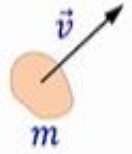
The simplest relation satisfying all the above criteria to describe the quantity of motion is the product of mass and velocity.

Linear Momentum:

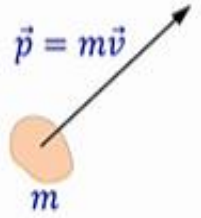
The product of mass and velocity of a body, known as linear momentum is equal to quantity of motion in the body.

$$\vec{p} = m\vec{v}$$

Linear momentum or simply momentum of a body is the quantity of motion in the body.



A body of mass m moving with velocity $\vec{v}$.



Quantity of motion in a body is equal to the momentum.

Inertia:

The tendency of an object to preserve its state of uniform motion or of rest is known as inertia of the object. It was first conceived by Galileo.

In other word:

The tendency of an object to preserve its quantity of motion is known as inertia of the object.

Due to its inertia, an object opposes any change in its momentum.

Mass: Quantity of Inertia.

In common usage, the term mass of a body refers to quantity of matter in that body.

But in mechanics, we are not concerned at all with quantity of matter in a material body but with other aspect that is related to change in its quantity of motion.

If two bodies of unequal masses are moving with the equal velocities, more effort is required to stop the body having greater mass. Therefore, mass serves as a suitable measure of inertia.

In fact in physical sciences, mass has no interpretation other then inertia.

Mass is measured in kilogram (kg), gram (g), and pound (lb) in SI, CGS, and FPS systems of units respectively.

$$1\ \text{kg} = 1000\ \text{g} = 2.205\ \text{lb}$$

Force:

A physical force or simply a force arises due to mutual interaction between two objects.

The concept of force explains mutual interaction between two objects as the action of one body on another in form of push or pull, which brings out or tries to bring out a change in the state of motion of the two bodies.

Action and Reaction:

A mutual interaction between two bodies, which creates force on one body, also creates force on the other body.

Force on the body under investigation is known as **action** and that on the other body as **reaction**.

Contact and Field Forces:

Forces between two bodies created by interactions due to direct contact are known as *contact forces* and forces created without any physical contact between the interacting bodies are known as *field forces*.

Tensile force of string, force applied by a spring, force of normal reaction and friction are the typical examples of contact forces; whereas, gravitational pull of the earth, electric force and magnetic force are examples of field forces.

Study of mechanics deals with how forces between two bodies affect their states of motion. It does not include study of nature of the mutual interactions. Therefore in mechanics, it becomes immaterial to know the nature of interaction i.e. electromagnetic, gravitational or nuclear or their combination or of some other kind.

Fundamental characteristics of a force:

1. Magnitude. 2. Direction. 3. Line of Action.

To predict effects of a force on the motion of a body, magnitude, direction and point of application of the force must be known.

Line of action of a force is decided by its point of application and direction.

Consider a uniform bar placed on a frictionless horizontal floor. A force $\vec{F}$ is applied on the bar.

If the line of action of the force passes through the mass center C, the bar undergoes translational motion.

If line of action of the force does not pass through the mass center C, the bar undergoes translational and rotational motion both.

The magnitude and direction of a force decide its effect on translation motion.

The magnitude, direction and the line of action a of a force decide its effect on rotational motion.

Laws of Motion:

These laws are of fundamental nature and consider forces acting on a body as the only cause of alteration in the state of motion of the body.

The first law of motion: Law of Inertia.

Every material body preserves its state of rest or of uniform motion in a straight line, unless it is compelled to change that state by external forces impressed on it

In other word, force is the only cause of acceleration or change in momentum of a body.

A force is an agent of change in the quantity of motion; it does not sustain motion.

If there is no force acting on a body, momentum of the body will remain unchanged.

Necessity of a force to change momentum of a body reveals that every material body has a natural tendency to preserve its state of motion and force applied is necessary to overcome this tendency. This tendency of a body to preserve its state of motion is the inertia. This is why, this law is also known as the **law of inertia**.

Inertial Frame of Reference:

The first law requires a frame of reference in which for any acceleration produced in a body; only the forces acting on the body can be responsible and not the acceleration of the frame of reference. These frames of reference are known as inertial frames.

Obviously, an inertial frame of reference must not be an accelerated reference frame.

The second law of motion:

The first law suggests that a force is necessary to change state of motion. The second law provides necessary quantitative description and relates the force applied with corresponding change in momentum.

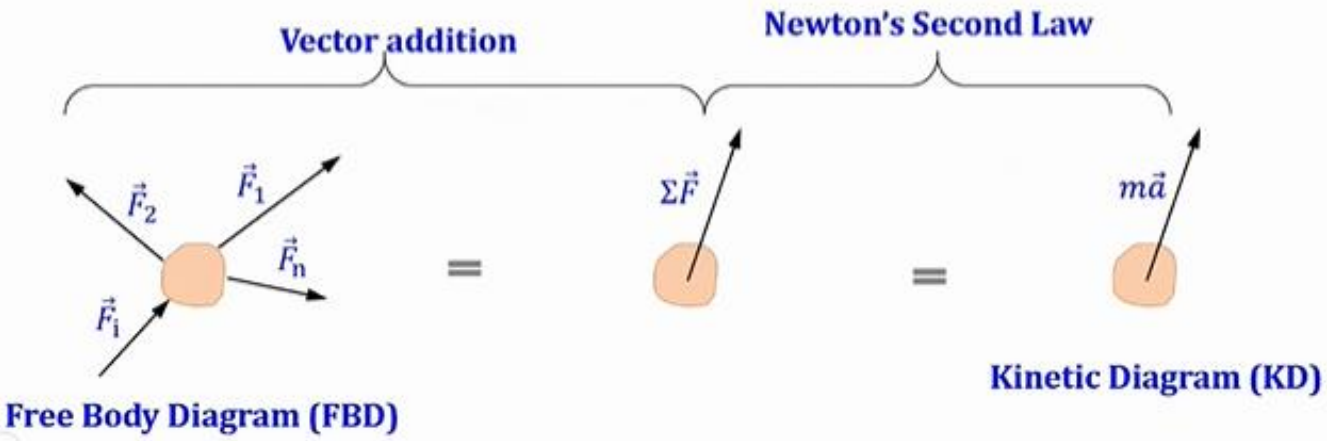
The law: The rate of change in momentum of a body is equal to and occurs in the direction of the net force applied.

A body of mass m in translational motion with velocity $\vec{v}$, if acted upon by a net external force $\Sigma\vec{F}$, the second law suggests:

$$\Sigma\vec{F} = \frac{\mathrm{d}}{\mathrm{d}t}(m\vec{v})$$

If mass of the body is a constant, the above equation relates acceleration $\vec{a}$ of the body with the net force $\Sigma\vec{F}$ acting on it.

$$\Sigma\vec{F} = m\vec{a}$$



The third law of motion:

The first law describe qualitatively and the second law quantitively, what happens to a body, if a net force acts on it. Both of these laws do not reveal anything about what happens to the other bodies participating in the interactions responsible for the net force.

The third law accounts for this aspect of the force.

The action and reaction originating from a mutual interaction between two bodies are equal in magnitude and opposite in direction.

Fundamental nature of the three laws of motion:

These laws are fundamental in nature. The first law tells us under what conditions there is no net external force, the second law shows how to measure a force when it exists and the third law reminds us that a force is interaction between two bodies.

The third law pair: Action-reaction pair:

Recoil of a Gun: