CH # 03 KINEMATICS OF LINEAR MOTION

KINEMATIC:

"Kinematics is the branch of physics which deals with the description of motion bodies without any reference of force."

SCALAR QUANTITIES (SCALARS):

"All those quantities which are completely specified by only their unit and magnitude is called scalar quantities E.g. Distance, Speed, time etc."

VECTOR QUANTITIES (VECTORS):

"All those quantities which are not completely specified by only their unit and magnitude as well as direction is required is called vector quantities"

- E.g. Momentum, Velocity, Acceleration etc.
- Vector are representing by arrow on the head of the quantities. E.g. $\vec{P}$, $\vec{V}, \vec{a}$ etc.

DISTANCE:

"The length between any two points is called distance."

UNIT:

In M.K.S or S.I system unit of distance is meter (m).

DISPLACEMENT:

"The shortest distance between the initial and the final position of the body is called displacement."

UNIT:

In M.K.S or S.I system unit of displacement is meter (m).

REST:

"If a body does not change its position with respect to its surrounding, it is said to be at rest."

MOTION:

"If a body does change its position with respect to its surrounding, it is said to be in motion."

TYPES OF MOTION:

1. **TRANSLATIONAL MOTION:**

"Translational motion is that type of motion in which every particle of the body is being displaced by the same amount."

Example:

Motion of a car.

2. **ROTATIONAL MOTION:**

"Rotational motion is that type of motion in which the body rotates or spines about a fixed point or axis."

Example:

Motion of a fan.

3. **VIBRATIONAL MOTION:**

"Vibration motion is that type of motion in which the body moves to and fro about the mean position at regular interval of time."

Example:
Motion of a pendulum.

SPEED:

"Distance covered by the body in unit time is known as its speed."

- It is represented by V.
- It is a scalar quantity.

FORMULA:

$$\text{Speed} = \frac{\text{Distance covered}}{\text{Time}}$$

$$\boxed{V = \frac{S}{t}}$$

UNIT:
In S.I or M.K.S system the unit of speed is meter per second (m/s).

AVERAGE SPEED:

"Total distance covered divided by total time taken is known as average speed."

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}}$$

$$\boxed{Vav = \frac{S}{t}}$$

UNIFORM SPEED:

"If a body covers equal distance in equal intervals of time then its speed is said to be uniform."

VELOCITY:

"Speed of a body in particular direction is called its velocity."

- It is represented by $\vec{V}$.
- It is a vector quantity.

FORMULA:

$$\text{Velocity} = \frac{\text{Dispacement}}{\text{Timen}}$$

$$\boxed{\vec{V} = \frac{\vec{S}}{t}}$$

UNIT:
In S.I or M.K.S system the unit of Velocity is meter per second (m/s).

AVERAGE VELOCITY:

"The total displacement divided by total time taken is known as average velocity."

$$\text{Average velocity} = \frac{\text{Total Displacement covered}}{\text{Total time taken}}$$

If "$\overrightarrow{V_i}$" and "$\overrightarrow{V_f}$" are the initial and final velocity of a body then its average velocity is also given by:

$$\overrightarrow{V_{av}} = \frac{\overrightarrow{V_i} + \overrightarrow{V_f}}{2}$$

UNIFORM VELOCITY:

"If a body covers equal distance in equal interval of time in a particular direction then its velocity is said to be uniform."

VARIABLE VELOCITY:

"If a displacement of a body in an equal interval of time is not equal then its velocity is said to be variable."

ACCELERATION:

"The time rate of change of velocity of a body is known as its acceleration"

- It is represented by $\vec{a}$.
- It is a vector quantity.

FORMULA:

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

$$\vec{a} = \frac{\overrightarrow{\Delta V}}{\Delta t}$$

$$\vec{a} = \frac{\overrightarrow{V_f} - \overrightarrow{V_i}}{\Delta t}$$

- Where ΔV and Δt is change in velocity and change in time of the body.
- Acceleration is a vector quantity.

UNIT:

In M.K.S or S.I system the unit of acceleration is meter per Second Square (m/s^2)

AVERAGE ACCELERATION:

"The total change in velocity divided by the total time taken is called average acceleration."

$$\text{Average acceleration} = \frac{\text{Total change in velocity}}{\text{total time taken}}$$

$$\vec{a}_{av} = \frac{\overrightarrow{\Delta V}}{\Delta t}$$

UNIFORM ACCELERATION:

"If a velocity of a body changes uniformly in equal interval of time then the body is said to be in uniform acceleration."

- **Positive Acceleration**:
  "If the velocity of body increases then it is said to be in positive acceleration"

- **Retardation or Deceleration or Negative Acceleration:**

"If the velocity of body is decreases then it is said to be in retardation or deceleration."

EQUATIONS OF UNIFORMLY ACCELERATED RECTILINEAR MOTION

FIRST EQUATION OF MOTION (Vf = Vi + at):

Suppose a body is moving with initial velocity Vi and is undergoing uniform acceleration 'a' for a time 't' such that its final velocity become Vf.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Total time taken}}$$

$$a = \frac{\Delta V}{t}$$

$$\text{Since } \Delta V = Vf - Vi$$

$$a = \frac{Vf - Vi}{t}$$

$$at = Vf - Vi$$

$$\boxed{Vf = Vi + at}$$

This is called first equation of motion.

SECOND EQUATION OF MOTION ($S = Vit + \frac{1}{2}at^2$):

Suppose a body starts with initial velocity Vi and travels with uniform acceleration 'a' for a period of time 't'. The distance covered by the body in this time is 'S' and its final velocity becomes Vf. Since the acceleration is uniform, the velocity of the body increases or decreases by equal amount in equal time intervals i.e. the velocity changes at constant rate.

$$Vav = \frac{S}{t}$$

$$S = V_{av} \times t$$

$$\therefore Vav = \frac{Vf + Vi}{2}$$

$$S = \frac{(Vf + Vi)}{2} \times t$$

From first equation of motion

$$\therefore vf = vi + at$$

$$S = \frac{(Vi + at + Vi)}{2} \times t$$

$$S = \left(\frac{2Vi + at}{2}\right) \times t$$

$$S = \frac{2Vit}{2} + \frac{at^2}{2}$$

$$\boxed{S = Vit + \tfrac{1}{2}at^2}$$

This is called second equation of motion.

THIRD EQUATION OF MOTION ($2aS = Vf^2 - Vi^2$):

Suppose a body starts with initial velocity Vi and travels with uniform acceleration 'a'. The distance covered by the body is 'S' and its final velocity becomes Vf. Since the acceleration is uniform, the velocity of the body increases or decreases by equal amount in equal time intervals i.e. the velocity changes at constant rate.

$$S = Vav \times t$$

$$\therefore Vav = \frac{Vf + Vi}{2}$$

$$\therefore a = \frac{Vf - Vi}{a}$$

$$S = \frac{(Vf + Vi)}{2} x \frac{(Vf - Vi)}{a}$$

$$\therefore (Vf + Vi)(Vf - Vi) = Vf^2 - Vi^2$$

$$S = \frac{Vf^2 - Vi^2}{2a}$$

$$\boxed{2aS = Vf^2 - Vi^2}$$

This is called third equation of motion.

MOTION UNDER GRAVITY:

If an object is thrown vertically upward it rises to a particular height and then falls back to the ground.

- During the upward motion of the object, this attraction causes deceleration in the object.
- During downward motion object is accelerated.

GRAVITY:

"The attraction of the earth on the thrown object is called gravitational attraction or gravity."

ACCELEARATION DUE TO GRAVITY OR GRAVITATIONAL ACCELERATION:

Introduction:

It was found by Galileo Galilee that all bodies irrespective of their weights are attracted by the same acceleration.

Definition:

"It is the acceleration with which all the freely falling bodies moves toward the centre of the earth"

Galileo experiment:

To prove this he released iron balls of different masses from the learning tower of Pisa and found that all of them struck the ground at the same time.

Notation:

The acceleration due to gravity is represented by 'g' and its value is $9.8m/s^2$ directed towards the centre of the earth.

Equations:

The equation of motion of bodies moving freely under gravity can be written as:

$$Vf = Vi + gt$$

$$h = Vit + \frac{1}{2} gt^2$$

$$2gh = Vf^2 - Vi^2$$

On the surface of the earth upward direction is usually taken as positive. By this convection, g being downward the value of g i.e. $-9.8ms^{-2}$.