Motion in a Straight Line

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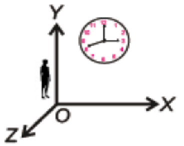
Frame of referenc

- A rectangular coordinate system consisting of three mutually perpendicular axes, along with a clock. The point of intersection of these three axes is called origin (O)
- If a body changes its position as time passes w.r.t. frame of reference, it is said to be in motion.
- Motion of objects along a straight line is called rectilinear motion.YXZO126931011124578



Distance and displacement

- **Distance:** Actual path length in motion. During motion it is non-zerom
- **Displacement:** The shortest path between initial and final position. Equal to change in position. May or may not be equal to path length travelled. It can be positive, negative or zero.

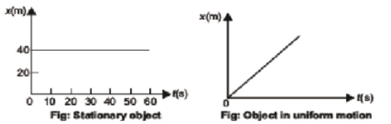


Fig: Stationary object   Fig: Object in uniform motion

Distance and displacement

- The rate of distance covered with time is called speed,

$$V = \frac{\text{distance}}{\text{total time}} = \frac{\ell}{t}$$

- **Average Speed**

$$V_{av} = \frac{\text{total distance}}{\text{total time}} = \frac{\text{total path length}}{\text{total time interval}}$$

- **Instantaneous speed**

$$V = \lim_{\Delta t \to 0} \frac{\Delta \ell}{\Delta t} = \frac{d\ell}{dt}$$

For motion with variable acceleration

- $\frac{dv}{dt} = a \Rightarrow v - u = \int a\,dt$
- $\frac{dx}{dt} = v \Rightarrow \Delta x = \int a\,dt$ (Area under $v - t$ curve)
- $\frac{vdv}{dx} = a$
- $\frac{d^2x}{dt^2} = a$

Velocity

- The rate of change of position, It tells how fast position is changing with time and in what direction.

Average velocity

$$\vec{v}_{av} = \frac{\Delta \vec{x}}{\Delta t}$$

Fig: Moving with positive velocity   Fig: Moving with negative velocity

- SI units are ms^{-1}

Instantaneous velocity

$$\vec{v}_{av} = \lim_{\Delta t \to 0} \frac{\Delta \vec{x}}{\Delta t} = \frac{d\vec{x}}{dt}$$

- Slope of position time graph

Acceleration

The time rate of change of velocity

Average Acceleration

$$\vec{a}_{av} = \frac{(v_2 - v_1)}{(t_2 - t_1)} = \frac{\Delta \vec{v}}{\Delta t}$$

Instantaneous Acceleration

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

Uniform Acceleration

Equal change in velocity in equalintervals of time

Non-Uniform Acceleration

Acceleration changes with time

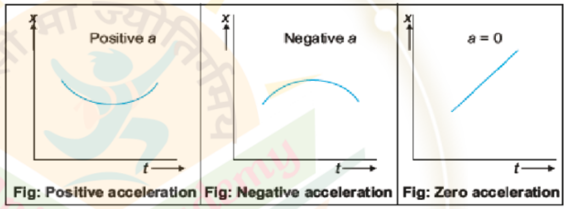


Fig: Positive acceleration   Fig: Negative acceleration   Fig: Zero acceleration

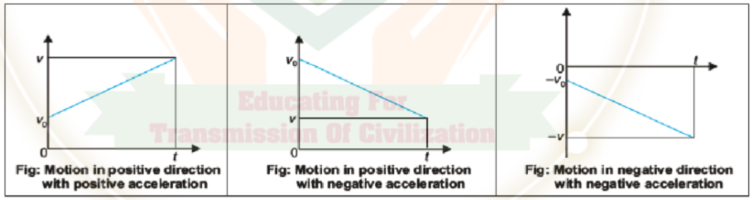


Fig: Motion in positive direction with positive acceleration   Fig: Motion in positive direction with negative acceleration   Fig: Motion in negative direction with negative acceleration

Relative Velocity

- The velocity with which an object moves with respect to another object is called relative velocity.

$v_{AB} = (v_A - v_B)$

$v_{AB} = (v_A + (-v_B))$

$v_{BA} = (v_B + v_A)$

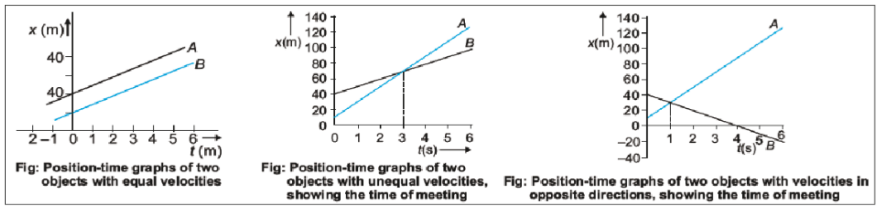
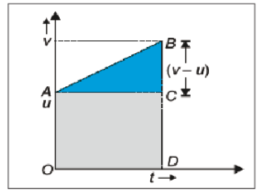


Fig: Position-time graphs of two objects with equal velocities   Fig: Position-time graphs of two objects with unequal velocities, showing the time of meeting   Fig: Position-time graphs of two objects with velocities in opposite directions, showing the time of meeting

Kinematic Equations

- A mathematical treatment to describe the motion of a body in one-dimension.

For uniformly accelerated motion



- $v = u + at$
- $s = ut + \frac{1}{2}at^2 = \left(\frac{u+v}{2}\right)t$
- $v^2 = u^2 + 2as$
- $s_n = u + \frac{a}{2}(2n-1)$
- $\bar{v} = \frac{u+v}{2}$

For motion under gravity

- A mathematical treatment to describe the motion of a body in one-dimension under free fall

Vertically downward motion

When object is released from $y = 0$

- $v = -gt$
- $y = -\frac{1}{2}gt^2$
- $y^2 = -2gy$

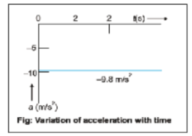


Fig: Variation of acceleration with time

Vertically upward motion

$u \neq 0$, acceleration $a = -g$

- $v = u - gt$
- $S = ut - \frac{1}{2}gt^2$
- $v^2 = u^2 - 2gh$
- Distance travelled during equal intervals of time by a body falling freely from rest is in ratio 1 : 3 : 5 : 7 : 9 : 11 .. (Galileo's law)

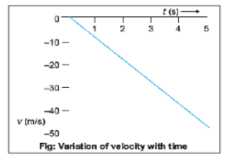


Fig: Variation of velocity with time

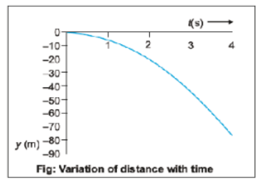


Fig: Variation of distance with time