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KINEMATICS

Displacement

Displacement refers to the change in position of a particle and is given by:

$$\Delta x = x_f - x_i$$

where x_i and x_f represent the initial and final positions, respectively. It is a vector quantity.

Average Velocity and Speed

Average Velocity: It is defined as total displacement divided by the total time taken:

$$v_{\text{avg}} = \frac{\Delta x}{\Delta t}$$

Average Speed: It is the ratio of total path length to total time:

$$\text{Average Speed} = \frac{\text{Total Distance}}{\text{Total Time}}$$

Average and Instantaneous Acceleration

Average Acceleration: Rate of change of velocity:

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

Instantaneous Acceleration: Defined as:

$$a(t) = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

Instantaneous Velocity

Velocity at a specific time:

$$v(t) = \frac{dx}{dt}$$

It represents the slope of the position-time graph.

Equations of Motion (Constant Acceleration)

1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3. $v^2 = u^2 + 2as$
4. $s_n = u + \frac{a}{2}(2n - 1)$ (Displacement in nth second)

Relative Velocity

Velocity of one object with respect to another:

$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$$

- Same direction: $|v_A - v_B|$
- Opposite direction: $|v_A + v_B|$

Projectile Motion

An object projected under gravity follows a parabolic trajectory.

- **Time of flight:** $T = \frac{2v_0 \sin\theta}{g}$
- **Horizontal range:** $R = \frac{v_0^2 \sin 2\theta}{g}$
- **Maximum height:** $H = \frac{v_0^2 \sin^2\theta}{2g}$
- **Trajectory:** $y = x\tan\theta - \frac{gx^2}{2v_0^2\cos^2\theta}$

- **Trajectory:** $y = x \tan\theta - \frac{g x^2}{2(v_0 \cos\theta)^2}$

Circular Motion

For a body moving in a circle of radius r with speed v:

- **Angular speed:** $\omega = \frac{v}{r}$
- **Centripetal acceleration:** $a_c = \frac{v^2}{r} = \omega^2 r$

Tangential and Normal Acceleration

- **Tangential acceleration (a_t):** Due to change in speed.
- **Normal (centripetal) acceleration (a_n):** Due to change in direction.
- **Total acceleration:**

$$a = \sqrt{a_t^2 + a_n^2}$$