KINEMATICS

JEE MAINS Physics — Class 11 — Complete formula Sheet

EQUATIONS OF MOTION (Uniform Acceleration)

$$v = u + at$$
$$s = ut + \tfrac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$
$$s = \tfrac{(u+v)}{2} \cdot t$$

Distance in n^{th} second

$$s_n = u + \frac{a}{2}(2n-1)$$

Stopping Distance

$$d = \frac{u^2}{2\mu g} \quad (\mu = \text{coeff. of friction})$$

GRAPHS IN KINEMATICS

Displacement–Time (x–t)

- Slope = v (instantaneous velocity)
- Straight line ⇒ uniform motion
- Curve ⇒ acceleration
- Negative slope ⇒ body moving back

Velocity–Time (v–t)

- Slope = a
- Area under curve = Δs (displacement)
- Horizontal line ⇒ uniform velocity

Acceleration–Time (a–t)

- Slope = $\dot{a}$ (jerk)
- Area under curve = Δv

Area (v-t) = displacement
Area (a-t) = change in velocity

PROJECTILE MOTION

Launched at angle θ with speed u:

$u_x = u\cos\theta$ $\quad u_y = u\sin\theta$

$x = u\cos\theta \cdot t$ $\quad y = u\sin\theta \cdot t - \tfrac{1}{2}gt^2$

Key Results

Time of Flight

$$T = \frac{2u\sin\theta}{g}$$

Maximum Height

$$H = \frac{u^2\sin^2\theta}{2g}$$

Horizontal Range

$$R = \frac{u^2\sin 2\theta}{g}$$

Max Range (at $\theta = 45$)

$$R_{\max} = \frac{u^2}{g}$$

Trajectory Equation

$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

Special Results

- R is same for θ and $(90-\theta)$
- At max height: $v_y = 0$, speed $= u\cos\theta$
- At $\theta = 45$: $H = R/4$
- $T = \dfrac{2H}{u\sin\theta} = \dfrac{2u\sin\theta}{g}$
- Angle of velocity at time t: $\tan\alpha = \dfrac{v_y}{v_x}$

Projectile on Incline

- Range on incline: $R = \dfrac{2u^2\sin(\theta-\beta)\cos\theta}{g\cos^2\beta}$ (β = incline angle)
- Max range on incline: $\theta = 45 + \beta/2$

RELATIVE MOTION

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

River-Boat Problem

- Shortest time: boat ⊥ river, $t = \dfrac{d}{v_b}$
- Shortest path: $\sin\theta = \dfrac{v_r}{v_b}$ (θ = angle upstream)
- Drift $= v_r \cdot t$

Rain-Man Problem

- $\vec{v}_{\text{rain w.r.t. man}} = \vec{v}_{\text{rain}} - \vec{v}_{\text{man}}$
- Hold umbrella in direction of relative velocity of rain

CIRCULAR & ANGULAR KINEMATICS

$v = r\omega \qquad a_c = \dfrac{v^2}{r} = \omega^2 r$

$\omega = \dfrac{d\theta}{dt} \qquad \alpha = \dfrac{d\omega}{dt}$

Angular Equations of Motion

- $\omega = \omega_0 + \alpha t$
- $\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2$
- $\omega^2 = \omega_0^2 + 2\alpha\theta$

Tangential & Centripetal Acceleration

- $a_t = r\alpha$ (tangential)
- $a_c = \omega^2 r$ (centripetal)
- $a = \sqrt{a_t^2 + a_c^2}$

IMPORTANT TRICKS & RESULTS

- If a = const: midpoint time speed ≠ midpoint distance speed
- Avg velocity ≠ avg speed (if direction changes)
- For symmetric projectile: $v_{\text{land}} = v_{\text{launch}}$
- $H_{\max}$ when $\theta = 90$: $H = \dfrac{u^2}{2g}$
- Time to reach max height $= T/2$
- Speed at $H/2 \Rightarrow v_y = \dfrac{u\sin\theta}{\sqrt{2}}$

Freely Falling Bodies

- $v = gt$, $h = \tfrac{1}{2}gt^2$, $v^2 = 2gh$
- $g = 9.8 \approx 10\,\text{m/s}^2$
- Distances in successive seconds: $1:3:5:7\ldots$
- Time ratios for equal distances: $1:\sqrt{2}:\sqrt{3}\ldots$