TURBO
ROTATIONAL MOTION
Detailed Technical Summary • Class 11 Physics

I. Kinematics of Rotation

Equation	Rotational Form	Linear Analogy
First Equation	$\omega = \omega_0 + \alpha t$	$v = u + at$
Second Equation	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$	$s = ut + \frac{1}{2}at^2$
Third Equation	$\omega^2 = \omega_0^2 + 2\alpha\theta$	$v^2 = u^2 + 2as$

Note: ω_0 = initial angular velocity, ω = final angular velocity, α = angular acceleration, θ = angular displacement.

II. Moment of Inertia (I)

- **Physical Meaning:** A measure of rotational inertia. Higher I makes it harder to change the rotational state.
- **Nature:** It is a **Tensor** (neither purely scalar nor vector).
- **Formulas:** $I = \sum m_i r_i^2$ (discrete) and $I = \int r^2 dm$ (rigid).
- **Radius of Gyration (K):** $I = MK^2$. It is the effective perpendicular distance where the mass is considered concentrated for rotation.
- **Units/Dimensions:** Unit: **kg m^2**. Dimensions: $[ML^2T^0]$.
- **Dependencies:** Depends on mass distribution, shape, size, and axis orientation.

III. Work, Energy & Momentum

- **Work Done:** $dW = \tau d\theta \Rightarrow W = \int \tau d\theta$.
- **Kinetic Energy:** $K.E_{rot} = \frac{1}{2}I\omega^2$.
- **Angular Momentum ($\vec{L}$):** $\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$.
- **Conservation of Angular Momentum:** If $\vec{\tau}_{ext} = 0$, then $\frac{d\vec{L}}{dt} = 0 \Rightarrow \vec{L}$ = constant ($I_1\omega_1 = I_2\omega_2$).

IV. Dynamics of Rolling on an Incline

- **Acceleration (a):** $a = \frac{g\sin\theta}{1+(K^2/R^2)}$.
- **Rolling Time:** As K/R increases, acceleration decreases, and time taken to reach the bottom increases.
- **Condition for Pure Rolling:** $\mu_s \geq \frac{\tan\theta}{1+(R^2/K^2)}$.
  - For a Disc ($R^2/K^2 = 2$): $\mu_s \geq \frac{1}{3}\tan\theta$.
- **Friction Note:** In pure rolling, static friction does no work, thus mechanical energy is conserved. Friction always acts **up** the plane (whether rolling up or down).