NEWTON'S LAWS OF MOTION

JEE MAINS Physics — Class 11 — Complete formula Sheet

NEWTON'S THREE LAWS

1st Law: Net $F = 0 \Rightarrow v = \text{const}$ (inertia)

2nd Law: $\vec{F}_{\text{net}} = m\vec{a}$

3rd Law: $\vec{F}_{AB} = -\vec{F}_{BA}$

$F = \frac{dp}{dt}$ (General 2nd Law)

$\vec{p} = m\vec{v}$ (linear momentum)

$\vec{J} = \Delta\vec{p} = \vec{F}_{\text{avg}} \cdot \Delta t$ (impulse)

FRICTION

Laws of Friction

$f_s \le \mu_s N$ (static, max $= \mu_s N$)

$f_k = \mu_k N$ (kinetic)

$\mu_k < \mu_s$ always

On Inclined Plane

- Normal: $N = mg\cos\theta$
- Friction (sliding down): $f = \mu mg\cos\theta$
- Net a (down): $a = g(\sin\theta - \mu\cos\theta)$
- Condition to slide: $\tan\theta > \mu_s$
- Angle of repose: $\theta_r = \tan^{-1}(\mu_s)$

Block on Block (Friction)

- Max friction between blocks: $f = \mu m_{\text{top}} g$
- Critical force before slipping: $F_{\max} = \mu(m_1 + m_2)g$

If two blocks move together: treat as one

Check if friction needed > max available

CONNECTED BODIES

Atwood Machine (Pulley)

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2}$$

$$T = \frac{2m_1 m_2 g}{m_1 + m_2}$$

Mass on Incline (Pulley)

Hanging mass m_2, block m_1 on incline θ:

$$a = \frac{m_2 g - m_1 g\sin\theta}{m_1 + m_2}$$

$$T = \frac{m_1 m_2 g(1 + \sin\theta)}{m_1 + m_2}$$

CIRCULAR MOTION (Newton)

Centripetal force: $F_c = \frac{mv^2}{r} = m\omega^2 r$

Centripetal accel: $a_c = \frac{v^2}{r} = \omega^2 r$

Banking of Roads

$\tan\theta = \frac{v^2}{rg}$ (frictionless banking)

$$v_{\max} = \sqrt{rg\frac{\mu + \tan\theta}{1 - \mu\tan\theta}}$$

$$v_{\min} = \sqrt{rg\frac{\tan\theta - \mu}{1 + \mu\tan\theta}}$$

Conical Pendulum

$$T = 2\pi\sqrt{\frac{l\cos\theta}{g}}$$

$$\omega = \sqrt{\frac{g}{l\cos\theta}}$$

$$T_{\text{string}} = \frac{mg}{\cos\theta}$$

Vertical Circle (Minimum Speeds)

At top: $v_{\min} = \sqrt{gr}$

At bottom: $v_{\min} = \sqrt{5gr}$

$T_{\text{bottom}} - T_{\text{top}} = 6mg$

PSEUDO FORCE

In non-inertial frame (acceleration a_0):

$\vec{F}_{\text{pseudo}} = -m\vec{a}_0$

Acts on every object in that frame

Applications

- Lift accelerating up: $N = m(g + a)$
- Lift accelerating down: $N = m(g - a)$
- Free fall ($a = g$): $N = 0$ (weightlessness)
- Pendulum in accelerating vehicle: $T = 2\pi\sqrt{\frac{l}{\sqrt{g^2 + a^2}}}$, $\tan\phi = \frac{a}{g}$

SPRING FORCE

$F = -kx$ (Hooke's Law)

Springs in series: $\frac{1}{k_{\text{eff}}} = \frac{1}{k_1} + \frac{1}{k_2}$

Springs in parallel: $k_{\text{eff}} = k_1 + k_2$

KEY TRICKS

- Normal force $\neq mg$ in accelerating systems
- Static friction is self-adjusting (0 to $\mu_s N$)
- Tension same throughout massless string
- In accelerating pulley: $a_1 + a_2 = 2a_{\text{pulley}}$
- Rolling without slipping: $a = g\sin\theta/(1 + I/mr^2)$