

Learn these by heart before the exam.

Kinematics

$v = v_0 + at, \quad x = x_0 + v_0t + \frac{1}{2}at^2, \quad v^2 = v_0^2 + 2a\Delta x$
constant acceleration only

$\bar{v} = \frac{\Delta x}{\Delta t}, \quad \bar{a} = \frac{\Delta v}{\Delta t}$

Graphs: slope of x - t is velocity; slope of v - t is acceleration; AREA under v - t is displacement.

Projectiles: horizontal $a = 0$ so $x = v_{0x}t$; vertical is free fall. The two axes share only t .

$g = 9.8 \text{ m/s}^2$ (downward) free fall means gravity is the only force; mass does not appear

Force and Translational Dynamics

$\sum \vec{F} = m\vec{a}$ always start with a free-body diagram, then apply per axis

$F_g = mg, \quad F_f \leq \mu_s F_N, \quad F_f = \mu_k F_N$ static friction is an inequality; it takes whatever value is needed up to the maximum

$F_s = k|\Delta x|$
 $F_G = \frac{Gm_1m_2}{r^2}, \quad g = \frac{GM}{r^2}$

$a_c = \frac{v^2}{r}, \quad F_c = \frac{mv^2}{r}$ centripetal is a direction, not a new force; some real force supplies it

Newton's third law: the pair acts on DIFFERENT bodies, so it never cancels on a free-body diagram.

Work, Energy, and Power

$W = Fd \cos \theta, \quad P = \frac{W}{\Delta t} = Fv \cos \theta$

$K = \frac{1}{2}mv^2, \quad U_g = mgh, \quad U_s = \frac{1}{2}k(\Delta x)^2$
 $W_{\text{net}} = \Delta K$

Energy is conserved when only conservative forces act. Friction converts mechanical energy to thermal: $\Delta E = -F_f d$.

Work is the AREA under a force-displacement graph, even when F varies.

Linear Momentum

$\vec{p} = m\vec{v}, \quad \vec{J} = \vec{F}\Delta t = \Delta \vec{p}$ impulse is the AREA under a force-time graph

Momentum is conserved in EVERY collision with no external force. Kinetic energy is conserved only if the collision is elastic.

Perfectly inelastic: the objects stick together and share one final velocity.

Torque and Rotational Dynamics

$\tau = rF \sin \theta, \quad \sum \tau = I\alpha$
 $\omega = \omega_0 + \alpha t, \quad \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$v = r\omega, \quad a_t = r\alpha$
 $I_{\text{point}} = mr^2, \quad I = \sum m_i r_i^2$ mass far from the axis raises I sharply

Equilibrium needs BOTH $\sum F = 0$ and $\sum \tau = 0$. Take torques about a point that kills an unknown.

Energy and Momentum of Rotating Systems

$K_{\text{rot}} = \frac{1}{2}I\omega^2, \quad L = I\omega$

$\Delta L = \tau \Delta t$
Angular momentum is conserved with no external torque: pull the arms in, I falls, so ω rises.

Rolling without slipping: $v = r\omega$ and total $K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$.

Oscillations

$T = \frac{1}{f}, \quad \omega = 2\pi f$

$T_s = 2\pi\sqrt{\frac{m}{k}}, \quad T_p = 2\pi\sqrt{\frac{L}{g}}$ neither period depends on amplitude (small angles for the pendulum)

$x = A \cos(\omega t)$ a is largest at maximum displacement; v is largest at equilibrium

SHM needs a restoring force proportional to displacement and directed back to equilibrium.

Fluids

$\rho = \frac{m}{V}, \quad P = \frac{F}{A}$
 $P = P_0 + \rho gh$ gauge pressure is ρgh ; absolute pressure adds P_0

$F_b = \rho_{\text{fluid}} V_{\text{disp}} g$ a floating object displaces its own WEIGHT of fluid

$A_1 v_1 = A_2 v_2$ narrower pipe means faster flow

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$ faster flow means lower pressure

Exam technique

Free-response: define your symbols, draw the free-body diagram, then write the principle BEFORE substituting numbers. Method earns marks even if the arithmetic slips.

Always check units and direction. A negative answer

usually means 'opposite to the axis I chose', not 'wrong'.

Paragraph-length response: make a claim, cite the physics principle by name, then link it to the specific situation.