Physics-1 Formulas
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Introduction, Measurement, Estimating

- **SI Base Units:** Meter (m), Kilogram (kg), Second (s), Ampere (A), Kelvin (K), Mole (mol), Candela (cd)
- **Dimensional Analysis:** Checking equations for consistency of units.
- **Significant Figures:** Rules for calculation precision.

Kinematics in One Dimension

- **Displacement:** $\Delta x = x_f - x_i$
- **Average Velocity:** $\bar{v} = \frac{\Delta x}{\Delta t}$
- **Instantaneous Velocity:** $v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$
- **Average Acceleration:** $\bar{a} = \frac{\Delta v}{\Delta t}$
- **Instantaneous Acceleration:** $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$
- **Constant Acceleration: v:** $v = v_0 + at$
- **Constant Acceleration: x:** $x = x_0 + v_0 t + \frac{1}{2}at^2$
- **Constant Acceleration: v^2:** $v^2 = v_0^2 + 2a(x - x_0)$
- **Free Fall (y):** $y = y_0 + v_{0y}t - \frac{1}{2}gt^2$

Kinematics in 2D/3D; Vectors

- **Position Vector:** $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$
- **Displacement Vector:** $\Delta\vec{r} = \vec{r}_f - \vec{r}_i$
- **Average Velocity Vector:** $\vec{\bar{v}} = \frac{\Delta\vec{r}}{\Delta t}$
- **Instantaneous Velocity Vector:** $\vec{v} = \frac{d\vec{r}}{dt} = v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$
- **Instantaneous Acceleration Vector:** $\vec{a} = \frac{d\vec{v}}{dt} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$
- **Projectile Motion (x):** $x = x_0 + (v_0 \cos\theta_0)t$
- **Projectile Motion (y):** $y = y_0 + (v_0 \sin\theta_0)t - \frac{1}{2}gt^2$
- **Relative Velocity:** $\vec{v}_{AB} = \vec{v}_{AE} - \vec{v}_{BE}$

Dynamics: Newton's Laws

- **Newton's First Law:** An object stays at rest or moves with constant velocity unless acted upon by a net force.
- **Newton's Second Law:** $\sum \vec{F} = m\vec{a}$
- **Newton's Third Law:** $\vec{F}_{AB} = -\vec{F}_{BA}$
- **Weight:** $\vec{W} = m\vec{g}$

Using Newton's Laws

- **Kinetic Friction:** $f_k = \mu_k N$
- **Static Friction:** $f_s \leq \mu_s N$
- **Centripetal Acceleration:** $a_c = \frac{v^2}{r}$
- **Centripetal Force:** $\sum F_c = ma_c = m\frac{v^2}{r}$
- **Drag Force (Approx. v):** $F_D = -bv$
- **Drag Force (Approx. v^2):** $F_D = \frac{1}{2}C\rho Av^2$

Gravitation and Newton's Synthesis

- **Newton's Law of Gravitation:** $F = G\frac{m_1 m_2}{r^2}$
- **Gravitational Field (g):** $g = G\frac{M}{r^2}$
- **Gravitational Potential Energy:** $U = -G\frac{m_1 m_2}{r} \quad (U = 0 \text{ at } r = \infty)$
- **Kepler's Third Law:** $T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$

Work and Energy

- **Work (Constant Force):** $W = Fd\cos\theta = \vec{F}\cdot\vec{d}$
- **Work (Variable Force):** $W = \int_a^b \vec{F}\cdot d\vec{l}$
- **Kinetic Energy:** $K = \frac{1}{2}mv^2$
- **Work-Energy Theorem:** $W_{net} = \Delta K = K_f - K_i$
- **Potential Energy (Gravity, near Earth):** $U_g = mgy$
- **Potential Energy (Elastic Spring):** $U_s = \frac{1}{2}kx^2$
- **Power (Average):** $\bar{P} = \frac{W}{\Delta t}$
- **Power (Instantaneous):** $P = \frac{dW}{dt} = \vec{F}\cdot\vec{v}$

Conservation of Energy

- **Conservative Force:** Work done is independent of path. $W = -\Delta U$
- **Non-Conservative Force:** Work done depends on path (e.g., friction).
- **Conservation of Mechanical Energy:** $K_1 + U_1 + W_{12} = K_2 + U_2$
- **Work by Non-Conservative Forces:** $W_{nc} = \Delta E_{mech} = \Delta K + \Delta U$

Linear Momentum

- **Linear Momentum:** $\vec{p} = m\vec{v}$
- **Newton's Second Law (Momentum Form):** $\sum \vec{F} = \frac{d\vec{p}}{dt}$
- **Impulse:** $\vec{J} = \int_{t_i}^{t_f} \sum \vec{F} dt$
- **Impulse-Momentum Theorem:** $\vec{J} = \Delta\vec{p} = \vec{p}_f - \vec{p}_i$
- **Conservation of Linear Momentum:** If $\sum \vec{F}_{ext} = 0,$ then $\vec{p}_{total} = \text{const} \implies \vec{p}_i = \vec{p}_f$
- **Elastic Collision (1D):** Momentum and Kinetic Energy conserved.
- **Inelastic Collision (1D):** Momentum conserved, Kinetic Energy not conserved.
- **Center of Mass (Discrete):** $\vec{r}_{CM} = \frac{\sum m_i \vec{r}_i}{\sum m_i} = \frac{\int \vec{r} dm}{M}$
- **Velocity of Center of Mass:** $\vec{v}_{CM} = \frac{\sum m_i \vec{v}_i}{M_{total}} = \frac{\vec{P}_{total}}{M_{total}}; \quad \vec{P}_{total} = M_{total}\vec{v}_{CM}$

Rotational Motion

- **Angular Position, Velocity, Acceleration:** $\omega = \frac{d\theta}{dt}, \alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$
- **Relating Linear and Angular Variables:** $v_t = r\omega, a_t = r\alpha, a_c = r\omega^2 = \frac{v_t^2}{r}$
- **Constant Angular Acceleration: ω:** $\omega = \omega_0 + \alpha t$
- **Constant Angular Acceleration: θ:** $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
- **Constant Angular Acceleration: ω^2:** $\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$
- **Torque:** $\vec{\tau} = \vec{r} \times \vec{F} \quad (\tau = rF\sin\phi)$
- **Moment of Inertia:** $I = \sum m_i r_i^2 = \int r^2 dm$
- **Parallel Axis Theorem:** $I = I_{CM} + Mh^2$
- **Newton's Second Law for Rotation:** $\sum \vec{\tau} = I\vec{\alpha}$
- **Rotational Kinetic Energy:** $K_{rot} = \frac{1}{2}I\omega^2$
- **Work in Rotation:** $W = \int \tau d\theta$
- **Power in Rotation:** $P = \tau\omega$

Angular Momentum

- **Angular Momentum (Particle):** $\vec{L} = \vec{r} \times \vec{p} \quad (L = rmv\sin\phi)$
- **Angular Momentum (Rigid Body, Fixed Axis):** $L = I\omega$
- **Torque and Angular Momentum:** $\sum \vec{\tau}_{ext} = \frac{d\vec{L}}{dt}$
- **Conservation of Angular Momentum:** If $\sum \vec{\tau}_{ext} = 0,$ then $\vec{L}_{total} =$ const $\implies \vec{L}_i = \vec{L}_f$

Oscillations

- **Simple Harmonic Motion (SHM):** $F = -kx, \quad \frac{d^2x}{dt^2} = -\omega^2 x$
- **Solution for SHM:** $x(t) = A\cos(\omega t + \phi)$
- **Angular Frequency (Spring-Mass):** $\omega = \sqrt{\frac{k}{m}}$
- **Period and Frequency:** $T = \frac{1}{f} = \frac{2\pi}{\omega}$
- **Energy in SHM:** $E = K + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$
- **Simple Pendulum (Small Angle):** $\omega = \sqrt{\frac{g}{L}}$
- **Physical Pendulum:** $\omega = \sqrt{\frac{mgd}{I}}$
- **Damped Oscillations:** $x(t) = Ae^{-bt/(2m)}\cos(\omega' t + \phi); \quad \omega' = \sqrt{\omega_0^2 - (b/2m)^2}$
- **Resonance Frequency (ω_0):** $\omega_0 = \sqrt{\frac{k}{m}}$ (Natural freq.)