

## Kinematics

$$x_f = x_i + v_{ix}t + \frac{1}{2}a_x(\Delta t)^2$$

$$x_f = x_i + \frac{1}{2}(v_{ix} + v_{fx})t$$

$$v_{fx} = v_{ix} + a_x\Delta t$$

$$v_{fx}^2 = v_{ix}^2 + 2a_x(x_f - x_i)$$

$$v_x = \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

$$a_x = \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt} = \frac{d^2x}{dt^2}$$

## Forces

$$f_s = \mu_s n$$

$$f_k = \mu_k n$$

$$F_{spring} = -k(x - x_0)$$

$$\vec{F}_{net} = m\vec{a}$$

## Momentum

$$\vec{p} = m\vec{v}$$

$$\Delta p_x = J_x = F_x \Delta t$$

$$\Delta \vec{p} = 0 \text{ (isolated system)}$$

## Energy

$$K = \frac{1}{2}mv^2$$

$$U_g = mg(y - y_0)$$

$$U_{spring} = \frac{1}{2}k(x - x_0)^2$$

$$\Delta E_{system} = W \text{ (Work)}$$

$$W = \vec{F} \cdot \vec{d} = F \Delta x \cos \theta = F_{\parallel} d$$

## Circular Motion

$$\sum F_r = \frac{mv^2}{r}$$

$$\omega = 2\pi f$$

$$T = \frac{1}{f}$$

## Rotational Motion

$$s = r\theta$$

$$v = r\omega$$

$$a = r\alpha$$

$$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha(\Delta t)^2$$

$$\omega_f = \omega_i + \alpha\Delta t$$

$$\omega_f^2 = \omega_i^2 + 2\alpha(\theta_f - \theta_i)$$

$$K_{rot} = \frac{1}{2}I\omega^2$$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\tau = rF_{\perp} = rF \sin \theta$$

$$\vec{\tau} = I\vec{\alpha}$$

$$I = \sum_i m_i r_i^2 \text{ (point masses)}$$

$$I = I_{CM} + md^2 \text{ (parallel axis theorem)}$$

$$\vec{L} = I\vec{\omega}$$

$$L = mvr \sin \theta$$

$$\Delta L = 0 \text{ (isolated system)}$$

## Fluids

$$F_{buoyant} = \rho_F V g$$

$$P = F/A$$

$$P = \rho g \Delta h$$

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

## Gravity

$$\vec{F}_G = -\frac{Gm_1m_2}{r^2}\hat{r}$$

## Electrostatics

$$F = K \frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E} = \frac{kQ}{r^2}\hat{r} \text{ (point charge)}$$

$$\Delta U = q \Delta V$$

$$U_e = K \frac{q_1 q_2}{r} \quad (\text{point charge})$$

$$E_x = -\frac{dV}{dx}$$

$$F_x = -\frac{dU}{dx}$$

$$V = k \frac{Q}{r} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r} \quad (\text{electric potential})$$

$$V_{\text{tot}} = \sum_i V_i$$

## Current & Circuits

$$I = \frac{\Delta Q}{\Delta t}$$

$$V = I R$$

$$R = \rho \frac{L}{A}$$

$$P = I V = I^2 R = \frac{V^2}{R}$$

$$R_{eq} = R_1 + R_2 + \dots = \sum_i R_i \quad (\text{series})$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots = \sum_i \frac{1}{R_i} \quad (\text{parallel})$$

$$C_{eq} = C_1 + C_2 + \dots = \sum_i C_i \quad (\text{parallel})$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots = \sum_i \frac{1}{C_i} \quad (\text{series})$$

$$Q = C V$$

$$C = \epsilon_0 \frac{A}{d}$$

$$E_{\text{capacitor}} = \frac{\eta}{\epsilon_0} = \frac{Q}{\epsilon_0 A}$$

$$U_{\text{capacitor}} = \frac{1}{2} Q V = \frac{1}{2} C V^2 = \frac{1}{2} \frac{Q^2}{C}$$

$$V_C = V_0 (1 - e^{-t/RC})$$

## Magnetism

$$\vec{F}_{\text{on } q} = q (\vec{E} + \vec{v} \times \vec{B})$$

$$\vec{F}_{\text{on wire}} = l \vec{I} \times \vec{B}, \quad |F| = IlB \sin\theta$$

$$B_{\text{wire}} = \frac{\mu_0 I}{2\pi r}$$

$$\Phi_B = \vec{B} \cdot \vec{A} = BA \cos\theta$$

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{\Delta\Phi_B}{\Delta t}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I \quad (\text{Ampère's Law})$$

## Maxwell's Equations

$$\left. \begin{aligned} \oint \vec{E} \cdot d\vec{A} &= \frac{Q_{\text{in}}}{\epsilon_0} \\ \oint \vec{B} \cdot d\vec{A} &= 0 \\ \oint \vec{E} \cdot d\vec{s} &= -\frac{d\Phi_B}{dt} \\ \oint \vec{B} \cdot d\vec{s} &= \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} \end{aligned} \right| \begin{aligned} \nabla \cdot \vec{E} &= \frac{\rho_{\text{in}}}{\epsilon_0} \\ \nabla \cdot \vec{B} &= 0 \\ \nabla \times \vec{E} &= -\frac{d\vec{B}}{dt} \\ \nabla \times \vec{B} &= \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{d\vec{E}}{dt} \end{aligned}$$

## Simple Harmonic Motion & Waves

$$x(t) =$$

$$A \cos(\omega t + \phi_0) \quad (\text{simple harmonic motion})$$

$$D(x, t) =$$

$$A \sin(kx - \omega t + \phi_0) \quad (\text{traveling wave})$$

$$k = 2\pi/\lambda$$

$$\omega = 2\pi f$$

$$f = \frac{1}{T}$$

$$v = f\lambda$$

$$T = 2\pi \sqrt{\frac{L}{g}} \quad (\text{pendulum})$$

$$T = 2\pi \sqrt{\frac{m}{k}} \quad (\text{mass on spring})$$

$$\omega = \sqrt{\frac{k}{m}}$$

$$U_{\text{spring}} = \frac{1}{2} k (\Delta x)^2$$

$$E_{\text{spring}} = \frac{1}{2} k A^2$$

$$v_{\text{string}} = \sqrt{\frac{F_T}{\mu}}$$

$$I = \frac{P}{4\pi r^2} \quad (\text{intensity})$$

$$L = \frac{m\lambda_m}{2} \quad (\text{standing waves on string})$$

## Sound

$$v_s = (331 + 0.60T) \text{ m/s}$$

$$\beta(\text{dB}) = 10 \log_{10} \left( \frac{I}{I_0} \right)$$

$$f' = f_0 \left( \frac{v \pm v_o}{v \pm v_s} \right) \quad (\text{Doppler effect})$$

## Geometric Optics

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \text{ or } \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$m = \frac{h'}{h} = -\frac{s'}{s}$$

$$n = \frac{c}{v_{\text{medium}}}$$

$$\lambda_{\text{medium}} = \lambda_{\text{vacuum}}/n$$

## Light as a wave

$$d \sin \theta_m = m \lambda (\text{double slit, bright fringes})$$

$$a \sin \theta_p = p \lambda (\text{single slit, dark fringes})$$

$$y_m = L \tan \theta$$

$$w = \frac{2\lambda L}{a}$$

$$\theta = 1.22 \frac{\lambda}{D} \quad (\text{Rayleigh criterion})$$

## Special Relativity

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$\begin{cases} x' = \gamma(x - vt) \\ t' = \gamma(t - vx/c^2) \\ y' = y \\ z' = z \end{cases}$$

$$\Delta t = \gamma \Delta t_0$$

$$L = \frac{L_0}{\gamma}$$

$$p = \gamma m_0 v$$

$$m_{\text{rel}} = \gamma m_0$$

$$E_0 = m_0 c^2$$

$$KE = (\gamma - 1)m_0 c^2$$

$$E = KE + m_0 c^2 = \gamma m_0 c^2$$

$$E^2 = p^2 c^2 + m_0^2 c^4$$

$$u'_x = \frac{u_x - v}{1 - \frac{vu_x}{c^2}} \quad u'_y = \frac{u_y}{\gamma \left(1 - \frac{vu_x}{c^2}\right)} \quad u'_z = \frac{u_z}{\gamma \left(1 - \frac{vu_x}{c^2}\right)}$$

$$f = \sqrt{\frac{1 + \beta}{1 - \beta}} f_0, \quad (\text{approaching})$$

$$f = \sqrt{\frac{1 - \beta}{1 + \beta}} f_0, \quad (\text{receding})$$

## Quantum & Atom

$$\lambda_P T = 2.90 \times 10^{-3} \text{ m K}$$

$$E = nhf$$

$$E = hf$$

$$p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$$

$$\lambda = \frac{h}{p}$$

$$r_n = n^2 a_o$$

$$E_n = -13.6 \text{ eV} \frac{Z^2}{n^2}$$

$$\frac{1}{\lambda_m} = R \left( \frac{1}{m^2} - \frac{1}{n^2} \right), \quad n > m$$

$$R = 1.096776 \times 10^7 \text{ m}^{-1} \text{ for hydrogen.}$$

$$(\text{Lyman, Balmer, Paschen for } m = 1, 2, 3)$$

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

$$H\psi = i\hbar \frac{d\psi}{dt}$$

$$H = -\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi$$

$$E_n = n^2 \frac{\hbar^2 \pi^2}{2mL^2} \quad (\text{infinite well})$$

$$E_n = \left( n + \frac{1}{2} \right) \hbar \omega \quad (\text{harmonic oscillator})$$

$$E_n^1 = \psi^0 H^1 \psi^0 \quad (\text{Perturbation Energy})$$

multiplicity of states

compton effect

## Thermodynamics and Statistical Mechanics

$$\Delta U = Q + W$$

$$Q = mc\Delta T$$

$$W = -P_{ext}V$$

$$U = NkT$$

$$PV = NkT$$

$$\beta = \frac{\Delta V/V}{\Delta T}$$

$$S = \frac{Q}{\Delta T} = k \ln \Omega$$

$$L = \frac{Q}{m}$$

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

## Classical Mechanics

$$\mathcal{L} = T - U$$

$$\frac{d}{dt} \left( \frac{\partial \mathcal{L}}{\partial \dot{q}_i} \right) - \frac{\partial \mathcal{L}}{\partial q_i} = 0$$

## Blackbody radiation

$$R = \sigma T^4, \quad \sigma = 5.67 \times 10^{-8} W/m^2 K^4$$

$$\lambda_m = a/T, \quad a = 2.898 \times 10^{-3} m \cdot K$$

$$u(\lambda) = \frac{8\pi hc\lambda^{-5}}{e^{\frac{hc}{\lambda kT}} - 1}$$

$$eV_0 = \left( \frac{1}{2}mv^2 \right) = hf - \phi$$

$$\lambda_2 - \lambda_1 = \frac{h}{mc}(1 - \cos \theta), \quad \text{where } \frac{h}{mc} = 0.00243 \text{ nm}$$

## Nuclear physics

$${}_Z^AX_N \rightarrow A = Z + N$$

$$B = ZM_Hc^2 + Nm_nc^2 - M_Ac^2$$

$$\text{where } M_H = 1.007825u, m_n = 1.008665u.$$

$$N(t) = N_0 e^{-\lambda t}$$

$$\tau = \frac{1}{\lambda}$$

$$t_{1/2} = \ln(2)\tau = 0.693\tau$$

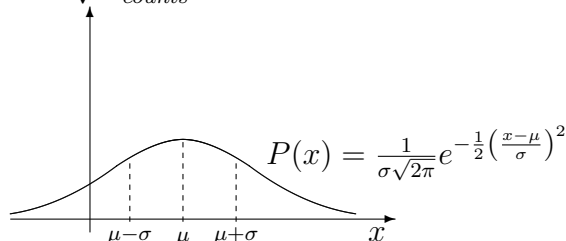
$$\alpha \text{ decay: } {}_Z^{>83}X_N \rightarrow {}_{Z-2}^{A-4}X_{N-2} + \alpha.$$

$$\beta^- \text{ decay: } {}_Z^AX_N \rightarrow {}_{Z+1}^AX_{N-1} + \beta^-.$$

$$\beta^+ \text{ decay: } {}_Z^AX_N \rightarrow {}_{Z-1}^AX_{N+1} + \beta^+.$$

## Statistics and Uncertainty

$$\sigma = \sqrt{N_{counts}}$$



## Astronomy

Kepler's First Law: planets orbit in elliptical orbits

Second Law: planets sweep out equal area in equal time

Third Law:  $p^2 \propto a^3$

Hubble's Law:  $v_{recession} = H_0 d$

## Miscellaneous

orthogonal vectors:  $\vec{A} \cdot \vec{B} = 0$