

Kinematics and Mechanics

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v = v_0 + a t$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$a_c = \frac{v^2}{r}$$

$$F = m a$$

$$E_{\text{tot}} = K + U$$

$$K = \frac{1}{2} m v^2 = \frac{p^2}{2m}$$

$$p = m v$$

$$W_F = F d \cos \theta$$

$$P = F v \cos \theta$$

Electrostatics

$$F_{12} = k \frac{q_1 q_2}{r^2}$$

$$E = \frac{F}{q_0}$$

Point Charge

$$E = \frac{kq}{r^2}$$

$$V = \frac{kq}{r}$$

$$U_{12} = k \frac{q_1 q_2}{r}$$

$$V \equiv \frac{U}{q_0}$$

$$W_E = -\Delta U = -W_{\text{you}}$$

Gauss' Law

$$\Phi_E = E A_S = \frac{q_{\text{enc}}}{\epsilon_0}$$

Electric Dipole

$$p = q d$$

$$\tau_{\text{dip}} = p E \sin \theta$$

$$U_{\text{dip}} = -p E \cos \theta$$

Resistance

$$R = \frac{V}{I}$$

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

Physical Resistance

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

Capacitance

$$C = \frac{Q}{V}$$

$$E = \frac{Q}{\epsilon_0 A}$$

$$V = Ed$$

Circuits

$$\Sigma \Delta V = 0$$

$$\Sigma I_{\text{in}} = \Sigma I_{\text{out}}$$

$$q(t) = q_{\infty}(1 - e^{-t/\tau})$$

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

$$R_S = R_1 + R_2 + \dots$$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

Parallel Plate Capacitor

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

$$U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

$$C_P = C_1 + C_2 + \dots$$

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

$$q(t) = q_0 e^{-t/\tau}$$

$$I(t) = I_0 e^{-t/\tau}$$

$$\tau = RC$$

Magnetism

$$F = qvB \sin \theta$$

$$r = \frac{mv}{qB}$$

$$F_{\text{wire}} = ILB \sin \theta$$

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

Magnetic dipole

$$\mu = NIA$$

$$F_{12} = \frac{\mu_0 I_1 I_2 L}{2\pi r}$$

$$B_{\text{sol}} = \mu_0 nI$$

$$\tau_{\text{loop}} = N IAB \sin \varphi$$

$$\tau_{\text{dip}} = \mu B \sin \varphi$$

$$U_{\text{dip}} = \mu B \cos \varphi$$

Right-hand Rule (RHR)

Find the force on a moving positive charge:

1. Fingers point along the velocity direction
2. Curl fingers toward the magnetic field
3. Magnetic force points in the direction of your thumb

Find the direction of a magnetic field due to a current:

1. Thumb points along the (positive) current
2. The curl of your fingers shows the orientation of the magnetic field around the current

Electromagnetic Induction

$$\mathcal{E} = -\frac{N\Delta\Phi}{\Delta t}$$

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}$$

$$|\mathcal{E}_{\text{bar}}| = BLv$$

$$I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}}$$

$$\Phi = BA\cos\varphi$$

$$\frac{V_p}{V_s} = \frac{I_s}{I_p} = \frac{N_p}{N_s}$$

$$\begin{aligned}\mathcal{E}_{\text{gen}} &= \mathcal{E}_{\text{max}}\sin\omega t \\ &= \omega NAB\sin\omega t\end{aligned}$$

$$\omega = 2\pi f$$

Electromagnetic Waves

$$\lambda = \frac{c}{f}$$

$$S = I = \bar{u}c = \frac{P}{A}$$

$$E = cB$$

$$f_0 = f_e \sqrt{\frac{1 + \frac{v_{\text{rel}}}{c}}{1 - \frac{v_{\text{rel}}}{c}}} \approx f_e \left(1 + \frac{v_{\text{rel}}}{c}\right)$$

$$u_E = \frac{1}{2}\epsilon_0 E^2$$

$$u_B = \frac{1}{2\mu_0} B^2$$

$$I = I_0 \cos^2 \theta$$

$$\bar{u} = \frac{1}{2}\epsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0} B_{\text{rms}}^2$$

$$= \epsilon_0 E_{\text{rms}}^2 = \frac{1}{\mu_0} B_{\text{rms}}^2$$

Reflection and Refraction

$$\theta_r = \theta_i$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$f = \pm \frac{R}{2}$$

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

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

$$v = \frac{c}{n}$$

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$M = \frac{\theta'}{\theta} \approx \frac{d_{\text{near}}}{f}$$

Compound Microscope:

$$m_{\text{obj}} = \frac{L_{\text{tube}}}{f_{\text{obj}}}$$

$$M_{\text{eye}} = \frac{d_{\text{near}}}{f_{\text{eye}}}$$

$$M_{\text{tot}} = M_{\text{eye}} m_{\text{obj}}$$

Interference and Diffraction**Double-slit Interference:**

$$d \sin \theta = m \lambda$$

$$d \sin \theta = \left(m + \frac{1}{2}\right) \lambda$$

$$m = 0, \pm 1, \pm 2, \dots$$

Single-slit Diffraction:

$$a \sin \theta = m \lambda \quad m = 0, \pm 1, \pm 2, \dots$$

Circular Aperture:

$$D \sin \theta \approx 1.22$$

Constants and Unit Conversion

$$g = 9.8 \text{ m/s}^2$$

$$e = 1.60 \times 10^{-19} \text{ C}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{\text{C}^2}{\text{Nm}^2}$$

$$k \equiv \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2}$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{\text{m}}{\text{A}}$$

$$c = \frac{1}{\sqrt{\epsilon_0\mu_0}} = 3 \times 10^8 \text{ m/s}$$

$$h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$$

$$hc = 1240 \text{ eV} \cdot \text{nm}$$

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$$

$$m_{\text{proton}} = 1.673 \times 10^{-27} \text{ kg}$$

$$= 938 \text{ MeV}/c^2$$

$$m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg}$$

$$= 511 \text{ keV}/c^2$$

$$m_{\text{neutron}} = 1.675 \times 10^{-27} \text{ kg}$$

$$= 939.5 \text{ MeV}/c^2$$

SI Prefixes

Power	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	K
10^0		
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p