Kinematics and Mechanics

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

$v = v_0 + at$

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

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

$F = ma$

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

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

$p = mv$

$W_F = Fd\cos\theta$

$P = Fv\cos\theta$

Electrostatics

$F_{12} = k\frac{q_1 q_2}{r^2}$ $E = \frac{F}{q_0}$

$U_{12} = k\frac{q_1 q_2}{r}$ $V \equiv \frac{U}{q_0}$

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

Gauss' Law

$\Phi_E = EA_S = \frac{q_{\text{enc}}}{\epsilon_0}$

Point Charge

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

Electric Dipole

$p = qd$

$\tau_{\text{dip}} = pE\sin\theta$

$U_{\text{dip}} = -pE\cos\varphi$

Resistance

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

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

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

$R_S = R_1 + R_2 + \cdots$

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

Capacitance

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

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

$V = Ed$

Parallel Plate Capacitor

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

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

$C_P = C_1 + C_2 + \cdots$

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

Circuits

$\Sigma \Delta V = 0$

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

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

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

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

$\tau = RC$

Magnetism

$F = qvB\sin\theta$

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

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

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

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

Magnetic dipole: $\mu = NIA$

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

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

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

$B_{\text{sol}} = \mu_0 n I$

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

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

$\Phi = BA\cos\varphi$

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

$\mathcal{E}_{\text{gen}} = \mathcal{E}_{\max}\sin\omega t = \omega NAB\sin\omega t$

$\omega = 2\pi f$

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

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

$\frac{V_{\text{p}}}{V_s} = \frac{I_{\text{s}}}{I_p} = \frac{N_{\text{p}}}{N_{\text{s}}}$

Electromagnetic Waves

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

$E = cB$

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

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

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

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

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

$f_0 = f_e\sqrt{\frac{1+\frac{v_{\text{rel}}}{c}}{1-\frac{v_{\text{rel}}}{c}}} \approx f_e\left(1 + \frac{v_{\text{rel}}}{c}\right)$ $I = I_0\cos^2\theta$

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:

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

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

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

Interference and Diffraction

Double-slit Interference:

$d\sin\theta = m\lambda$

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

$m = 0, \pm1, \pm2, \ldots$

Single-slit Diffraction:

$a\sin\theta = m\lambda \quad m = 0, \pm1, \pm2, \ldots$

Circular Aperture:

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

Constants and Unit Conversion

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

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

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

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

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

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

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

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

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

$m_{\text{proton}} = 1.673 \times 10^{-27}\text{kg}$
$= 938\ \text{MeV/c}^2$

$m_{\text{electron}} = 9.11 \times 10^{-31}\text{kg}$
$= 511\ \frac{\text{keV}}{\text{c}^2}$

$m_{\text{neutron}} = 1.675 \times 10^{-27}\text{kg}$
$= 939.5\ \text{MeV/c}^2$

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