

### Chapter 19: Electric Charges, Forces, and Fields

- $F = k \frac{|q_1||q_2|}{r^2}$
- $\vec{F} = q\vec{E}$
- $\Phi = \frac{Q_{encl}}{\epsilon_0}$
- $E = k \frac{|q|}{r^2}$
- $\Phi = EA \cos \theta$

### Chapter 20: Electric Potential and Electric Potential Energy

- $V = \frac{U}{q_0}$
- $E_x = -\frac{\Delta V}{\Delta x}, E_y = -\frac{\Delta V}{\Delta y}, E_z = -\frac{\Delta V}{\Delta z}$
- $V = k \frac{q}{r}$
- $U = k \frac{q_1 q_2}{r}$
- $Q = CV$
- $C = \kappa \epsilon_0 \frac{A}{d}$  (parallel-plate capacitor)
- $U = \frac{1}{2} CV^2 = \frac{Q^2}{2C} = \frac{1}{2} QV$
- $u_E = \frac{1}{2} \epsilon_0 E^2$  (energy density)

### Chapter 21: Electric Current and Direct-Current Circuits

- $I_{av} = \frac{\Delta Q}{\Delta t}$
- $P_{av} = \frac{\Delta U}{\Delta t}$
- $V = IR$
- $R = \rho \frac{L}{A}$
- $I = \lim_{\Delta t \rightarrow 0} \frac{\Delta Q}{\Delta t}$
- $P = IV$
- $P = I^2 R = \frac{V^2}{R}$  (for resistor)

#### Resistors and Capacitors in Series and Parallel

- Series:  $R_{eq} = R_1 + R_2 + \dots + R_N$
- Series:  $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_N}$
- Parallel:  $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}$
- Parallel:  $C_{eq} = C_1 + C_2 + \dots + C_N$

#### RC Circuits

*Charging:*

- $q(t) = C\mathcal{E} \left( 1 - e^{-\frac{t}{RC}} \right)$
- $I(t) = \left( \frac{\mathcal{E}}{R} \right) e^{-\frac{t}{RC}}$

*Discharging:*

- $q(t) = Q_0 e^{-\frac{t}{RC}}$
- $I(t) = \frac{Q_0}{RC} e^{-\frac{t}{RC}}$

## Chapter 22: Magnetism

- $F = |q|vB \sin \theta$
- $r = \frac{mv}{|q|B}$  (uniform magnetic field)
- $B = \frac{\mu_0 I}{2\pi r}$  (long, straight wire)
- $F = ILB \sin \theta$
- $v = \frac{E}{B}$  (velocity selector)
- $\sum B_{\parallel} = \mu_0 I$
- $B = \mu_0 n I$  (inside ideal solenoid)
- $F = \frac{\mu_0 I_1 I_2 L}{2\pi d}$

## Chapter 23: Magnetic Flux and Faraday's Law of Induction

- $\Phi = BA \cos \theta$
- $\mathcal{E}_{av} = -N \frac{\Delta \Phi}{\Delta t}$

### Motional EMF

- $|\mathcal{E}| = B\ell v$
- $I = \frac{B\ell v}{R}$
- $F = \frac{B^2 \ell^2 v}{R}$
- $P = \frac{B^2 v^2 \ell^2}{R}$

### Inductance

- $|\mathcal{E}_{av}| = L \left| \frac{\Delta I}{\Delta t} \right|$
- $U = \frac{1}{2} LI^2$
- $L = \mu_0 n^2 A \ell = \mu_0 \left( \frac{N^2}{\ell} \right) A$  (solenoid)
- $u_B = \frac{B^2}{2\mu_0}$  (energy density)

### Transformers

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

### Chapter 24: AC Circuits

Root-mean-square Voltages and Currents	
• $I_{rms} = \frac{I_{max}}{\sqrt{2}}$	• $V_{rms} = \frac{V_{max}}{\sqrt{2}}$
• $P_{av} = I_{rms}^2 R = \frac{V_{rms}^2}{R}$ (average power dissipated in resistor)	
Capacitors in AC Circuits	
• $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$	• $V_{max} = I_{max} X_C$
• $V_{rms} = I_{rms} X_C$	
RC Circuits	
• $Z = \sqrt{R^2 + X_C^2}$	• $V_{max} = I_{max} Z$
• $V_{rms} = I_{rms} Z$	• $P_{av} = I_{rms} V_{rms} \cos \phi$
• $\phi = \tan^{-1}\left(\frac{X_C}{R}\right) = \cos^{-1}\left(\frac{R}{Z}\right)$ (phase angle by which voltage lags current)	
Inductors in AC Circuits	
• $X_L = \omega L = 2\pi fL$	• $V_{max} = I_{max} X_L$
• $V_{rms} = I_{rms} X_L$	
RL Circuits	
• $Z = \sqrt{R^2 + X_L^2}$	• $V_{max} = I_{max} Z$
• $V_{rms} = I_{rms} Z$	• $P_{av} = I_{rms} V_{rms} \cos \phi$
• $\phi = \tan^{-1}\left(\frac{X_L}{R}\right) = \cos^{-1}\left(\frac{R}{Z}\right)$ (phase angle by which voltage leads current)	
RLC Circuits and Resonance	
• $Z = \sqrt{R^2 + (X_L - X_C)^2}$	• $V_{max} = I_{max} Z$
• $V_{rms} = I_{rms} Z$	• $P_{av} = I_{rms} V_{rms} \cos \phi$
• $\omega_0 = \frac{1}{\sqrt{LC}}$	• $f_0 = \frac{1}{2\pi\sqrt{LC}}$
• $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \cos^{-1}\left(\frac{R}{Z}\right)$ (phase angle by which voltage leads current)	

## Chapter 25: Electromagnetic Waves

### Propagation of Electromagnetic Waves & The Electromagnetic Spectrum

- $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$
- $v = \lambda f$

### Energy in Electromagnetic Waves

- $u_E = \frac{1}{2} \epsilon_0 E^2$
- $u_B = \left( \frac{1}{2\mu_0} \right) B^2$
- $u_{total} = u_E + u_B = \epsilon_0 E^2$
- $E = cB$
- $I_{av} = \frac{\Delta U}{A \Delta t}$
- $P_{av} = \frac{\Delta U}{\Delta t}$
- $I = \frac{P}{A}$
- $I = c \epsilon_0 E^2$

### Polarization

- $I_{trans} = I_0 \cos^2 \theta$  (Law of Malus)
- $I_{trans} = \frac{1}{2} I_0$  (for *unpolarized* light hitting a polarizer)

## Chapter 26: Geometrical Optics

### Reflection of Light & Spherical Mirrors

- $\theta_r = \theta_i$  (Law of Reflection)
- $f = \pm \frac{1}{2} R$
- $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$  (Mirror Equation)
- $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$  (magnification)

### Refraction of Light

- $v = \frac{c}{n}$
- $n_1 \sin \theta_1 = n_2 \sin \theta_2$  (Snell's law)

### Thin Lenses

- $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$  (Thin-lens Equation)
- $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$  (magnification)

## Chapter 28: Physical Optics

### Superposition and Interference

- $\ell_2 - \ell_1 = m\lambda$ ,  $m = 0, \pm 1, \pm 2, \dots$  (condition for constructive interference)
- $\ell_2 - \ell_1 = \left(m - \frac{1}{2}\right)\lambda$ ,  $m = 0, \pm 1, \pm 2, \dots$  (condition for destructive interference)

### Young's Double-Slit Experiment

- $d \sin \theta = m\lambda$ ,  $m = 0, \pm 1, \pm 2, \dots$  (constructive interference)
- $d \sin \theta = \left(m - \frac{1}{2}\right)\lambda$ ,  $m = 0, \pm 1, \pm 2, \dots$  (destructive interference)
- small-angle approximation:  
 $\tan \theta \approx \sin \theta \approx \theta$ 
  - $y = L \tan \theta$

### Diffraction

- $W \sin \theta = m\lambda$ ,  $m = \pm 1, \pm 2, \dots$  (destructive interference – single-slit diffraction)
- $d \sin \theta = m\lambda$ ,  $m = 0, \pm 1, \pm 2, \dots$  (constructive interference – diffraction grating)

## Modern Physics

- $E = hf$
- $K_{\max} = hf - W_0$
- $\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos \theta)$
- $L = L_0 \sqrt{1 - v^2/c^2}$
- $E_n = nhf$ ,  $n = 0, 1, 2, 3, \dots$
- $f_0 = \frac{W_0}{h}$  (cutoff frequency)
- $\Delta t = \frac{\Delta t_0}{\sqrt{1 - v^2/c^2}}$

### Physical Constants

- $k = 9.00 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$   $\left(k = \frac{1}{4\pi\epsilon_0}\right)$
- $\epsilon_0 = 8.85 \times 10^{-12} \frac{\text{C}^2}{\text{N} \cdot \text{m}^2}$
- $\mu_0 = 4\pi \times 10^{-7} \frac{\text{T} \cdot \text{m}}{\text{A}}$
- $e = 1.60 \times 10^{-19} \text{ C}$  (magnitude of charge on electron)
- $m_e = 9.11 \times 10^{-31} \text{ kg}$  (mass of electron)
- $m_p = 1.673 \times 10^{-27} \text{ kg}$  (mass of proton)
- $m_n = 1.675 \times 10^{-27} \text{ kg}$  (mass of neutron)
- $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$
- $c = 3.00 \times 10^8 \text{ m/s}$  (speed of light in vacuum)
- $h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$  (Planck's constant)

▪ Areas & Volumes

- Circumference of a circle, radius  $r$ :  $C = 2\pi r$
- Area of a circle, radius  $r$ :  $A = \pi r^2$
- Surface area of sphere, radius  $r$ :  $A = 4\pi r^2$
- Volume of sphere, radius  $r$ :  $V = \frac{4}{3}\pi r^3$
- Area of lateral surface of a right circular cylinder, radius  $r$ , length  $\ell$ :  $A = 2\pi r\ell$
- Volume of right circular cylinder, radius  $r$ , length  $\ell$ :  $V = \pi r^2\ell$

▪ Trigonometric Identities

- $\sin(A + B) = \sin A \cos B + \cos A \sin B$
- $\sin(\omega t + 90^\circ) = \cos \omega t$