

## Final Exam Equation Sheet

### Sound:

$$v = 331 \text{ m/s} \sqrt{\frac{T(\text{K})}{273 \text{ K}}} \quad f_O = f_S \left( \frac{v + v_O}{v - v_S} \right)$$

$$v = \sqrt{\frac{F}{\mu}} \quad v = \sqrt{\frac{B}{\rho}}$$

$$f_n = \frac{nv}{2L} \quad n = 1, 2, 3, \dots \quad f_n = \frac{nv}{4L} \quad n = 1, 3, 5, \dots$$

$$I = \frac{P}{A} \quad \beta \equiv 10 \log \left( \frac{I}{I_0} \right) \quad f_b = |f_2 - f_1|$$

### Electric Forces and Fields:

$$|F| = k_e \frac{|q_1||q_2|}{r_{12}^2} \quad |E| = k_e \frac{|q|}{r^2} \quad \vec{E} \equiv \frac{\vec{F}}{q_0}$$

$$EA = \Phi_E = \frac{Q_{\text{inside}}}{\epsilon_0}$$

### Electrical Energy and Capacitance:

$$\Delta PE = -W_{AB} = -qE_x \Delta x$$

$$\Delta V = V_B - V_A = \frac{\Delta PE}{q} \quad \Delta V = -E_x \Delta x$$

$$V = k_e \frac{q}{r} \quad PE = k_e \frac{q_1 q_2}{r}$$

$$C \equiv \frac{Q}{\Delta V} \quad C = \epsilon_0 \frac{A}{d} \quad C = \kappa \epsilon_0 \frac{A}{d}$$

$$PE_C = \frac{1}{2} Q \Delta V = \frac{1}{2} C (\Delta V)^2 = \frac{Q^2}{2C}$$

$$C_{\text{parallel}} = C_1 + C_2 + C_3 + \dots$$

$$\frac{1}{C_{\text{series}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

### Current and Resistance:

$$I_{\text{av}} \equiv \frac{\Delta Q}{\Delta t} \quad I = \lim_{\Delta t \rightarrow 0} I_{\text{av}} \quad I = nqv_d A$$

$$R \equiv \frac{V}{I} \quad \Delta V = IR \quad R = \rho \frac{\ell}{A}$$

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

### Direct-Current Circuits:

$$\Delta V = \varepsilon - Ir \quad P = \varepsilon I$$

$$R_{\text{series}} = R_1 + R_2 + R_3 + \dots$$

$$\frac{1}{R_{\text{parallel}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

$$\Sigma I_{\text{in}} = \Sigma I_{\text{out}} \quad \Sigma V_{\text{closed loop}} = 0$$

$$q = Q \left( 1 - e^{-t/RC} \right) \quad q = Q e^{-t/RC} \quad \tau = RC$$

### Magnetism:

$$F = qvB \sin \theta \quad F = BI \ell \sin \theta \quad \tau = BIAN \sin \theta$$

$$B = \frac{\mu_0 I}{2\pi r} \text{ (long straight wire)} \quad B = N \frac{\mu_0 I}{2R} \text{ (flat loop)}$$

$$B = \mu_0 n I \quad n = \frac{N}{L} \text{ (solenoid)}$$

$$r = \frac{mv}{qB} \quad \sum B_{\parallel} \Delta \ell = \mu_0 I \quad \frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

### Induced Voltages and Inductance:

$$\Phi_B \equiv BA \cos \theta \quad \varepsilon = -N \frac{\Delta \Phi_B}{\Delta t}$$

$$|\varepsilon| = Blv \quad \varepsilon = NBA \omega \sin \omega t$$

$$\varepsilon \equiv -L \frac{\Delta I}{\Delta t} \quad L = \frac{N \Phi_B}{I} \quad L = \frac{\mu_0 N^2 A}{\ell}$$

$$I = \frac{\varepsilon}{R} \left( 1 - e^{-t/\tau} \right) \quad \tau = \frac{L}{R} \quad PE_L = \frac{1}{2} LI^2$$

### Alternating-Current Circuits:

$$A_{\text{rms}} = \frac{A}{\sqrt{2}} \quad \omega = 2\pi f \quad X_C = \frac{1}{\omega C} \quad X_L = \omega L$$

$$\Delta V_{R,\text{rms}} = I_{\text{rms}} R \quad \Delta V_{C,\text{rms}} = I_{\text{rms}} X_C \quad \Delta V_{L,\text{rms}} = I_{\text{rms}} X_L$$

$$Z \equiv \sqrt{R^2 + (X_L - X_C)^2} \quad \tan \phi = \frac{X_L - X_C}{R}$$

$$\Delta V_{\text{max}} = \sqrt{\Delta V_R^2 + (\Delta V_L - \Delta V_C)^2} \quad \Delta V_{\text{max}} = I_{\text{max}} Z$$

$$P_{\text{av}} = I_{\text{rms}} \Delta V_{\text{rms}} \cos \phi \quad f_0 = \frac{1}{2\pi \sqrt{LC}}$$

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{Z} = \frac{\Delta V_{\text{rms}}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$\Delta V_2 = \frac{N_2}{N_1} \Delta V_1$$

### Electromagnetic Waves:

$$\frac{E}{B} = c \quad c = f \lambda \quad f_O \approx f_S \left( 1 \pm \frac{u}{c} \right)$$

$$I = \frac{E_{\text{max}} B_{\text{max}}}{2\mu_0} = \frac{E_{\text{max}}^2}{2\mu_0 c} = \frac{c B_{\text{max}}^2}{2\mu_0}$$

$$\text{(absorption)} \quad \frac{U}{c} \leq p \leq \frac{2U}{c} \quad \text{(reflection)}$$

### Reflection and Refraction of Light:

$$E = hf \quad \theta'_1 = \theta_1 \quad n = \frac{c}{v} \quad n = \frac{\lambda_0}{\lambda_n}$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad \sin \theta_c = \frac{n_2}{n_1} \text{ for } n_1 > n_2$$

**Mirrors and Lenses:**

$$M = \frac{h'}{h} = -\frac{q}{p} \quad \frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{f} = \frac{2}{R} \quad \frac{1}{f} = (n-1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R} \quad M = \frac{h'}{h} = -\frac{n_1 q}{n_2 p}$$

**Wave Optics:**

$$d \sin \theta_{\text{bright}} = m\lambda \quad m = 0, \pm 1, \pm 2, \dots$$

$$d \sin \theta_{\text{dark}} = (m + \frac{1}{2})\lambda \quad m = 0, \pm 1, \pm 2, \dots$$

$$y_{\text{bright}} = \frac{\lambda L}{d} m \quad \lambda_n = \frac{\lambda}{n}$$

$$2nt = (m + \frac{1}{2})\lambda \quad 2nt = m\lambda \quad m = 0, 1, 2, \dots$$

$$\sin \theta_{\text{dark}} = m \frac{\lambda}{a} \quad m = \pm 1, \pm 2, \pm 3, \dots$$

$$I = I_0 \cos^2 \theta \quad n = \tan \theta_p$$

**Relativity:**

$$\Delta t = \frac{\Delta t_p}{\sqrt{1 - v^2/c^2}} \quad L = L_p \sqrt{1 - v^2/c^2}$$

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

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

**Quantum Physics:**

$$\lambda_{\text{max}} T = 0.2898 \times 10^{-2} \text{ m} \cdot \text{K} \quad E_n = nhf$$

$$KE_{\text{max}} = hf - \phi$$

$$\lambda_{\text{min}} = \frac{hc}{e\Delta V} \quad 2d \sin \theta = m\lambda \quad m = 1, 2, 3, \dots$$

$$\Delta\lambda = \lambda - \lambda_0 = \frac{h}{m_e c} (1 - \cos \theta)$$

$$\lambda = \frac{h}{p} = \frac{h}{mv} \quad E = hf$$

$$\Delta x \Delta p \geq \frac{h}{4\pi} \quad \Delta E \Delta t \geq \frac{h}{4\pi}$$

**Atomic Physics:**

$$mvr = n\hbar \quad \hbar = \frac{h}{2\pi}$$

$$r_n = \frac{n^2 \hbar^2}{mk_e e^2} \quad E_n = -\frac{m_e k_e^2 e^4}{2\hbar^2} \left( \frac{1}{n^2} \right) \quad n = 1, 2, 3, \dots$$

$$r_n = n^2 a_0 \quad E_n = -E_1 \left( \frac{1}{n^2} \right) \quad hf = |\Delta E|$$

$$a_0 = 0.529 \times 10^{-10} \text{ m} \quad E_1 = 13.6 \text{ eV}$$

**Nuclear Physics:**

$$\Delta m = (\Sigma m_{\text{particles}}) - m_{\text{system}} \quad r = r_0 A^{1/3}$$

$$r_0 = 1.2 \times 10^{-15} \text{ m} = 1.2 \text{ fm}$$

$$R = \left| \frac{\Delta N}{\Delta t} \right| = \lambda N \quad N = N_0 e^{-\lambda t} \quad T_{1/2} = \frac{\ln 2}{\lambda}$$

$$\text{Dose in rem} = \text{Dose in rad} \times \text{RBE}$$

$$KE_{\text{min}} = \left( 1 + \frac{m}{M} \right) |Q| \quad Q = c^2 \Delta m$$