Physics 251 Formula Sheet Exam 3

Electric Fields

$$\vec{F} = q\vec{E}$$
$$\Delta U = q\Delta V$$
$$W_{a\to b} = -\Delta U$$
$$V_{ab} = \int_a^b \vec{E}\cdot d\vec{l}$$
$$\vec{E} = -\nabla V$$

Point Charges

$$\vec{E} = \frac{q}{4\pi\epsilon_0 r^2}\hat{r}$$
$$V = \frac{q}{4\pi\epsilon_0 r}$$
$$\vec{F} = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}\hat{r}$$
$$U = \frac{q_1 q_2}{4\pi\epsilon_0 r}$$

Collection of Charges

$$\vec{E}_T = \sum_i \vec{E}_i$$
$$U_T = \sum_{pairs} U_{ij}$$

Distributed Charges

$$\vec{E} = \int \frac{dq}{4\pi\epsilon_0 r^2}\hat{r}$$
$$V = \int \frac{dq}{4\pi\epsilon_0 r}$$

Dipoles

$$\vec{p} = q\vec{d}$$
$$\vec{\tau} = \vec{p}\times\vec{E}$$
$$U = -\vec{p}\cdot\vec{E}$$
$$\vec{\mu} = I\vec{A}$$
$$\vec{\tau} = \vec{\mu}\times\vec{B}$$
$$U = -\vec{\mu}\cdot\vec{B}$$

"Elementary" E fields

$$\vec{E} = \frac{Q}{4\pi\epsilon_0 r^2}\hat{r} \text{ sphere}$$
$$\vec{E} = \frac{\lambda}{2\pi\epsilon_0 r}\hat{r} \text{ line}$$
$$\vec{E} = \frac{\sigma}{2\epsilon_0}\hat{n} \text{ plane}$$

Flux & Gauss's Law

closed surfaces:

$$\Phi_E = \oint_S \vec{E}\cdot d\vec{A} = \frac{q_{encl}}{\epsilon_0}$$
$$\Phi_B = \oint_s \vec{B}\cdot d\vec{A} = 0$$

open surfaces:

$$\Phi_E = \int \vec{E}\cdot d\vec{A}$$
$$\Phi_B = \int \vec{B}\cdot d\vec{A}$$

Capacitors

$$C = \frac{Q}{V}$$
$$C_{eq} = \sum_i C_i \text{ parallel}$$
$$\frac{1}{C_{eq}} = \sum_i \frac{1}{C_i} \text{ series}$$
$$C = \epsilon_0\frac{A}{d} \quad \parallel\text{-plate}$$
$$U = \frac{1}{2}CV^2$$
$$u = \frac{1}{2}\epsilon_0 E^2$$

Current

$$I = \frac{dq}{dt}$$
$$I = \int \vec{J}\cdot d\vec{A}$$
$$J = nqv_d$$

Ohm's Law & Power

$$\vec{E} = \rho\vec{J}$$
$$R = \int \rho\frac{dL}{A}$$
$$V = IR$$
$$P = IV$$

Resistors

$$R_{eq} = \sum_i R_i \text{ series}$$
$$\frac{1}{R_{eq}} = \sum_i \frac{1}{R_i} \text{ parallel}$$

Kirchoff's Rules

$$\sum_{loop} V = 0$$
$$\sum_{node} I = 0$$

Magnetic Fields

$$\vec{F} = q\vec{v}\times\vec{B}$$
$$\vec{F} = \int I d\vec{l}\times\vec{B}$$
$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$$
$$\vec{B} = \int \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$$

Cyclotron Motion

$$R = \frac{mv}{qB}$$
$$T = \frac{2\pi m}{qB}$$
$$\omega_c = \frac{qB}{m}$$

Ampere's Law

$$\oint \vec{B}\cdot d\vec{\ell} = \mu_0(I_c + I_d)_{encl}$$
$$I_d = \epsilon_0\frac{d\Phi_E}{dt}$$

Faraday's Law

$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$
$$\mathcal{E} = \oint \vec{E}\cdot d\vec{\ell}$$
$$\mathcal{E} = \oint (\vec{v}\times\vec{B})\cdot d\vec{\ell}$$

Inductance

$$M = \frac{N_1\Phi_1}{I_2} = \frac{N_2\Phi_2}{I_1}$$
$$\mathcal{E}_1 = -M\frac{dI_2}{dt}$$
$$\mathcal{E}_2 = -M\frac{dI_1}{dt}$$
$$L = \frac{N\Phi}{I}$$
$$\mathcal{E} = -L\frac{dI}{dt}$$
$$U = \frac{1}{2}LI^2$$
$$u = \frac{B^2}{2\mu_0}$$

RC circuits

$$\tau = RC$$
charging
$$Q = Q_f\left(1 - e^{-\frac{t}{\tau}}\right)$$
discharging
$$Q = Q_0 e^{-\frac{t}{\tau}}$$

RL circuits

$$\tau = \frac{L}{R}$$
charging
$$I = I_f\left(1 - e^{-\frac{t}{\tau}}\right)$$
$$V_L = V_0 e^{-\frac{t}{\tau}}$$
discharging
$$I = I_0 e^{-\frac{t}{\tau}}$$
$$V_L = V_0 e^{-\frac{t}{\tau}}$$

LC circuits

$$Q = Q_0 \cos(\omega t + \varphi)$$
$$\omega = \frac{1}{\sqrt{LC}}$$

LRC series circuits

$$Q = Q_0 e^{-\frac{t}{\tau}} \cos(\omega t + \varphi)$$
$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$
$$\tau = \frac{2L}{R}$$

LRC series circuits

$$Q = Q_0 e^{-\frac{t}{\tau}} \cos(\omega t + \varphi)$$
$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$
$$\tau = \frac{2L}{R}$$

AC circuits

$$V(t) = V_0 \cos(\omega t + \varphi)$$
$$X_L = \omega L$$
$$X_C = \frac{1}{\omega C}$$
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$\tan\varphi = \frac{X_L - X_C}{R}$$
$$V_0 = I_0 Z$$
$$V_{rms} = \frac{V_0}{\sqrt{2}}$$
$$I_{rms} = \frac{I_0}{\sqrt{2}}$$
$$V_L = I_0 X_L$$
$$V_C = I_0 X_C$$
$$V_R = I_0 R$$
$$P_{av} = I_{rms}^2 R$$
$$P_{av} = \frac{1}{2} I_0^2 Z \cos\varphi$$

Light

$$E_{max} = cB_{max}$$
$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$
$$c = \lambda f$$
$$f = \frac{\omega}{2\pi}$$
$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$
$$\mathcal{I} = S_{av} = \frac{E_{max}B_{max}}{2\mu_0}$$
$$p_{rad}^{abs} = \frac{\mathcal{I}}{c}$$
$$p_{rad}^{ref} = \frac{2\mathcal{I}}{c}$$

Light Propagation

$$n = \frac{c}{v}$$
$$\lambda = \frac{\lambda_0}{n}$$
$$n_a \sin\theta_a = n_b \sin\theta_b$$
$$\sin\theta_c = \frac{n_b}{n_a}(TIR)$$
$$\mathcal{I} = \mathcal{I}_0 \cos^2\phi$$
$$\tan\theta_p = \frac{n_b}{n_a}$$

Mirrors & Lenses

$$f = \frac{R}{2}$$
$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$
$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$m = \frac{y'}{y} = -\frac{s'}{s}$$

Interference & Diffraction

$$(m = 0, \pm 1, \pm 2, ...)$$
$$d\sin\theta = m\lambda \text{ constr.}$$
$$d\sin\theta = (m + \frac{1}{2})\lambda \text{ destr.}$$

$$y_m = R\frac{m\lambda}{d}$$
$$\mathcal{I} = \mathcal{I}_0 \cos^2\frac{\phi}{2}$$
$$\phi = \frac{2\pi}{\lambda} r_2 - r_1$$
$$2t = m\lambda$$
$$(m' = \pm 1, \pm 2, ...)$$
$$a\sin\theta = m'\lambda$$
$$\mathcal{I} = \mathcal{I}_0\left(\frac{\sin\beta/2}{\beta/2}\right)^2$$
$$\beta = \frac{2\pi}{\lambda} a(\sin\theta)$$
$$d\sin\theta = m\lambda \text{ grating}$$