Equations for Physics 122 Midterm 1:

Constants:

$$k = \tfrac{1}{4\pi\epsilon_0},$$
$$k = 8.99 \times 10^9 \ \tfrac{\mathrm{N{\cdot}m^2}}{\mathrm{C^2}},$$
$$\epsilon_0 = \tfrac{1}{4\pi k},$$
$$\epsilon_0 = 8.85 \times 10^{-12} \tfrac{\mathrm{C^2}}{\mathrm{N{\cdot}m^2}},$$
$$e = 1.60 \times 10^{-19}\ \mathrm{C},$$
$$m_e = 9.1 \times 10^{-31}\ \mathrm{kg}$$

Charge densities & dipole moment:

$$\sigma = \tfrac{Q}{A},$$
$$\lambda = \tfrac{Q}{L},$$
$$\rho = \tfrac{Q}{v},$$
$$\vec{p} = q\vec{L}$$

Force and torque:

$$\vec{F} = q\vec{E},$$
$$\vec{\tau} = \vec{p} \times \vec{E},$$
$$\vec{F} = \vec{p} \cdot \vec{\nabla}\vec{E},$$

Electric Field:

$$\vec{E}(\vec{r}) = -\vec{\nabla}V(\vec{r}),$$
$$\vec{E}(\vec{r}) = \frac{q\hat{r}}{4\pi\epsilon_0 r^2},$$
$$\vec{E}(\vec{r}) = \sum_i \frac{q_i\hat{r}_i}{4\pi\epsilon_0 r_i^2},$$
$$\vec{E}(\vec{r}) = \int dq_{\vec{r}\,'} \frac{\vec{r} - \vec{r}\,'}{4\pi\epsilon_0|\vec{r} - \vec{r}\,'|^3},$$
$$\vec{E}(\vec{r}) = \frac{\lambda\,\hat{r}}{2\pi\epsilon_0 r},$$
$$\vec{E}(\vec{r}) = \frac{\sigma\,\hat{n}}{2\epsilon_0},$$
$$\vec{E}(\vec{r}) = \frac{\sigma\,\hat{n}}{\epsilon_0},$$
$$\vec{E}(\vec{r}) = \frac{1}{4\pi\epsilon_0 r^3}\left[3(\hat{r}\cdot\vec{p})\hat{r} - \vec{p}\right],$$

Electric flux and Gauss Law:

$$\Phi_{\mathcal{M}} \equiv \oint_{\mathcal{M}} d^2A\,\hat{n}\cdot\vec{E}(\vec{r}),$$
$$= \frac{Q_{\text{ins}}}{\epsilon_0},$$
$$\vec{\nabla}\cdot\vec{E} = \frac{\rho}{\epsilon_0},$$

Electric Potential:

$$V(\vec{r}) = -\int_\infty^{\vec{r}} \mathrm{d}\vec{\ell}\,' \cdot \vec{E}(\vec{r}\,'),$$
$$V(\vec{r}) = \frac{q}{4\pi\epsilon_0 r},$$
$$V(\vec{r}) = \sum_i \frac{q_i}{4\pi\epsilon_0 r_i},$$
$$V(\vec{r}) = \int dq_{\vec{r}\,'} \frac{1}{4\pi\epsilon_0|\vec{r} - \vec{r}\,'|},$$
$$V(\vec{r}) = -\frac{\lambda}{2\pi\epsilon_0}\log r,$$
$$V(\vec{r}) = \frac{\vec{p}\cdot\hat{r}}{4\pi\epsilon_0 r^2}$$

Energy and work:

$$\mathrm{d}U = \mathrm{d}Q\,V,$$
$$dW = \mathrm{d}\vec{\ell}\cdot\vec{F},$$
$$W = -\Delta U,$$
$$U = \tfrac{1}{2}\sum_{i\neq j} \tfrac{q_i q_j}{4\pi\epsilon_0 r_{ij}},$$
$$U = -\vec{p}\cdot\vec{E},$$
$$K = \tfrac{1}{2}mv^2,$$

Capacitance:

$$Q = CV,$$
$$C = \tfrac{\epsilon_0 A}{\ell},$$
$$C = \tfrac{4\pi\epsilon_0 R_1 R_2}{R_2 - R_1},$$
$$C = \tfrac{2\pi\epsilon_0 L}{\log\frac{R_2}{R1}},$$
$$U = \tfrac{1}{2}CV^2 = \tfrac{1}{2}QV = \tfrac{1}{2C}Q^2,$$
$$C_{\text{eq}} = C_1 + C_2,$$
$$C_{\text{eq}}^{-1} = C_1^{-1} + C_2^{-1},$$

Energy density:

$$u = \tfrac{1}{2}\epsilon_0 E^2,$$

Differential geometry:

$$\vec{\nabla} \equiv \hat{x}\frac{\partial}{\partial x} + \hat{y}\frac{\partial}{\partial y} + \hat{z}\frac{\partial}{\partial z},$$
$$\equiv \hat{r}\frac{\partial}{\partial r} + \hat{\theta}\frac{1}{r}\frac{\partial}{\partial y} + \hat{\phi}\frac{1}{r\sin\theta}\frac{\partial}{\partial\phi},$$
$$\equiv \hat{r}\frac{\partial}{\partial r} + \hat{\phi}\frac{1}{r}\frac{\partial}{\partial y} + \hat{z}\frac{\partial}{\partial z},$$

$$\mathrm{d}\vec{\ell} = \hat{x}\,\mathrm{d}x + \hat{y}\,\mathrm{d}y + \hat{z}\,\mathrm{d}z,$$
$$\mathrm{d}\vec{\ell} = \hat{r}\,\mathrm{d}r + \hat{\theta}\,r\mathrm{d}\theta + \hat{\phi}\,r\,\sin\theta\,\mathrm{d}\phi,$$
$$\mathrm{d}\vec{\ell} = \hat{r}\,\mathrm{d}r + \hat{\phi}\,r\mathrm{d}\phi + \hat{z}\,\mathrm{d}z,$$
$$\mathrm{d}^2A = r^2\sin\theta\,\mathrm{d}\theta\,\mathrm{d}\phi,$$
$$\mathrm{d}^2A = r\,\mathrm{d}\theta\,\mathrm{d}z,$$
$$\mathrm{d}^3v = r^2\sin\theta\,\mathrm{d}r\,\mathrm{d}\theta\,\mathrm{d}\phi,$$
$$\mathrm{d}^3v = r\,\mathrm{d}r\,\mathrm{d}\theta\,\mathrm{d}z$$

Geometry:

$$A = 4\pi R^2,$$
$$v = \tfrac{4}{3}\pi R^3,$$
$$A = 2\pi RL,$$
$$v = \pi R^2 L$$

Quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Equations for Physics 122 Midterm 2+:

Constants:

$$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{N/A^2}, \quad \approx 1.26 \times 10^{-6}\ \mathrm{N/A^2}, \quad c \approx 3 \times 10^8\ \mathrm{m/s},$$

Force and torque:

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}), \quad \vec{F} = I\vec{L} \times \vec{B}, \quad \vec{\tau} = \vec{\mu} \times \vec{B},$$

Circular motion:

$$R_\circ = \frac{mv}{qB}$$

Current and resistance:

$$I = \tfrac{d}{dt}Q, \quad I = \int \mathrm{d}^2A\, \hat{n} \cdot \vec{\jmath}, \quad \vec{E} = \rho\vec{\jmath}, \quad V = IR, \quad P = I^2R = IV = V^2/R, \quad R = \rho L/A,$$

$$R_{||}^{-1} = \sum_i R_i^{-1}, \quad R_{\text{series}} = \sum_i R_i,$$

Kirchhoff Laws:

$$\sum_{\text{in}} I_i = \sum_{\text{out}} I_i, \quad 0 = \sum_{\text{loop}} \Delta V_i, \quad \Delta V = IR, \quad \Delta V = L\tfrac{d}{dt}I, \quad \Delta V = Q/C,$$

RC Circuits:

$$\tau = RC, \quad Q = Q_0\, e^{-t/\tau}, \quad Q = Q_\infty\, (1 - e^{-t/\tau}),$$

RL Circuits:

$$\tau = L/R, \quad I = I_0\, e^{-t/\tau}, \quad I = I_\infty\, (1 - e^{-t/\tau}),$$

Magnetic moment:

$$\vec{\mu} = -\tfrac{1}{2}\oint_{\partial\mathcal{M}} \mathrm{d}\vec{\ell} \times \vec{r}, \quad = IAN\hat{n}, \quad U = -\vec{\mu} \cdot \vec{B},$$

Faraday law & emf:

$$\mathcal{E} = \int \mathrm{d}\vec{\ell} \cdot (\vec{E} + \vec{v} \times \vec{B}), \quad \mathcal{E} = -\tfrac{d}{dt}\Phi_B, \quad \Phi_B = \int \mathrm{d}^2A\, \hat{n} \cdot \vec{B},$$

Biot-Savart & Ampere:

$$\mathrm{d}\vec{B} = \frac{\mu_0 I\, \mathrm{d}\vec{\ell} \times \hat{r}}{4\pi\, r^2}, \quad \oint \mathrm{d}\vec{\ell} \cdot \vec{B} = \mu_0 I_{\text{ins}},$$

B fields:

$$B = \tfrac{1}{2}\mu_0 nI, \quad B = \mu_0 nI, \quad \vec{B} = \frac{\mu_0 I}{2\pi R}\hat{\theta},$$

Energy and energy density:

$$U = \tfrac{1}{2}LI^2, \quad u_B = \tfrac{1}{2\mu_0}B^2,$$

Maxwell Eqns:

$$\oint \mathrm{d}^2A\, \hat{n} \cdot \vec{E} = Q/\epsilon_0,$$

$$\oint \mathrm{d}^2A\, \hat{n} \cdot \vec{B} = 0,$$

$$\oint_{\partial\mathcal{M}} \mathrm{d}\vec{\ell} \cdot \vec{B} = \mu_0 \left[I + \epsilon_0 \int_{\mathcal{M}} \mathrm{d}^2A\, \hat{n} \cdot \tfrac{\partial}{\partial t}\vec{E}\right],$$

$$\oint_{\partial\mathcal{M}} \mathrm{d}\vec{\ell} \cdot \vec{E} = -\int_{\mathcal{M}} \mathrm{d}^2A\, \hat{n} \cdot \tfrac{\partial}{\partial t}\vec{B},$$

Induction:

$$L = \Phi_B/I, \quad L = \mu_0\, n^2\, A\, \ell, \quad \mathcal{E} = -L\tfrac{d}{dt}I,$$

Geometry in cylindrical coordinates:

$$\hat{r} = \cos\theta\, \hat{x} + \sin\theta\, \hat{y}, \quad \hat{\theta} = -\sin\theta\, \hat{x} + \cos\theta\, \hat{y},$$

RLC circuits:

$$V(t) = V_0\, \cos(\omega t + \phi)\, e^{-\beta t}, \quad \beta = \tfrac{R}{2L}, \quad \omega^2 = \omega_0^2 - \beta^2, \quad \omega_0 = \tfrac{1}{\sqrt{LC}},$$

Driven RLC circuits:

$$\vec{\mathcal{E}}(t) = \mathcal{E}_m \cos\omega t\, \hat{x} + \mathcal{E}_m \sin\omega t\, \hat{y},$$

$$\vec{I}(t) = I_m \cos(\omega t - \phi)\, \hat{x} + I_m \sin(\omega t - \phi)\, \hat{y},$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}, \quad X_L = \omega L, \quad X_C = 1/\omega C, \quad \tan\phi = \tfrac{X_L - X_C}{R}, \quad V_m = ZI_m,$$

Transformers:

$$V_s/N_s = V_p/N_p, \quad I_sN_s = I_pN_p,$$

EM Waves:

$$ck = \omega, \quad k = \tfrac{2\pi}{\lambda}, \quad \omega = 2\pi\nu, \quad \mu_0\epsilon_0 = c^{-2},$$

$$\nabla^2\vec{E} = \mu_0\epsilon_0\partial_t^2\vec{E}, \quad \vec{E} = \vec{E}_0\, \cos(\vec{k} \cdot \vec{r} - \omega t), \quad \vec{B} = \vec{B}_0\, \cos(\vec{k} \cdot \vec{r} - \omega t),$$

$$\vec{B}_0 = \tfrac{1}{c}\tfrac{\vec{k}}{k} \times \vec{E}_0, \quad \vec{k} \cdot \vec{E}_0 = 0,$$