SP212 Spring 2023 Exam 3 Equation Sheet

Electric fields

$$F_{1\,\text{on}\,2} = \frac{K|q_1||q_2|}{r^2}$$

$$\vec{E} = K\frac{q}{r^2}\,\hat{r}$$

$$\vec{F}_{\text{on}\,q} = q\vec{E}$$

$$\vec{p} = q\vec{s}$$

$$\vec{E}_{\text{dipole}} \approx K\frac{2\vec{p}}{r^3} \text{ (on axis)}$$

$$\vec{E}_{\text{dipole}} \approx -K\frac{\vec{p}}{r^3} \text{ (bisecting plane)}$$

$$E_{\text{line}} = \frac{|\lambda|}{2\pi\epsilon_0 r}$$

$$E_{\text{plane}} = \frac{|\eta|}{2\epsilon_0}$$

$$E_{\text{capacitor}} = \frac{Q}{\epsilon_0 A}$$

$$\vec{\tau}_{\text{dipole}} = \vec{p} \times \vec{E}$$

$$\Phi_e = \int_{\text{surface}} \vec{E} \cdot d\vec{A}$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}$$

$$E_{\text{cond. surf.}} = \frac{|\eta|}{\epsilon_0}$$

Electric potential

$$U_{\text{elec}} = K\frac{q_1 q_2}{r}$$

$$U_{\text{dipole}} = -\vec{p} \cdot \vec{E}$$

$$U_{q+\text{sources}} = qV$$

$$V = K\frac{q}{r}$$

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$$

$$\vec{E} = -\left(\frac{\partial V}{\partial x}\hat{\imath} + \frac{\partial V}{\partial y}\hat{\jmath} + \frac{\partial V}{\partial z}\hat{k}\right)$$

$$Q = C(\Delta V_C)$$

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

$$\frac{1}{C_{\text{eq}}} = \sum_{i=1}^{n} \frac{1}{C_i} \quad \text{(series)}$$

$$C_{\text{eq}} = \sum_{i=1}^{n} C_i \quad \text{(parallel)}$$

$$U_C = \frac{Q^2}{2C} = \frac{1}{2} C (\Delta V_C)^2$$

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

Continuous charge distributions

$$\lambda = \frac{dQ}{ds}$$

$$\eta = \frac{dQ}{dA}$$

$$\rho = \frac{dQ}{dV}$$

$$d\vec{E} = K \frac{dQ}{r^2} \, \hat{r}$$

$$dV = K \frac{dQ}{r}$$

Current and resistance

$$I = \frac{Q}{\Delta t}$$

$$I = n_e e v_d A$$

$$v_d = \frac{e\tau}{m_e} E$$

$$J = \frac{I}{A}$$

$$J = \sigma E$$

$$\rho = \frac{1}{\sigma} = \frac{m_e}{n_e e^2 \tau}$$

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

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

Circuits

$$P_{\text{bat}} = I\mathcal{E}$$

$$P_R = I(\Delta V_R) = I^2 R = \frac{(\Delta V_R)^2}{R}$$

$$R_{\text{eq}} = \sum_{i=1}^{n} R_i \quad \text{(series)}$$

$$\frac{1}{R_{\text{eq}}} = \sum_{i=1}^{n} \frac{1}{R_i} \quad \text{(parallel)}$$

$$\tau_{\text{c}} = RC$$

$$Q_{\text{discharging}} = Q_0 e^{-t/\tau_{\text{c}}}$$

$$I = I_0 e^{-t/\tau_{\text{c}}}$$

$$Q_{\text{charging}} = C\mathcal{E}(1 - e^{-t/\tau_{\text{c}}})$$

Magnetism

$$\vec{B}_{\text{point charge}} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

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

$$B_{\text{coil center}} = \frac{\mu_0}{2} \frac{NI}{R}$$

$$\vec{m} = NI\vec{A}$$

$$\vec{B}_{\text{dipole}} \approx \frac{\mu_0}{4\pi} \frac{2\vec{m}}{r^3} \text{ (on axis)}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{through}}$$

$$B_{\text{solenoid}} = \frac{\mu_0 N I}{l} = \mu_0 n I$$

$$\vec{F}_{\text{on } q} = q\vec{v} \times \vec{B}$$

$$|q| v B = \frac{m v^2}{r}$$

$$f_{\text{cyc}} = \frac{|q| B}{2\pi m}$$

$$\vec{F}_{\text{wire}} = I\, \vec{l} \times \vec{B}$$

$$F_{\text{parallel wires}} = \frac{\mu_0 l I_1 I_2}{2\pi d}$$

$$\vec{\tau}_{\text{dipole}} = \vec{m} \times \vec{B}$$

Induction

$\mathcal{E} = vlB$

$$\Phi_m = \int_{\text{surface}} \vec{B} \cdot d\vec{A}$$

$$\mathcal{E} = \left| \frac{d\Phi_m}{dt} \right|$$

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_m}{dt}$$

$$L = \frac{\Phi_m}{I}$$

$$L_{\text{solenoid}} = \frac{\mu_0 N^2 A}{l}$$

$$\Delta V_L = -L\frac{dI}{dt}$$

$$U_L = \frac{1}{2}LI^2$$

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

$$Q = Q_0 \cos \omega t$$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$I = \omega Q_0 \sin \omega t$$

$$\tau_{\text{L}} = \frac{L}{R}$$

$$I = I_0 e^{-t/\tau_{\text{L}}}$$

Maxwell's Equations and Electromagnetic Waves

$$I_{\text{disp}} = \epsilon_0 \frac{d\Phi_e}{dt}$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{in}}}{\epsilon_0}$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_m}{dt}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{through}} + \epsilon_0 \mu_0 \frac{d\Phi_e}{dt}$$

$$v_{\text{em}} = c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = \lambda f = \frac{\omega}{k}$$

$$E_y = E_0 \sin(kx - \omega t)$$

$$B_z = B_0 \sin(kx - \omega t)$$

$$E_0 = cB_0$$

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

$$I = S_{\text{avg}} = \frac{1}{2c\mu_0}E_0^2$$

$$I = \frac{P_{\text{source}}}{4\pi r^2}$$

$$p_{\text{rad}} = \frac{I}{c}$$

$$I = I_0 \cos^2\theta$$

$$I = \frac{1}{2}I_0$$

Optics

$$\Delta r = d\sin\theta$$

$$\Delta r = m\lambda$$

$$\Delta r = (m + \frac{1}{2})\lambda$$

$$a\sin\theta_p = p\lambda$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$m = -\frac{s'}{s}$$

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

$$f = \frac{R}{2}$$

Geometry

Circle: area $= \pi R^2$, circumference $= 2\pi R$

Sphere: volume $= \frac{4}{3}\pi R^3$, surface area $= 4\pi R^2$

Cylinder: volume $= \pi R^2 h$, side area $= 2\pi R h$