

## Equations for Exam 4

### Electrostatics

$$\Phi_e = \int \vec{E} \cdot d\vec{A}, \quad \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}, \quad V = -\int \vec{E} \cdot d\vec{s}, \quad \epsilon_0 = 8.85 \frac{\text{pF}}{\text{m}},$$

$$Q = C\Delta V, \quad U = \frac{1}{2}CV^2 = \frac{Q^2}{2C}, \quad u_e = \frac{1}{2}\epsilon_0 E^2, \quad \text{parallel plates: } C = \frac{\epsilon_0 A}{d}$$

### Currents and Resistance

$$I = \frac{dQ}{dt}, \quad \Delta V = IR, \quad 1\Omega = 1\text{V/A}, \quad \mathcal{P} = I\Delta V = I^2R = (\Delta V)^2/R.$$

### Magnetic Fields / Ampere's Law

$$\mu_0 = 4\pi \times 10^{-7} \frac{\text{T} \cdot \text{m}}{\text{A}} = 4\pi \times 10^{-7} \frac{\text{N}}{\text{A}^2} \quad \text{cross product: } |\vec{A} \times \vec{B}| = AB \sin\theta$$

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

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enc}}, \quad \oint \vec{B} \cdot d\vec{A} = 0, \quad \text{long wire: } B = \frac{\mu_0 I}{2\pi r}, \quad \text{solenoid: } B = \frac{\mu_0 NI}{l}$$

### Faraday's Law

$$\Phi_m = \int \vec{B} \cdot d\vec{A}, \quad 1 \text{ Wb} = 1 \frac{\text{T}}{\text{m}^2}, \quad \mathcal{E} = -N \frac{d\Phi_m}{dt}, \quad \oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_m}{dt}, \quad \mathcal{E} = -\vec{l} \cdot (\vec{v} \times \vec{B})$$

### Inductance

$$L = \frac{N\Phi_m}{I}, \quad \mathcal{E} = -L \frac{dI}{dt}, \quad 1 \text{ H} = 1 \frac{\text{Wb}}{\text{A}} = 1\Omega \cdot \text{s}, \quad \tau = \frac{L}{R}, \quad I = I_f(1 - e^{-t/\tau})$$

$$U = \frac{1}{2}LI^2, \quad u_m = \frac{B^2}{2\mu_0}, \quad M = \frac{N_2\Phi_{12}}{I_1}, \quad \mathcal{E}_2 = -M \frac{dI_1}{dt}$$

### Electromagnetic Waves

$$I_d = \epsilon_0 \frac{d\Phi_e}{dt}, \quad \oint \vec{B} \cdot d\vec{s} = \mu_0 (I_{\text{enc}} + I_d), \quad \frac{\partial^2}{\partial x^2} E = \mu_0 \epsilon_0 \frac{\partial^2}{\partial t^2} E, \quad \frac{\partial^2}{\partial x^2} B = \mu_0 \epsilon_0 \frac{\partial^2}{\partial t^2} B$$

$$E = cB, \quad \mu_0 \epsilon_0 = \frac{1}{c^2}, \quad c = 3.00 \times 10^8 \text{ m/s}, \quad c = f\lambda, \quad \omega = 2\pi f = ck, \quad k = \frac{2\pi}{\lambda}$$

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}, \quad S = c(u_e + u_m) = \frac{\mathcal{P}}{A}, \quad \text{EM wave: } u_e = u_m, \quad S_{\text{avg}} = \frac{1}{2} S_{\text{max}}$$