Electromagnetism II Formula Sheet

Magnetostatics

Magnetic Force on a Moving Charge:

$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B}), \quad F = qvB\sin\theta$$

where **B** is magnetic field, **v** is velocity, θ is the angle between **v** and **B**.

Magnetic Force on a Current-Carrying Wire:

$$\mathbf{F} = I(\mathbf{L} \times \mathbf{B}), \quad F = ILB\sin\theta$$

where I is current, **L** is wire length.

Biot-Savart Law:

$$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{I\,d\mathbf{l} \times \hat{\mathbf{r}}}{r^2}, \quad \mu_0 = 1.256\,637\,061\,4 \times 10^{-6}\,\mathrm{T\,m\,A^{-1}}$$

Magnetic Field of a Long Straight Wire:

$$B = \frac{\mu_0 I}{2\pi r}$$

Magnetic Field at Center of a Circular Loop:

$$B = \frac{\mu_0 I}{2R}$$

where R is the loop radius.

Ampere's Law:

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}}$$

where I_{enc} is enclosed current.

Electromagnetic Induction

Faraday's Law:

$$\mathcal{E} = -\frac{d\Phi_B}{dt}, \quad \Phi_B = \int \mathbf{B} \cdot d\mathbf{A}$$

where $\mathcal{E}$ is induced EMF, Φ_B is magnetic flux.

Lenz's Law: Induced current opposes the change in magnetic flux.

Motional EMF:

$$\mathcal{E} = vBL$$

where v is velocity of a conductor moving in a magnetic field, L is length.

Mutual Inductance:

$$\mathcal{E}_2 = -M\frac{dI_1}{dt}, \quad M = \frac{N_2\Phi_{B2}}{I_1}$$

where M is mutual inductance, N_2 is number of turns in coil 2.

Self-Inductance:

$$\mathcal{E} = -L\frac{dI}{dt}, \quad L = \frac{N\Phi_B}{I}$$

where L is self-inductance.

Energy Stored in an Inductor:

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

AC Circuits

AC Voltage and Current:

$$V = V_0 \sin(\omega t), \quad I = I_0 \sin(\omega t - \phi)$$

where ω is angular frequency, ϕ is phase angle.

Impedance:

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

where $X_L = \omega L$ (inductive reactance), $X_C = \frac{1}{\omega C}$ (capacitive reactance).

RLC Series Circuit:

$$V_{\text{rms}} = I_{\text{rms}} Z, \quad I_{\text{rms}} = \frac{V_{\text{rms}}}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}$$

Resonant Frequency:

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Power in AC Circuits:

$$P_{\text{avg}} = I_{\text{rms}} V_{\text{rms}} \cos\phi$$

where $\cos\phi$ is the power factor.

Maxwell's Equations

Gauss's Law for Electricity:

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

Gauss's Law for Magnetism:

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

Faraday's Law:

$$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$$

Ampere-Maxwell Law:

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}} + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

where $\Phi_E = \int \mathbf{E} \cdot d\mathbf{A}$ is electric flux.

Electromagnetic Waves

Speed of Electromagnetic Waves:

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \approx 3.00 \times 10^8 \,\text{m s}^{-1}$$

Wave Equations:

$$E = E_0 \sin(kx - \omega t), \quad B = B_0 \sin(kx - \omega t), \quad E_0 = cB_0$$

where k is wave number, ω is angular frequency.

Poynting Vector:

$$\mathbf{S} = \frac{1}{\mu_0}(\mathbf{E} \times \mathbf{B}), \quad S_{\text{avg}} = \frac{E_0 B_0}{2\mu_0}$$

Energy Density:

$$u = \frac{1}{2}\epsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$$