Electrodynamics Master Formula Sheet

Comprehensive Summary for Advanced Physics

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1. Electrostatics

Coulomb's Law:

$$\mathbf{F} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{\mathbf{r}}$$

Electric Field:

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0}\int \frac{\rho(\mathbf{r}')}{R^2}\hat{\mathbf{R}}d^3r'$$

Gauss's Law (Differential):

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

Electrostatic Potential:

$$V(\mathbf{r}) = -\int_{\mathcal{O}}^{\mathbf{r}} \mathbf{E}\cdot d\mathbf{l}, \quad \mathbf{E} = -\nabla V$$

2. Magnetostatics

Lorentz Force Law:

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B})$$

Biot-Savart Law:

$$\mathbf{B} = \frac{\mu_0}{4\pi}\int \frac{\mathbf{I}\times\hat{\mathbf{R}}}{R^2}d^3r'$$

Ampere's Law (Differential):

$$\nabla \times \mathbf{B} = \mu_0\mathbf{J}$$

Magnetic Vector Potential:

$$\mathbf{B} = \nabla\times\mathbf{A}, \quad \nabla\cdot\mathbf{A} = 0 \text{ (Coulomb Gauge)}$$

3. Electrodynamics

Faraday's Law:

$$\nabla\times\mathbf{E} = -\frac{\partial\mathbf{B}}{\partial t}$$

Maxwell-Ampere Law:

$$\nabla\times\mathbf{B} = \mu_0\mathbf{J} + \mu_0\epsilon_0\frac{\partial\mathbf{E}}{\partial t}$$

Maxwell's Equations (Vacuum):

$$\nabla \cdot \mathbf{E} = 0, \quad \nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}, \quad \nabla \times \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

4. Electromagnetic Waves

Wave Equation for E and B:

$$\nabla^2 \mathbf{E} = \mu_0 \epsilon_0 \frac{\partial^2 \mathbf{E}}{\partial t^2}, \quad \nabla^2 \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial^2 \mathbf{B}}{\partial t^2}$$

Speed of Light:

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

Poynting Vector (Energy Flux):

$$\mathbf{S} = \frac{1}{\mu_0}(\mathbf{E} \times \mathbf{B})$$