1. Electrostatics

Coulomb's Law: Force between two point charges q_1 and q_2 separated by distance r:

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

Electric Field ($\vec{E}$):

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{1}{4\pi\epsilon_0}\sum\frac{q_i}{r_i^2}\hat{r}_i$$

Electric Flux (Φ_E):

$$\Phi_E = \int \vec{E}\cdot d\vec{A}$$

Gauss's Law (Integral Form):

$$\oint_{\partial V}\vec{E}\cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

Electric Potential (V):

$$V = -\int \vec{E}\cdot d\vec{l}, \quad \vec{E} = -\nabla V$$

Electrostatic Potential Energy (U):

$$U = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

Capacitance (C):

$$C = \frac{Q}{V}, \quad U = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

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2. Magnetostatics

Lorentz Force Law: Force on a moving charge q in electric and magnetic fields:

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

Biot-Savart Law: Magnetic field due to a current element $Id\vec{l}$:

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\times\hat{r}}{r^2}$$

Ampere's Law (Integral Form):

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

Magnetic Force on Current-Carrying Wire:

$$\vec{F} = I\int d\vec{l}\times\vec{B}$$

Magnetic Dipole Moment (μ):

$$\vec{\mu} = I\vec{A}, \quad \tau = \vec{\mu}\times\vec{B}$$

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3. Electrodynamics

Faraday's Law of Induction:

$$\mathcal{E} = -\frac{d\Phi_B}{dt}, \quad \oint \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t}\int \vec{B}\cdot d\vec{A}$$

Inductance (L and M):

$$\mathcal{E} = -L\frac{dI}{dt}, \quad U = \frac{1}{2}LI^2$$

Displacement Current (I_d):

$$I_d = \epsilon_0\frac{d\Phi_E}{dt}$$

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4. Maxwell's Equations

Differential Form in Vacuum:

1. **Gauss's Law for Electricity:**

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

2. **Gauss's Law for Magnetism:**

$$\nabla\cdot\vec{B} = 0$$

3. **Faraday's Law:**

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

4. **Ampere-Maxwell Law:**

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

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5. Electromagnetic Waves

Wave Equation (in vacuum):

$$\nabla^2\vec{E} = \mu_0\epsilon_0\frac{\partial^2\vec{E}}{\partial t^2}$$

Speed of Light (c):

$$c = \frac{1}{\sqrt{\mu_0\epsilon_0}} \approx 3\times10^8 \text{ m/s}$$

Poynting Vector ($\vec{S}$ - Energy Flux):

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

Intensity (I):

$$I = \langle S\rangle = \frac{1}{2}c\epsilon_0 E_0^2$$