Electromagnetism I Formula Sheet

Electrostatics

Coulomb's Law:

$$F = k\frac{|q_1 q_2|}{r^2}, \quad k = \frac{1}{4\pi\epsilon_0}$$

where F is the force, q_1, q_2 are charges, r is distance, $k \approx 8.99 \times 10^9\,\mathrm{N\,m^2\,C^{-2}}$, $\epsilon_0 \approx 8.85 \times 10^{-12}\,\mathrm{C^2\,N^{-1}\,m^2}$.

Electric Field:

$$\mathbf{E} = \frac{\mathbf{F}}{q}, \quad E = k\frac{|q|}{r^2} \quad \text{(point charge)}$$

Electric Field (Continuous Charge):

$$d\mathbf{E} = \frac{k\,dq}{r^2}\hat{\mathbf{r}}, \quad \mathbf{E} = \int \frac{k\,dq}{r^2}\hat{\mathbf{r}}$$

Gauss's Law

Gauss's Law:

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

where Q_{enc} is enclosed charge, $d\mathbf{A}$ is differential area vector.

Electric Field for Symmetric Charge Distributions:

$$E = \frac{\sigma}{2\epsilon_0} \quad \text{(infinite plane)}, \quad E = \frac{\lambda}{2\pi\epsilon_0 r} \quad \text{(infinite line)}$$

where σ is surface charge density, λ is linear charge density.

Electric Potential

Electric Potential Energy:

$$U = k\frac{q_1 q_2}{r}$$

Electric Potential:

$$V = k\frac{q}{r}, \quad V = -\int \mathbf{E} \cdot d\mathbf{l}$$

Electric Field from Potential:

$$\mathbf{E} = -\nabla V$$

Potential for Continuous Charge:

$$V = \int \frac{k\,dq}{r}$$

Capacitors and Dielectrics

Capacitance:

$$C = \frac{Q}{V}$$

Parallel-Plate Capacitor:

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

where A is plate area, d is separation.

Capacitors in Series:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$$

Capacitors in Parallel:

$$C_{\text{eq}} = C_1 + C_2 + \cdots + C_n$$

Energy Stored in a Capacitor:

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

Dielectrics:

$$C = \kappa C_0, \quad \mathbf{E} = \frac{\mathbf{E}_0}{\kappa}$$

where κ is the dielectric constant, C_0 is capacitance without dielectric.

Current and Resistance

Current:

$$I = \frac{dQ}{dt}$$

Current Density:

$$\mathbf{J} = \sigma \mathbf{E}, \quad I = \int \mathbf{J} \cdot d\mathbf{A}$$

where σ is conductivity.

Ohm's Law:

$$V = IR$$

Resistance:

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

where ρ is resistivity, L is length, A is cross-sectional area.

DC Circuits

Resistors in Series:

$$R_{\text{eq}} = R_1 + R_2 + \cdots + R_n$$

Resistors in Parallel:

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

Kirchhoff's Rules:

$$\sum I_{\text{in}} = \sum I_{\text{out}} \quad \text{(junction rule)}, \quad \sum V = 0 \quad \text{(loop rule)}$$

Power:

$$P = IV = I^2R = \frac{V^2}{R}$$