

Electric Charges and Field

Important Formulas

1. Coulomb's Law (Force between two point charges)

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

where $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$ is the permittivity of free space.

2. Electric Field (E) due to a Point Charge

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

- Direction: Radially outward for positive charge, inward for negative charge.

3. Electric Dipole Moment (p)

$$p = q \times 2a$$

- Direction: From negative to positive charge.

4. Electric Field due to a Dipole

- **On the axial line:**

$$E = \frac{1}{4\pi\epsilon_0} \frac{2p}{r^3}$$

- **On the equatorial line:**

$$E = \frac{1}{4\pi\epsilon_0} \frac{p}{r^3}$$

- Direction: Opposite to dipole moment.

5. Torque (τ) on an Electric Dipole in a Uniform Field

$$\tau = pE \sin \theta$$

- Maximum when $\theta = 90^\circ$.

6. Electric Flux (ϕ)

$$\phi = \oint \mathbf{E} \cdot d\mathbf{S}$$

- Measured in $\text{Nm}^2 \text{C}^{-1}$.

7. Gauss's Law

$$\oint \mathbf{E} \cdot d\mathbf{S} = \frac{q_{\text{enclosed}}}{\epsilon_0}$$

- Useful for symmetrical charge distributions.

8. Electric Field due to a Uniformly Charged Infinite Plane Sheet

$$E = \frac{\sigma}{2\epsilon_0}$$

9. Electric Field due to a Long Straight Charged Wire

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

10. Electric Field due to a Charged Sphere

- **Outside the sphere:**

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

- **Inside a conducting sphere:**

$$E = 0$$

Units and Constants

1. **Charge of an Electron:** $e = 1.6 \times 10^{-19} C$
2. **Permittivity of Free Space:** $\epsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$
3. **Coulomb's Constant:** $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 Nm^2 C^{-2}$
4. **Electric Flux Unit:** $Nm^2 C^{-1}$
5. **Electric Field Unit:** NC^{-1} or Vm^{-1}
6. **Electric Dipole Moment Unit:** Cm
7. **Surface Charge Density (σ):** Cm^{-2}
8. **Linear Charge Density (λ):** Cm^{-1}
9. **Volume Charge Density (ρ):** Cm^{-3}