Electricity and Magnetism - Lecture 2 Notes

Joshua Clement

October 7, 2024

Electric Field Strength

- **Electric Forces** are typically much stronger than **gravitational forces**.
- **Electric field** is a vector field that defines a vector at each point in space.
  - Represented graphically with arrows or lines parallel to the field.
  - Measured in **N/C**.
  - Greater **line density** indicates a stronger electric field.

Electric Field of Uniformly Charged Spherical Shell

- **Outside the Shell** ($r > R$):

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$$

- **Inside the Shell** ($r < R$):

$$E = 0$$

- The electric field outside behaves like that of a **point charge**.
- Calculations involve the **superposition principle** and **Gauss' law**.

Superposition Principle

- The net electric field at any point is the **vector sum** of the individual fields from all charges.
- Electric field from a charged particle is **unaffected** by the presence of other charges.

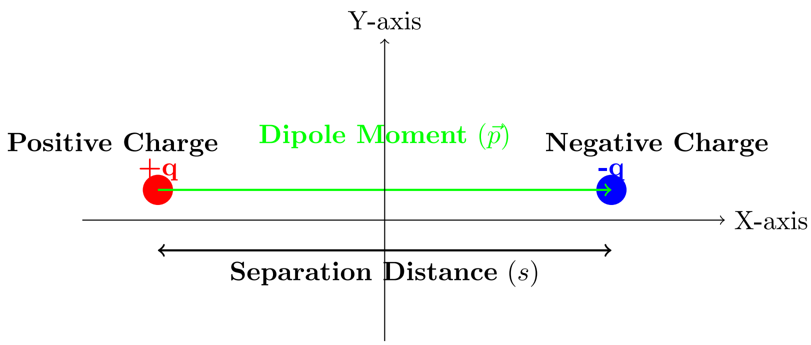

Figure 1: Graphical representation of an electric dipole showing positive (+q) and negative (-q) charges, dipole moment ($\vec{p}$), and separation distance (s).

Electric Dipole

- **Electric Dipole**: Consists of two equal but opposite charges, $+q$ and $-q$, separated by distance s.
- **Dipole Moment ($\vec{p}$)**:

$$\vec{p} = q\vec{s}$$

$$or$$

$$\vec{p} = qs\hat{s}$$

- Units: **C·m**.
- **Importance**:
  - Neutral matter contains both positive and negative charges.
  - **Far away**, the electric field of neutral matter approximates to that of a dipole.
  - Dipoles are common in nature, e.g., **HCl molecule**.
- **Electric Field of Dipole**:

$$p = qs$$

  - **Along the Axis** ($r \gg s$):

$$\vec{E}_{\text{axis}} = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}\hat{p}$$

  - **Along Bisecting Plane**:

$$\vec{E}_{\perp} = -\frac{1}{4\pi\epsilon_0}\frac{p}{r^3}\hat{p}$$

Dipole in Uniform Electric Field

- A dipole in a **uniform electric field** experiences **torque**.

$$\tau = \vec{p} \times \vec{E}_{\text{app}}$$

- **Equilibrium Position**: Minimizes potential energy.

$$U = -\vec{p} \cdot \vec{E}_{\text{app}}$$