Electricity and Magnetism - Lecture 3 Notes

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Conservation of Charge

- **Electric charge** is quantized.
- SI unit: **Coulomb (C)**.
- **Conservation of Charge**: The net charge of a closed system never changes.
- Charges can be created or destroyed in **(+,-) pairs** (e.g., electron-positron annihilation).
- Charge transfer occurs via **contact** (e.g., triboelectric effect, rubbing a balloon on hair).

Triboelectric Effect

- Transfer of charge through **contact/friction**.
- Rubbing produces many points of contact, facilitating charge transfer.
- Mechanisms:
  - Breaking large molecules or transferring ions.
  - Transfer of **electrons**.
- Determines whether an object becomes **positively or negatively charged**.

Electric Dipole

- Consists of two equal but opposite charges, $+q$ and $-q$, separated by distance s.
- **Dipole Moment ($\vec{p}$)**:
$$\vec{p} = q\vec{s}$$
- The **dipole moment** is not the electric field; it is a different physical quantity.

Electric Field of a Dipole

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

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

- **Electric Field Along the Bisecting Plane**:

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

Dipole in an External Uniform Electric Field

- **Forces** on $+q$ and $-q$ have the same magnitude but opposite direction.
- The dipole experiences a **torque**:

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

- **Equilibrium Position**: Dipole aligns with the external field, minimizing potential energy.

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

Polarization of Atoms

- An **atom** becomes polarized when placed in an electric field, forming an **induced dipole**.
- **Polarization**: The dipole moment per atom or per molecule.
- The **polarizability** (α) is proportional to the strength of the applied electric field.

Interaction Between Neutral Atom and Point Charge

- A **neutral atom** becomes polarized when placed near a point charge, forming an **induced dipole**.
- The interaction is always **attractive**.
- The point charge is always on the **axis** of the induced dipole.
- The interaction strength is proportional to $\frac{1}{r^5}$.