Chapter 21 - Coulomb's Law

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22.1 Electric Field

Key Ideas

- An electric field is a vector field that describes the force per unit charge experienced by a small positive test charge.
- The electric field **E** is defined as:
$$\mathbf{E} = \frac{\mathbf{F}}{q_0}$$
where **F** is the force experienced by the test charge q_0.
- Field lines provide a visualization of electric fields:
  - Lines originate on positive charges and terminate on negative charges.
  - The density of lines corresponds to the field's magnitude.

Field of a Point Charge

The electric field due to a point charge q at distance r is:

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

where:

- $\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C}^2/\mathrm{N}\cdot\mathrm{m}^2$ is the permittivity of free space.

22.2 Electric Dipoles

Definition

- An electric dipole consists of two charges of equal magnitude but opposite signs, separated by a distance d.
- The dipole moment **p** is defined as:
$$\mathbf{p} = q \cdot d$$

Electric Field of a Dipole

The field of a dipole at a distant point along its axis is:

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

where z is the distance from the dipole's center.

22.3 Continuous Charge Distributions

Key Concept

The electric field due to a continuous charge distribution is found by integrating the fields of infinitesimal charge elements:

$$\mathbf{E} = \int \frac{1}{4\pi\epsilon_0}\frac{\mathrm{d}q}{r^2}\hat{r}$$

22.4 Applications and Examples

Force on a Charge in an Electric Field

The force on a charge q in a field $\mathbf{E}$ is:

$$\mathbf{F} = q\mathbf{E}$$

Torque on a Dipole

An electric dipole in a field $\mathbf{E}$ experiences a torque:

$$\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$$

The potential energy associated with the dipole is:

$$U = -\mathbf{p} \cdot \mathbf{E}$$

Summary

- Electric fields describe how charges interact at a distance.
- Coulomb's Law and superposition principles are fundamental in calculating electric fields.
- Fields from continuous distributions require integration.