Electricity and Magnetism - Lecture 1 Notes

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Electric Charge

- **Electric charge**: intrinsic characteristic of fundamental particles.
- Types of charge: **Positive (+)** and **Negative (-)**.
- **Electrically Neutral**: Equal amounts of positive and negative charges.
- **Net Charge**: Imbalance in charge, resulting in a non-zero algebraic sum.
- Charge is **quantized**.
- SI unit: **Coulomb (C)**.
- **Conservation of Charge**: Net charge of a closed system remains constant.

Coulomb's Law

- **Coulomb Force Law**: Describes the electric force between two point charges.
- Magnitude of electric force $F_{1,2}$ between charges Q_1 and Q_2:

$$|\vec{F}_{1,2}| = |\vec{F}_{2,1}| = \frac{1}{4\pi\epsilon_0}\frac{|Q_1 Q_2|}{r^2}$$

- **Direction of Electric Force**:
  - **Attractive** if charges have opposite signs.
  - **Repulsive** if charges have the same sign.
  - Force acts along the line connecting the charges.
- **SI Units**:
  - **Force**: Newton (N)
  - **Electric Charge**: Coulomb (C)

- **Constants**:
  - Vacuum permittivity: $\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C}^2/\mathrm{N}\cdot\mathrm{m}^2$
  - $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\mathrm{N}\cdot\mathrm{m}^2/\mathrm{C}^2$

Electric Field

- **Electric Field (E)**: Force per unit charge.
- **Electric Field of a Point Charge**:

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q_1}{r^2}\hat{r}$$

- **Field Direction**:
  - Points away from **positive** charges.
  - Points towards **negative** charges.
- **Electric Field Representation**:
  - Lines of electric field start on positive charges and end on negative charges.
  - **Greater density of lines** indicates a **stronger electric field**.
  - Electric field is measured in **N/C**.

Electric Field to Electric Force

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

Magnitude of the Electric Field Example

- A particle with charge $q_1 = 2\,\mathrm{nC} = 2 \times 10^{-9}\,\mathrm{C}$ is located at the origin.
- Electric field at location $< -0.2, -0.2, -0.2 >$ m:

$$|r| = \sqrt{(-0.2)^2 + (-0.2)^2 + (-0.2)^2} = 0.35\,\mathrm{m}$$

$$\hat{r} = \frac{< -0.2, -0.2, -0.2 >}{0.35} =< -0.57, -0.57, -0.57 >$$

$$E = \frac{1}{4\pi\epsilon_0}\frac{q_1}{r^2} = \frac{9 \times 10^9}{0.35^2} \times 2 \times 10^{-9} = 147\,\mathrm{N/C}$$

Electric Field in Vector form

$$\vec{E} = E\hat{r} = (147\frac{N}{C}) < -0.57, -0.57, -0.57 >$$

$$\vec{E} =< -84, -84, -84 > \frac{N}{C}$$

Key Concepts

- **Point Charge**: A charged object whose radius is much smaller than the distance between itself and all other objects of interest. The charge is considered concentrated at a single point.
- **Electric Field**: A vector field that has a value at every location in space.