Electricity and Magnetism - Lecture 8 Notes

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Review of Potential Energy

- **Potential Energy** (U): Energy due to the interaction between charges.
- **Interaction Energy**: Comes from the interaction of two or more charges.
- **Internal Work**: Work done within a system to move charges from one position to another.

$$\Delta U = -W_{\text{internal}}$$

- Another way for a uniform field in the x-direction:

$$\Delta U = -qE\Delta x$$

Electric Potential Energy

- **Electric Potential Energy** (U_{el}): The work required to bring a charge from infinity to a specific position in the presence of other charges.

$$U_{\text{el}} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

where q_1 and q_2 are charges and r is the distance between them.

- **Like Charges** ($q_1, q_2 > 0$): $U_{\text{el}} > 0$, indicating repulsion.
- **Opposite Charges** ($q_1, q_2 < 0$): $U_{\text{el}} < 0$, indicating attraction.

Electric Potential

- **Electric Potential** (V): The potential to have electric potential energy if a test charge is introduced.
- **Electric Potential Due to a Point Charge**:

$$V(r) = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

where q is the source charge and r is the distance from the charge.

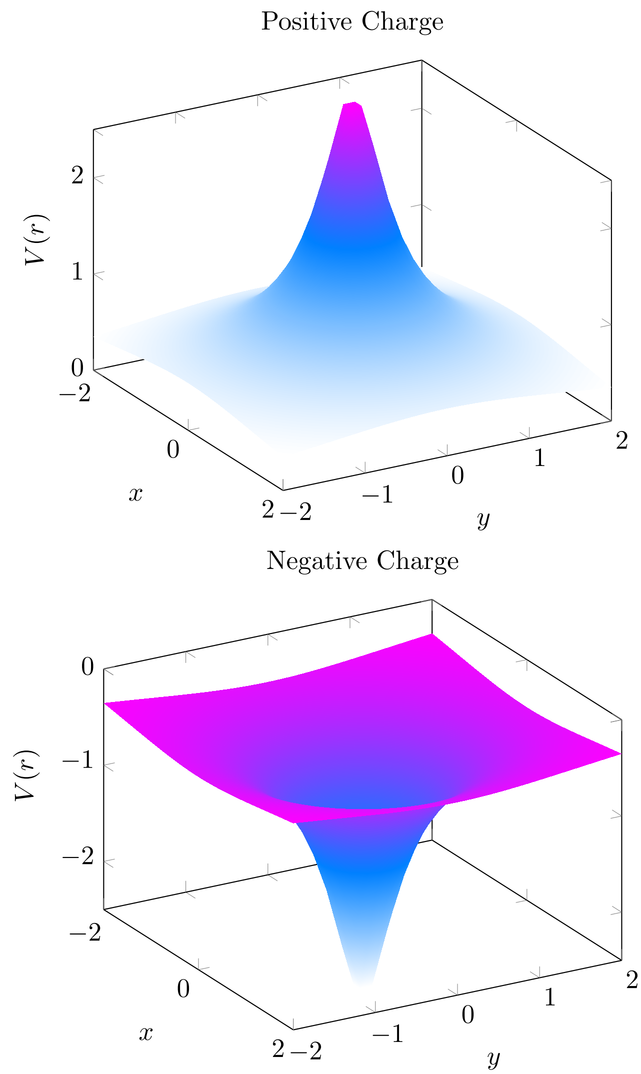

Figure 1: Electric potential ($V(r)$) as a scalar field for a positive (left) and negative (right) charge.

- **Units**: The unit of electric potential is **Volts (V)**.
- **Equipotential Surfaces**: Surfaces where the electric potential is constant; for a point charge, these surfaces are spherical.

Electric Potential Difference

- **Electric Potential Difference in a Nonuniform E-Field** (ΔV):

$$\Delta V = V_B - V_A = -\int_i^f \vec{E} \cdot d\vec{l}$$

- **Potential Difference** (ΔV): The difference in electric potential between two points.

$$\Delta V = V_B - V_A = -E\Delta x$$

  where E is the electric field and Δx is the displacement in the direction of the field.

- **Relation to Work**: The work done by the electric field in moving a charge q between two points is:

$$W = q\Delta V$$

Electric Potential Energy of Multiple Charges

- **System of Charges**: The total electric potential energy is the sum of the interaction energies between all pairs of charges.

$$U_{\text{sys}} = \sum_{i<j} \frac{1}{4\pi\epsilon_0} \frac{q_i q_j}{r_{ij}}$$

- **Adding a New Charge** (q_3): The work needed to bring a new charge q_3 from infinity to point C is given by:

$$U_{\text{sys}} = U_{12} + V_C q_3$$

  where V_C is the electric potential at point C due to the other charges.

Electron-Volt (eV)

- **Electron-Volt (eV)**: The energy required to move a charge of $1e$ through a potential difference of $1V$.

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

- **Example**: If a proton moves in an electric field and loses 1 eV of potential energy, its kinetic energy increases by 1 eV.

Electric Potential as a Scalar Field

- **Scalar Field**: The electric potential is a scalar quantity and can be represented as a field in space.
- **Superposition Principle**: The total electric potential at a point is the sum of the potentials due to individual charges.

$$V_P = \frac{1}{4\pi\epsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

- **Equipotential Surfaces**: For a point charge, these surfaces are spherical and indicate regions with the same potential.