Theme Music: Joni Mitchell

Electricity

Cartoon: Bill Watterson

Calvin & Hobbes
Recap: Scalar Fields

- A **field** is a concept we use to describe anything that varies in space. It is a set of values assigned to each point in space (e.g., temperature or wind speed).

- An **potential energy field** is the assignment of a potential energy that a test charge would feel (add to the system) if placed at each point in space.

- A **gravitational, electric potential** is a potential energy field with something (a “coupling strength”) divided out so the field no longer depends on what test object is used.

\[
gh = \frac{\Delta U_{\text{grav}}}{m} \quad V = \frac{\Delta U_{\text{electric}}}{q} \quad V(\vec{r}) = - \int_{\text{ref. pt.}}^{\vec{r}} \vec{E}(\vec{r}') \cdot d\vec{r}'
\]
Foothold ideas:
Electric potential energy and potential

- The potential energy between two charges is

\[ U_{12}^{\text{elec}} = \frac{k_C Q_1 Q_2}{r_{12}} \]

- The potential energy of many charges is

\[ U_{12\ldots N}^{\text{elec}} = \sum_{i<j=1}^{N} \frac{k_C Q_i Q_j}{r_{ij}} \]

- The potential energy added by adding a test charge \( q \) is

\[ \Delta U_q^{\text{elec}} = \sum_{i=1}^{N} \frac{k_C q Q_i}{r_{iq}} = qV \]
Positive test charge near a single (+) source charge

Potential energy of a positive test charge near a positive source.

\[ U = \frac{kqQ}{r} \]

Electric Potential of a positive test charge near a positive source.

\[ V = \frac{kQ}{r} \]

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Negative test charge near a single (+) source charge

Potential energy of a negative test charge near a positive source.

$U = \frac{kqQ}{r}$

Electric Potential of a negative test charge near a positive source.

$V = \frac{kQ}{r}$
Representations

■ Representing $E$
  – Arrows (length shows $|E|$)
  – Arrows (fixed length, color or width shows $|E|$)
  – Field lines (show direction only)
  – Field lines (color shows $|E|$)

■ Representing $V$
  – 1D: Graph
  – 2D: Isoclines (lines of equal value)
  – 3D: Equipotential surfaces (surfaces of $= \text{value}$)
$E$ field