- **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.

$$gh = \frac{\Delta U_m^{\text{grav}}}{m} \qquad V = \frac{\Delta U_q^{\text{electric}}}{q} \qquad V(\vec{r}) = -\int_{\text{ref. pt.}}^{\vec{r}} \vec{E}(\vec{r}\,') \cdot d\vec{r}\,'$$

Foothold ideas:
Electric potential energy and potential

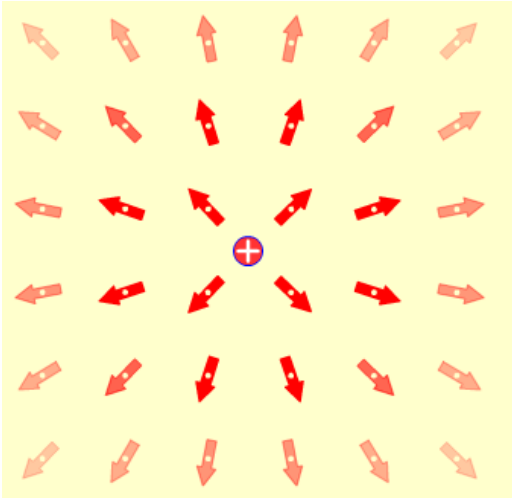
- The potential energy between two charges is
- The potential energy of many charges is
- The potential energy added by adding a test charge q is

$$U_{12}^{elec} = \frac{k_C Q_1 Q_2}{r_{12}}$$

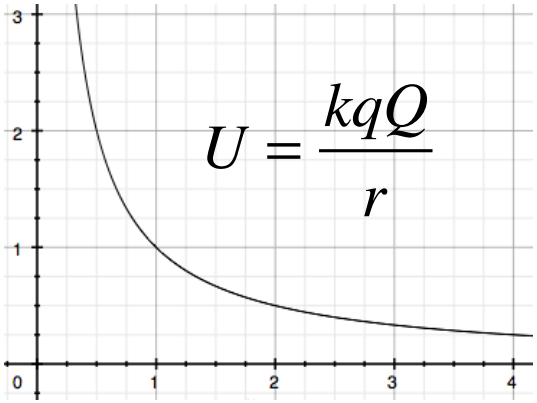
$$U_{12\ldots N}^{elec} = \sum_{i<j=1}^{N} \frac{k_C Q_i Q_j}{r_{ij}}$$

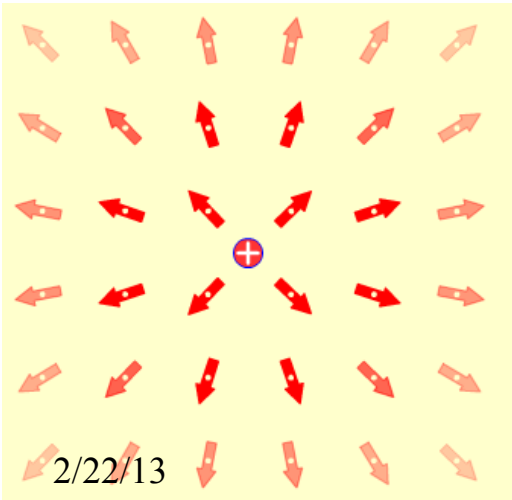
$$\Delta U_q^{elec} = \sum_{i=1}^{N} \frac{k_C q Q_i}{r_{iq}} = qV$$

Positive test charge near a single (+) source charge

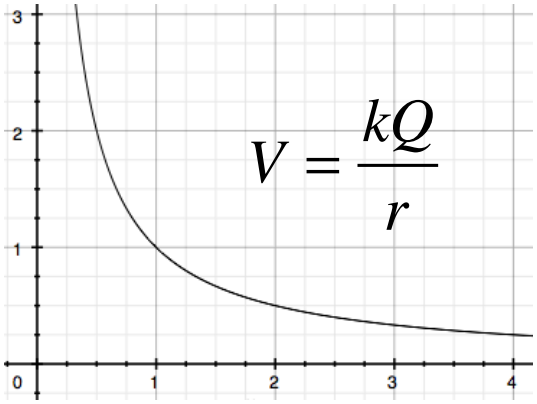


Potential energy
of a positive test charge
near a positive source.

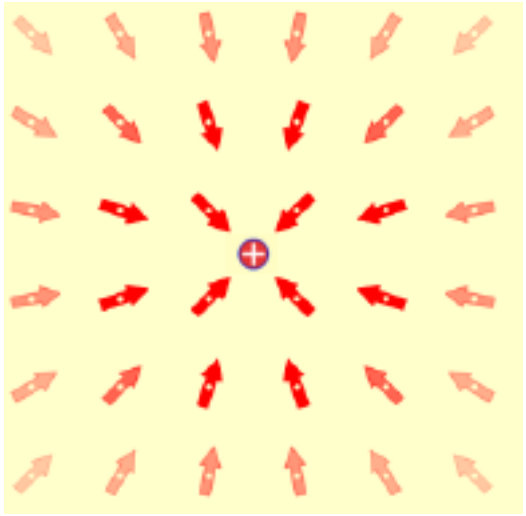




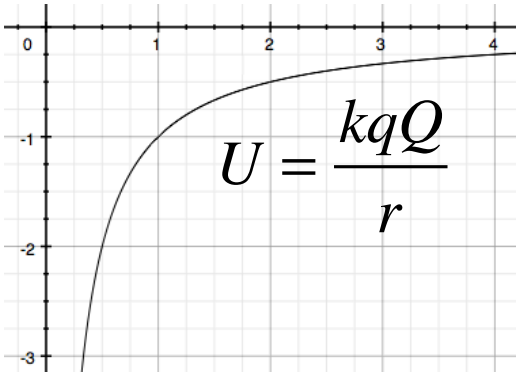
Electric Potential
of a positive test charge
near a positive source.

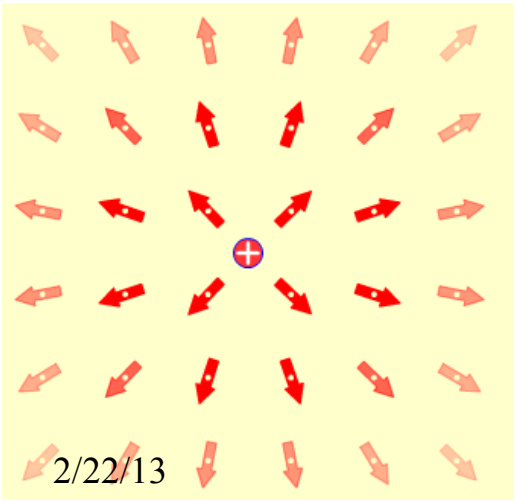


Negative test charge near a single (+) source charge

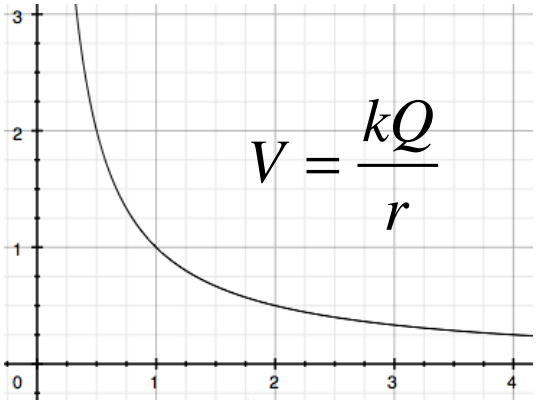


Potential energy
of a negative test charge
near a positive source.





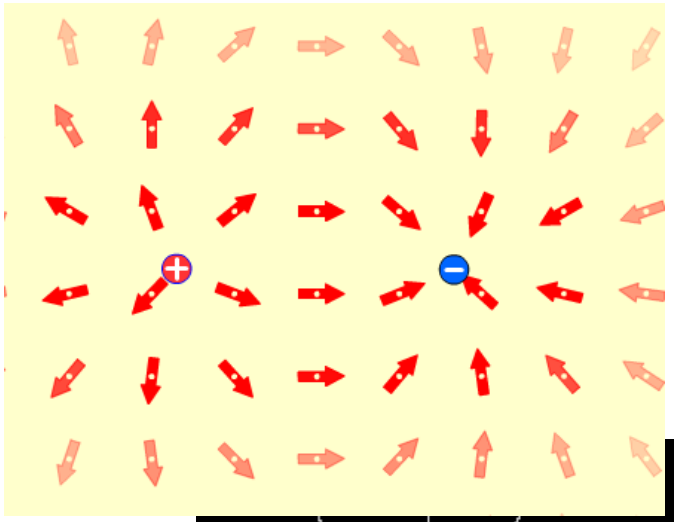
Electric Potential
of a negative test charge
near a positive source.

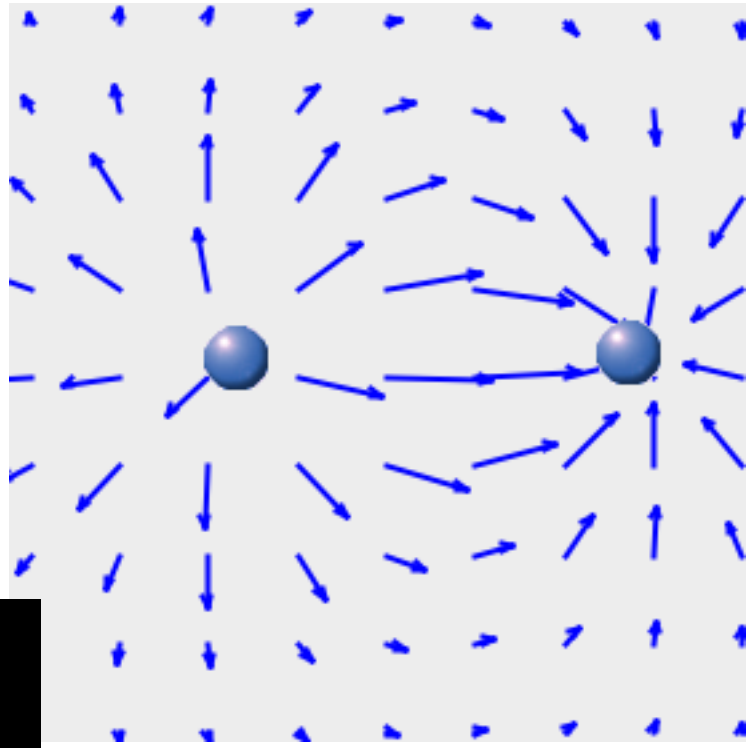


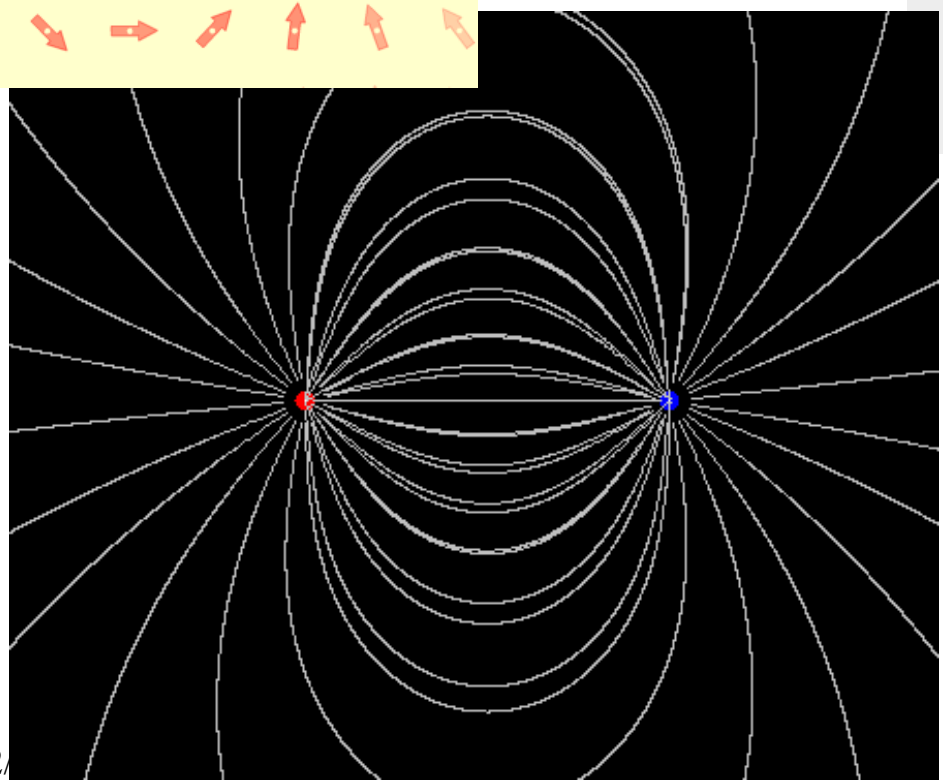
Representations

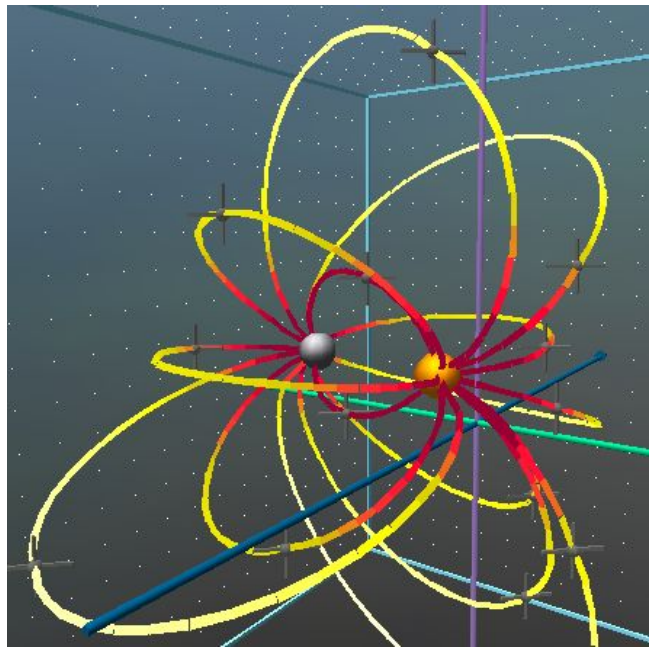
- Representing E
  - Arrows (length shows $|E|$)
  - Arrows (fixed length, color or width shows $|E|$)
  - Field lines (show direction only)
  - Field lines (color shows $|E|$)
- Representing V
  - 1D: Graph
  - 2D: Isoclines (lines of equal value)
  - 3D: Equipotential surfaces (surfaces of = value)

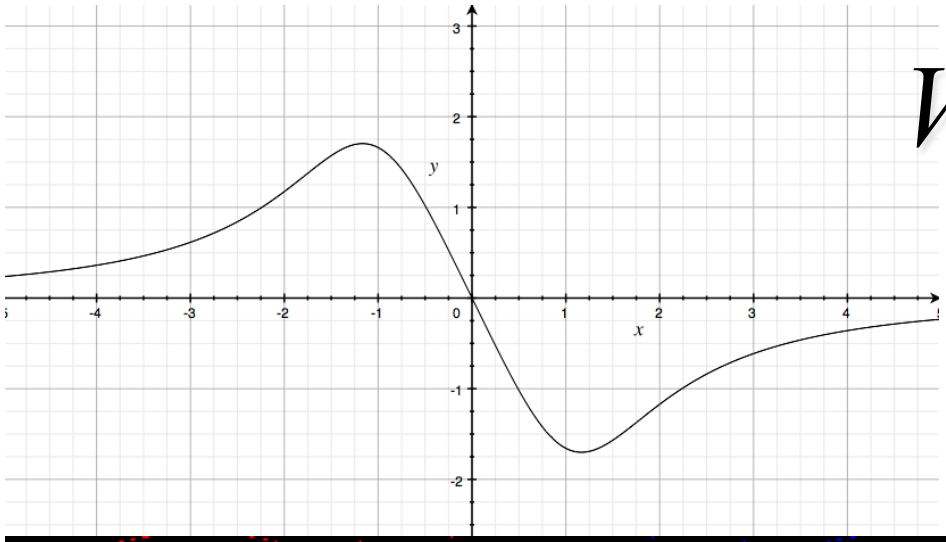
E field











V