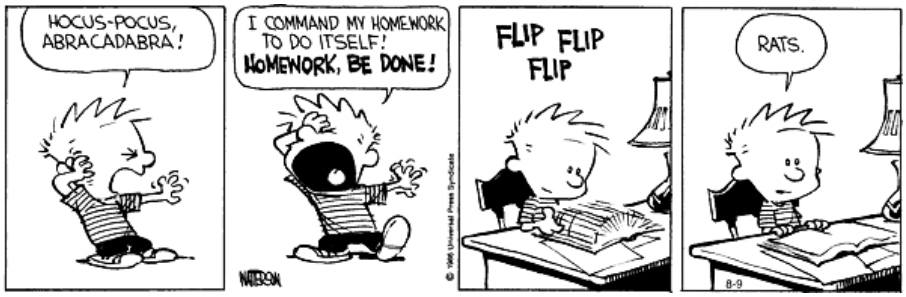
February 22, 2017 Physics 132 Prof. E. F. Redish

- **Theme Music: Joni Mitchell**
  ***Electricity***
- **Cartoon: Bill Watterson**
  ***Calvin & Hobbes***

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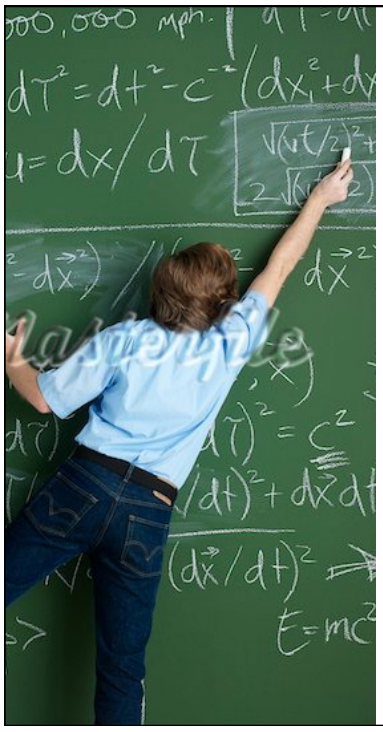

## The Equation of the Day

The Electric Field in simple model systems

$$E(\vec{r}) = k_C q / r^2$$

$$E(\vec{r}) = 2k_C \lambda / d$$

$$E(\vec{r}) = 4\pi k_C \sigma$$

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# Recap: Vector 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).
- A *force field* is an idea we use for non-touching forces. It puts a force vector at each point in space, summarizing the effect of all objects that would exert a force on a particular object placed at that point.
- A *gravitational*, *electric, or magnetic field* is a force field with something (a "coupling strength") divided out so the field no longer depends on which test object is used.

$$\vec{g} = \frac{\vec{F}_{\text{acting on } m}}{m} \qquad \vec{E} = \frac{\vec{F}_{\text{acting on } q}}{q}$$

Field is the value at a position in space " $r$ " assuming that the force is measured by placing the object at $r$.



# 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

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

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

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

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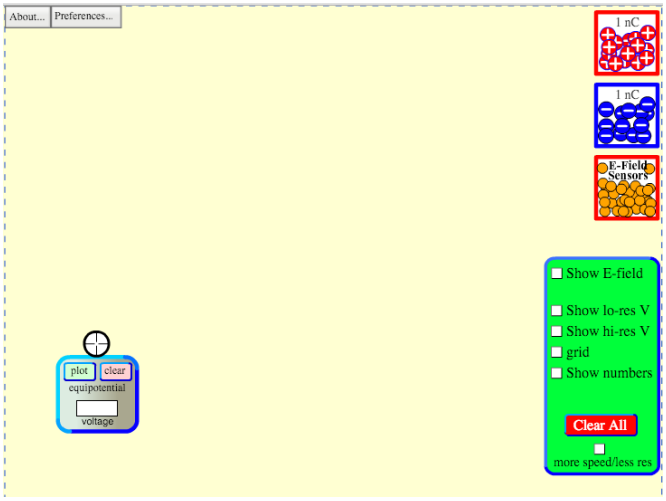
# Explore the potential near a point charge




https://phet.colorado.edu/en/simulation/charges-and-fields

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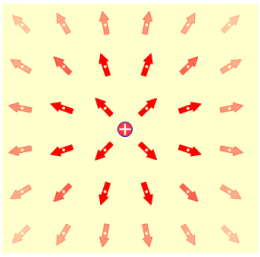
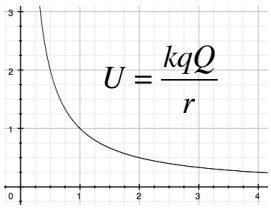
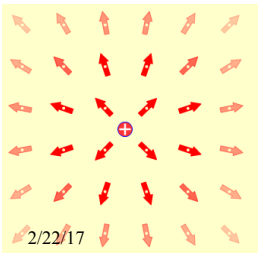
# Positive test charge near a single (+) source charge

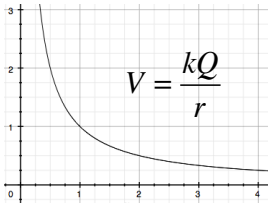


Potential energy
of a positive test charge
near a positive source.



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

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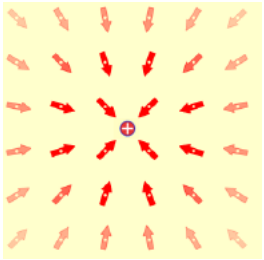
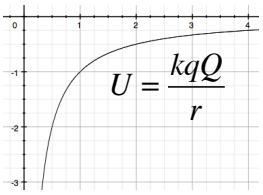
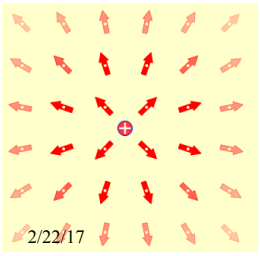
# Negative test charge near a single (+) source charge



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



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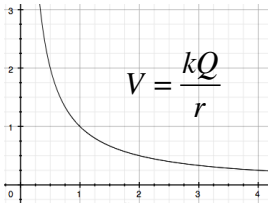


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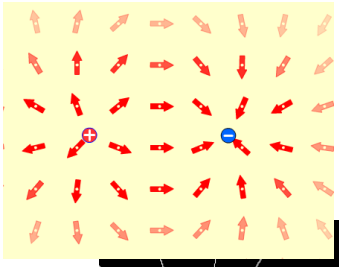
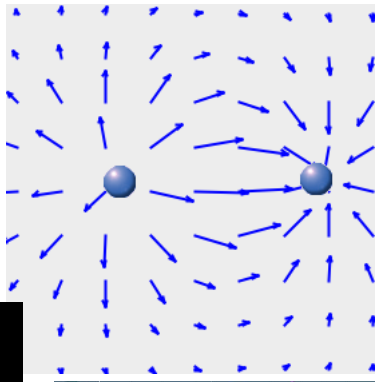
# Representations

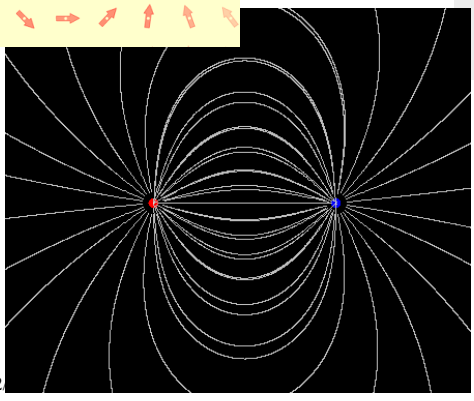
- Representing $E$
  - Arrows (length shows $|E|$)
  - Arrows (fixed length, color or width shows $|E|$)
  - Field lines (show direction only)
  - Field lines (color shows $|E|$)
- Representing $V$
  - 1D: Graph
  - 2D: Isoclines (lines of equal value)
  - 3D: Equipotential surfaces (surfaces of = value)

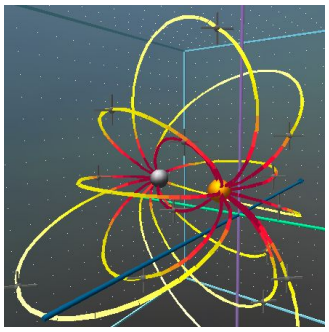


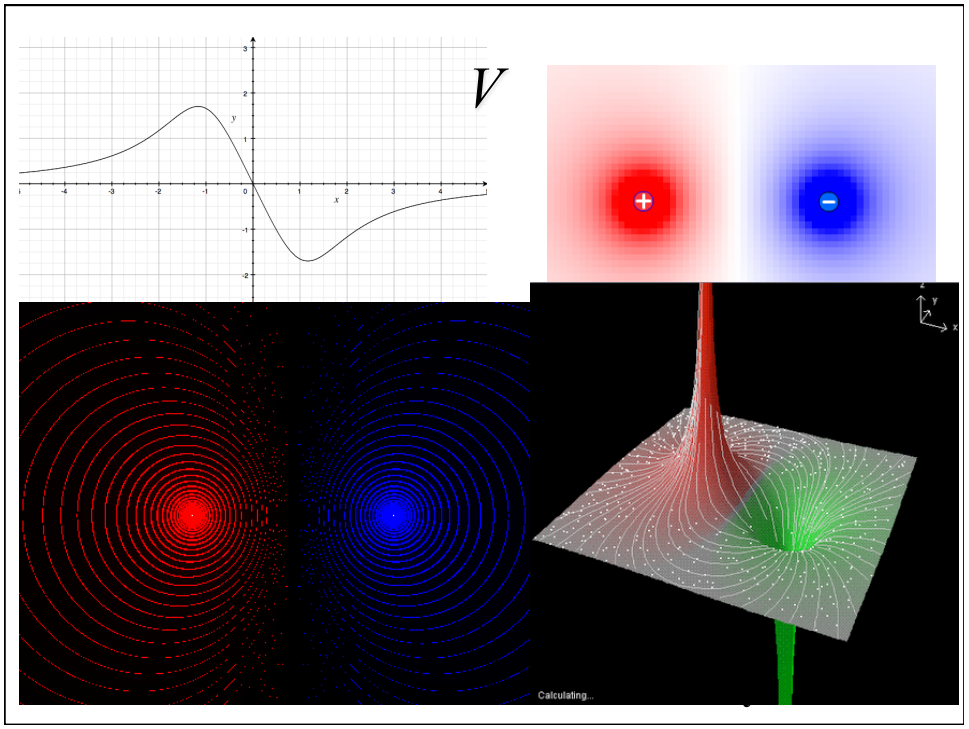
# $E$ field







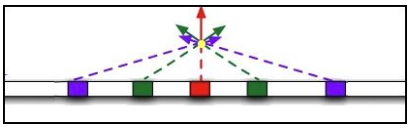




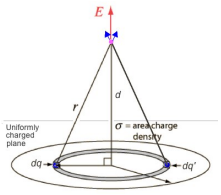

# Some simple models

Why?

- Line charge $\lambda = \frac{Q}{L}$



- Sheet of charge $\sigma = \frac{Q}{A}$




- Sphere of charge $\rho = \frac{Q}{V}$ ← Volume!