April 11, 2011 Physics 122 Prof. E. F. Redish

- **Theme Music: Linkin Park**
  High Voltage
- **Cartoon:**
  Ted Goff

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Outline

- Quiz 8: Electric forces and fields
- Recap: Electric Field
- Electric Potential
- ILD #5: Electrostatic potential and analogies
- Examples

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Electric potential energy

General case

$$\Delta U_E = -\vec{F}_E \cdot \Delta\vec{r} \quad \text{(small step)}$$

$$\Delta U_E = -\sum\left(\vec{F}_E \cdot \Delta\vec{r}\right) \quad \text{(lots of little steps)}$$

$$\Delta U_E = -\int_{start}^{finish} \vec{F}_E \cdot d\vec{r}$$

Simplest case (one source charge, one test charge)

$$\Delta U_E = -\int_{start}^{finish} \vec{F}_E \cdot d\vec{r} = -\int_{r_i}^{r_f} \frac{k_C qQ}{r^2} dr = -k_C qQ \int_{r_i}^{r_f} \frac{dr}{r^2} = -k_C qQ\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$$

$$U_E(r) = \frac{k_C qQ}{r}$$ ← NOT A VECTOR – JUST A NUMBER

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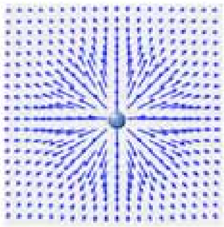
Example: Electric PE of a Point Charge

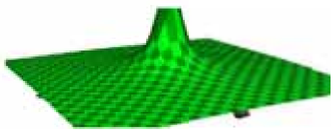


Field

$\Delta U_E = -\vec{F} \cdot \Delta\vec{r}$

= work done moving charge against field

$$U_{\text{pt. ch. q in field of pt. ch. Q}} = \frac{k_C qQ}{r}$$



PE

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Foothold ideas: Fields

- The force between a pair of charges is given by Coulomb's law
- The force exerted by many charges on a charge is the vector sum of the forces (superposition)
- We describe the electric effect on a charge by a *field*: a set of vectors at every point in space
- The field at a particular point is the force per unit charge a charge would feel if placed at that point.

grav. field of earth $= \vec{F}_{E\to m}/m = \vec{g}$ $\quad \vec{E}(\vec{r}) = \vec{F}_q/q \quad \vec{F}_q = q\vec{E}(\vec{r})$

(test charge q placed at the point $\vec{r}$)

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A change in potential energy leads to force

$$\Delta U = -\vec{F} \cdot \Delta\vec{r}$$

$$F = -\frac{\Delta U}{\Delta r}$$

(stepping in the direction of the steepest descent)

- Constant PE → no force
- Change in PE → force (pointing downhill)

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Electric Potential

- In the same way that we "removed the test charge" from Coulomb's law to define the electric field, we "remove the test charge" from the electric potential energy to create the <u>electric potential</u>, *V*.

$$\vec{E} = \frac{\vec{F}}{q} \qquad V = \frac{U}{q} \qquad E_x \approx -\frac{\Delta V}{\Delta x}$$

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Electric Potential: Meaning

- Just like the electric field, the electric potential can be defined at any point in space.
- For any point in space, $\vec{r}$, the electric potential at the point is the negative of the work required to bring a test charge, *q*, from ∞ to $\vec{r}$ divided by *q*.
- The electric potential is a scalar (has no direction) so it's easier to work with than the E-field.

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ILD #5: Electrostatic Potential & Analogies

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