October 14, 2011 Physics 131 Prof. E. F. Redish

- **Theme Music:** Oasis
  She's Electric
- **Cartoon:** Bob Thaves
  Frank & Ernest

10/14/11 Physics 131 1

Outline

- Review of Vectors
- Coulomb's Electric Force Law
- Electric Field

10/14/11 Physics 131 2

Foothold ideas: Charge – A hidden property of matter

- Matter is made up of two kinds of electrical matter (positive and negative) that usually cancel very precisely.
- Like charges repel, unlike charges attract.
- Bringing an unbalanced charge up to neutral matter polarizes it, so both kinds of charge attract neutral matter
- The total amount of charge (pos – neg) is constant.

Foothold ideas: Conductors and Insulators

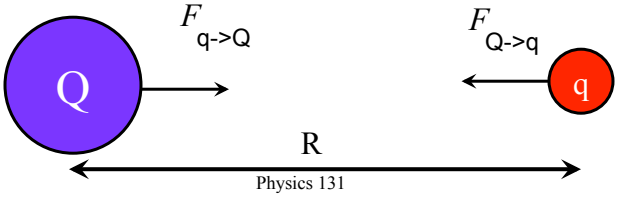
- Insulators
  - In some matter, the charges they contain are bound and cannot move around freely.
  - Excess charge put onto this kind of matter tends to just sit there (like spreading peanut butter).
- Conductors
  - In some matter, charges in it can move around throughout the object.
  - Excess charge put onto this kind of matter redistributes itself or flows off (if there is a conducting path to ground).

Reading question

- I don't quite understand why we need to include the product of the two charges in our formula for force. The charge of interest only feels the force from the other charge, and when considering the motion of an object, we only consider forces that directly affect the object. Why, then, does the formula utilize the product of both charges if the one charge only feels one force?

Inventing an Electric Force Law

- What law should we propose? $F = ? / R^2$.
- What goes on top?
- We expect
  - $F_{Q->q}$ proportional to q (Why?)
  - $F_{q->Q}$ proportional to Q (from N3)
  - $F_{q->Q} = F_{Q->q}$



Foothold idea: Coulomb's Law

- All objects attract each other with a force whose magnitude is given by

$$\vec{F}_{q\to Q} = -\vec{F}_{Q\to q} = \frac{k_C qQ}{r_{qQ}^2}\hat{r}_{q\to Q}$$

- k_C is put in to make the units come out right.

$$k_C = 9\times 10^9 \text{ N-m}^2/\text{C}^2$$

Making Sense of Coulomb's Law

- Changing the test charge
- Changing the source charge
- Changing the distance
- Interpret the sign

$$F_{Q\to q} = F_{q\to Q} = \frac{k_C qQ}{R^2}$$

Quantifying Charge

- Need an operational definition.
- Charge is a new kind of quantity (to M, L, T, add Q).
- Choose our scale:
  A small object has a charge of 1 C (= 1 Coulomb) if two identical such charges held at a distance of 1 m exert forces of 9 x 10^9 N on each other.
- This corresponds to choosing the constant

$$k_C = 9 \times 10^9 \text{ N-m}^2/\text{C}^2.$$

Reading question

- I don't understand why the electric field does not depend on the charge of the test charge, because isn't it the strength of the charge that would depend on how many source charges it affects - which would affect the electric field? (not sure if this question even makes sense; I guess I am confused by electric field as a whole).

Foothold ideas: Electric Fields

- When we focus our attention on the electric force on a particular charge (a test charge) we see the force it feels factors into the magnitude of its charge times a factor that depends on position (and the other charges).

$$\vec{F}_{q_0}^{Enet} = \frac{k_C q_0 q_1}{r_{01}^2}\hat{r}_{0\to 1} + \frac{k_C q_0 q_2}{r_{02}^2}\hat{r}_{0\to 2} + \frac{k_C q_0 q_3}{r_{03}^2}\hat{r}_{0\to 3} + \ldots \frac{k_C q_0 q_N}{r_{0N}^2}\hat{r}_{0\to N}$$

$$\vec{F}_{q_0}^{Enet} = q_0\vec{E}(\vec{r}_0)$$

$$\vec{E}(\vec{r}_0) = \frac{k_C q_1}{r_{01}^2}\hat{r}_{0\to 1} + \frac{k_C q_2}{r_{02}^2}\hat{r}_{0\to 2} + \frac{k_C q_3}{r_{03}^2}\hat{r}_{0\to 3} + \ldots \frac{k_C q_N}{r_{0N}^2}\hat{r}_{0\to N}$$

Reading question

- How come we can ignore the effects of the test charge on all other charged objects? It says that the other objects may be" held down" by forces that are much stronger than the force from the test charge. What causes a charge to be "held down" since we said that the gravitational force is weaker than the electromagnetic force?