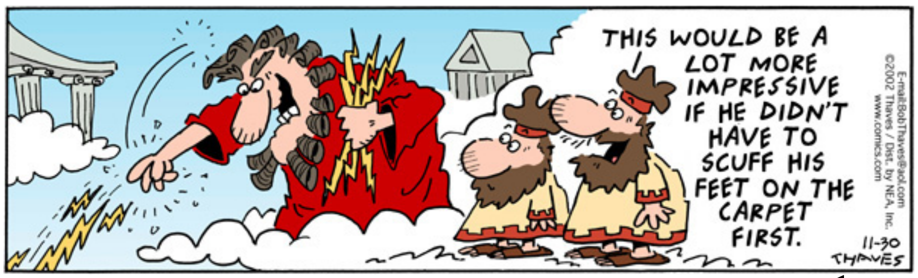
October 14, 2016 Physics 131 Prof. E. F. Redish

- **Theme Music:** **Bob Dylan**
  Mr. Tambourine Man
- **Cartoon:** **Bob Thaves**
  Frank & Ernest



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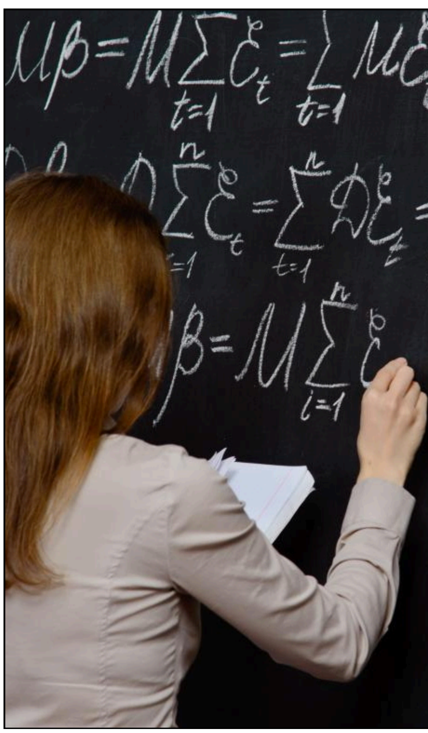

The Equation of the Day

Coulomb's Law

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

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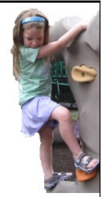


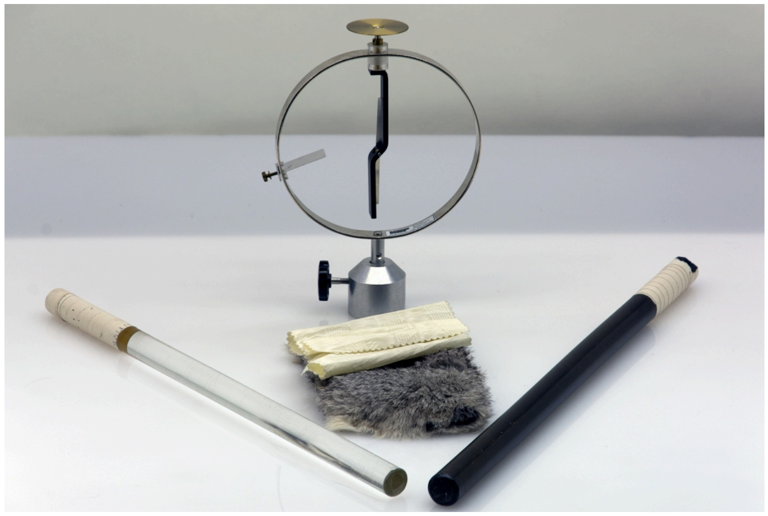
Foothold ideas: Charge – A hidden property of matter

- 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).

Demonstration



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Quantifying Charge

- Need an operational definition.
- Charge is a new kind of quantity (to M, L, T, add Q).
- We will define our unit of charge once we understand the force law – the relationship among the charges, distance, and the force that results.

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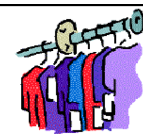
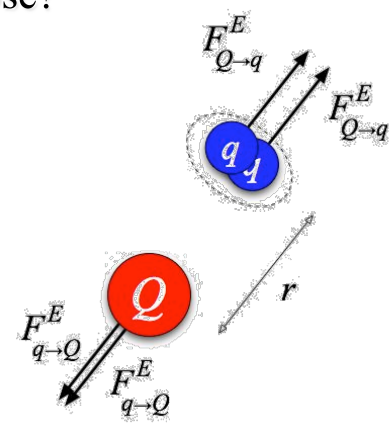
Inventing an Electric Force Law



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



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Foothold idea: Coulomb's Law

- Point charges attract each other with a force whose magnitude is given

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

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

$$[k_C] = \left[\frac{Fr^2}{q_1 q_2}\right] = \frac{\mathrm{ML}}{\mathrm{T}^2}\frac{\mathrm{L}^2}{\mathrm{Q}^2} = \frac{\mathrm{ML}^3}{\mathrm{Q}^2\mathrm{T}^2}$$

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Quantifying Charge

- 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 9×10^9 N on each other.

- This corresponds to choosing the constant
  $k_C = 9 \times 10^9$ N-m^2/C^2. (Actually 8.99)

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Making Sense of Coulomb's Law

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

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

?? Which is the test charge and which is the source charge??

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Adding forces for many charges!

$$\vec{F}_q = \vec{F}_{Q_1 \to q} + \vec{F}_{Q_2 \to q} + \vec{F}_{Q_3 \to q} + \vec{F}_{Q_4 \to q} + \dots$$

$$\vec{F}_q = \frac{k_C q Q_1}{r_1^2}\hat{r}_1 + \frac{k_C q Q_2}{r_2^2}\hat{r}_2 + \frac{k_C q Q_3}{r_3^2}\hat{r}_3 + \frac{k_C q Q_4}{r_4^2}\hat{r}_4 + \dots$$

where

$r_1 =$ distance from Q_1 to q $\hat{r}_1 =$ direction from Q_1 to q (mag. 1, no units!)

$r_2 =$ distance from Q_2 to q $\hat{r}_2 =$ direction from Q_2 to q (mag. 1, no units!)

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