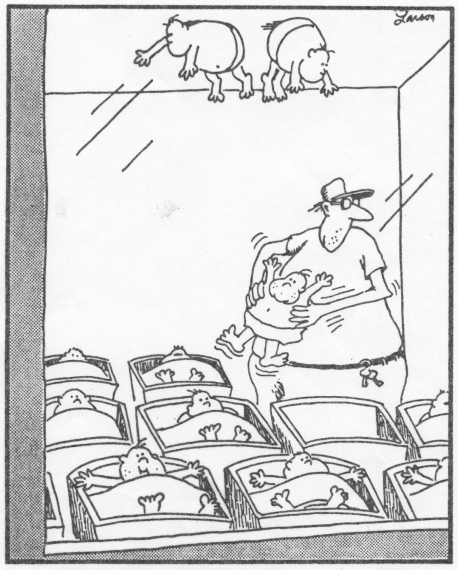
October 15, 2013 Physics 131 Prof. E. F. Redish

- **Theme Music:**
  Moby
  Electricity
- **Cartoon:**
  Gary Larson
  The Far Side



Late at night, and without permission, Reuben would often enter the nursery and conduct experiments in static electricity.

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Outline

- Quiz 5
- Foothold ideas: Electric phenomena
- Model of Matter
  - Conductors and Insulators
  - Polarization
- Electric forces
  - Coulomb's law

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Experiencing Electrostatics

http://phet.colorado.edu/simulations/sims.php?sim=Balloons_and_Static_Electricity

Model: Charge
A hidden property of matter

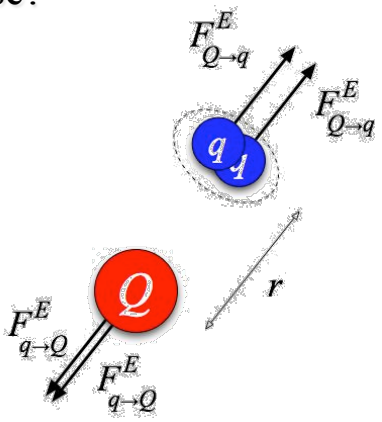
- Matter is made up of two kinds of electric matter (positive and negative) that have equal magnitude and that cancel when they are together and hide matter's electrical nature.
- Matter with an equal balance is called neutral.
- Like charges repel, unlike charges attract.
- The algebraic sum of postive and negative charges is a constant (i.e, $N_+ - N_- = \text{const.}$)

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.
- 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).
- Unbalanced charges attract neutral matter (polarization)

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.

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

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Making sense

- Our equations don't just provide a way of calculating something: They express ideas and relationships about the physical world.
- We need to not just "know" our equations: We have to "see the dog" in our equations.

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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

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

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

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

Review of Vectors (2-dimensional coordinates)

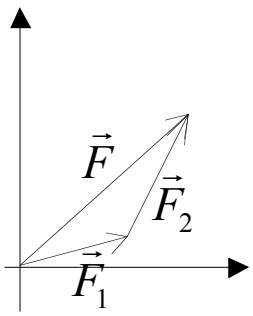
- We have 2 directions to specify. We must
  - Choose a reference point (origin)
  - Pick 2 perpendicular axes (x and y)
  - Choose a scale
- We specify our x and y directions by drawing little arrows of unit length in their positive direction. $\hat{i}, \hat{j}$
- A force vector is written

$$\vec{F} = F_x\hat{i} + F_y\hat{j} = (F_x, F_y)$$

Adding Forces

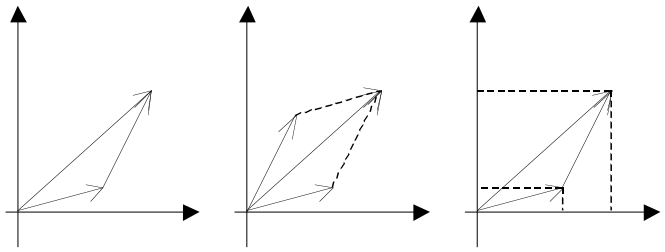
- We define the sum of two vectors as if they were successive displacements.

$$\vec{F} = \vec{F}_1 + \vec{F}_2$$



Adding Vectors: Methods

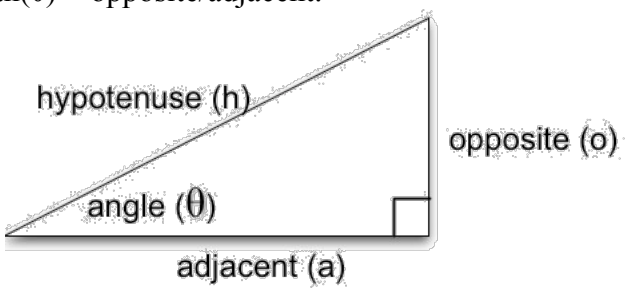
- There are 3 mathematical ways to add vectors



head to tail | parallelogram rule | add components (may use trig)

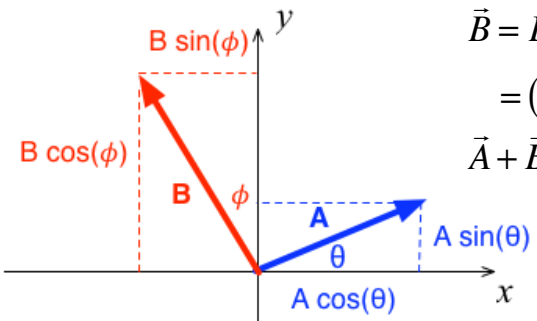
Trig review

- The ratios of a triangle's sides only depend on θ.
  - sin(θ) = opposite/hypotenuse
  - cos(θ) = adjacent/hypotenuse
  - tan(θ) = opposite/adjacent.



Vectors with trig – by components

$$\vec{A} = A_x\hat{i} + A_y\hat{j}$$
$$= \left(A\cos(\theta)\right)\hat{i} + \left(A\sin(\theta)\right)\hat{j}$$
$$\vec{B} = B_x\hat{i} + B_y\hat{j}$$
$$= \left(-B\sin(\phi)\right)\hat{i} + \left(B\cos(\phi)\right)\hat{j}$$
$$\vec{A} + \vec{B} = ?$$



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