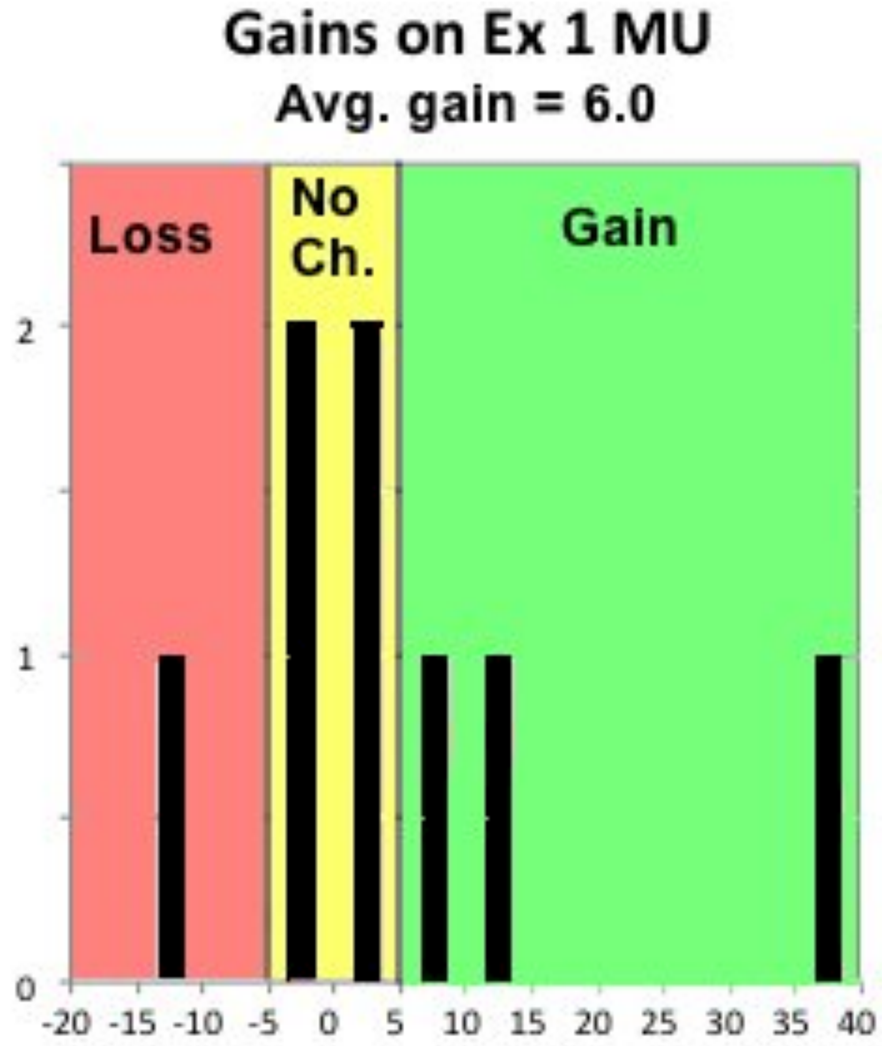
- **Theme Music:** **Human League**
  Together in Electric Dreams
- **Cartoon:** **Bill Watterson**
  Calvin & Hobbes

Exam 1 Makeup

N = 7

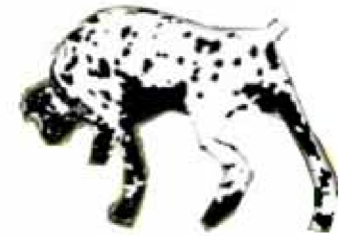
#1	**57%**
#2	**56%**
#3	**16%**
#4	**43%**
#5	**77%**

New Ex1 Av = 62.4%



Making Sense of Coulomb's Law

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



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

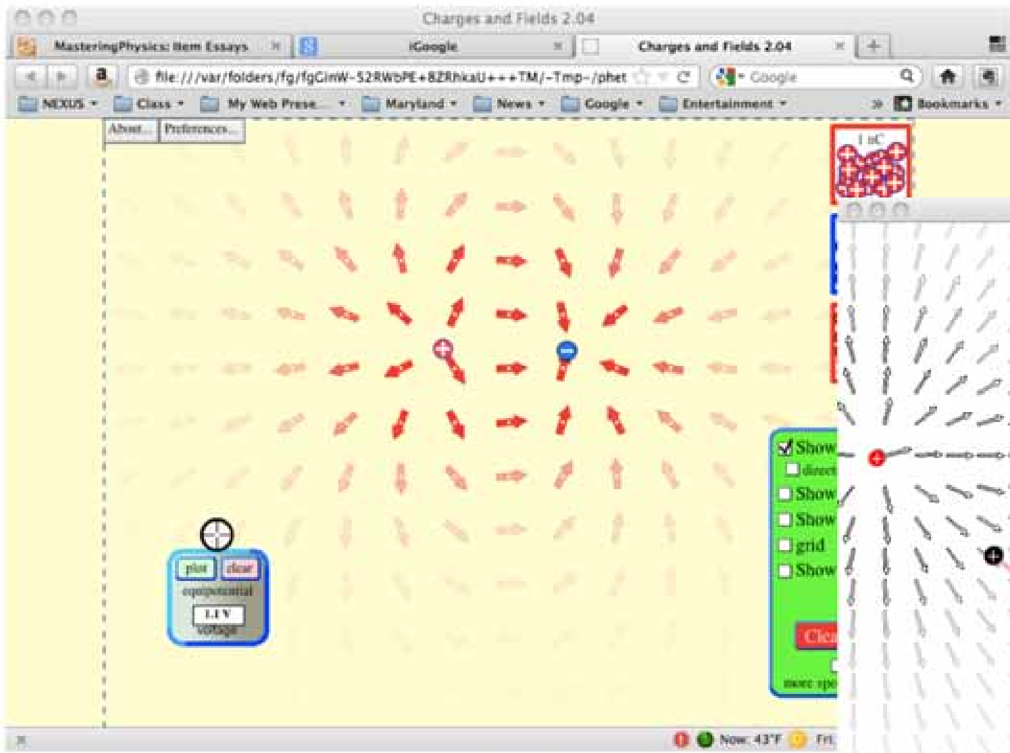
Foothold ideas: Electric Forces and Fields

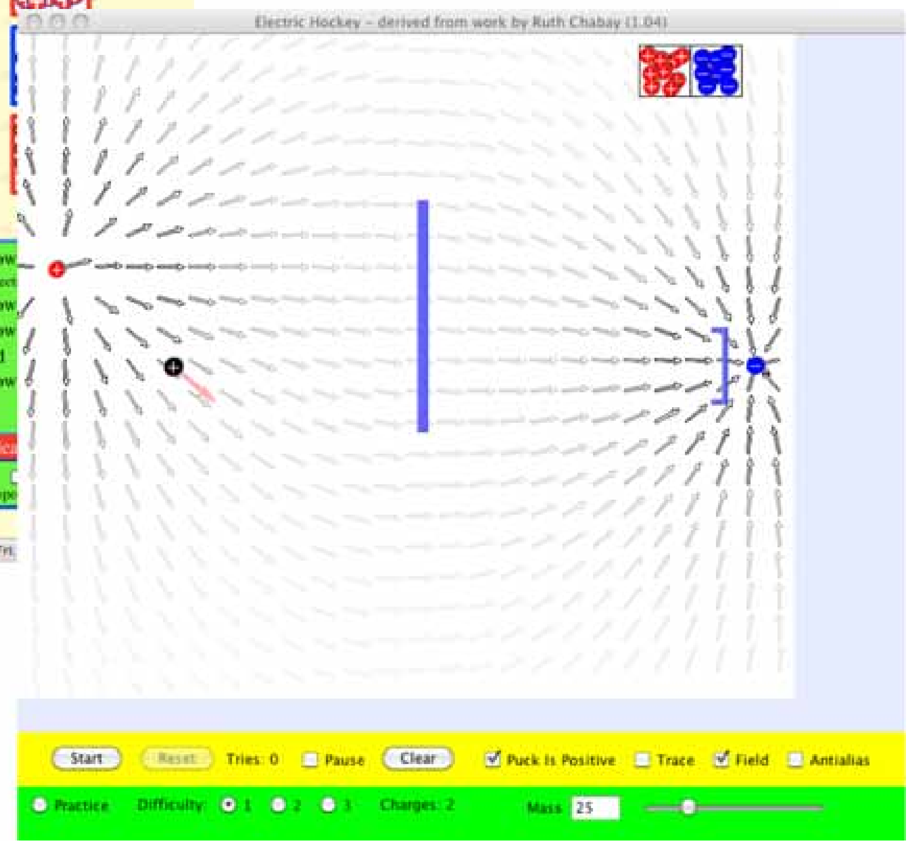
- When we focus our attention on the electric force on a particular charge (a test charge) we see the force it feels factors into the magnitude of its charge times a factor that depends on position (and the other charges).

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

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

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





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

http://phet.colorado.edu/en/simulation/electric-hockey

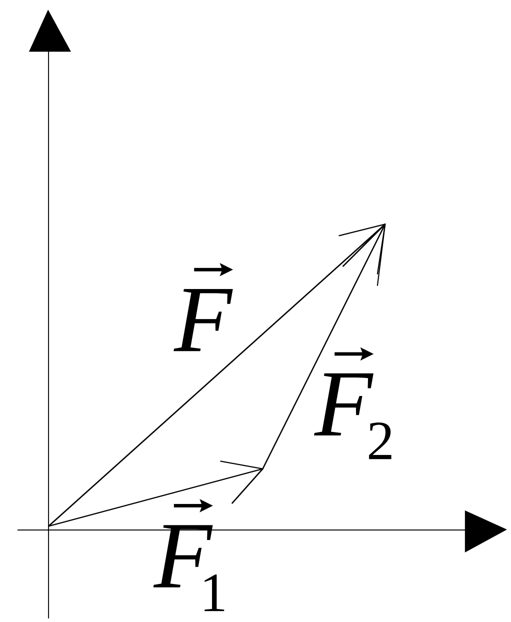
Review of Vectors (2-dimensional coordinates)

- 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

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

Adding Forces

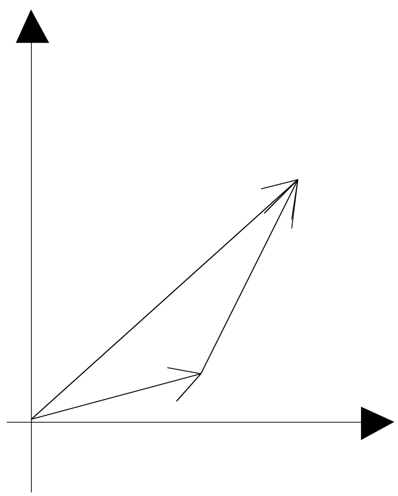
- We define the sum of two vectors as if they were successive displacements.



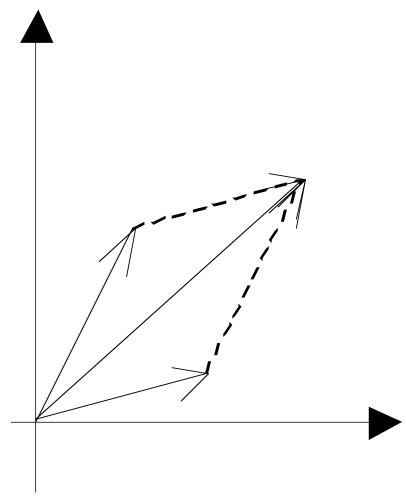
$$\vec{F} = \vec{F}_1 + \vec{F}_2$$

Adding Vectors: Methods

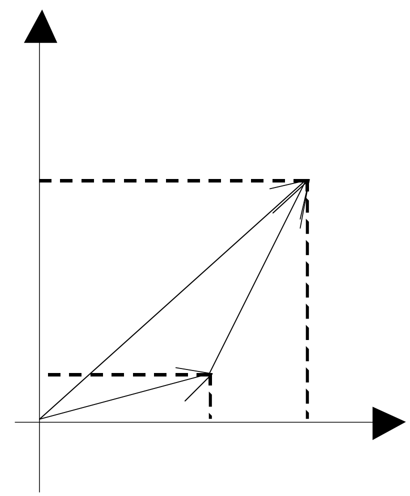
- There are 3 mathematical ways to add vectors



head to tail



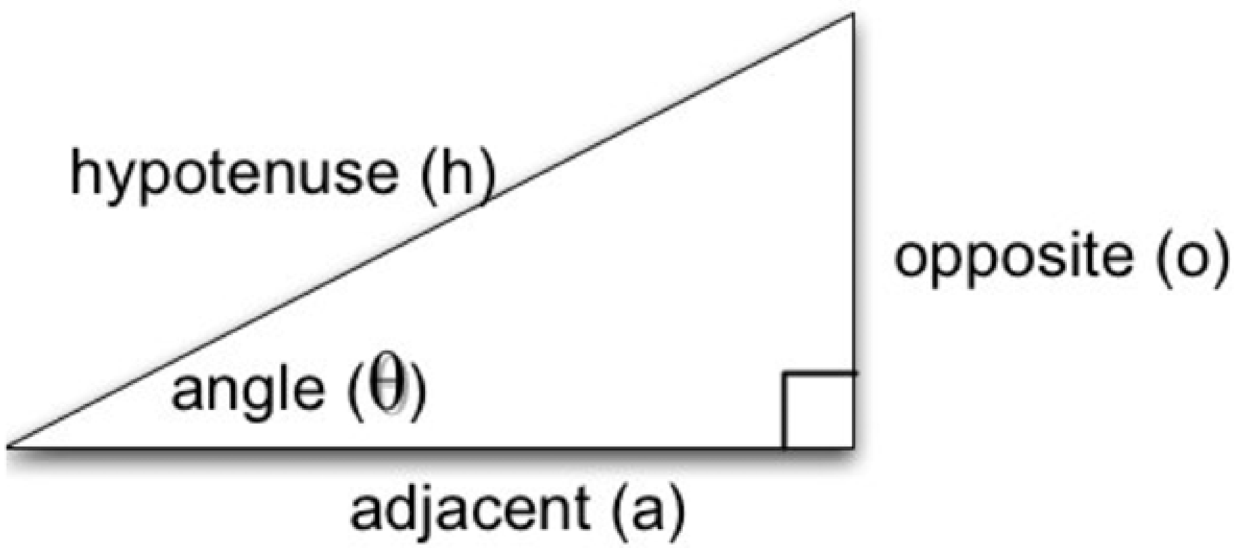
parallelogram rule



coordinates

Trig recap

SOH-CAH-TOA
sin(θ) = opposite/hypotenuse
cos(θ) = adjacent/hypotenuse
tan(θ) = opposite/adjacent



Foothold ideas: 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 what 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* .

In Equations

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

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

where

$r_1 =$ distance from Q_1 to q

$r_2 =$ distance from Q_2 to q

...

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

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

Making sense

- Notice that F_q/q does NOT depend on q!
- For one source charge

$$\vec{F}_q = \frac{k_C q Q_1}{r_1^2}\hat{r}_1 \qquad \vec{E}_q = \frac{\vec{F}_q}{q} = \frac{k_C Q_1}{r_1^2}\hat{r}_1$$

- For many sources

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

- Why not? Why did I label E with a q?