

October 15, 2012

Physics 131

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



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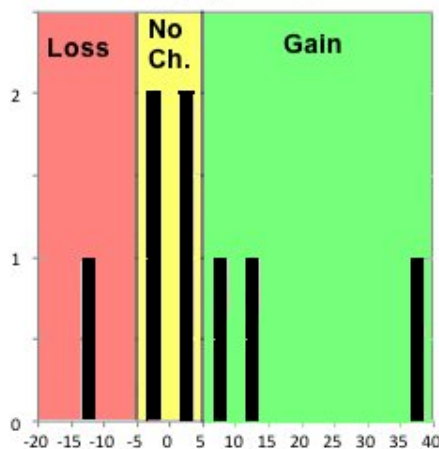
## Exam 1 Makeup

N = 7

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

New Ex1 Av = 62.4%

Gains on Ex 1 MU  
 Avg. gain = 6.0



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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



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

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## 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).



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

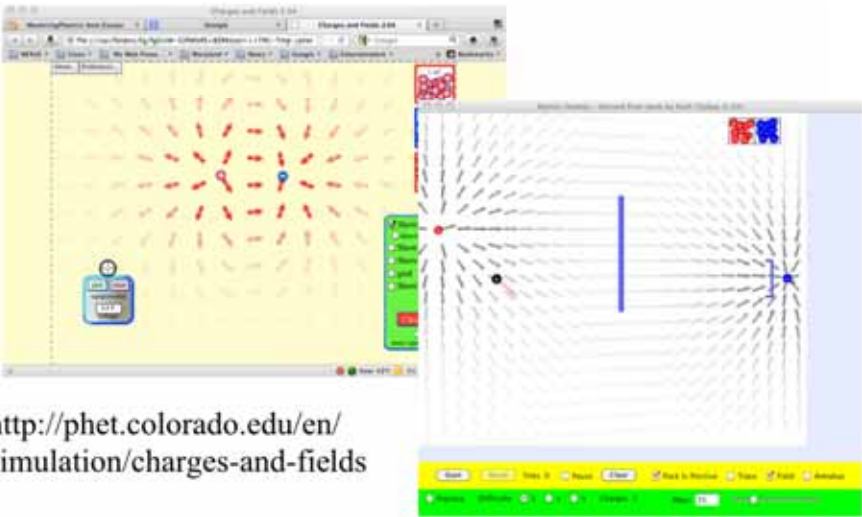
$$\vec{F}_{q_0}^{E_{net}} = q_0 \vec{E}(\vec{r}_0)$$

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

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

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

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

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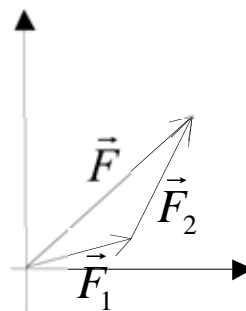
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## Adding Forces

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

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



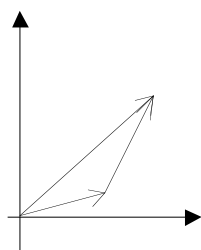
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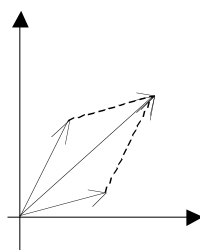
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## Adding Vectors: Methods

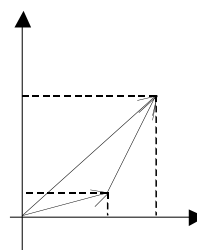
- There are 3 mathematical ways to add vectors



head  
to tail



parallelogram  
rule



coordinates

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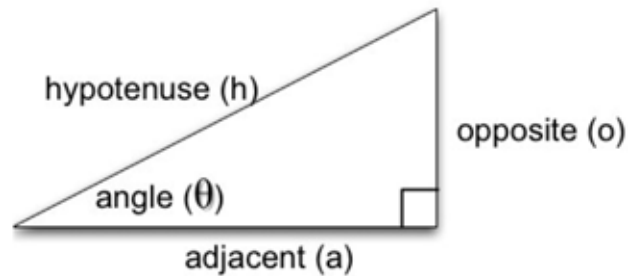
## Trig recap

SOH-CAH-TOA

$\sin(\theta) = \text{opposite/hypotenuse}$

$\cos(\theta) = \text{adjacent/hypotenuse}$

$\tan(\theta) = \text{opposite/adjacent}$



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## 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.

$$\vec{g} = \frac{\vec{F}_{\text{acting on } m}}{m}$$

$$\vec{E} = \frac{\vec{F}_{\text{acting on } q}}{q}$$

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Field is the value at a position in space “ $r$ ” assuming that the force is measured by placing the object at “ $r$ ”.



## In Equations

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

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

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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## Making sense



■ Notice that  $F_q/q$  does NOT depend on  $q$ !

■ For one source charge

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

■ For many sources

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

■ Why not? Why did I label  $E$  with a  $q$ ?

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