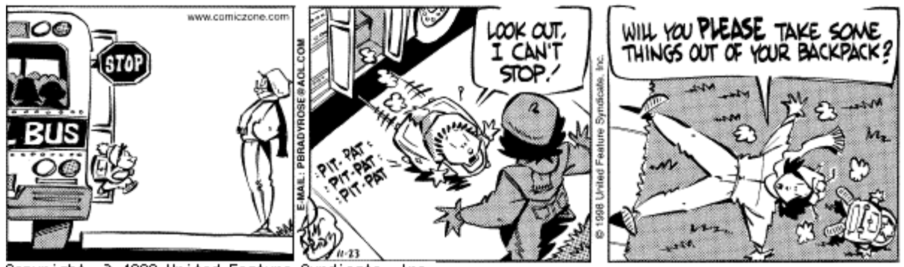
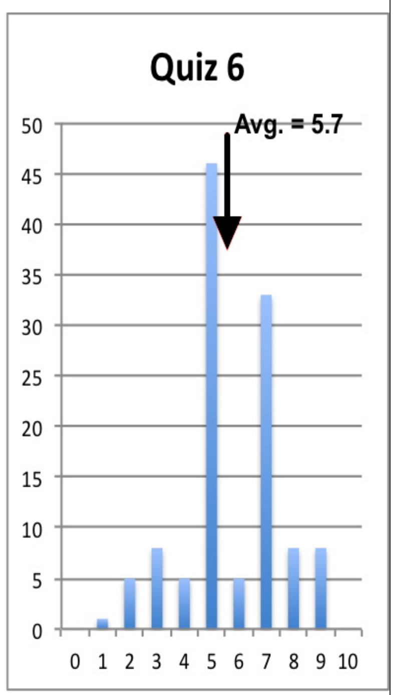
October 19, 2016 Physics 131 Prof. E. F. Redish

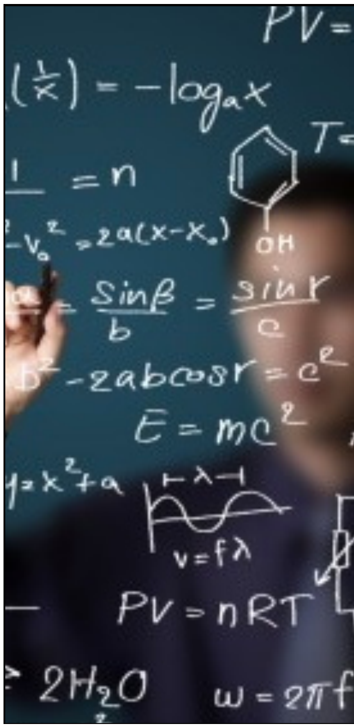
- **Theme Music: Aimee Mann**
  Momentum
- **Cartoon: Pat Brady**
  Rose is Rose



Quiz 6

	1.1	1.2			2.a	2.b	2.c	2.d
a	13%	2%		A	3%	**40%**	7%	**24%**
b	19%	**93%**		B	4%	35%	9%	12%
c	17%	16%		C	2%	4%	8%	12%
d	3%	2%		D	34%	3%	12%	10%
e	**85%**	40%		E	**39%**	3%	**24%**	7%
f	**8%**	**1%**		F	3%	4%	17%	8%
				G	7%	3%	7%	3%
				H	5%	5%	8%	13%
				I	0%	0%	0%	0%
				J	0%	0%	3%	5%
				K	0%	0%	3%	2%





The Equation of the Day

The Impulse-Momentum Theorem

$$\Delta\left(m_A \vec{v}_A\right) = \vec{F}_A^{net} \Delta t$$

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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).

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

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

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

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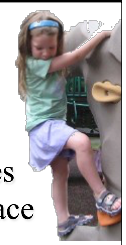
Foothold ideas: Fields



- 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.

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

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

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Making sense

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

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

- For many sources

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

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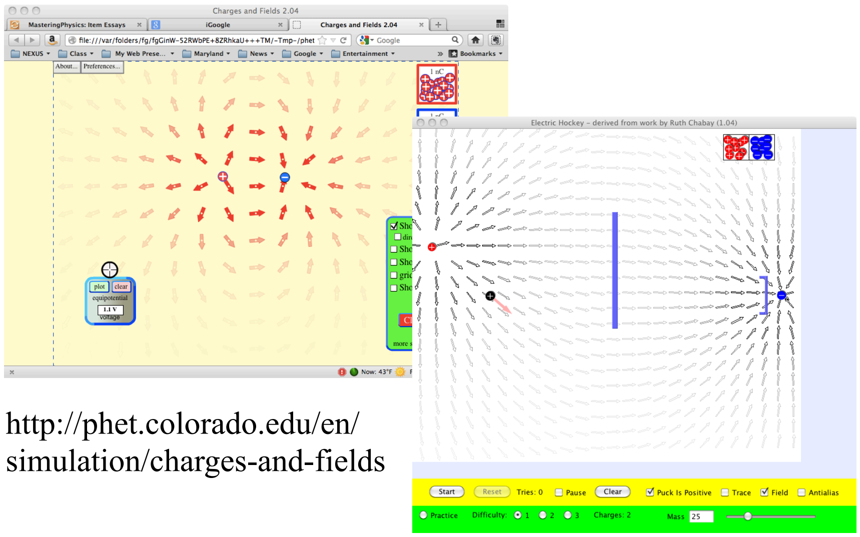

http://phet.colorado.edu/en/simulation/charges-and-fields

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

Foothold ideas: Momentum

- We define the <u>momentum</u> of an object, A:

$$\vec{p}_A = m_A \vec{v}_A$$

- This is a way of defining "the amount of motion" an object has.
- Our "delta" form of N2 becomes

$$\left\langle \vec{F}_A^{net} \right\rangle = m_A \frac{\Delta \vec{v}_A}{\Delta t} = m_A \left\langle \vec{a}_A \right\rangle$$

which we can rewrite as

$$\left\langle \vec{F}_A^{net} \right\rangle = \frac{\Delta \left(m_A \vec{v}_A \right)}{\Delta t} = \frac{\Delta \vec{p}_A}{\Delta t}$$

Foothold idea: The Impulse-Momentum Theorem

- Newton 2 $\vec{a}_A = \vec{F}_A^{net} / m_A$
- Put in definition of *a* $\dfrac{d\vec{v}_A}{dt} = \dfrac{\vec{F}_A^{net}}{m_A}$
- Multiply up by Δt $m_A \Delta\vec{v}_A = \langle \vec{F}_A^{net} \rangle \Delta t$
- Define Impulse $\vec{\mathscr{J}}_A^{net} = \langle \vec{F}_A^{net} \rangle \Delta t$
- Combine to get Impulse-Momentum Theorem for any object A

$$\Delta\vec{p}_A = \vec{\mathscr{J}}_A^{net}$$

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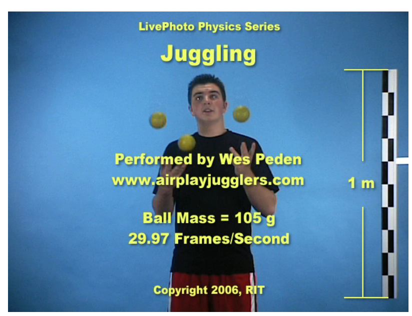
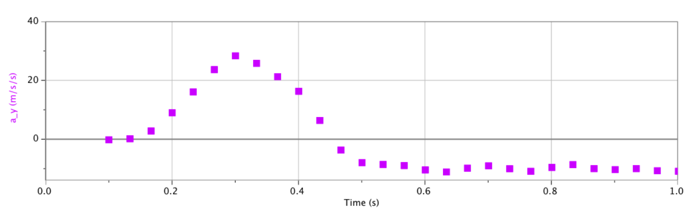
Rethinking the juggler

- As the juggler throws the ball up, the ball rises, and then falls, how is momentum added to or taken away from the ball?



$$\Delta(m_B\vec{v}_B) = \langle \vec{F}_B^{net} \rangle \Delta t$$



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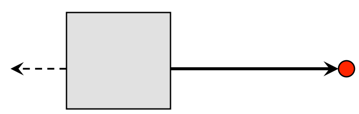
Example: Recoil

- When an object at rest emits a part of itself, in order to conserve momentum, it must go back in the opposite direction.
- What forces are responsible for this motion?



(object goes backwards)