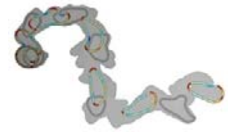
Physics 131- Fundamentals of Physics for Biologists I



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Electrical forces

Outline

- Electric Fields
- Momentum

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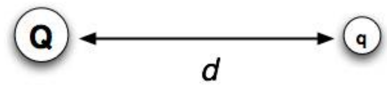
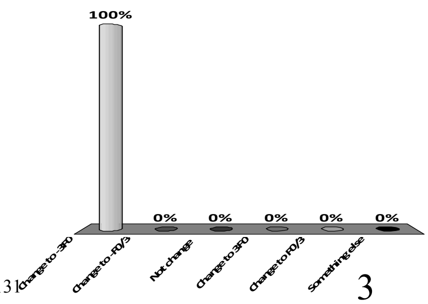
A test charge, q, is a distance d from a charge Q as shown. It feels an electric force, F_0. If q were replaced by a charge $-3q$, **the electric force** on it would

1. Change to $-3F_0$
2. Change to $-F_0/3$
3. Not change
4. Change to $3F_0$
5. Change to $F_0/3$
6. Something else





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Foothold idea: Electric Forces and Fields

When we focus our attention on the electric force on a particular object with charge q_0 (a "test charge") we see the force it feels depends on q_0.

Define quantity that does not depend on charge of test object "test" charge -> **Electric Field E**

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

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

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

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Foothold ideas: Fields

- A *field* is a concept we use to describe anything that exists at all points in space, even if no object is present.
- A *field* can have a different in magnitude at different points in space. (and if it's a vector field, direction). Examples: temperature, wind speed, wind direction
- A *gravitational*, *electric, or magnetic field* is a force field. Fields allow us to predicts the force that a test object would experience. The field does not depend on what test object is used.

$$\vec{g}\left(\vec{r}\right) = \frac{\vec{F}_{\text{acting on } m}\left(\vec{r}\right)}{m} \qquad \vec{E}\left(\vec{r}\right) = \frac{\vec{F}_{\text{acting on } q}\left(\vec{r}\right)}{q}$$

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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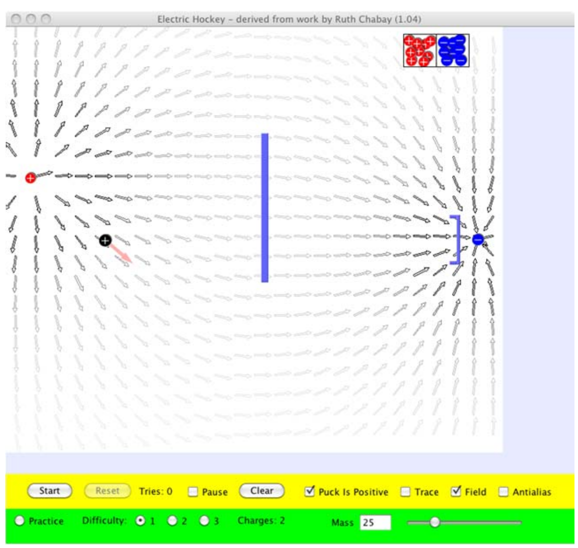

http://phet.colorado.edu/en/simulation/electric-hockey

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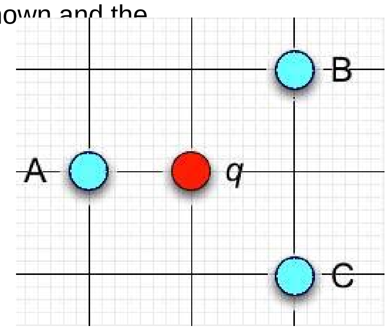
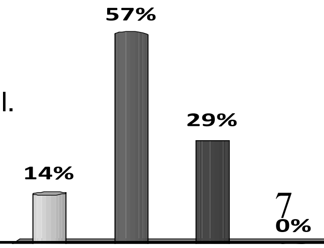
A test charge (labeled *q*) is placed in a situation in which it feels the electrical force from three other charges (of opposite sign to it) labeled A, B, and C. (The charges are on a uniform grid as shown and the positions are to scale.) Which of the following combinations of forces has the greatest magnitude?



1. $\vec{F}_{A \to q}$
2. $\vec{F}_{B \to q} + \vec{F}_{C \to q}$
3. $\vec{F}_{A \to q} + \vec{F}_{B \to q} + \vec{F}_{C \to q}$
4. There is not enough information to tell.



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Momentum

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Momentum: Definition

- We define momentum:

$$\vec{p} = m\vec{v}$$

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

which we can rewrite as $\vec{F}^{net} = m\frac{\Delta\vec{v}}{\Delta t} = m\vec{a}$

$$\vec{F}^{net} = \frac{\Delta(m\vec{v})}{\Delta t} = \frac{\Delta\vec{p}}{\Delta t}$$

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The Impulse-Momentum Theorem

- Newton 2 $\vec{a} = \vec{F}^{net}/m$
- Put in definition of *a* $\frac{d\vec{v}}{dt} = \frac{\vec{F}^{net}}{m}$
- Multiply up by Δt $m\Delta\vec{v} = \vec{F}^{net}\Delta t$
- Define Impulse $\vec{\mathscr{J}}^{net} = \vec{F}^{net}\Delta t$
- Combine to get Impulse-Momentum Theorem $\Delta\vec{p} = \vec{\mathscr{J}}^{net}$

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Momentum Conservation: 1

- If two objects, A and B, interact with each other and with other ("external") objects,

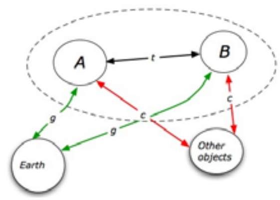
$$m_A \, \Delta\vec{v}_A = (\vec{F}_A^{ext} + \vec{F}_{B\to A})\Delta t$$

$$m_B \, \Delta\vec{v}_B = (\vec{F}_B^{ext} + \vec{F}_{A\to B})\Delta t$$

- Adding:

$$m_A \, \Delta\vec{v}_A + m_B \, \Delta\vec{v}_B = \left[\vec{F}_A^{ext} + \vec{F}_B^{ext} + \left(\vec{F}_{A\to B} + \vec{F}_{B\to A}\right)\right]\Delta t$$

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = \vec{F}_{AB}^{ext}\,\Delta t$$



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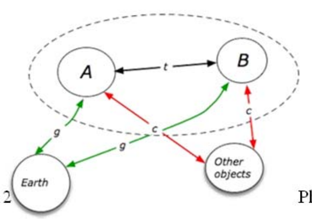
Momentum Conservation: 2

- If the external forces on the "system of interest" cancel, then momentum is conserved.

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = 0$$

$$m_A\vec{v}_A^{\,i} + m_B\vec{v}_B^{\,i} = m_A\vec{v}_A^{\,f} + m_B\vec{v}_B^{\,f}$$



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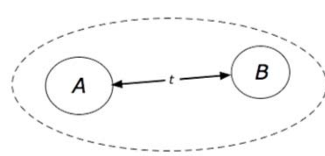

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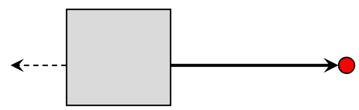
Example: Recoil

- 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)

Do it!

- Practice with equations

http://www.physics.umd.edu/perg/abp/TPProbs/Problems/P&E/P&E26.htm

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