BEFORE CLASS:
Show that a charged stick or sphere exerts a force on an uncharged object (wood or metal sticks; can).
What determines whether the force is attractive or repulsive?
Why is there a force at all??

RECITATIONS START TOMORROW!

FIRST HOMEWORK ASSIGNMENT IS DUE
11:59PM Tuesday Sept 17

class web site
http://www.physics.rutgers.edu/ugrad/227H
Example:

What is the direction of the net electric force on the middle particle, if the particles on the x axis are equidistant from the origin?
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What is the direction of the net force on the middle particle, if the particles on the x axis are equidistant from the origin?
Four particles with identical charges $q$ are arranged as shown below. In which of the three arrangements is the magnitude of the net electric force on the central charge LARGEST?
Electrical charge
Property of an object, electric force

units: C (coulombs)
Q or q

Matter is made up of charged particles:
electrons and nuclei (protons and neutrons)

Electron is elementary particle with charge \(-e = -1.604 \times 10^{-19} \text{ C}\)

Charge of composite object is sum of charges
Charge of nucleus is \(+Ze\) (Z=number of protons, charge +e)

Charge of atom is exactly zero
Charge conservation

Simple charge conservation
Cut an object into two pieces
Put two objects together
(count up the electrons and nuclear charges)

In high energy physics
particles are created and destroyed
but total charge does not change
Can there be an electric force between a charged object and a neutral object?
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Object can have charged regions and still have net charge $= 0$

$+q$ $-q$ $+q$
Can there be an electric force between a charged object and a neutral object?

Object can have charged regions and still have net charge = 0
Simple example where net force is not zero
All materials are made of nuclei and electrons

Insulators (wood, plastic, glass)

electrons have to stay close to their home nuclei – charges move only about an interatomic spacing

Conductors: (metal, tap water, the human body)

Some fraction of the electrons are free to move anywhere in the material
External charge induces rearrangement of charges in an object

Atomic nuclei

+q ----------- -q

electrons

+q
Can there be an electric force between a charged object and a neutral object?

Induced charge rearrangement leads to a net force
What is the direction of the force for a negative external charge?

-\( q \)  

(A) towards the external charge  
(B) away from the external charge  
(C) the force is zero  
(D) cannot determine without more information
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Charged particle $Q$
Charged particle Q

\[ \vec{F} = q_1 \left( kQ / r^2 \right) \hat{r} \]

\[ \vec{r} = \text{vector from Q to } q_1 \]

\[ \hat{r} = \frac{\vec{r}}{|\vec{r}|} \]
Charged particle $Q$

\[ \vec{F} = q_2 \left( \frac{k Q}{r^2} \right) \hat{r} \]
Charged particle $Q$

Repeat for any value $q$ of the charge of the 2$^{\text{nd}}$ particle
Repeat for any position $r$

$$\vec{F} = q \left( \frac{kQ}{r^2} \right) \hat{r}$$

Electric field $\vec{E}(\vec{r}) = \left( \frac{kQ}{r^2} \right) \hat{r}$ (vector field, units are N/C)

$$\vec{F} = q \vec{E}(\vec{r})$$
Electric field

More than just a computational convenience

A charged particle produces a electric field, modifying the space around it

The electric field produced by a system of two or more charges is the vector sum of the electric field produced by each particle
Iclicker: The figure shows four systems in which charges are arranged on a line. In which system is the magnitude of the electric field at the central point GREATEST?
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Electric field lines point in the direction of $\mathbf{E}$ at any point.

Spacing of lines decreases as magnitude of $\mathbf{E}$ increases.

$q > 0$

$q < 0$
Definition of **dipole**

Electric field of the dipole?
Electric field at points on the x-axis

Q  -Q
Electric field at points on the x-axis
Electric field at points on the y-axis
Continuous charge distributions

Volume density $\rho$: charge/volume (C/m$^3$)

Surface charge density $\sigma$: charge/area (C/m$^2$)
EXAMPLE: uniform spherical shell $Q$, $R$
$\sigma = Q/(4\pi R^2)$

Line charge density $\lambda$: charge/length (C/m)
EXAMPLE: uniform straight wire $Q$, $L$
$\lambda = Q/L$