Welcome to PY106

-The syllabus is your guide to this course. It contains information about the discussions, labs., the class, lab. and exam. schedules and grading scheme, etc.
- Discussion sessions begin today!
- Labs. begin on Jan. 28.
- Assignment 1 is a hand-in, and will be posted on Blackboard soon. It is due on Tuesday (Jan. 28) 10:00pm.
- Most other assignments are posted on WebAssign. To access the assignment, you need to acquire an access code from WebAssign. Instructions for WebAssign can be found in the syllabus.
- Lecture notes can be downloaded from http://physics.bu.edu/~okctsui/PY106.html. Note that the URL is case sensitive.

Setting the Channel Number for Your Clicker

1. Press and release the "CH" button.
2. While the light is flashing red and green, enter the two digit channel code "41" for this class.
3. After the second digit is entered, press and release the "CH" button. The light should flash green to confirm.
4. Press and release the "1/A" button. The light should flash amber ONCE to confirm. If it flashes continuously, there is probably an error and you should try it again.

Electric Charge

Electric charges

There are two kinds of electric charge, positive and negative.

Objects are generally charged by either acquiring extra electrons (a net negative charge), or giving up electrons (a net positive charge).

Forces between charged objects can be very large. Such forces are really what stop us from falling through the floor. In other words, what we called the normal force is really associated with repulsive forces between electrons.

Our symbol for charge is Q or q.
The unit is the coulomb (C).

Observations

Place one nylon rod on a rotating stand, and bring another nylon rod close to the first rod, without allowing the rods to touch.

Nothing happens.

Repeat after rubbing both rods with a piece of silk.

Now the rods repel one another.

How can we explain this? Rubbing a nylon rod with silk transfers electrons from one to the other, giving the rod a net charge. Both rods have a net charge of the same sign, and like charges repel.

Observations

When we go through a similar process with rubber rods, using felt or fur, we also observe that the rods repel one another, after they are rubbed with the felt or fur.

What happens when a rubber rod, after being rubbed with felt or fur, is brought close to a nylon rod that has been rubbed with silk?

The rods attract each other.

In the last experiment, we learned that like charges repel. The behavior found here, being opposite to that found in the last experiment must tell us that the signs of the net charges on the rods are opposite. Therefore, unlike charges attract.

Charging an object

An object can acquire a net charge by touching another material. Which material acquires electrons is determined by where the materials fit in the ***triboelectric series***.

MORE POSITIVE
rabbit's fur
glass
nylon
cat's fur
silk
polyethylene
rubber balloon
MORE NEGATIVE

When materials are rubbed together, the one higher up the list gives electrons to the one further down the list.

Nylon is higher up than silk, so nylon gives up electrons, becoming positive, when rubbed with silk.

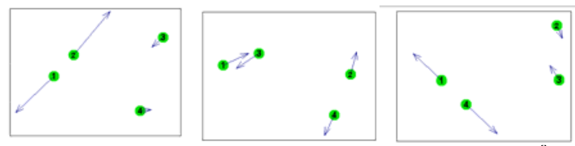
Rubber is lower than fur (or felt), so rubber acquires electrons and a negative charge.

Four charged objects

Simulation (fourcharges_sim.html)

The pictures below show four charged objects, numbered 1, 2, 3 and 4. The net force that each of the objects experiences because of the presence of the other three objects.

If object 1 is positive, how many of these objects are positive?



Four charged objects

If Object 1 has a positive charge, how many objects (including Object 1) have a positive charge?

1. One of them
2. Two of them
3. Three of them
4. Four of them
5. One or three of them, we can't tell.

Electric charge

Charges that we encounter in daily life is quantized – comes in integer multiples of e, the magnitude of the charge on the electron.

$$e = 1.60 \times 10^{-19}\ \text{C}$$

An electron has a charge of $-e$.

When an object gains (loses) an electron, the object becomes charged with a charge of $-e$ ($+e$).

Calculating charges

In solving a problem, you calculate the charges on three objects to be:

$Q_1 = 5 \times 10^{-15}$ C; $Q_2 = 5 \times 10^{-19}$ C; $Q_3 = 5 \times 10^{-23}$ C

Are any of these results clearly incorrect?

1. They're all wrong
2. Q_1 and Q_3 are wrong
3. Q_2 and Q_3 are wrong
4. Q_3 is wrong
5. No - all three of these answers are possible.

Calculating charges

$Q_3 = 5 \times 10^{-23}$ C is definitely a problem.

Q_2 is probably $3e$, 4.8×10^{-19} C.

Similarly, Q_1 is probably $30{,}000e$.

Charge and mass

A charged rod is touched to a neutral object. When the rod is removed, the object is found to have acquired a charge of +1 C (this is actually an extremely large charge). Is the object heavier or lighter than when it was neutral?

1. Heavier by a significant amount
2. Heavier by just a small amount
3. The mass is unchanged
4. Lighter by just a small amount
5. Lighter by a significant amount

Charge and mass

Charging an object almost always involves transferring electrons. In this case, the object must have lost 6.25 x 10^{18} electrons, making it lighter.

The charge-to-mass ratio of the electron is:

$$\frac{e}{m} = \frac{1.60 \times 10^{-19} \text{ C}}{9.11 \times 10^{-31} \text{ kg}} = 1.76 \times 10^{11} \text{ C/kg}$$

So the mass loss per 1 C change in charge is the inverse of this, which is:

$$\frac{m}{e} = 5.69 \times 10^{-12} \text{ kg/C}$$

Two spheres

Simulation

Two identical metal spheres are charged. Sphere A has a net charge of +7Q. Sphere B has a net charge of -3Q. The spheres are brought together, allowed to touch, and then separated. What is the net charge on each sphere now?

Two spheres

Two identical metal spheres are charged. Sphere A has a net charge of +7Q. Sphere B has a net charge of -3Q. The spheres are brought together, allowed to touch, and then separated. What is the net charge on each sphere now?

1. Each sphere has a net charge of +4Q
2. Each sphere has a net charge of +2Q
3. Sphere A has +4Q, Sphere B has no net charge
4. Sphere A has +7Q, Sphere B has -3Q
5. Sphere A has -3Q, Sphere B has +7Q

Two spheres

As long as we allow the spheres to touch in a way that no charge is transferred in or out of the system, we can use the idea that charge is conserved – the net charge in the system must be constant at all times.

In this case, the net charge is +7Q -3Q = +4Q. Because the spheres are metal, electrons can move around easily on the spheres. The spheres are identical, so the net charge of +4Q divides evenly between the spheres, giving each sphere a charge of +2Q.

Classifying materials

We can classify materials into three broad categories, based on how easily charge flows through them.

Conductors: charge flows easily (e.g., metals).

Semi-conductors: charge flows, but not easily (e.g. graphite).

Insulators: very little charge flow (e.g. plastic).

Application: a power cord you plug into a wall socket has two conducting wires to carry electricity to your cell phone and back, but the wires are wrapped with a rubber coating so you do not get a shock.

An electroscope

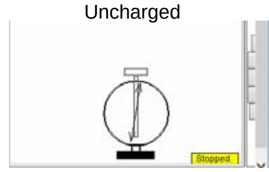
Simulation (electroscope sim)

An electroscope is a device that indicates the presence of charge. An electroscope is made from conducting materials (generally metal). If you put charge at a particular point, the charge will distribute itself over the surface of the conductor.

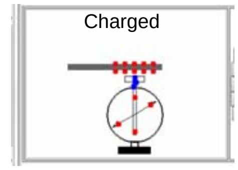
When our electroscope is uncharged, its rotating arm is vertical. When the electroscope is charged, the arm moves away from vertical. Why? This is true as long as there are no charged objects nearby - in a few minutes we'll discuss what happens when there are charged objects nearby.

Charging an electroscope

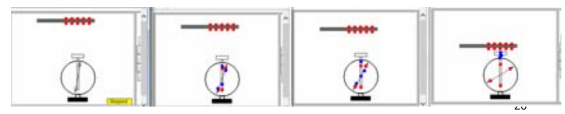
Uncharged



Charged



Charging process:



Charging an electroscope

Let's charge an electroscope by touching it with a charged insulating rod at one spot. Is there a more effective way to charge the electroscope?

1. Rubbing the rod over the electroscope is better
2. Touching and rubbing are equivalent
3. It depends on whether the insulating rod has + charge or - charge

Charging an electroscope

If the charged object is an insulator, touching it to the conductor transfers charge only at the few points of contact.

Rubbing the insulator over the conductor is much more effective at transferring charge.

It makes no difference whether the rod has a positive charge or a negative charge.

The conductor acquires charge of the same sign as the charged object brought into contact with it.

Playing with an electroscope

We're given an electroscope that has a positive charge. We then bring a positively charged rod close to, but not touching, the electroscope. What does the indicator arm do?

1. Nothing
2. The arm deflects even more
3. The arm deflects less

Playing with an electroscope

The arm deflects more. Bringing a positively charged rod close to the top of the electroscope means electrons are attracted from the arms of the electroscope to the top. With even more positive charge on the arms than before, the repulsive force is stronger.

Bringing a negatively charged rod close to the positively charged electroscope makes the arm deflect less.

Thus, a charged electroscope can distinguish between positively charged objects and negatively charged objects.

A soda can

A soda can is an excellent charge detector. If we bring a positively charged nylon rod close to the can, the can is attracted to the rod.

What happens when a negatively charged rubber rod is brought close to the can instead?

1. nothing
2. the can is attracted to the rod
3. the can is repelled by the rod

A soda can

In both cases, the can is attracted.

Whether the rod is positive or negative, the rod polarizes the can (the can acts like a huge polar molecule) so the side of the can closest to the rod has a charge opposite to the charge on the rod. This leads to a net attractive force between the can and the rod.

Try this at home

A thin stream of water is another excellent charge detector. Amaze your friends by charging an object by rubbing it, and then attracting the stream of water toward the charged object.