Lab 01B Electrostatics: The law of charges   Revised for 2013

Note: Please refer to the worksheet on our website as a guide to help with your writeup today.

In lab 01A, you verified an important aspect of Coulomb's law:

$$\vec{F}_{21} = k\frac{q_1 q_2}{\vec{r}_{12}^{\,2}}\hat{r}_{12},$$

namely that the force between two charges varies as

$$\frac{1}{(\text{separation})^2}.$$

You did this by measuring the electrostatic force between two charges for different separations between the charges. When the force which was proportional to sin(θ) was plotted vs. separation, a characteristic $1/R^2$ curve should have resulted which is due to Coulomb's law. We did this part of lab01A early in order to obtain favorable humidity conditions: it really does not work well at all in warmer temperatures. This lab is a continuation of that lab which will perform a qualitative investigation of the validity of the law of charges.

I hope that you come away from labs 01A and 01B with a better feeling for the nature of electrical charges. You will need to know before hand that charge comes in units of Coulombs (C) and the smallest unit of charge is the charge on an electron or a proton which is of magnitude $1.60\text{x}10^{-19}$C.

The law of charges

You are provided with an electroscope. The electroscope is simple enough to make that you might consider making them for yourself. It consists of two pieces of aluminum foil which are free to swing attached to a copper wire all enclosed in a plastic cup for protection. In smaller labs, however, the store-bought electroscopes will be used since aluminum oxide formation on the leaves produces undesirable results. You will also need for this lab glass and rubber rods and wool, cat's fur and acetate and an electrophosphorus. In general, static charges are created by rubbing two materials together: rubbing the rubber rod on cat's fur will produce what **we define to be a negative charge on the rubber rod** while rubbing the glass rod on acetate will produce what we define to be a positive charge. It is amazing that this definition of negative charge still persists even in our modern era. But it is a good definition since rubber is relatively easy to find and cats are even easier to find. Use the cats fur sparingly however since in my lifetime, I hope to never have to buy any cats fur: this was here when I came. Also do not hold it in your hand for extended periods since it will become humid.

Experiment 1 (Two types of charges)
Completely discharge your electroscope by touching the copper loop at the top with your finger.
Rub your rubber rod with cat's fur about 20 times.
Touch the rubber rod to the electroscope ball.
You will observe that the leaves separate.
Rub the glass rod on the acetate about 20 times.
Touch the glass rod to the electroscope.
You will observe that the leaves are now separated by less distance.
An important note: don't hold the cat's fur very long since you will make it have a higher humidity than is desirable.

The results of Experiment 1 should now leave you with little doubt that there are two types of charges. The sign of each of these charges is only a result of convention. Charges aren't born with little + and – signs on them.

Now devise an experimental method to test for the sign of rubber on acetate and glass on wool. Perform your experiment and report the signs of the charges on the rods that result.

Experiment 2: (Like negative charges repel each other)

It is possible to now do a quick experiment that ought to convince you about some elementary behavior of charges, namely that like charges repel. It stands to reason that if you rub a balloon with cat's fur the result will be that the balloon will contain a negative charge.

However you will want to devise an experiment to test this. On the worksheet, describe the experiment that will test the sign of the charge deposited on a balloon when rubbed with cats fur.

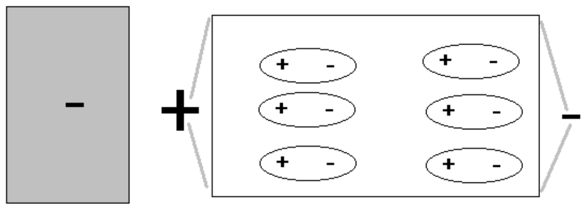
Take two balloons and inflate them and then tie the two balloons to each end of a thread which is about 1 m long. Support the string in the middle above your head in some way so that the two balloons are hanging downward but are free to move around. Rub each of the balloons with cat's fur so that the charge is the same on both balloons.
Do the balloons attract or repel each other?

You could, if you wished, knowing the mass of the balloons and by knowing the length of the string from the pivot point determine the magnitude of the force.

Now, we are pretty sure that the charge on the balloons is negative. If you think of how to confirm this quickly, you may think that the easiest way is to charge the rubber rod and then bring it close to the balloons. If the balloon were attracted to the rod, it would seem to be positive, right? Try this and see what happens.

For a reason which is less obvious (see later experiments for some additional help here), this technique will not necessarily give you the result that you expect. Here is the way to confirm the sign on the balloons: rub the electroscope loop over the charged balloons until the leaves separate. Be careful to make sure that the leaves remain separated when you remove the electroscope away from the balloon. Then with the charged rubber rod, touch the electroscope ball. If the leaves separate more, then the charge on the balloons is the same as on the rubber rod. What is the sign of the charge on the balloons from your observations?

The "reason which is less obvious" is now something to look at. With your balloons hanging in the air, walk in a circle around them. You will see that one of the balloons seems to follow you, always pointing towards you. I call this device, therefore, a people locator. The balloon is inducing a charge in your body (which is mostly water) and since opposite charges are attracted to each other, the balloon is attracted to your body. This is also easily demonstrated with a third balloon. Inflate your third balloon and then rub it with cat's fur. Place it against the wall. If luck (in the form of correct humidity) is with us, you will see that the balloon sticks to the wall. The reason both of these phenomena happen is because of polarization. Look at the picture below.



A negative charged object such as a balloon when brought close to a polar object such as a wall will tend to reorient the molecules inside the wall providing an attractive force. Most likely, the molecules which are being reoriented are water molecules since they are highly polar. This is also a demonstration of the second part of the law of charges which is that unlike charges attract. Thus, we have the law of charges stated as:

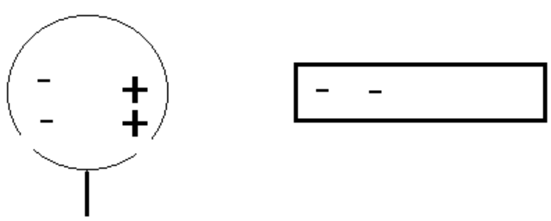
Unlike charges will be attracted towards each other and like charges will be repelled from each other.

You should regard this law as one of the fundamental laws governing electricity and magnetism and you must stick this inside your mind for use whenever you are working with electrostatics problems.

Experiment 3: Charging by induction

The type of charging which you have just done is called charging by contact. The charges actually flow to or from the body directly when charged by contact. We can charge bodies in another way, however.

We can charge the electroscopes positively by inducing a charge on them. Inside a metal conductor, the electrons are free to move about (the physical term for a conductor is equipotential surface). If a negatively charged rubber rod is brought close to the loop of the electroscope (but not in contact with the loop) you will observe a migration of the charges to the ball of the electroscope as shown below.



If you momentarily touch your finger to the negatively charged side of the electroscope loop, you will remove the negative charge located there. Upon removal of the rubber rod (after removing your finger from the electroscope), you will find that the electroscope has a net positive charge. Go through the steps required to place a positive charge on the electroscope (in this manner) until you are sure you understand the process. You should use your glass rod in order to confirm that the charge placed on the electroscope through this technique is indeed positive.

Now that you know how to charge your electroscope positively by induction, you also should know what you need to do to charge your electroscope negatively by induction. Do this and confirm that you have indeed placed a negative charge on the electroscope.

Your assignment here is to use your electroscope to determine the charge on the pie pan (positive or negative). You will need to devise the steps need to justify this judgment and discuss them in your writeup.

While we are talking about polarization, and charging by induction **an essential experiment must be done.**

Design a method to test the charge obtained from the pie pan which charged with the styrofoam in the normal way. See if the **uncharged** balloon is attracted to or repelled from this charge.

Design a method (i.e. by induction) to give the pie pan the opposite charge. See if the **uncharged** balloon is attracted to or repelled from this charge.

In your write up, you must represent that you performed this portion of the lab correctly or you will need to do it again. And, make sure your balloon is uncharged: if the balloon has a charge on it, it will not provide correct results.

however, you need to investigate what happens to an uncharged balloon in the presence of a positively and negatively charged pie pan.

The electrostatic chime (demonstration)

A really neat electrostatic engine is the electrostatic chime. This is a demonstration that you may use in the lab today. Charge it with your electrophorus and the small ball will bounce back and forth as charge is transferred between the plates. Explain (in your words) how this works.