Lab 1: Electric Charge and Electrostatic Forces

Follow along with the following activities. Questions are highlighted in red. Please write your answer in blue!

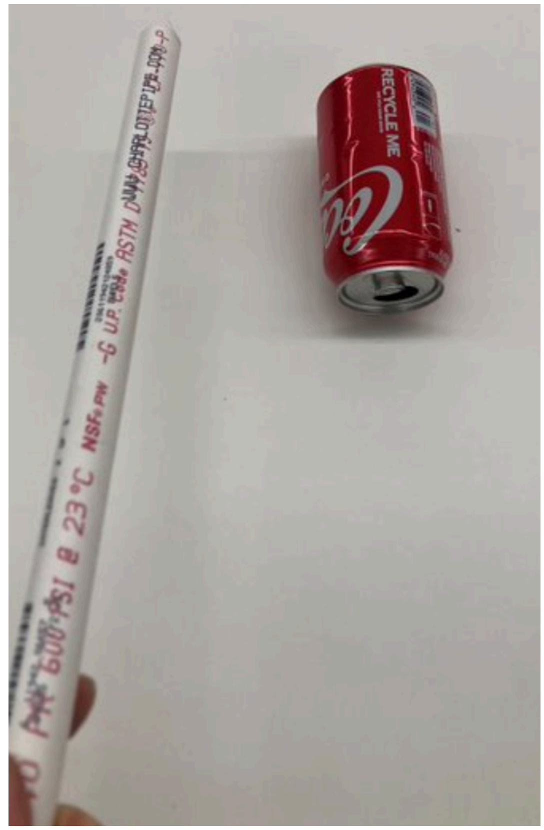
If a question is left unanswered your lab report will be considered incomplete. Please check in with a TF after you have completed every section so that we can be sure this doesn't happen! There are five activities altogether.

Have one group member make a copy of this notebook in your drive, and share with the other group members. Just one group member will submit a copy of the notebook on Gradescope, but please remember to add everyone's name to the submission.

Who are you? Take a photo of your group and paste it below. Please include group member names.

Activity 1: Electrostatic Forces!

We have all had some experience with electrostatic phenomena. You might have rubbed a latex balloon on your hair and then stuck it to the wall, or perhaps scuffed your shoes on a carpet and then picked up a painful shock when you went to grab a door handle.



Materials:
- Aluminum can
- PVC pipe + rabbit fur

We begin our exploration investigating a phenomenon that you have already seen in lecture, involving an aluminum can and a PVC pipe.

If you lay the aluminum can on the table and bring the PVC pipe alongside it, you won't be surprised to discover that nothing happens. On the other hand, if you now rub the pipe (quite vigorously) with fur, you may see some interesting behavior…

What happens when you put the rubbed PVC pipe next to the aluminum can?

Now rub the PVC pipe with your hand.
Does this change anything?

What about if you rub the can with the fur?

Try rubbing the PVC pipe on your clothing or some other material.
Does this change the behavior of the system?

One of our goals in this lab is to fully understand the behavior of this apparently simple system.

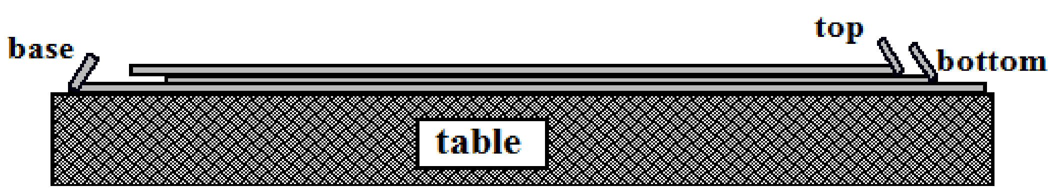
Activity 2: Scotch Tape Electroscope

Materials:

- Scotch Tape
- Marker
- Aluminum foil
- Paper
- PVC pipe + fur
- Glass rod + silk

If we tear a piece of Scotch Tape off the roll, even the side that isn't sticky tends to cling to your fingers, or indeed other objects. It's usually pretty annoying, but it turns out that we get some interesting behavior if we stick *two* pieces of tape together and then separate them, as follows:

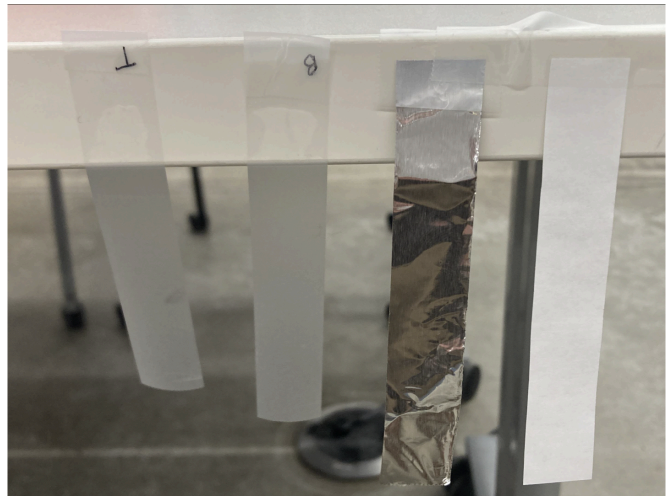
1. Take a piece of Scotch Tape around 3 or 4 inches long, fold over a bit of the end to make a 'handle' and then stick it to the table.
2. Take a second piece, fold over the end and stick the second piece down to the first. Label this one 'B' for bottom.
3. Take a third piece, fold over the end and stick the second piece down to the first. Label this one 'T' for top.
4. Remove the top 2 pieces (the "top" and "bottom" tapes) **together**.
5. Rub the smooth side of the two tapes on a metal desk leg or your finger.
6. Separate the "top" and "bottom" tapes.



Stick your bottom and top tapes to the edge of the table, so that they hang down. Cut two pieces of aluminum foil and two pieces of paper that are of a similar length and width to your two tapes. Stick one each of these alongside your tapes, so that you have four strips altogether, as shown in the photograph below.

Finally, make another pair of top and bottom tapes.

Investigate the nature of the interaction between the various strips and, based on your experimental results, fill in the grid below. Each interaction should be classified as either an attraction (A), repulsion (R), or no interaction (N). (T = top tape, B = bottom tape, F = foil (metal), and P = paper). Ignore the 'PVC' row for now - we'll fill that in shortly.



Summary of interactions:

	T	B	F	P
T				
B				
F				
P				
PVC				

A = Attraction, R = Repulsion, N = No interaction

As you are probably aware, the top and bottom tapes behave the way they do because each of them acquires an 'electric charge', and as we know from lecture, electric charges exert forces on one another.

How many types of charge do we need to include in our hypothesis about electric forces, on the basis of your observations? Explain your answer.

If you rub a piece of PVC pipe with fur, how does the PVC interact with the top and bottom tapes and the strips of foil and paper? Fill in the bottom row in the table.

Out in the wild, as you are no doubt aware, people use the words 'positive' and 'negative' to describe two different forms of electric charge. It turns out that a piece of PVC pipe rubbed with fur gains a **negative** charge (and the fur a **positive** charge).

Which of the pieces of Scotch Tape acquires a negative charge, and which a positive? How do you know?

Note that our saying that the PVC pipe acquires a negative charge and the fur a positive is really just a **definition** of what we mean by negative and positive. These are literally just labels, and we could just as meaningfully call them red and green. However, the negative and positive nomenclature is handy because it turns out that electric charge is **conserved**, which means that charges add algebraically. From your observations, it will have been evident that unless you exert some sort of frictional force on the surface of an object, it doesn't carry an electric charge. Objects without a charge are called **neutral** objects, and it turns out that these have (amazingly) exactly the same (very large) numbers of positive and negative charges. Rubbing (or tearing, in the case of the tape) seems to transfer electric charges from one object to another.

Develop a list of general rules based on your results about the interactions between the different combinations of charged and neutral objects. The results can be boiled down to 4 general rules. Record these general rules below.

Rule #1:

Rule #2:

Rule #3:

Rule #4:

Discuss the following questions with your group and then with a TF before proceeding:

If you are given an object, how could you unequivocally determine its charge state (positive, negative or neutral) using your top and bottom tapes?

You will likely have concluded that there are only two sorts of charge, but how can we know for sure?! If you were given an object and tested it with your strips, what sort of behavior would have led you to believe that there was, in fact, a third form of charge?

Activity 3 - Metal Spheres

Materials:

- Scotch Tape
- Two metal spheres
- Aluminum foil
- Paper
- PVC pipe + fur

We have seen that there are certain materials that we can charge by rubbing. What about metals, though?

Try charging a PVC pipe and touching one of the metal spheres with it. Maybe do it a few times.

What is the charge state of the metal sphere after you have done this (positive, negative or neutral)?

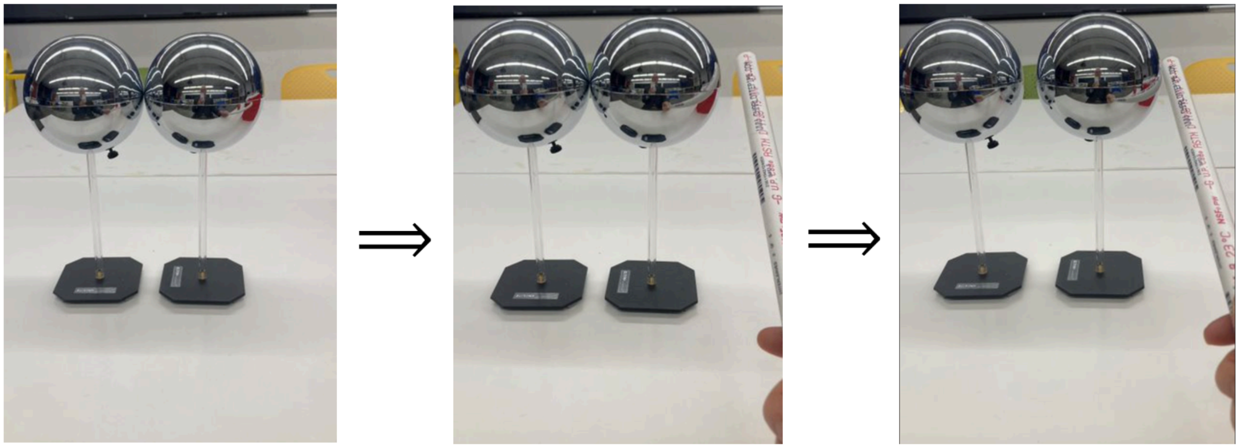
Now rub your hand all over the sphere.

What is the charge state of the metal sphere after you have done this (positive, negative or neutral)?

It turns out that it is possible to charge a metal object by touching it with another charged object, and the easiest way to discharge it is to touch it with your (slightly moist!) skin.

Now do the following:

1. Take two spheres and put them in contact with one another, as shown in step 1 of the diagram below.
2. Charge up a PVC pipe and bring it CLOSE TO, BUT NOT TOUCHING the sphere on the right, as shown in step 2.
3. While you hold the PVC pipe in position, have your lab partner grab the plastic 'stalk' of the left-hand sphere and gently move it away from the right-hand sphere (step 3).



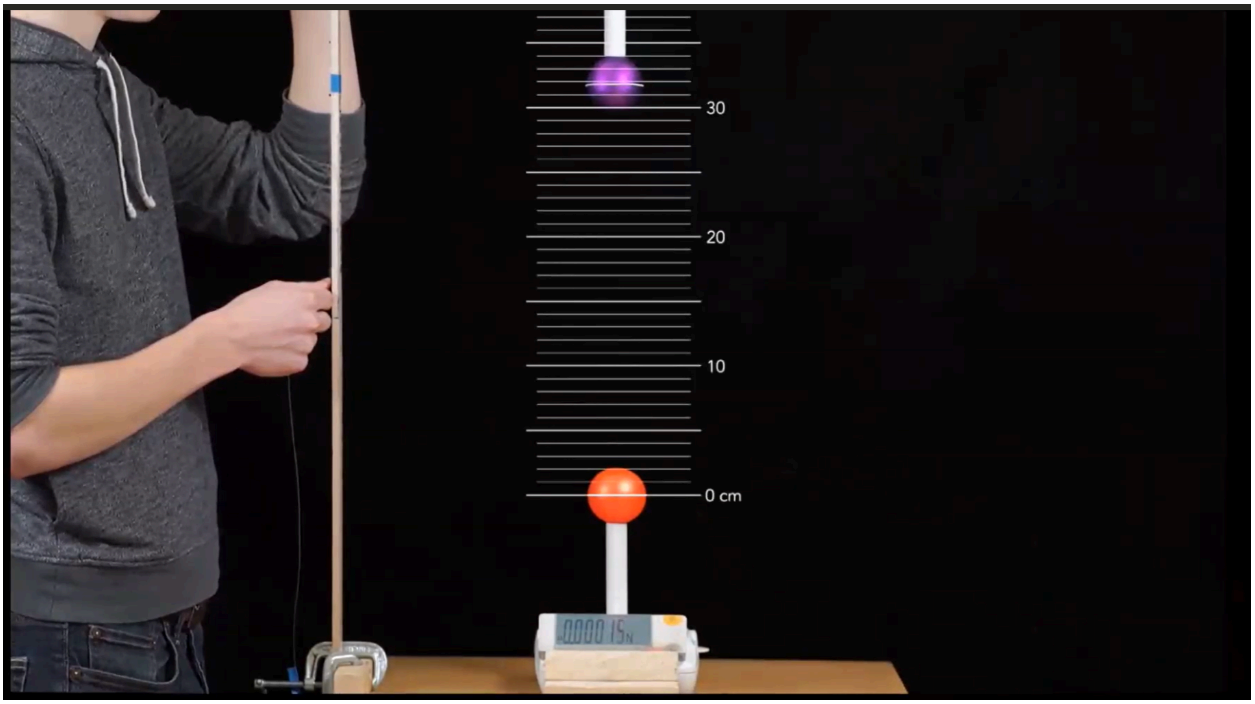
Step 1 Step 2 Step 3

What is the charge state of each sphere at the after step 3?

If either of the spheres is charged at the end, would you say that the charge is evenly distributed over the surface, or are some parts more charged than others?

It seems that the spheres become charged, even though they haven't been touched by a charged object. How can we explain your observations? This tells us something important about metals.

Activity 4 - Electrostatic Forces - A (slightly) more quantitative exploration



In the next activity, we will plot the magnitude of the force exerted on one charged object on another as the two get closer together. We'll be analyzing the 'force vs distance' video that can be found in the Lab 1 folder on in 'Files' on Canvas. Open up the video and watch it all the way through. You will see that the experimental apparatus consists of two metal spheres, one above the other. One of the spheres is sitting on top of (but electrically isolated from) a lab scale, while the other is directly above it. One of the students uses a device called an electrophorus to give each of the spheres approximately equal amounts of charge. Once the spheres have been charged, the lab scale directly measures the force between the two spheres, which changes as the second student adjusts the distance between them.

Use the Colab notebook here to make a plot of the force measured by the scale as the distance between the centers of the spheres changes (each sphere has a helpful white reference line). Note that the reading on the scale is in Newtons, but you should enter the number of **microNewtons (μN)** into your data array. The separation should be measured in **meters**.

Cut and paste a screenshot of your graph here.

You can also use the notebook to plot the force against $\frac{1}{r^2}$, where r is the separation between the spheres. This should be a straight line if the data is consistent with the point charge model. Paste a screenshot of your new graph below.

Cut and paste a screenshot of your graph here.

Discuss the following questions with your group and then with a TF before proceeding: Is the point charge model a good fit for large separations? How about small ones? Thinking about the previous activities, when might we expect the model to break down?

Activity 5 - Wrap up

Well done for getting this far! You are now in a position to explain the phenomenon that we saw in Activity 1, with the aluminum can and the PVC pipe.

Discuss with your group and then with a TF before leaving today!:

Explain your observations from Activity 1 *in detail* (diagrams are strongly encouraged!), step-by-step. What is the charge state of each object at the very beginning? After you have rubbed the pipe? What happens to the charges in the can when you bring the pipe close? Why is there a force, and why is it always attractive?

When you are done, please make sure you have removed all the pieces of Scotch Tape from the table!!

Submission:

- Submit your completed document by uploading it to Gradescope. There is no need to upload a copy of the Colab notebook - please just make sure that you have cut and pasted the graphs into this document. Only one group member needs to upload these materials, but should add their group members to the submission. PLEASE DON'T FORGET TO DO THIS!
- Please be sure to complete the Post-Lab Survey!