PHYS 40C: Lab 1
Electrostatic Charge and Simple Circuits
(Includes Pre-Lab Assignment)

Objectives

These lab activities will focus on the concepts of charge interactions and charge transfer. You should read all the steps in each part before you start. Work in your assigned groups and maintain a collaborative and communicative team.

You will first establish a model of electrostatic charge based on some experimental observations. You will then use the knowledge you gain about charges and how they move to explore what conditions allow for charges to traverse around an electric circuit. You will connect wires, light bulbs, and batteries in different configurations to see which form functional circuits, and you will determine what kinds of materials are required to form functional circuits.

Part I: Electrostatics
1. Charge and Conduction

1.1: There are two kinds of charges: “positive” and “negative”. Make a table indicating how positive charges interact with other positive charges, how negative charges interact with negative charges, and how the opposite charges interact with each other. This table is about the forces charged objects exert on each other, so it should be consistent with Newton’s 3rd Law. (That is, force exerted by object 1 on object 2 has the same magnitude and opposite direction of the force exerted by object 2 on object 1).

- *Thought Experiment:* If there were additional types of charge, how would the physics change? Describe how you think a third type of charge might interact with positive and negative charges (and with itself). Extend your table with an additional type of charge – let’s call it the “Side” charge. Can you definitely fill in all of the spaces in the table for the Side charge? Fill in possibilities for all the spaces in the table consistent with the additional type of charge. How does Newton's 3rd Law constrain possible entries in your table?

1.2: Hang two small strips (about 1 cm wide by 3 cm long) of aluminum foil from a rod using transparent tape so that the pieces of foil are close but not touching. Ensure the foil is not in contact with the rod as well. Rub a PVC pipe with wool then touch the pipe to each piece of aluminum foil.

Touch the rubbed PVC pipe to each piece of the aluminum foil.

- This method of charging the PVC pipe (charging via friction) is called triboelectrification (the study of friction is called tribology). It works better on clear, dry (low-humidity) days. Why do you think that may be?
- This method of charging the aluminum foil by bringing it into contact with an electrically charged object (the PVC pipe) is called conduction.
- What is the difference between conduction and triboelectrification?

1.3: How do the two pieces of aluminum foil interact with each other? You may move the pieces of foil by lifting their respective pieces of tape off the rod. Be sure not to touch the foil as you might accidentally discharge it.

1.4: Consider the questions below. Determine which can be definitely answered based on your observations and answer them. Determine which questions cannot be answered based on only your observations. Of the questions that cannot be answered, could you answer them by doing more experiments? Describe the experiments you might do to answer the questions.

- We have discovered that charge can be transferred from one object to another by conduction or by triboelectrification. Are there other mechanisms by which charge can be transferred? Explain.
- Is it possible for an object to not have any charge at all? Explain.
- Is it possible for an object to have more than one type of charge (*i.e.* both positive and negative) at the same time? Explain.

1.5: Both the PVC pipe and the aluminum foil start with equal amounts of positive and negative charge. When you charge the PVC pipe by rubbing it, is the whole pipe charged or just where the pipe was in contact with the wool? Are the charges in the PVC pipe free to move? (An object in which charges are not free to move is called an insulator.)

1.6: Objects that allow charges to move freely throughout are called conductors. If charges are free to move in an object that has equal amounts of positive and negative charge, what will happen when a second object with excess positive or negative charge is brought near (it may help you to refer to your answers to the questions in 1.1)? How will charges move within the first object in response to the excess charge? Is aluminum an insulator or a conductor? What about PVC pipe? Are all metals conductors?

- Electronic devices are constructed fundamentally around the physics of controlling the location and movement of charges. How is it possible to manipulate the location and movement of charges? Explain your thinking.
- *Thought Experiment:* Semiconductors can simplistically be thought of as an intermediate state between insulators and conductors. In a semiconductor, charges are normally bound in place (like in an insulator), but when injected with enough energy, the charges can move freely (like in a conductor). Given what we have observed about the behavior of conductors and insulators in this exploration, what would happen if we replaced the PVC rod with a semiconductor material? What mechanisms could we employ to inject energy into the bound charges in the semiconductor to force it to act like more of a conductor?

Part II: Circuits

2. Simple Circuit Components: Batteries, Bulbs, and Wires

2.1: Compare your predictions for each configuration from the pre-lab assignment with those of your lab partner(s). Explain your reasoning and come to a joint conclusion about which circuits will light the bulb. Write the shared conclusion in your notebook before proceeding.

2.2: Try each of the six configurations from the pre-lab assignment. Use the pieces of bare wire and hold them in contact with the battery and bulb as the figures in the pre-lab assignment show. In each case note if the light bulb comes on. Note that your light bulb may be screwed into a little holder that is used later on in the lab, and your battery may be similarly in a plastic case with a spring. **Make sure to unscrew the light bulb and take the battery out of the case before testing these configurations!**

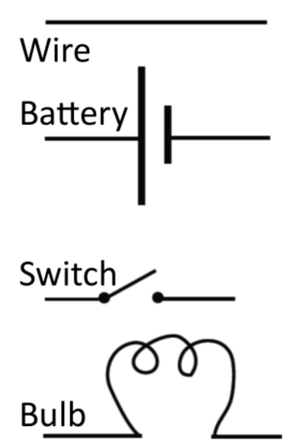
2.4: Look at all of the diagrams from the pre-lab assignment and write your answers to these questions:

- Which part or parts of the battery need to be involved in the circuit in order for the bulb to light?
- Does the wire need to touch the knob on the positive end of the battery, or can the wire touch any part of the positive end?
- Which part or parts of the bulb must be touched for the bulb to light?
- Make a diagram in your notebook of what you think is the "best" configuration to light the bulb.

2.5: Imagine a friend who couldn't attend this lab asked you to describe how you needed to connect the light bulb to the battery in order for the bulb to light. Write down in your manual what you would say without using physics jargon (like "circuit" or "current" or "potential" or etc.).

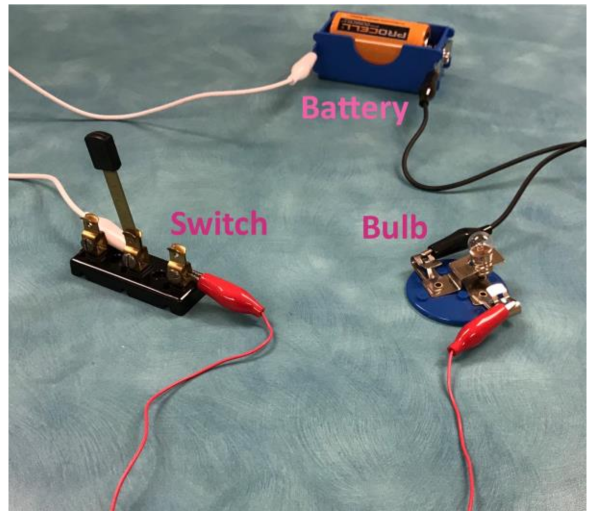
3. Schematic Diagrams of Circuits

Drawing circuits with realistic pictures for the electrical components takes some time and drawing skill to complete (as you have probably already observed), but physicists are lazy and good at finding shortcuts. It is customary to use symbols for circuit elements. A wire is drawn as a line connecting two circuit elements. Symbols for switches, light bulbs, and batteries are shown in the figure to the right.



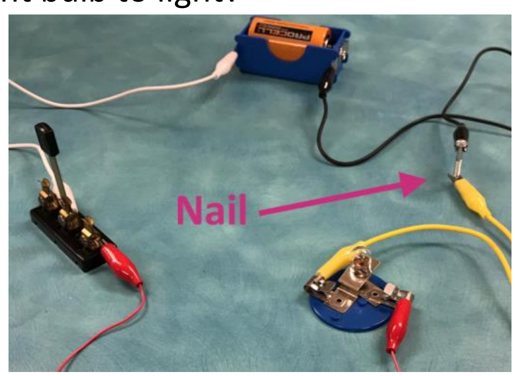
3.1: Using these symbols, draw the circuit schematic for the diagram you produced in 2.4 in your notebook.

4. Materials of Circuit Elements



4.1: Make the circuit shown in the figure to the right. Use the special holders provided to make holding the electrical elements less awkward. Get a battery holder, bulb holder, switch, and three hook-up wires with plastic sheaths and clips at the ends. Snap the battery into its holder and use the hook-up wires to connect the battery, bulb, and switch. When the handle of the switch is down, the circuit is said to be “closed”. When the handle of the switch is up, the circuit is said to be “open”. Verify that you can make the bulb light up. The switch, battery, and bulb holders you use may not be identical to those shown here but they will be similar and they will perform the same functions. Draw a schematic diagram for this circuit.

4.2: Does it matter what kind of materials connect the battery to the bulb? In Section 1 you used a PVC rod and aluminum foil, in Section 2 you used bare wire, in 4.1 you used wire with a plastic sheath – will any material connecting a complete circuit allow the light bulb to light?



4.3: Construct a circuit like shown in the figure to the right. The nail is placed in the circuit. Before you begin, the circuit should be open (*i.e.* the handle of the switch should be up). Now close the switch. Does the bulb light?

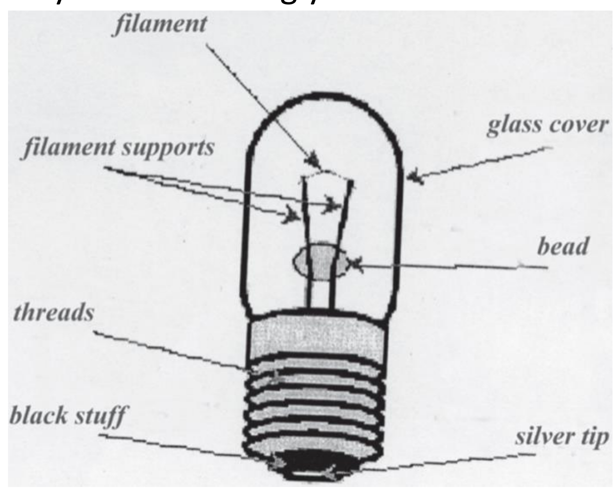
4.4: Open the switch. Remove the nail from the circuit and replace with one of the other items available in the lab (you should have a nail/screw, a string, a paper clip, and a toothpick). Close the switch. Does the bulb light? Repeat this with the other items. Create a table in your lab notebook that notes which items make the bulb light, and which do not.

4.5: Is there anything similar about the items that allow the bulb to light? Which of these items do you expect to be conductors? Which are insulators?

4.6: Hook up the circuit with the battery and bulb. Close the switch so the bulb lights up. Look closely at the bulb. Which part is actually glowing?

4.7: You should have access to a larger light bulb which has had the protective glass removed. Examine this bulb closely. On the picture to the right, write in whether or not you think each labeled part of the bulb is made of conducting or insulating material. Test your ideas using your results above. Which part glows?

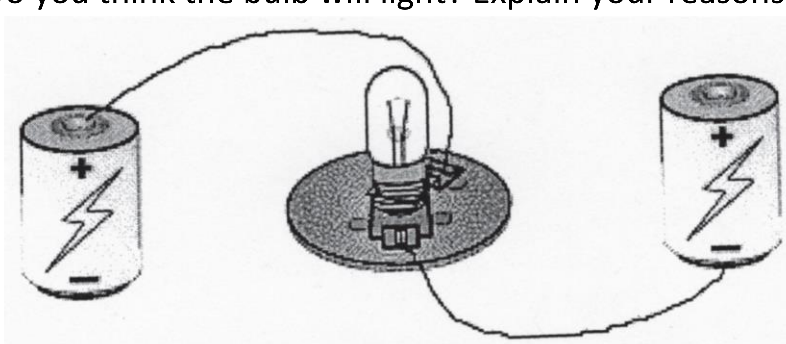
4.8: Draw a schematic diagram of a battery and a bulb connected by two wires. Show in your bulb diagram how you think the wires touching the side and bottom of the bulb connect to the filament support wires?



5. How Does the Battery Need to Be Connected?

The evidence from Section 2 suggests that one side of the bulb needs to be connected to the positive end of the battery, and also that the other side of the bulb needs to be connected to the negative end of the battery.

5.1: Do the two sides of the bulb need to be connected to the positive and negative ends of the same battery? Consider the configuration in the figure below. Do you think the bulb will light? Explain your reasons.

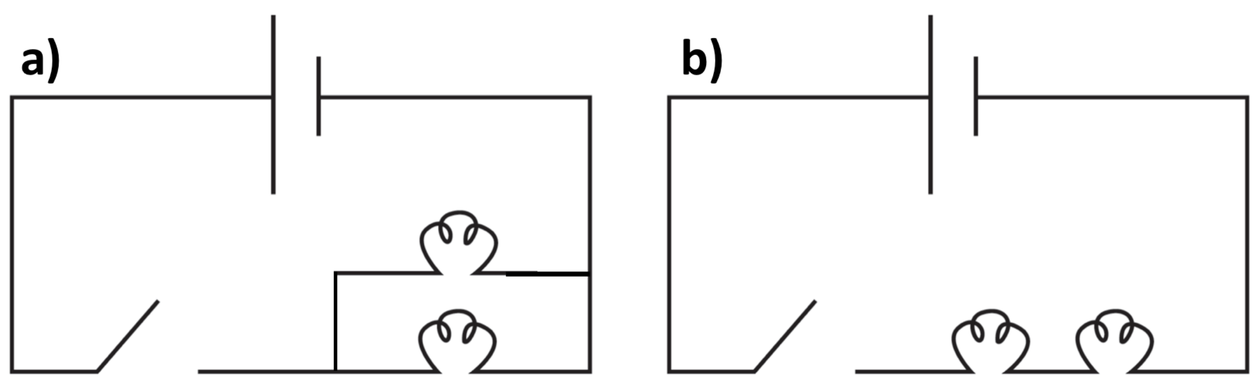


5.2: Get two batteries, two wires, and a bulb. Hook up the arrangement shown on the previous page. Does the bulb light up? Why do you think the bulb behaves this way? Describe three ways you can add one wire (only one wire, not more) to this arrangement to get the bulb to light. Which of the ways causes the bulb to appear brightest?

5.4: Put the two batteries in holders and snap them together end-to-end with the positive end of the original battery attached to the negative end of the second battery. Then connect the positive end of the new battery to one terminal of the bulb holder.

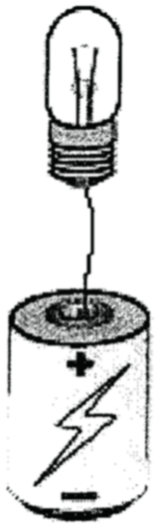
- Does the bulb still light? Compare its brightness now to its brightness in the single battery circuit. Comment on any differences.
- Draw the circuit diagram for this circuit. Why do you think the brightness is/is not different? Explain.

- *Thought Experiment:* How would the brightness of the bulb change if you added a second light bulb to your circuit in either of the configurations shown below? (Feel free to join forces with another team to try these configurations out – you may need to use both batteries).

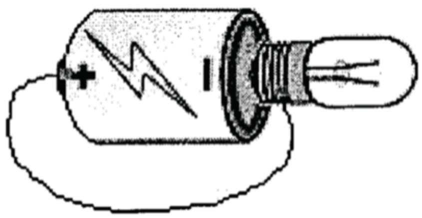


Pre-Lab Assignment (1 point)

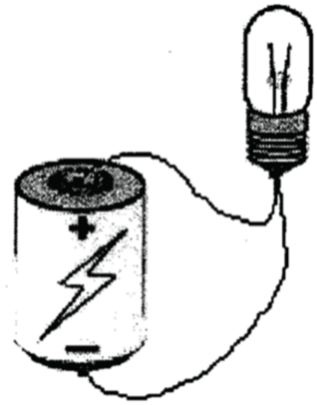
1. Below are diagrams of six different configurations of bulbs, wires, and batteries. Make a prediction about whether or not each configuration will result in the bulb lighting up.



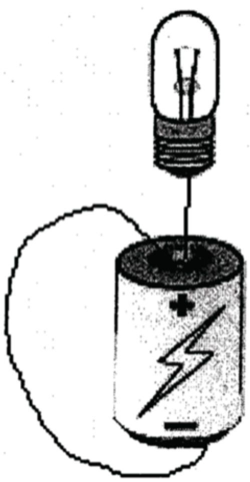
#1: A wire touches the positive end of the battery and the tip of the bulb.



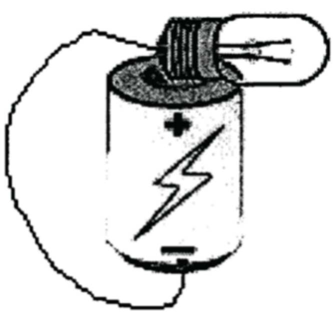
#2: The tip of the bulb touches the negative end of the battery. A wire touches the positive end of the battery and the metal side of the bulb.



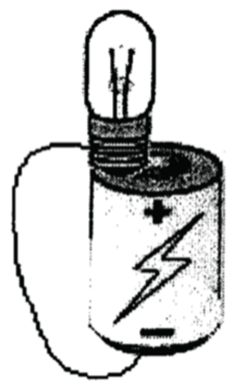
#3: A wire touches the positive end of the battery and the tip of the bulb. A second wire touches the negative end of the battery and the tip of the bulb.



#4: One wire touches the positive end of the battery and the tip of the bulb. A second wire touches the positive end of the battery (not the knob in the middle) and the negative end of the battery.



#5: The metal side of the bulb touches the positive end of the battery. A wire touches the tip of the bulb and the negative end of the battery.



#6: The tip of the bulb touches the positive end of the battery (but not the knob in the middle). A wire touches the metal side of the bulb and the negative end of the battery.