Tutorial Instructor’s Guide

Working from a model: Static electricity

This is usually the first tutorial of the second semester, so many of the students (and TAs) will have had experience with tutorials, although some will not.

The main goal of this tutorial is for students to come up with a model for how objects become charged. Along the way, they use a common representation for charge and make a variety of observations.

Equipment:

- Styrofoam picnic plates or other panels of Styrofoam. At least two per table.
- Cloth for rubbing the Styrofoam and other objects – it can be wool, silk, fur, or whatever does a decent job of charging the Styrofoam. Students can also use their clothes, especially sweaters. At least one cloth per table.
- Pith ball on a thread. At least one per table.
- Magic tape (the translucent kind, not the clear kind). One roll per table, preferably in a cutter, plus plenty extra for the week (this gets used up).
- An aluminum pie plate with a Styrofoam cup attached to it as a handle. One per table.
- A foil-covered straw. Thin coffee-stirrers work well. One per table.
- A dehumidifier. It’s optional, but it can really help the experiments to work more reliably. One for the room.

I. In this part students develop a mechanism for how things acquire an electrostatic charge. (** Is this section titled appropriately? Is its goal stated accurately? I think we want to be prompting them to come up with and test explanations, not just observe phenomena.)

A. Students do fine with this – it’s really just getting familiar with the equipment. Notice the test of charged-ness that is included in the question. I wonder if it wouldn’t be time well spent to have the students explore tests of charge themselves? Possibly, in the process, testing the bits of paper themselves, a bar magnet, and a battery?

B. Most students are pretty sure that rubbing their hands together won’t make sparks, and if they’re not sure, they can try it. Explaining that observation, though, is difficult and interesting. Few students start with the idea that materials can’t get charged by running on an identical material, because the charge would have no reason to prefer one material to the other and would therefore stay where it was. Instead, many students think it’s something about hands in particular that prevents charge from building up, *e.g.,* that they’re moist, or they’re connected to the rest of the body. Many of them have a sense that touching objects removes the charge from them, which may be informing their answers.

C. Students often think styrofoam plates would charge from rubbing on one another even though hands don't, possibly revealing that their model is more about "chargability" than about a mechanism by which things become charged. The matter is complicated by the fact that styrofoam plates rubbed together often do have a charge – left over from part A! A TA can come by and say, "Oh, did you make sure the plates were uncharged to begin with," but that definitely gives students the message that they didn't get the result they were "supposed to." Perhaps the tutorial should start by having students articulate a test for charge (picks up little bits of paper), which might give a more natural motivation to test objects before beginning each experiment.

   It's not all that easy to un-charge the plates, either – depending on the environment, they don't lose all their charge just from sitting around for a minute, or even from being touched. Wiping them all over with your hand is pretty reliable, but wiping them with anything else might charge them. Again, TAs can help students with this, but it comes across as being technical information the students would have no way to know. Maybe the tutorial should have the students find ways to get the charge off objects, first.

D. Four to six inches is better, in my experience, than the 2-3 inches the tutorial recommends. Note the surprise embedded instruction about how to remove charge – makes me think, again, that there could have been an earlier exercise for students to determine that.

   This question is pretty open-ended and I don't know much about what students make of it, in spite of the checkpoint. They can follow the instructions about making the tapes, but what they actually draw from that conceptually, I don't know. Should we have them make more than one set of tapes and test how the different types interact with one another?

<u>*Checkpoint:*</u> TAs should see what observations the students have made up to now, and have the students share their current thoughts about how objects come to be charged. (**What else should be here depends on what the goals of this section are… and I'm not so clear on that. That said, I have the idea that this piece of tutorial is fun and generative for the students, so maybe it's good the way it is, and only my instructor perspective needs to be clarified? We need video.)

II. In this part the students learn that in order for a bulb to light there has to be a loop of conductors around the circuit.

   A. Students tend to have a hard time seeing where the wires go and/or they're sloppy and don't go further than saying they go "into the base." Make them draw what they actually mean – where the wires end. **TAs have trouble with this too!** Try to get people to see where the wires actually connect to the base. Usually the wire that goes to the screw part actually comes up over the top of the screw and is soldered there; observing that can help. The other wire is often visible too, soldered to the tip on the outside.

E. The kind of answer we're looking for at this point is, "There has to be a continuous path of conductors all the way around the closed loop of the circuit., including through the bulb."

Interesting bonus questions at this point include:
What does it mean for a bulb to be burned out – what happens physically, and why does that matter?
Provide a regular, large, cheapo flashlight, one where you can see the innards, and ask students to figure out how it works.

III. This part introduces students to the what and why of circuit diagrams.

B. People tend to start with needlessly complex circuit diagrams and sometimes need help simplifying them. This is an opportunity to emphasize that circuit diagrams show electrical connections, not physical layout.

C. The answers we're looking for are that a line means an electrical connection – not necessarily a wire. That's why the symbols for bulbs and so on have lines coming out the sides, because there are electrical connections indicated.

IV. Bulbs in series

A. Try to enforce people making a prediction before they get the equipment! The most common wrong idea is that one bulb will be dimmer because the first bulb uses up some of the current.

Another, subtler idea is wrong but doesn't lead to a wrong prediction: the idea that the two bulbs "share" the current, so that each gets half, and that's why they're dimmer. For this one, TAs should ask students to trace the flow of current around the circuit with their finger. This usually makes the inconsistency apparent.

C. To hook up this circuit, people should use <u>two</u> batteries in the holder and bulbs in sockets – otherwise the bulbs are too dim (which exposes minor irregularities) and the arrangement gets a little hard to manage.

People are good at realizing the flow though the bulbs must be the same if they're the same brightness. They should be prompted to make the theoretical connection as well – that the flow through the two bulbs has to be the same because of the way they're connected.

It's reasonably easy for people to recognize that the fact that the bulbs are dimmer than a single bulb means there must be less flow through the bulbs in series. For some reason, though, people have a hard time recognizing that that means the current *through the battery* is also reduced. People really want to think the battery is a constant current source. TAs should check whether students have made this deduction.

If the bulbs aren't identical, incorrect predictions may be confirmed, which is inconvenient. However, if that happens, TAs can have students predict the effect of switching the bulb order, and then try it. This usually clears things up.

Good bonus questions for people who finish early (in addition to those mentioned earlier):

Predict the brightness of two bulbs in parallel. Explain reasoning to a TA before you try it. (This cheats a little because that's the first question for next week, but it's fun because people are almost always startled by the observation.)

Predict the brightness of the bulbs in a circuit that has one bulb followed by two bulbs in parallel. Explain reasoning to a TA before you try it. (Before or after the above. If they try it, the parallel bulbs will probably be too dim to see, which throws them for a loop but is actually fine. More batteries solves the mystery, or they can reason theoretically. The increased brightness of the "indicator bulb" surprises people and is hard for them to account for.)