Tutorial Instructor's Guide

Batteries and bulbs (Circuits, part I)

<u>Equipment:</u>

- Ziploc baggies containing one flashlight battery (C or D), one flashlight bulb (NOT in a socket), and one piece of straight wire with stripped ends, about four inches long. One per person.
- Large light bulbs, with the glass broken off so that you can see the innards (especially where the wires connect in the base). One per table.
- Magnifying glass. One per table.
- A small collection of different conducting and non-conducting materials (such as copper, paper, iron, steel, plastic, glass, aluminum, rubber, and whatever else you have handy). One per table.
- Flashlight-bulb sockets. The most desirable ones have the electrical connections visible rather than covered up with plastic or ceramic housing. At least two per table.
- Identical flashlight bulbs – meaning they not only look similar but are the same brightness when connected in series. You have to test them yourself every time. (It's possible to use non-identical bulbs and still learn the ideas but it's a bigger hassle.) At least two per table.
- Big cheap flashlights (optional). A few for the room.
- Battery holders that hold a pair of batteries in series. One per table.
- Enough connecting wire and/or alligator clips for each table to conveniently build a two-bulb circuit.

I. In this part the students learn the basic idea of a complete circuit. Start with tables empty except for paper – no equipment available.

A. Students plan a way to light the flashlight bulb with a battery and a single wire. They can see the equipment if they want to, but not use it (yet). Many students don't know how, no matter how much circuits instruction they've had. **TAs have trouble too,** though less often. Common ideas include touching one end of the wire to the positive terminal and the other end to the tip of the bulb (looks sort of like a lamp!), or shorting the battery with the wire and then touching the tip of the bulb to the positive terminal. TAs should not correct students on any of this – just make sure they draw a clear sketch of what they think will work and explain their reasoning verbally. TAs should also try to refrain from using any technical vocabulary like "current," or really doing any explaining at all at this time. Just listen.

B. Give each person at the table the Ziploc bag of equipment at the same time, and let them try to light the bulb. Many will not be able to do it. They may think their bulb is burned out or their battery is dead. TAs can check their equipment, but should not show them how to do it! Once someone gets it it tends to spread quickly around the room. The challenge then becomes finding four different ways to light the bulb. (Answer: Flip the battery for two ways, flip the bulb for two more.)

If students are really stuck the following questions may help: *The wire has two ends. How do you tell which are the key parts of the wire?* (The metal parts.) *How about the battery?* (Two ends also, identified by being metal.) *How about the bulb?* (People tend to think the bulb has just one "end" – the tip; but it does have another metal part – the screw.) *Try to find some arrangement that includes both "ends" of the bulb.*

C. The kind of answer we're looking for is that all the arrangements that light the bulb form a loop that includes both ends of every element. Sometimes students say something else, like "one end of the bulb is connected to the positive and the other to the negative": that's okay too. TAs should allow a range of vocabulary.

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.

D. 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.)