Tutorial Instructor's Guide

Batteries and bulbs, continued (Circuits, part II)

<u>Equipment:</u>

- Flashlight-bulb sockets. The most desirable ones have the electrical connections visible rather than covered up with plastic or ceramic housing. At least three 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 three per table.
- 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 various two- and three-bulb circuits.
- Voltmeter with appropriate leads, as simple as possible (for example, it's better if it's not a multimeter, or powered, or fancy in any other way). One per table.

In this whole tutorial students can just help themselves to equipment as they need it.

I. In this part students use the current-based reasoning they used last week to reason about circuits, and show that that reasoning isn't sufficient for everything.

A. & B. Most students will not have seen a parallel circuit yet, and most are startled that the bulbs are the same brightness as a single bulb. They need to conclude that the current through the battery must increase when you connect another bulb in parallel. This is likely to freak them out. It sometimes freaks TAs out too. The following questions may help: *What does the current do in this circuit after it leaves the battery? Show me with your finger. How does the current through one bulb compare to the current in the single-bulb circuit, and how do you know? What does that mean about the current here (going into or coming out of the junction)?*

It can help students to think in terms of the number of paths affecting how much current flows: the more paths, the more current can flow.

C. Students should be able to predict that A will be brighter than B=C. They sometimes think this is because A uses up current; check. Students have more trouble with whether A will change when you unscrew C. Just listen and elicit their thinking. The right answer is that since unscrewing C removes a path from the circuit, the overall resistance goes up, less current flows from the battery, and A gets dimmer.

Usually when people set this up with two batteries in series, bulbs B and C don't light up. This really freaks people out but there's really nothing funny going on; they still have current through them, they're just too dim to see. Helpful questions include: *Do you think these two bulbs have current through them? Why do you think so?* (The current has to go all the way around the circuit, and those bulbs are the only way.) *How could we test if these bulbs are working properly?* (1. They must be, or bulb A would not light. 2. We could unscrew one of them and the other one should light up. 3. We could put more batteries in and see if they light up. ** Be careful with that last one, you might burn out bulb A.)

It's hard for students to understand why they can't predict what happens to B when you unscrew C. Most of them think that since now B gets all the current instead of only half, it will be brighter – and in fact it is, so they think their reasoning was right. In fact, although B now gets all the current, there is now less current overall, so there's not enough information to make a prediction. *Which is greater – half of more, or all of less?*

II. In this part students learn the basis for thinking about circuits in terms of voltage. People will probably never have used a voltmeter before. Help them out. The main points of this part are to learn that the voltage across a battery is always the same, that the voltage across a bulb is an indicator of its brightness, and that the voltages across circuit parts in series add to the battery voltage. It usually goes smoothly. The checkout should focus on the summary questions in part D and the evidentiary basis for those statements.

III. This part is hard for students because the right answers are known, and they will have trouble putting their attention onto anything other than the right answers. They will tend to mark each of the various "students" either right or wrong depending on whether their prediction agrees with the observation they've already made and consider themselves finished. This is NOT the point. The point is to assess the *reasoning* each "student" is using and see whether it's valid. Note that Susan and Lauren use identical reasoning but one is right and one is wrong. Mariel and Jason are both right and both use correct reasoning even though their reasoning is different. Nate has the right answer for the wrong reasons. Sheryl's reasoning would be right if she weren't confusing current with voltage.

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

Would Nate be right if he had said "voltage" where he says "current"?
Propose more complicated circuits and have students predict relative brightness.