Make a Mystery Circuit with a Bar Light Fixture

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Teachers have been building mystery circuits or so-called "black box circuits" to use as a demonstration with their students for years.[1] This paper presents an easy way to make simple mystery circuits using inexpensive light fixtures (see Fig. 1) available at almost any home improvement store.[2] In a black box circuit, only the lightbulbs are visible and the wiring in these circuits is hidden from the students. The students are then presented with the challenge of deducing the nature of the electrical connections hidden by the black box. The students may remove one or more lightbulbs from the circuit to watch how the brightness of the other bulbs changes and, from this, deduce which bulbs are connected in series and which are connected in parallel.

It is a simple task to rewire lighting fixtures (sometimes known as "bath bars") so that the lightbulbs are no longer merely wired in parallel but in simple circuits that are a combination of series and parallel. One advantage of using these bath bars to make mystery circuits is that the connecting wires are safely tucked away inside the bar so that the students cannot see or touch them. Another advantage is that bath bars are already wired so the bulbs are connected in parallel; with a few cuts and a little bit of rewiring, a wide variety of combination series and parallel circuits can be created. Over several years I have made six different circuits for a full lab set. The students rotate in groups through the six circuits and determine the electrical configuration of each.[3]

Bath bars are available from most home improvement stores, such as Home Depot or Menards, for

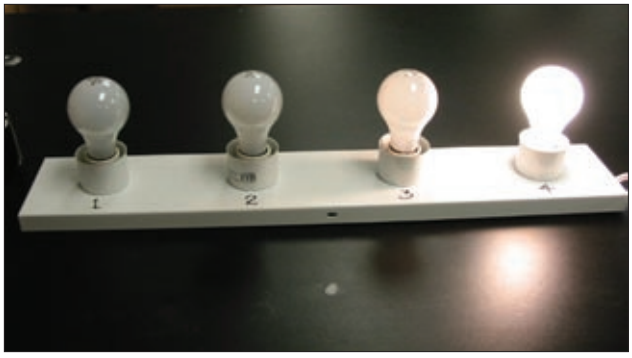

Fig. 1. The two bulbs on the left are lit but only barely.

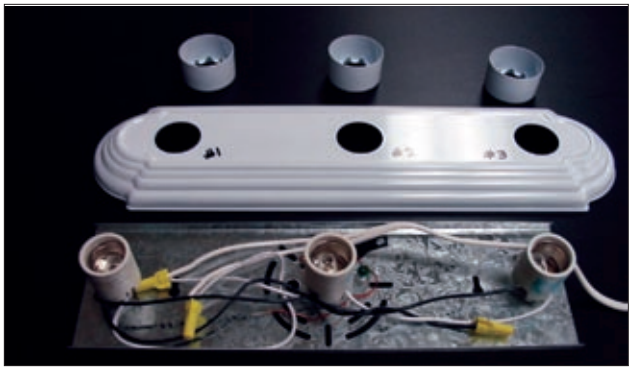

Fig. 2. The lighting fixture is simple to take apart and rewire.

$10–$20 depending on the number of bulbs. To make the mystery circuits, you will also need a wire stripper and cutter, several wire nuts, and a short, two-pronged extension cord. The extension cords I use are only six feet long and cost about a dollar. I have been able to rewire some of the circuits with just the wires provided in the bath bar, but it never hurts to have some extra wire on hand just in case.

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The bath bars are easy to modify. The round pieces around the lightbulb sockets simply twist and lift off easily. Then the cover of the bath bar can be lifted off, exposing the wiring (see Fig. 2). Carefully design your circuit in advance; in this case, it is best to follow your carpenter's advice and "measure twice, cut once." Double check your plans before you cut the wires on the bath bar.[4] When you cut off unused wires, it never hurts to leave an extra inch or two of wire in case you find you've made a mistake. It is best to cap off the unused wires with a wire nut so they don't accidentally contact other wires in your circuit. Cut the female end of the extension cord off and split the wire down the middle about 8- to 12-in in length. Then strip the ends of these two pieces and thread them through the hole in the bottom of the light fixture before connecting them with wire nuts to your circuit. Replace the cover and the round lightbulb socket covers. Add either 40-W or 60-W bulbs and test your circuit. For some circuits, the bulbs are so dimly lit that it is best to use clear bulbs. For other circuits, frosted bulbs are fine. Only trial and error will tell you which kind works best. I generally use identical bulbs in the bath bars, but if a greater challenge is desired, different wattage bulbs could be used.

There are several safety concerns that should be mentioned. First, this device runs on 120-V ac line voltage and, if improperly constructed, could present a shock hazard to the person who constructs it and to any students who might use it. If a teacher is not comfortable assembling the circuit, he or she should seek the assistance of another individual who is more experienced working with electrical circuits. In addition, the students should be given the typical warnings regarding working with 120-V ac line voltage. They should not be allowed to take apart the bath bar to examine the wiring, except with direct teacher supervision. If your school has an isolation transformer, this could be used as an added security measure. I advise my students to only unscrew the light bulbs as much as necessary to electrically disconnect them and never to completely remove the bulb from the socket. The students should not be exposed to an open socket, which is connected to the line voltage.

The students should also be warned that the lightbulbs can become very hot if left on for an extended period of time. The teacher might consider including at each station an inexpensive workman's glove[5] or a cloth rag for handling hot bulbs. The teacher should also encourage the students to unplug the light fixture when it is not being used.

The spontaneous feedback from the students has been very positive. They are amazed when you unscrew one bulb and the others change brightness. I have had many AP students enter my classroom on the day that my Honors students were doing the lab and exclaim, "I remember that lab: that was really fun." And then they proceed to play with circuits and try to figure them out all over again. The students have fun with this activity, and their conceptual understanding of series and parallel circuits is challenged and strengthened by working backwards from the behavior of the bulbs to the circuit diagram.[6]

References

1. C. Keller and Y. Wang, "A golden oldie —A black box circuit," *Phys. Teach.* **32,** 222–223 (April 1994).
2. Original idea from a conversation with Debra Gough of Boise, Idaho.
3. In an ideal circuit, the only resistance would be in the bulbs themselves. Due to nonnegligible wire resistances, practical circuits do not always behave like ideal circuits. In a practical parallel circuit, the remaining lightbulbs may grow brighter as one bulb is removed. However, experience using these bath bars both in my classroom and in my home has shown that this increase in brightness is very difficult to notice. Even though these circuits are nonideal, their behavior simulates that of an ideal circuit sufficiently well so as not to confuse the students.
4. A Microsoft Word document with more detailed instructions is available at http://www.niles-hs.k12.il.us/marlie/phys/bathbarcircuit.doc.
5. I found some brown cloth gloves at a local convenience store for approximately $1 per pair.
6. The concept and cognitive benefits of "working backwards tasks" are presented in A.Van Heuvelen and D. Maloney, "Playing physics jeopardy," *Am. J. Phys.* **67**, 252–256 (March 1999).

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