Extending Our Model of Electric Current Flow

Important Ideas

*Note: Words shown in **bold** are vocabulary words with which you should now be familiar. If you don't remember what these words mean, please ask.*

In the previous few labs we have been working to develop a ***model,*** or ***theory***, that helps us explain and predict the behavior of electric ***circuits.*** Both of these aspects are important in developing scientific theories. Theories in science don't just explain how or why things work the way that they do. A scientific theory allows us to make predictions about what will happen in future experiments. If predictions based on a theory turn out to be incorrect, the theory must be modified or even discarded.

So far, our model for electric circuits includes the following ideas:

-Electric current flows through a complete circuit including through the wires, bulbs and battery.

-The brightness of identical bulbs can be compared to make inferences about the amount of current flowing through a bulb.

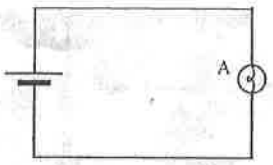
-The amount of current into a bulb or junction is equal to the amount of current out of the bulb or junction. (Current is ***conserved***. It is not used up).

-If you keep the battery used in a circuit the same but change the number of bulbs in the circuit, or how those bulbs are arranged, the total amount of current flowing in the circuit will change.

In this lab, we will look at more complex circuits in an attempt to build a more complete and/or detailed model for electric circuits.

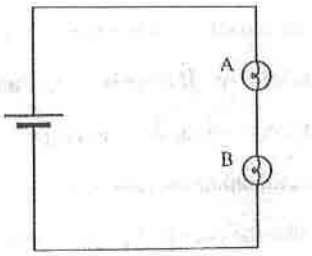
Experiment 1

Connect a single bulb to a battery as shown below.



The bulb should light. Note the brightness of the bulb. We will call this bulb our **indicator bulb** because its brightness is an indication of amount of current flowing through the battery (as well as the amount of current through the bulb itself).

1. Predict how the brightness of your indicator bulb (bulb A) will change if you add another bulb (bulb B) in series with it as shown below.
2. Predict how the brightness of bulb A will compare to the brightness of bulb B. Which will be brighter or will they be the same brightness?

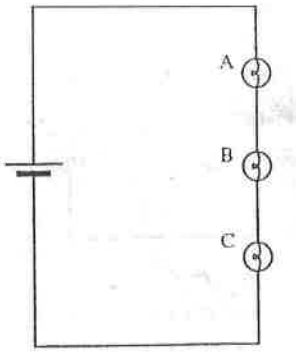


Now add another identical bulb in *series* as shown below and observe the bulb brightness.

3. Were your prediction above correct? If not, record your observations of the actual brightness.

Throughout this entire lab, REMEMBER to consider only significant differences in brightness, not minor differences that might occur if two bulbs are not perfectly identical.

4. Predict how the brightness of your indicator bulb (Bulb A) will change if you add another bulb in series with it as shown below.



Now add another identical bulb so that you have three bulbs in *series*.

5. Was your prediction of the brightness of the indicator bulb correct? If not, record your observations of the actual brightness.
6. You should see a pattern in how the brightness of the indicator bulb changes as more bulbs are added in series. What pattern do you notice?
7. Based on your observations of bulb brightness, what can you infer about how the amount of current through the indicator bulb and the battery changes as additional bulbs are added in series? Answer in a complete, clear sentence. **Your answer may be graded based on your writing.**
8. Do you think that a bulb could be too dimly lit to see but still have some current flowing through it?

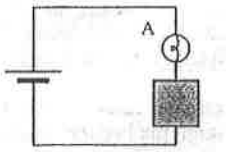
We can make sense of our observations by understanding that a bulb, with its very thin filament wire, presents an obstacle or blockage to the flow of current. We call the obstacle or blockage presented by a bulb or other circuit element **Resistance.**

9. Using the terms ***resistance*** and ***current,*** state a rule that you can include in your model of electric circuits that will allow you to predict whether the current through the battery increases, deceases or stays the same when the total resistance of the circuit is increased or decreased. Answer in a complete, clear sentence. **Your answer may be graded based on your writing.**
10. How would you expect that the total resistance (or total amount of blockage) in a circuit to change if you add more bulbs in series?

✓ **Check your answers with your instructor.**

Exercise 2

Imagine that you have a closed box in a circuit as shown below.

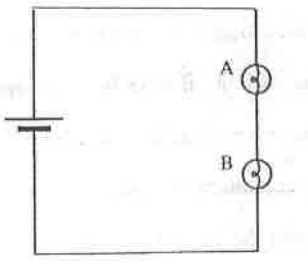


Suppose you observe a certain brightness in the indicator bulb A. Imagine that someone then makes a change of some kind within the box and you see that the indicator bulb gets brighter.

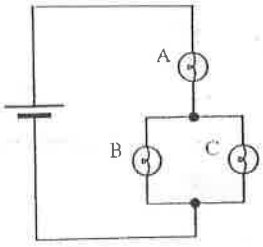
11. Did the current through the battery increase, decrease or stay the same?
12. What can you conclude about the total resistance in circuit? Has it increased, decreased or stayed the same? Explain your reasoning.

Experiment 3

Set up a circuit with two bulbs in series as shown below. Bulb A will be your indicator bulb. Notice its brightness.



13. Predict how the brightness of bulb A will change when you add another bulb C in parallel with bulb B as shown below.



Set up the circuit shown below and observe the brightness of the bulbs.

14. Was your prediction correct? If not, how did the brightness of bulb A change when you added bulb C in parallel with bulb B?
15. What can you infer about the current through bulb A (and hence through the battery) when bulb C is added in parallel with bulb B?

The result of this experiment (bulb A gets brighter) may seem puzzling. You saw in Experiment 1 that increasing the number of bulbs in series decreased the amount of current flowing in the circuit. This is because adding bulbs in series increased the amount of obstruction or resistance in the circuit. Increasing the resistance in circuit causes the current through the battery to decrease.

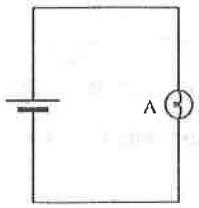
Here, we added bulb C in parallel and the current through the battery increased (bulb A got brighter.) Doesn't adding a bulb increase the resistance (blockage) in circuit? Not if the bulb is added in parallel. One way to think about the changes in current when bulbs are added in parallel is to consider that there are now additional pathways available for the current to flow through after it passes through bulb A. The additional pathways decrease the amount of obstruction or resistance in the circuit and allow more current to flow through just like extra roads allow more cars to travel from one place to another at that same time. More pathways create less blockage.

16. In question #10 you were asked to state a rule that should have sounded something like "If you increase the total resistance in a circuit the current through the battery will decrease. If you decrease the total resistance in the circuit the current through the battery will increase." Based on this rule, what can you conclude happens to the total resistance of the circuit when bulb C is added in parallel with bulb B?
17. State a general rule for how the total resistance in a circuit changes when bulbs are added in parallel.
18. Go back to the circuit above and remove bulb C for a moment and then add it back. Observe that while bulb A gets brighter when bulb C is added in parallel, bulb B actually dims. Explain why this happens. Hint: It has nothing to do with resistance but everything to do with pathways for current flow.

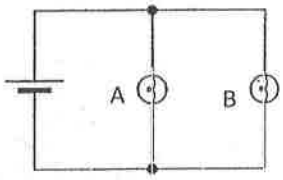
✓ **Check your answers with your instructor.**

Experiment 4

Set up a single bulb circuit as shown below and note the brightness of the bulb.

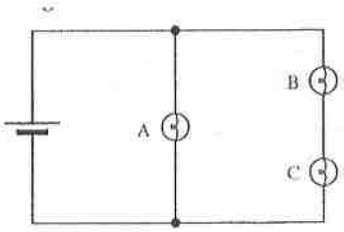


Add a second bulb B in parallel with bulb A as shown.



19. Did the brightness of bulb A change when you added bulb B? Did the current through bulb A increase, decrease of stay the same when bulb B was added?
20. Did the current through the battery change when you added bulb B? Explain how you know.
21. In Experiment 3 (question 17, for example) you should have found that when you add a bulb in parallel you decrease the resistance of the circuit and thereby increase the total current in the circuit (the current through the battery). Given this, why didn't bulb A get brighter when bulb B was added? Explain, in terms of current flow, why bulbs A and B are equally bright.

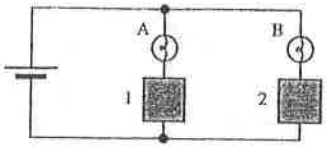
Now add bulb C in series with bulb B as shown.



22. Does the current divide equally at the junction J in this circuit? If not, does more current go down the path with just bulb A or with bulbs B and C? Explain how your answer is consistent with the brightness of bulbs A, B and C. **Your explanation may be graded for writing.**
23. Devise a rule that states how current divides at a junction. Your rule should allow you to predict how the current divides at a junction when the paths have equal resistance and how the current divides when the resistance in the paths is not equal.

Exercise 5

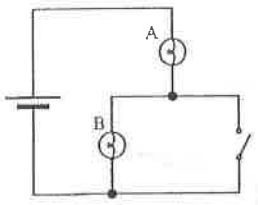
24. Based on the rule you devised above, answer the following:
Imagine the circuit shown. Suppose that bulb A is brighter than bulb B. Is the resistance of the circuit element represented by Box 1 the same as, greater than or less than the resistance of the circuit element represented by Box 2? Explain how you know.



✓ **Check your answers with your instructor.**

Experiment 6

25. For the circuit shown below, predict the relative brightness of bulbs A and B with the switch open and with the switch closed. Explain your reasoning. Use clear and complete sentences. **Your answer may be graded for writing.**



Now set up the circuit shown.

26. Open and close the switch a few times and observe the brightness of the bulbs. Was your prediction above correct? If not, record your observation.

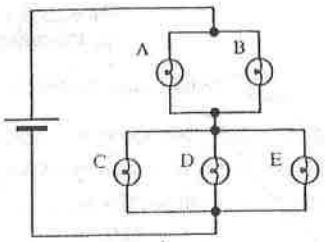
When the switch in this circuit is closed, the bulb B is essentially in parallel with a wire. You should have seen that bulb B goes out when the switch is closed.

27. What does this experiment tell you about the resistance of a wire or switch as compared to that of a bulb? Explain your reasoning. **Your answer may be graded for writing.**

When a bulb or other circuit elements gets little or no current because there is an alternative path for the current that has very, very low resistance (as is the case for a wire or switch) we say that there is a **short** in circuit.

Experiment 7

28. Consider the circuit shown below. Predict the relative brightness of the all the bulbs. Explain your reasoning.



Now set up the circuit and test your predictions.

29. Were your predictions correct? If not, record your observations.
30. Predict how the brightness of bulbs A and B will change if bulb E is completely unscrewed.

Unscrew bulb E and notice how the brightness of the bulbs changes.

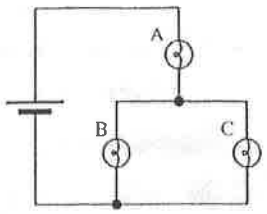
31. Were your predictions correct? If not, record your observations.
32. Explain why the brightness of bulbs A and B changed the way that they did when you unscrewed bulb E.

Exercise 8

33. Consider the following dispute between two students:

Student 1: "Unscrewing bulb C removes a path for the current. Thus the resistance of the circuit increases and the current through the battery and the remaining bulbs decreases. So bulb A and bulb B will dim."

Student 2: "I agree that bulb A will dim, but I disagree about bulb B. Before you unscrew bulb C, only part of the current through bulb A goes through bulb B. Afterward, all of the current through bulb a goes through bulb B. So bulb B should get brighter."



Do you agree with student 1, student 2 or neither? Set up the circuit and make observations if necessary.

✓ **Check your answers with your instructor.**