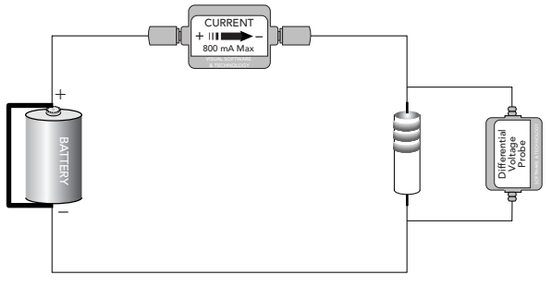
RealTime Physics

Active Learning Laboratories

Module 3

Electricity and Magnetism



I have a strong resistance to understanding the relationship between voltage and current.
Anonymous Introductory Physics Student

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Contents

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PRE-LAB PREPARATION SHEET FOR LAB 5—CURRENT IN SIMPLE DC CIRCUITS

(Due at beginning of lab)

Directions:
Read over Lab 5 and then answer the following questions about the procedures.

1. What do you predict for the rankings of the brightness of bulbs A, B, and C in Figure 5-1?

2. How do you think changing the direction of the current flow by reversing the connections to the battery in Figure 5-1 will change the rankings in (1)?

3. How can you compare the currents in the circuits in Figure 5-1 experimentally? List the equipment you will need.

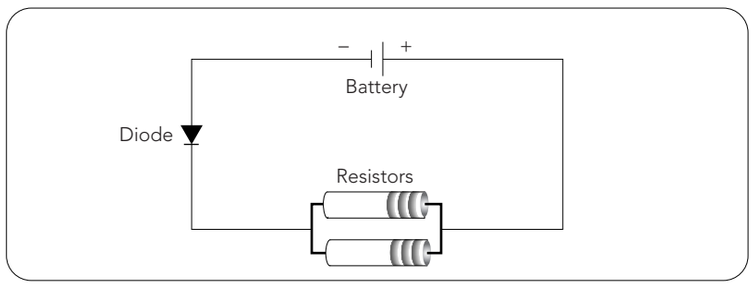
4. Define *series* and *parallel* connections. Sketch two light bulbs connected to a battery in series and two light bulbs connected to a battery in parallel.

5. Predict how the brightness of bulb D will change when the switch is closed in Figure 5-6.

6. Predict how the current flowing through the battery will change when the switch is closed in Figure 5-6.

Name_____ Date_____ Partners_____

LAB 5: CURRENT IN SIMPLE DC CIRCUITS*



If it's green and it wiggles, it's biology.
If it stinks, it's chemistry.
If it doesn't work, it's physics.
If it's incomprehensible, it's mathematics.
If it doesn't make sense, it's either economics or psychology.

—From A. Bloch's
Murphy's Law Book 3

OBJECTIVES

- To understand how current flows in a circuit when a battery lights a bulb.
- To understand what a series connection is in an electric circuit.
- To understand the relationship between the currents in all parts of a series circuit.
- To understand what a parallel connection is in an electric circuit.
- To understand the relationship between the currents in all parts of a parallel circuit.
- To begin to understand the concept of resistance.

OVERVIEW

In Lab 4 you saw that when there is an electric current through a light bulb, the bulb lights. You also saw that to cause current to flow through a bulb, you must have a complete circuit that includes a voltage source such as a battery. You found that in a simple circuit containing a battery, a single bulb and wires connecting them, current will only flow when there is a complete path from the positive terminal of the battery, through the connecting wire to the bulb, through the bulb, through the connecting wire to the negative terminal of the battery.

By measuring the current at different points in a simple circuit consisting of a bulb, a battery, and connecting wires, you discovered a model for current flow,

*Some of the activities in this lab have been adapted from those designed by the Physics Education Group at the University of Washington, as adapted for Workshop Physics, Module 4.

namely, that the electric current is the same in all parts of the circuit. By measuring the current and voltage in this circuit and adding a second bulb, you also discovered that a fresh battery maintains essentially the same voltage whether it is connected to one light bulb or two.

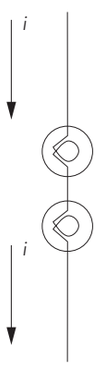
You also observed that the current was smaller when a second bulb was added to the circuit. This led us to introduce the concept of *resistance* of a circuit element such as a bulb. The total resistance of the elements in a circuit determines how much current is provided by the battery.

In this lab you will examine more complicated circuits than a single bulb connected to a single battery. You will compare the currents through different parts of these circuits by comparing the brightness of the bulbs, and also by measuring these currents using current sensors. Later, in Lab 6, you will examine the role of the battery in causing a current in a circuit, and compare the potential differences (voltages) across different parts of your circuits.

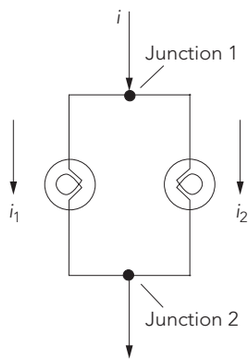
INVESTIGATION 1: CURRENT IN SERIES CIRCUITS

INVESTIGATION 2: CURRENT IN PARALLEL CIRCUITS

There are two basic ways to connect resistors, bulbs, or other elements in a circuit: *series* and *parallel*. So far you have been connecting bulbs and resistors *in series*. To make predictions involving more complicated circuits, we need to have a more precise definition of series and parallel. These are summarized below.



Series connection:
Two resistors are in series if they are connected so that the same current that passes through one passes through the other.



Parallel connection:
Two resistors are in parallel if their terminals are connected so that at each junction one terminal of one resistor is directly connected to one terminal of the other.

It is important to keep in mind that in more complex circuits, say with three or more elements, not every element is necessarily connected in series or in parallel with other elements.

Let's compare the behavior of a circuit with two bulbs wired in parallel to the circuit with a single bulb (see Figure 5-5).

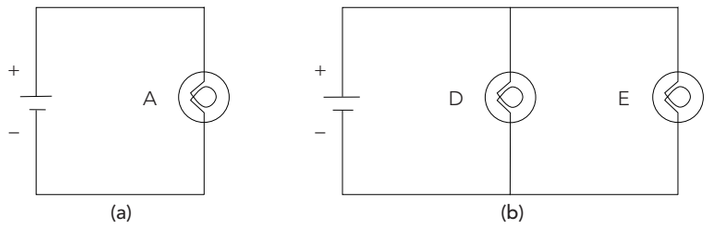


Figure 5-5: Two different circuits: (a) a single-bulb circuit and (b) a circuit with two bulbs identical to the one in (a) connected *in parallel* to each other and *in parallel* to the battery.

Note that if bulbs A, D, and E are identical, then the circuit in Figure 5-6 is equivalent to circuit 5-5a when the switch is open (as shown) and equivalent to circuit 5-5b when the switch is closed.

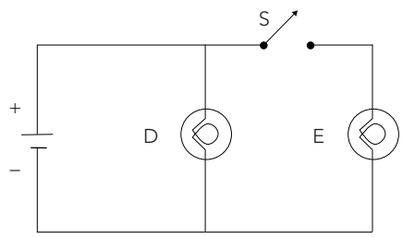


Figure 5-6: When the switch is open, only bulb D is connected to the battery. When the switch is closed, bulbs D and E are connected *in parallel* to each other and *in parallel* to the battery.

Question 2-1: Explain how you know that the caption of Figure 5-6 correctly describes the circuit.

Prediction 2-1: Predict how the brightness of bulbs D and E in the parallel circuit of Figure 5-5b will compare to bulb A in the single bulb circuit of Figure 5-5a. How will D and E compare with each other? Rank the brightness of all three bulbs. Explain the reasons for your predictions.

To test this and other predictions, you will need:

- computer-based laboratory system
- two current sensors
- *RealTime Physics Electricity and Magnetism* experiment configuration files

Click HERE to view a video of the behavior of the two-bulb curcuit as bulb E is connected and disconnected. Computer-based current sensors will measure the currents through Bulb D and E.

- a very fresh, alkaline 1.5-V D cell battery with holder
- 8 wires with alligator clip leads
- 3 #14 bulbs in sockets
- contact switch

Activity 2-1: Brightness of Bulbs in a Parallel Circuit

Set up the circuit in Figure 5-6, and describe your observed rankings for the brightness of bulb D with the switch open, and D and E with the switch closed.

Question 2-2: Did the observed rankings agree with your prediction? If not, can you explain what assumptions you made that now seem false?

Prediction 2-2: Based on your observations of brightness, what do you predict about the relative amount of current flowing through each bulb in a parallel connection, i.e., bulbs D and E in Figure 5-5b?

Prediction 2-3: Based on your observations of brightness, how do you think that closing the switch in Figure 5-6 affects the current flowing through bulb D?

Activity 2-2: Current in Parallel Branches

Skip steps 1-6. Click HERE to view the computer-based current sensor measurements for I_D and I_E.

You can test Predictions 2-2 and 2-3 by connecting current probes to measure the currents through bulbs D and E

1. Open the experiment file called **Two Currents (L05A1-2),** if it is not already opened.
2. **Calibrate** the current sensors, or load the calibration, if this hasn't already been done. **Zero** the sensors with them disconnected from the circuit.
3. Connect the circuit shown in Figure 5-7.

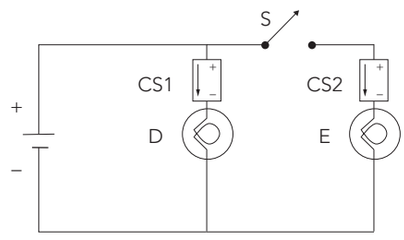
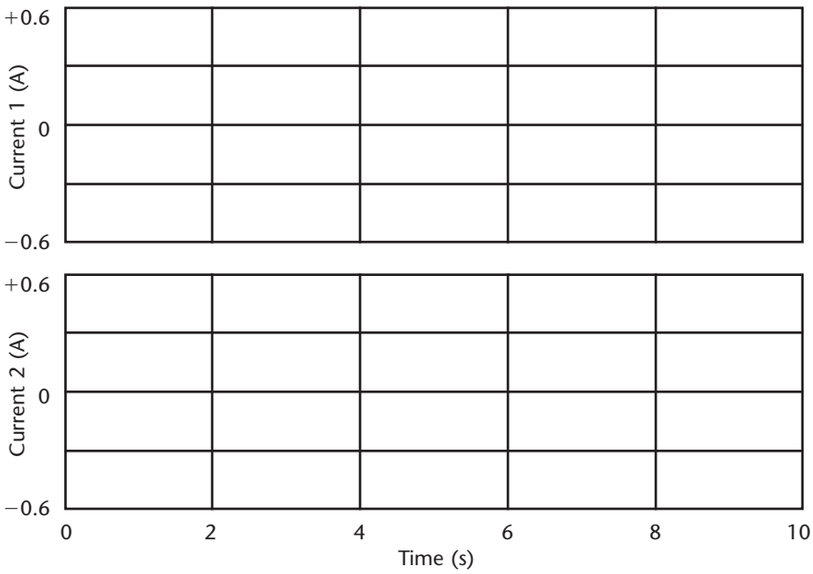


Figure 5-7: Current sensors connected to measure the current flowing through bulb D and the current flowing through bulb E.

4. **Begin graphing** the currents flowing through both sensors, then close the switch for a second or so, open it for a second or so, and then close it again.
5. Sketch the graphs on the axes below, or **print** them and affix them over the axes.
6. Use the **analysis feature** of the software to measure both currents.

   Switch open: Current flowing through bulb D:_____
   Current flowing through bulb E:_____

   Switch closed: Current flowing through bulb D:_____
   Current flowing through bulb E:_____



Question 2-3: Based on your graphs and measurements, were the currents flowing through bulbs D and E what you predicted based on their brightness? If not, can you now explain why your prediction was incorrect?

Question 2-4: Did closing the switch and connecting bulb E *in parallel* with bulb D significantly affect the current flowing through bulb D? How do you know? [**Note:** You are making a *very significant* change in the circuit. Think about whether the new current flowing through D when the switch is closed reflects this.]

You have already seen in Lab 4 that the voltage maintained by a battery doesn't change appreciably no matter what is connected to it. But what about the current flowing through the battery? Is it always the same no matter what is connected to it, or does it change depending on the circuit? (Is the current flowing through the battery the same whether the switch in Figure 5-6 is open or closed?) This is what you will investigate next.

Prediction 2-4: Based on your observations of the brightness of bulbs D and E in Activity 2-2, what do you predict about the amount of current flowing through

the battery in the parallel bulb circuit (Figure 5-5b) compared to that flowing through the single bulb circuit (Figure 5-5a)? Explain.

Activity 2-3: Current Flowing Through the Battery

Skip steps 1-3. Click HERE to view the computer-based current sensor measurements for I_D and $I_{Battery}$.

1. Test your prediction with the circuit shown in Figure 5-8. Use the same experiment file, **Two Currents (L05A1-2),** as in the previous activities.

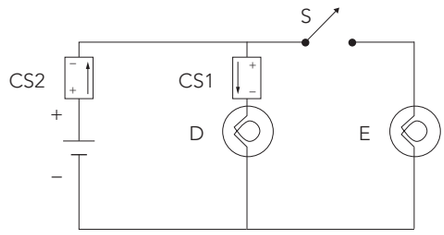


Figure 5-8: Current sensors connected to measure the current through the battery and the current through bulb D.

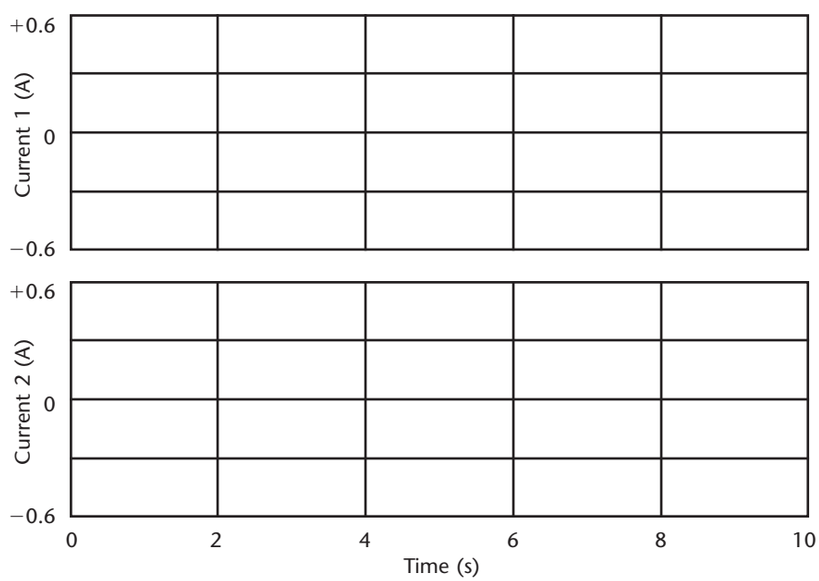
2. **Begin graphing** while closing and opening the switch as before. Sketch your graphs on the axes that follow, or **print** and affix over the axes. Label on your graphs when the switch is open and when it is closed.

3. Measure the currents flowing through the battery and through bulb D.

   Switch open: Current flowing through battery:_____
   Current flowing through bulb D:_____

   Switch closed: Current flowing through battery:_____
   Current flowing through bulb D:_____

Question 2-5: Describe how the connection of current sensors in Figure 5-8 differs from that in Figure 5-7. How do you know that sensor 2 is measuring the current flowing through the battery?



Question 2-6: Use your observations to formulate a rule to predict how the current flowing through a battery will change as the number of bulbs connected *in parallel* increases. Can you explain why?

Question 2-7: Compare your rule in Question 2-6 to the rule you stated in Questions 1-10 and 1-14 relating the current flowing through the battery to the total *resistance* of the circuit. Does adding more bulbs in parallel increase, decrease, or not change the total *resistance* of the circuit? Explain.

Question 2-8: Can you explain your answer to Question 2-7 in terms of the number of paths for current available in the circuit? Explain.

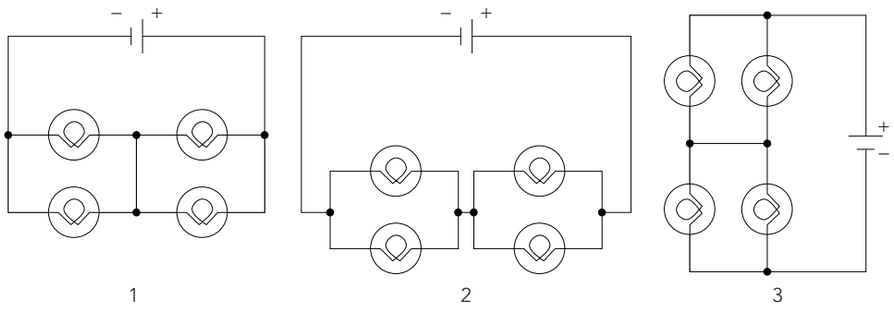
Question 2-9: Considering your experiences with series and parallel circuits in Investigations 1 and 2, does the current flowing through the battery depend only on the number of bulbs or resistors in the circuit, or does the arrangement of the circuit elements matter?

Question 2-10: Since current and resistance are related, does the resistance depend just on the number of bulbs or resistors, or does it depend on the arrangement of the circuit elements as well? Explain.

Name_____ Date_____ Partners_____

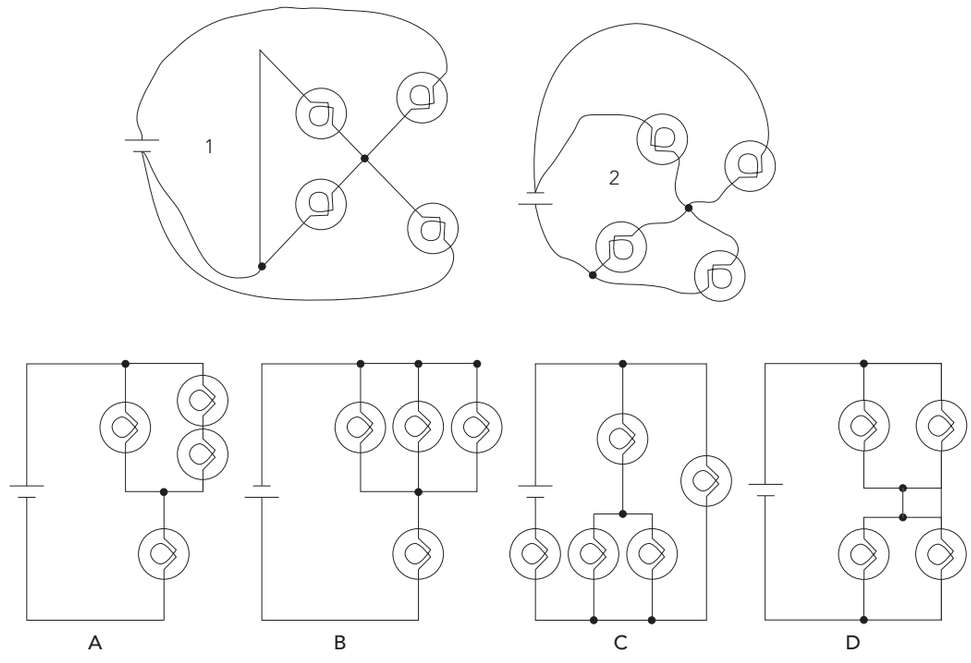
HOMEWORK FOR LAB 5
CURRENT IN SIMPLE DIRECT CURRENT CIRCUITS

1. Which of the three circuits shown below, if any, are the same electrically? Which are different? Explain your answers.



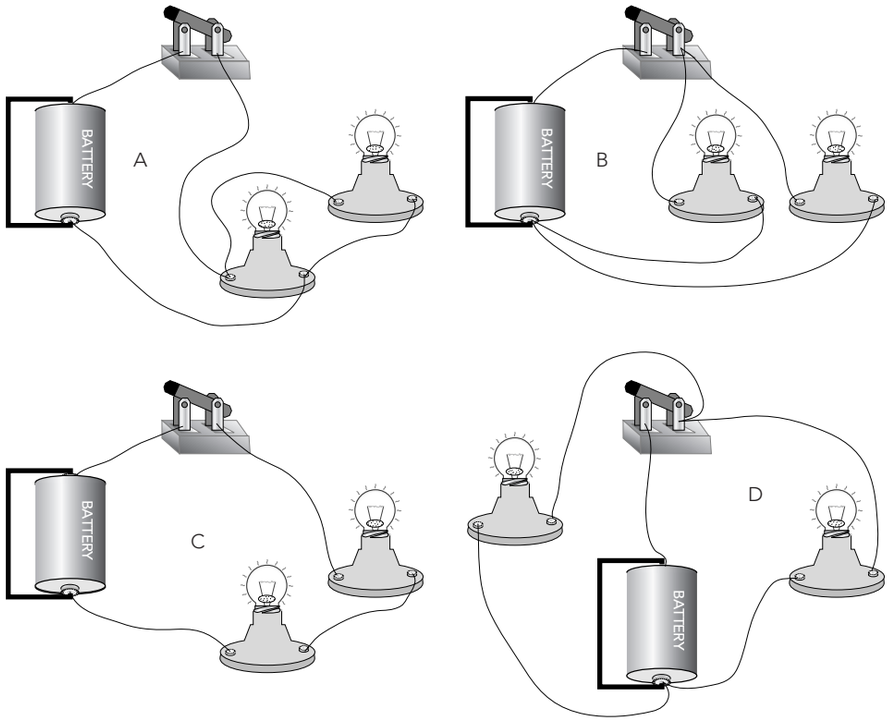
2. Consider the two messy circuit diagrams 1 and 2 below.

a. Identify which of the nice neat circuit diagrams below (A, B, C, or D) corresponds to circuit 1. Explain the reasons for your answer.



b. Which circuit diagram (A, B, C, or D) corresponds to circuit 2? Explain the reasons for your answer.

3. Three of the circuits drawn below are electrically equivalent and one is not.



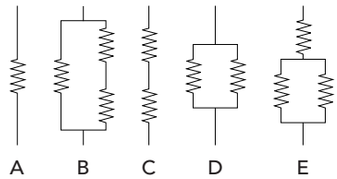
a. Which circuit is not like the others? Explain how it is different.

b. Which circuits represent parallel arrangements for the bulbs? Which represent series arrangements?

c. In the boxes below, draw neat circuit diagrams for each of the arrangements.

A	B
C	D

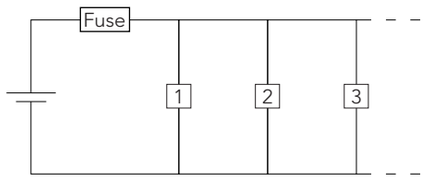
4. Use the model for electric current to rank the resistor networks shown below in order by resistance from largest to smallest. Explain your reasoning.



5. If a battery were connected to each of the circuits in Question 4, in which network would the current flowing through the battery be the largest? The smallest? Explain your reasoning.

6. The diagram below shows a typical household circuit. The appliances (lights, television, toaster, etc.) are represented by boxes labeled 1, 2, 3, and so on. The fuse, or circuit breaker, shown in the diagram is a switch intended to shut off the circuit automatically if the wires become too hot because the current flowing in the circuit is too large.

Note: Although houses in the United States use alternating current (AC), which differs in some important ways from the direct current (DC) we have been studying, you can still use the model you developed in answering these questions.



a. What happens to the current flowing through the fuse when more appliances are added to the circuit? Describe evidence from this lab for your answer.

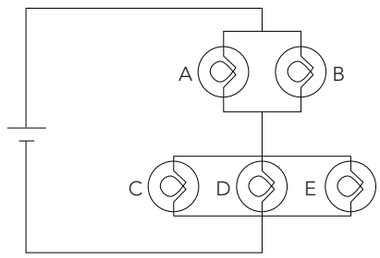
b. Does the current flowing through element 1 change when elements 2 and 3 are added to the circuit? Describe evidence from this lab for your answer.

c. Is this model consistent with your observations of everyday household electricity? For example, what happens to the brightness of a light bulb in a room when a second one is turned on?

d. What may happen to the fuse if too many appliances are added to the circuit? Why?

e. What kind of circuit connection for elements 1, 2, and 3 is shown in the diagram?

7. Consider the circuit shown on the right.

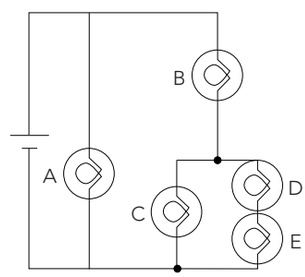


a. Are the bulbs C, D, and E connected in series, parallel, or neither? Explain.

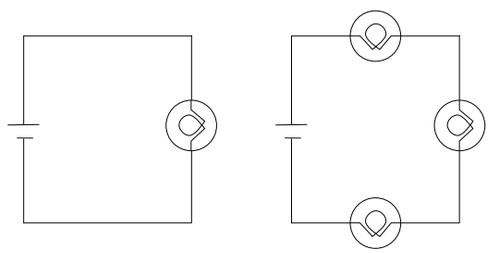
b. Rank the bulbs in order of brightness. Use the symbols =, <, and >. Explain your ranking.

c. How will the brightness of bulbs A and B change if bulb C is unscrewed? Will the result be different if bulb D or E is unscrewed instead? Explain.

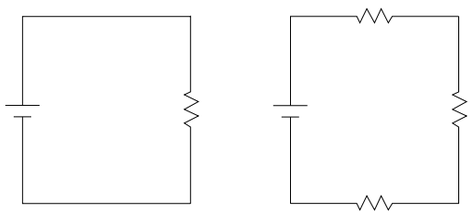
8. Consider the circuit shown on the right. Rank the brightness of the bulbs in the circuit. Use the symbols =, <, and >. Explain your ranking.



9. In the two circuits below, the batteries and all bulbs are identical. Compare the current flowing in the circuit on the left to the current flowing in the circuit on the right. Be as quantitative as possible.



10. In the two circuits below, the batteries and all resistors are identical. Compare the current flowing in the circuit on the left to the current flowing in the circuit on the right. Be as quantitative as possible.



Is your answer the same as in Question 9? Explain any differences.