D1: Electric Circuits I

Goals

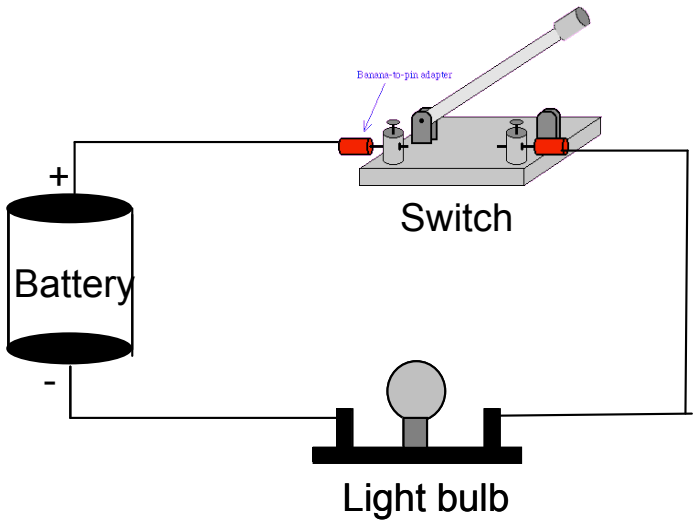
- To develop a model for how current flows in a circuit
- To see how a power supply provides current and voltage to a circuit
- To measure current flow in series and parallel circuits
- To determine the behavior of current at a circuit junction

Equipment

- 6 Volt power supply
- 1 switch
- 3 light bulbs (6 V) and holders
- Digital multimeter with leads
- Several wires with alligator clips on both ends
- 2 Current probes
- 2 Differential Voltage probes
- Computer interface
- LoggerPro software
- Experiment files: TWOCURRENTS, TWOVOLTAGES, CURVOLT

Activity 1: Warm-up circuit

Design a circuit that causes a light bulb to light up when a switch is closed. Your circuit might resemble the following:



Test the circuit. Answer the following questions:

- Q1.1: What does the switch do?

- Q1.2: Starting at the power supply, describe how you think the current flows through the circuit when the switch is closed.

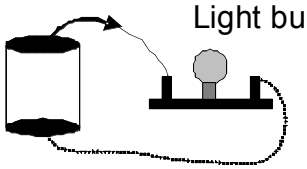
- Q1.3: Leave the bulb on for 10-20 seconds. Touch the bulb. How does it feel? Besides giving off

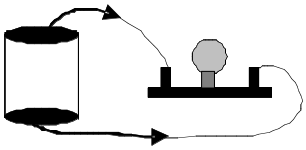
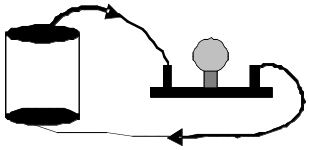
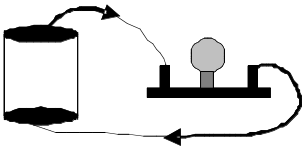
light, what else happens to the bulb when current runs through it?

- Q1.4: What can you conclude about the path needed by the current to make the bulb light up?

Activity 2: Establishing a model for electric current

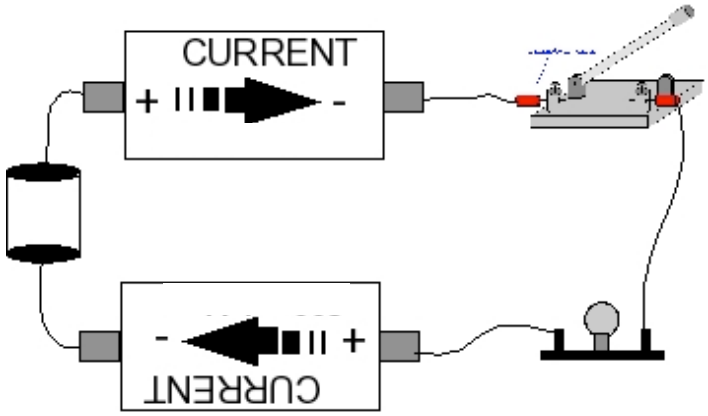
You probably know that the bulb glows because current from the power supply flows through it. What model would you propose for this current flow?

<table>
<tr>
<td> 

Model A: There will be no current left to flow in the bottom wire since all the current is used up lighting the bulb.</td>
<td> 
Model B: The current will travel toward the bulb in both wires.</td>
</tr>
<tr>
<td> 
Model C: The direction of current will be in the direction shown, but there will be less current in the return wire since some of the current is used up lighting the bulb</td>
<td> 
Model D: The direction of the current will be as shown, and the magnitude will be the same in both wires.</td>
</tr>
</table>

My best choice for the model describing current is Model _____.

Let's test this by building a circuit. We will measure the current flow on both sides of a light bulb, as suggested in the models above. Build the circuit shown below. You will need a switch, power supply, light bulb, two current probes, and several alligator clip leads (wires). A current probe measures the current that passes through it. When software called "LoggerPro" is run on the computer, the amount of current flowing through the probe can be seen "live" on a graph, and in numbers near the top left corner of the screen.



After you build the circuit, test it by closing the switch. The light bulb should light when the switch is closed.

- Q2.1: We "close" a switch to turn circuits "on" and "open" a switch to turn circuits "off." Why do we use the words "closed" and "open"?

The thick black wires coming out of the current probes should be connected to "CH1" and "CH2" on the green "LabPro" box, which connects to the USB port on your computer. Open the file **TWOCURRENTS**, this will start the LoggerPro program. Two axes should appear with current on the vertical axes and time on the horizontal axes. With the switch open (e.g. no current flow), click the "Zero" icon near the top of the screen, and follow the on-screen directions to "zero" or "reset" the current probes.

The icon used to zero an electrical probe.

Now, click the green "Collect" button near the top of the screen. Data should start appearing toward the right. While taking data, press and hold the switch closed. The light bulb should light and your graph should indicate the current flowing through each of the current probes. Open the switch and cycle it closed and open a few times.

The icon used to start reading the probes and making a graph.

- Q2.2: Did you observe a significant difference in the currents at the two locations in the circuit?

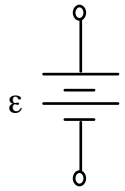
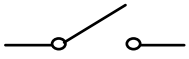
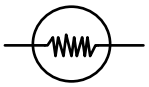
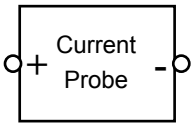
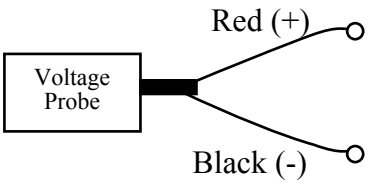
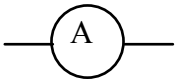
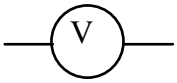
- Q2.3: Based on your observations, which of the current models given above, A-D, explains the behavior of your circuit?

- Q2.4: The circuit you built is called a "series circuit" because there is one (and only one) path current can take from the power supply, through the circuit, and back into the power supply again. What can you conclude about the amount of current that passes through circuit elements that are connected in series?

Summary Question 2.1: Is the current used up by the bulb? Explain. Record the answer to this and other summary questions on the lab sheet at the end of this write up.

Activity 3: Circuit Schematics

Electrical elements wired in a circuit, are not typically presented as little pictures as done above. Instead, elements in a circuit are given symbols, like this:

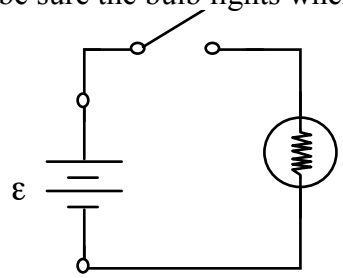
 Battery or power supply. Outer longest line is positive terminal.	 Switch
 Light bulb.	Interconnecting wire.
 Current Probe	 Differential Voltage Probe (Potential difference)
 Current meter (ammeter) (traditional symbol)	 Voltage meter (voltmeter) (traditional symbol)

Additionally, elements are almost always oriented horizontally or vertically (not diagonally). For example, the battery symbol could be rotated 90 degrees, if needed. For hand drawings, a ruler is always used. On actual circuit elements, red usually means positive (+) and black usually means negative (-).

- In the space below, draw a nice neat "textbook" style schematic of the circuit that you built above, containing the power supply, switch, bulb, and interconnecting wire.

Activity 4: Measuring Potential Difference (Voltage) and Current

Build the following circuit, test it, and be sure the bulb lights when the switch is closed.

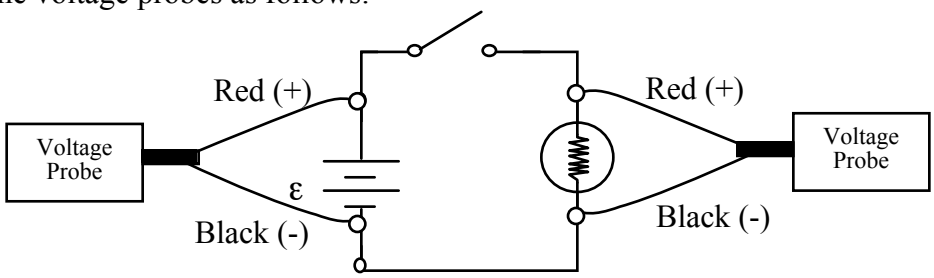


Next, connect two "Differential Voltage probes" to the green LabPro box. With LoggerPro, open the file called **TWOVOLTAGES**.

"Zeroing" the voltage probes.
Before connecting voltage probes to the circuit, on a single voltage probe, connect the red and black leads together. Click the "zero" icon to inform the probe what zero voltage means physically.
Repeat for the other voltage probe.
Connect both of the voltage probe leads from a single probe to the same point in the circuit. Choose any connecting "point" you wish, it can be any exposed conductor in the circuit.

- Q4.1: What voltage do you read from the probe when the ends are at the same point with the switch open? With the switch closed?

Now, connect the voltage probes as follows:



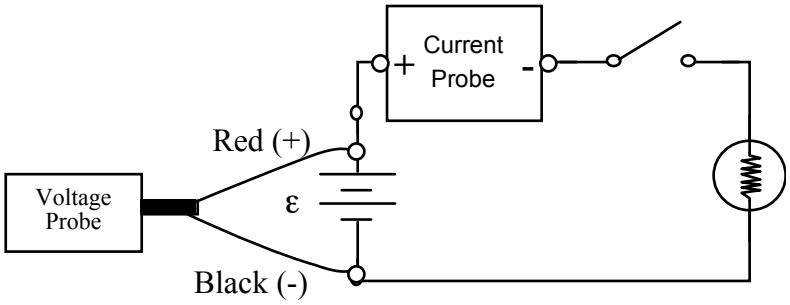
Start collecting data; open and close the switch several times.

- Q4.2: What do you conclude about the voltage across the power supply and the voltage across the bulb when the switch is open and when it is closed?

Summary Question 4.1: How does the voltage across the power supply compare to the voltage across the bulb?

Activity 5: Measuring Current and Voltage

Using the same circuit, connect a voltage probe *across* the power supply. Also, connect a current probe so that you can measure current *through* the power supply, as shown in this circuit.



- Q5.1: Discuss the use of the words *across* and *through* in the above sentence.

Circuit Measurement Strategy
When measuring current and voltage in electrical circuits follow these steps:
—Build a working circuit without any meters/probes.
—"Break" the circuit and insert a current probe so the current runs through it.
—Put a voltage probe across the relevant part of the circuit.

Open the file called **CURVOLT.** Press the "Collect" button, then close and open the switch several times. Title your graph: "Voltage and Current in a One Bulb Circuit." **Print out your graph**. Attach it to your lab report.

Explain the appearance of your current and voltage graphs. In particular:

- Q5.2: What happens to the current through the power supply when the switch is closed?

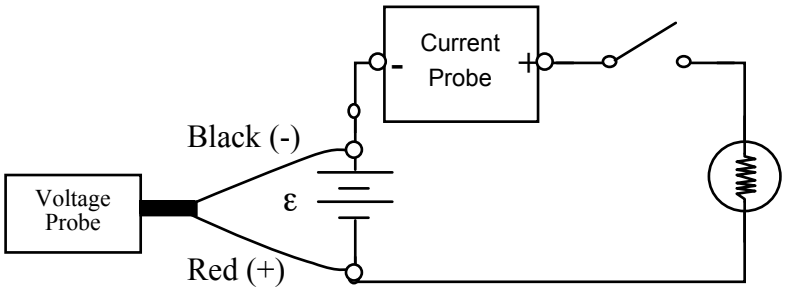
- Q5.3: What happens to the current through the power supply when the switch is opened?

- Q5.4: What happens to the voltage across the power supply when the switch is closed? Opened?

- Q5.5: Find the voltage across and the current through the power supply while the switch is closed and the bulb is lit.

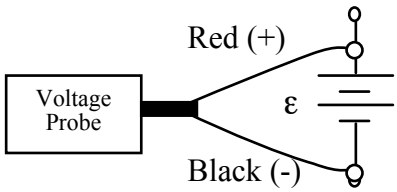
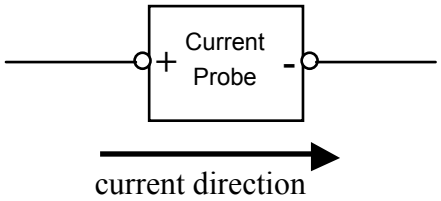
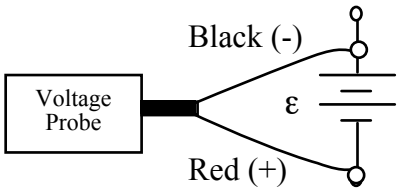
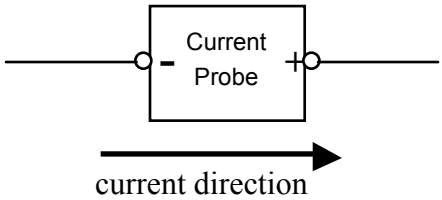
Average Voltage: _____ Average Current: _____

Measuring Current and Voltage: the Sign Conventions
Using the same basic circuit, but with the polarity of both probes reversed (as shown below) take a data set with several closings and openings of the switch



- What do you notice about the magnitude of the voltage compared with the previous data?
- What do you notice about the sign of the voltage compared with the previous data?
- What do you notice about the magnitude of the current compared with the previous data?
- What do you notice about the sign of the current compared with the previous data?

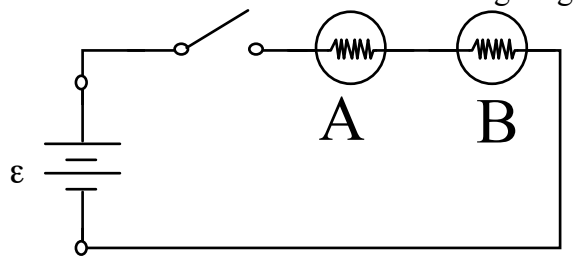
CONVENTIONS
The signs of voltage and current will depend on the orientation of the probe relative to the circuit.

Voltage	Current
 **voltage is Positive** positive terminal of probe is at a higher potential than the negative terminal	 **current is Positive** current enters the positive terminal of probe
 **voltage is Negative** positive terminal of probe is at a lower potential than the negative terminal	 **current is Negative** current enters the negative terminal of probe

Activity 6: Two light bulbs in series

Overview

Imagine another bulb is added to the circuit as shown in the following diagram.



- P6.1: Predict how you think the brightness of the two bulbs in series will compare with the bulb brightness in the single-bulb circuit?

- P6.2: Predict whether the voltage across the power supply will increase, stay the same, or decrease with the addition of the second bulb?

- P6.3: Predict whether the current though the power supply will increase, stay the same, or decrease with the addition of the second bulb?

Now, add a second light bulb into your actual circuit, so that it is IN SERIES with the first bulb**,** as shown in the diagram above.

- Q6.1: Is the brightness of the bulbs different for the one-bulb circuit, compared to the two-bulb circuit? If so, describe how.

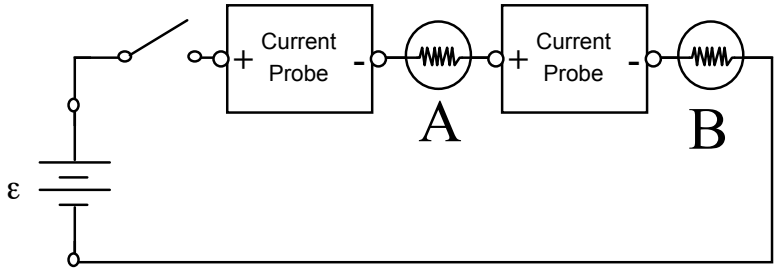
Bulbs

- P6.4: Predict how the current entering bulb A will compare to the current exiting bulb A?

- P6.5: Predict how the current exiting bulb A will compare to the current entering bulb B?

- P6.6: Predict how the current entering bulb B will compare to the current exiting bulb B?

Test your predictions by adding current probes to your circuit as shown below. Close the switch and take some data.

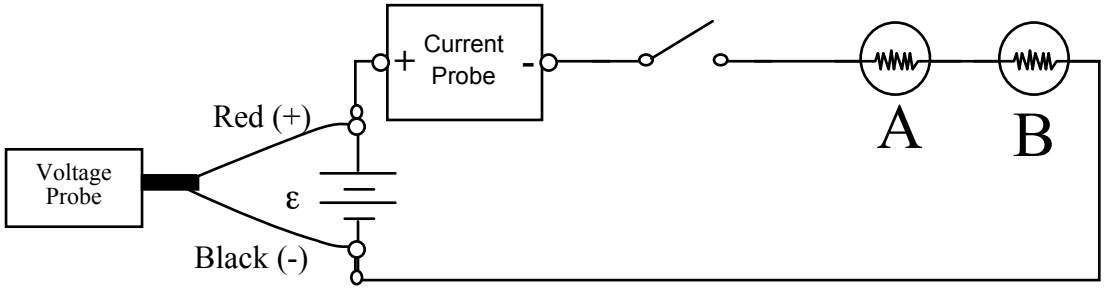


- Q6.2: What is the current that enters bulb A? _____
- Q6.3: What is the current that exits bulb A? _____
- Q6.4: What is the current that enters bulb B? _____
- Q6.5: What is the current that exits bulb B? (You have to move a current probe.) _____
- Q6.6: Is current "used up" in bulb A? In bulb B?

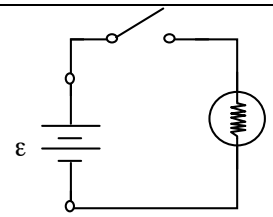
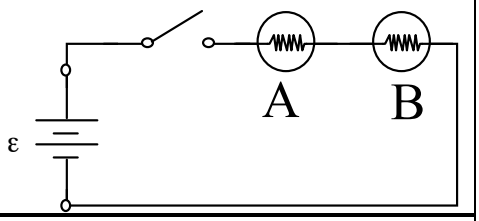
- Q6.7: How does the current through bulb A and bulb B compare to the current through the power supply?

Power Supply

Now we look at what happens to the power supply when another bulb is added to the series circuit. We will need to measure both current and voltage. Hook up the voltage and current probes as shown below.



Take data. **Print out your graph** and label it: "Two Bulb Series- power supply." Fill in the appropriate spaces in the table below. You may have already taken some of this data in the previous activities.

	One bulb	**Two bulb-series**
		
Switch open		
$I_{\text{Power Supply}}$		
$V_{\text{Power Supply}}$		
Switch closed		
$I_{\text{Power Supply}}$		
$V_{\text{Power Supply}}$		

- Q6.8: Did the current through the power supply change significantly when you added the second bulb?

- Q6.9: Did the voltage across the power supply change significantly when you added the second bulb?

- Q6.10: Does the power supply appear to be a device with constant current, constant voltage, or neither when circuit elements are added? Explain.

- Q6.11: Can you correlate current and bulb brightness between the two circuits? If so, how do they correlate?

- Q6.12: How does the amount of current from the power supply in the single-bulb circuit compare to the current from the power supply in the two-bulb series circuit? Be quantitative.

- Q6.13: Suppose you think of a bulb as providing a resistance to the current rather than something that uses up current. How is the total resistance of a circuit affected by the addition of more bulbs?

- Q6.13: Formulate a rule predicting whether current increases or decreases as the total resistance of a circuit is increased.

Test your prediction on a three-bulb circuit.

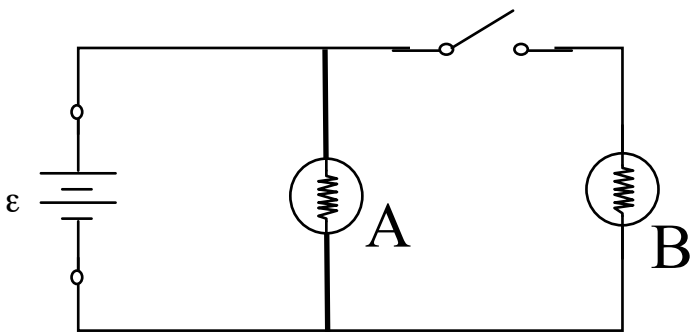
Summary Question 6.1: Does the power supply appear to be a constant voltage source or a constant current source? Record this answer on the lab sheet.

Summary Question 6.2: How is the current in a circuit affect by an increase of resistance, assuming the voltage remains constant? Record this answer on the lab sheet.

Activity 7: Circuit elements connected in parallel

Overview

There is another way to connect the two bulbs. This is the **parallel** configuration, as shown in the diagram below.



- P7.1: Predict what will happen to the brightness of bulb A when the switch is closed?

- P7.2: Predict what will happen to the current through bulb A when the switch is closed?

- P7.3: Predict how the brightness of bulb A will compare to the brightness of bulb B when the switch is closed?

- P7.4: Predict whether the voltage across the power supply will increase, stay the same, or decrease?

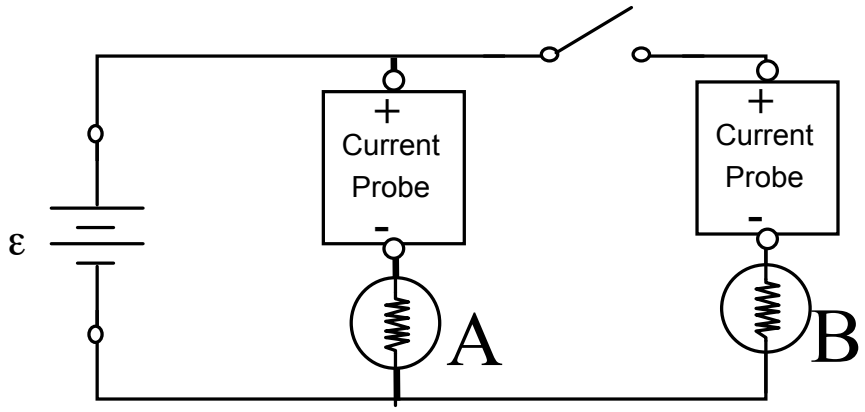
- P7.5: Predict whether the current through the power supply will increase, stay the same, or decrease

Build the circuit. Then close the switch.

- Q7.1: Does the brightness of bulb A increase, stay the same, or decrease?

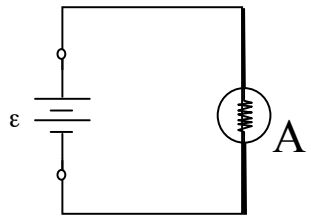
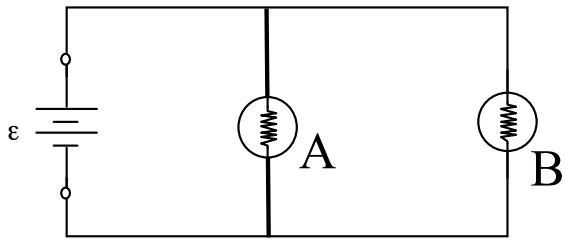
- Q7.2: How does the brightness of bulb A compare to the brightness of bulb B?

Bulbs Add two current probes to your circuit, so that you can measure the current through each bulb. This is shown below.



Using Logger Pro, open the experiment called **TWOCURRENTS** to display two sets of current axes. **Zero** the current probes while they are disconnected from the circuit. Click the *Collect* button and close the switch for a second or two, open it, then close it again. Put your data in the table below.

Using a voltage probe, check the voltage across each bulb and the power supply when the switch is closed and the bulbs are lit. After plugging in a voltage probe a new graph will *not* appear. You can read the voltage using the "live" numbers that appear in the upper left corner ("Potential") of the main window. Put your data in the table below.

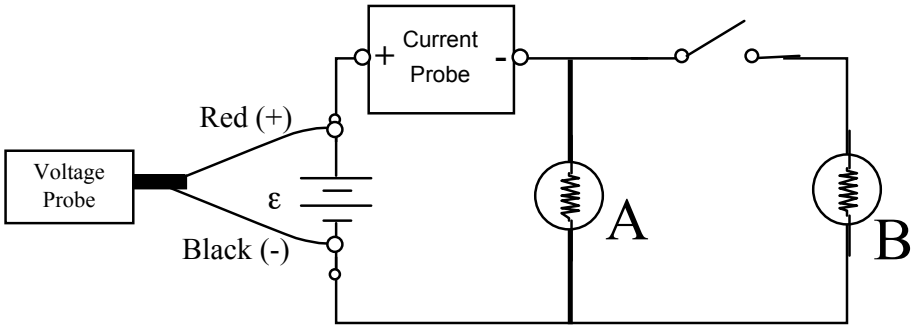
	Switch open	Switch closed
		
Current through A		
Current through B		
Voltage across A		
Voltage across B		

- Q7.3: How does the current through bulb A compare to the current through bulb B when the switch is closed?

- Q7.4: How does the voltage across bulb A compare to the voltage across bulb B when the switch is closed?

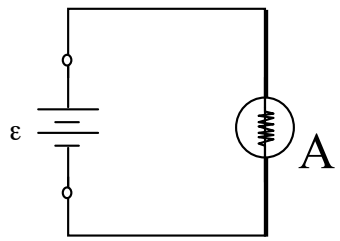
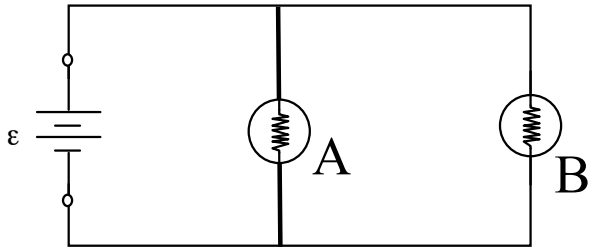
Power Supply

We now explore the power supply's behavior when a second bulb is added in a parallel circuit. Connect voltage and current probes to measure the "current through" and the "voltage across" the power supply.



In Logger Pro, open the experiment called **CURVOLT** to display voltage and current axes. **Zero** the current probe while it is disconnected from the circuit. **Zero** the voltage probe by connecting the leads together. Click the *Collect* button and close the switch for a second or two, open it, then close it again.

Print out your graph and label it: "Parallel-power supply." Put your data in the table below.

	Switch open	**Switch closed**
		
Current through the power supply		
Voltage across the power supply		

- Q7.5: Did the current through the power supply change significantly when you added the second bulb?

- Q7.6: Did the voltage across the power supply change significantly when you added the second bulb?

- Q7.7: Does the power supply appear to be a device with constant current, constant voltage, or neither when circuit elements are added? Explain.

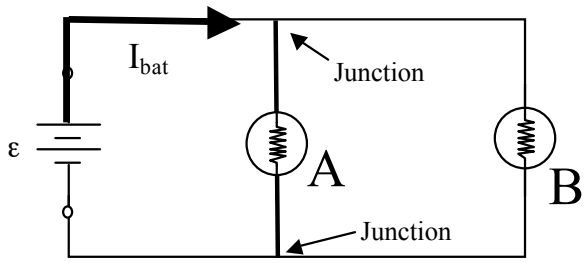
- Q7.8: In section 6 you determined that for a given power supply, the current decreased as the resistance of a circuit increased. How is the total resistance of a circuit affected by the addition of a bulb in parallel? Explain.

- Q7.9: Formulate a rule predicting how the resistance of a circuit changes with the addition of more bulbs in parallel.

Test your prediction.

- Q7.10: When the switch is closed, how does the current through the power supply compare to the current through bulbs A and B that you measured above?

Points in a circuit where the current must split along two or more paths are called "junctions." For current leaving the power supply and returning to the power supply, the important junctions are shown here.



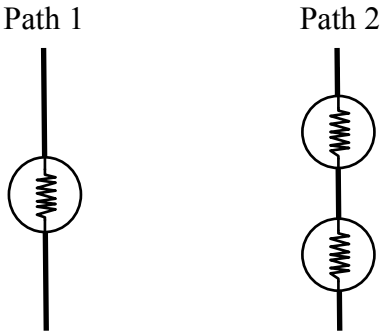
- Q7.11: Based on the measurements you just performed, explain what the current does as it leaves the power supply following the solid path shown, and encounters the junction? In your answer use the numerical measurements you just made to justify your reasoning.

Summary Question 7.1: Does the power supply appear to be a constant voltage source or a constant current source? Record this answer on the lab sheet.

Summary Question 7.2: Formulate a rule to explain what happens when current splits at a junction. Record this answer on the lab sheet

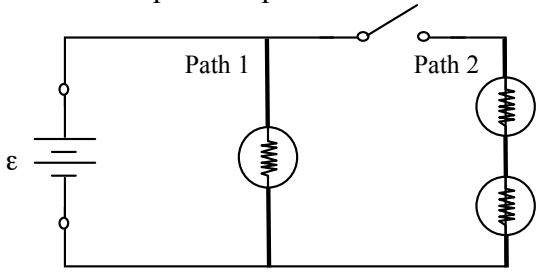
Activity 8: More Circuits

Two independent paths are shown below.



The resistance of path 1 is **larger** **equal to** **smaller** than the resistance in path 2. (Circle the appropriate choice).

Imagine that we hook both of these paths in parallel as shown below.

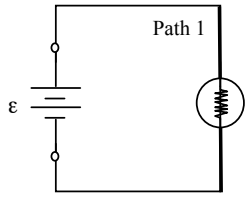
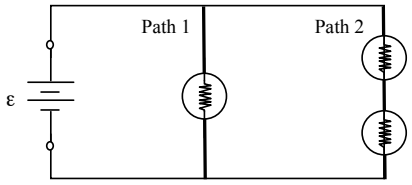


- P8.1: Predict whether the current through the power supply will increase, decrease, or stay the same when the switch is closed?

- P8.2: Predict whether the voltage across the power supply will increase, decrease, or stay the same when the switch is closed?

- P8.3 Predict whether the current in path 1 will be **larger, equal to, smaller** than the current in path 2. (Circle the appropriate choice). Explain.

Build the circuit, measure the appropriate quantities, and fill in the following table.

	Switch open	**Switch closed**
		
Current through the power supply		
Voltage across the power supply		
Current through path 1		
Voltage across path 1		
Current through path 2		
Voltage across path 2		

- Q8.1: How does the current through path 1 compare to the current through path 2 when the switch is closed?

- Q8.2: How does the voltage across path 1 compare to the voltage across path 2 when the switch is closed? What happened to the voltage across the power supply?

- Q8.3: When the switch is closed, how does the current through the power supply compare to the current through path 1 and path 2?

Summary Question 8.1: Does the power supply appear to be a constant potential difference (voltage) source or a constant current source? Record this answer on the lab sheet.

Summary Question 8.2: Formulate a rule to explain what happens when current splits at a junction. Record this answer on the lab sheet.

Summary Question 8.3: Formulate a rule about the potential difference (voltage) across parallel paths. Record this answer on the lab sheet.

NAME:_____

COURSE/SECTION:_____

REPORT.

ANSWERS TO SUMMARY QUESTIONS.