

Lab 6: Electric Circuits

Essentials of Physics: PHYS 101

During the past 100 years we have come to rely on the movement of extremely small particles carrying charge— electrons— to do work for us in a variety of ways. For example, connecting a light bulb to a voltage source using wires allows that source to push electrons through the bulb's filament... and that skinny wire glows giving us light. Inside the filament electrons in motion are colliding with the atoms of the filament. The energy in motion of the electrons is transferred to the atoms, causing them to emit light.

Moving electrons also cause electric motors to turn, gasoline/air mixtures to ignite, phosphors to emit colored light, signals to be transmitted... etc. A single electron is extremely small (its mass is about $1 / 10^{29}$ kg) and carries only $2 / 10^{19}$ C charge, so we must rely on large numbers of moving electrons to do useful work for us. Imagine how expensive electricity would be if the power company charged us to supply and push each electron travelling into our home!

In this lab we will explore how batteries push on electrons and how the latter travel through simple circuits. There are two experiments to complete, below.

Experiment One: *What a pushy battery*

Part A: Introduction:

We saw in lecture that one could connect a battery to a light bulb using a simple circuit and bask in the glow of our efforts. What if we connected two batteries to the same light bulb as follows?

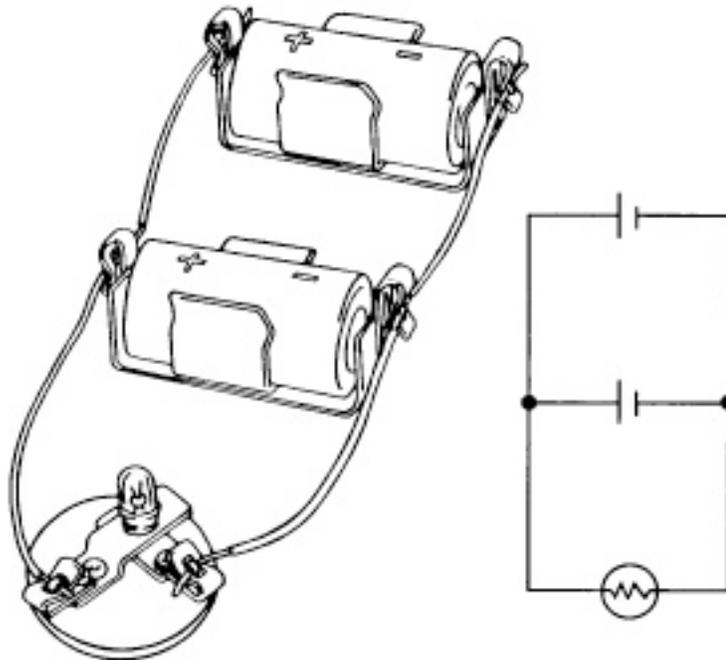


Figure 1

Question: Say we connect one battery to the bulb, as before and observe the results. Then we connect a second bulb to the circuit, as shown above. What would be the differences between what we observe for the one battery and the two battery circuits? Frame your answer as an hypothesis, below:

Hypothesis: When I add the second battery, I will observe that the...

During this part of the experiment you will be using materials from the “Electric Circuits” Science Kit to wire up the simple one- and two-battery circuits and observe your results.

Part A: Procedure:

1. Wire up a complete circuit so that one battery is able to push electrons through the bulb (see Figure 1, above).
2. Observe the bulb and write your observations in the data table, below:
3. Attach wires to the second battery in its holder. Connect the + sides of the two batteries together. While watching the bulb, touch the – wires together.
4. In the data table, below, write your observations of what happens when the – wires are connected below:
5. Now disconnect the second battery and wire it up according to the following diagram (Figure 2). (this is called a “series” configuration.) Connect a wire from the – of one battery to the + of the other. Connect wires to the other battery terminals. Connect one of these to the bulb. (see Figure 2, below).

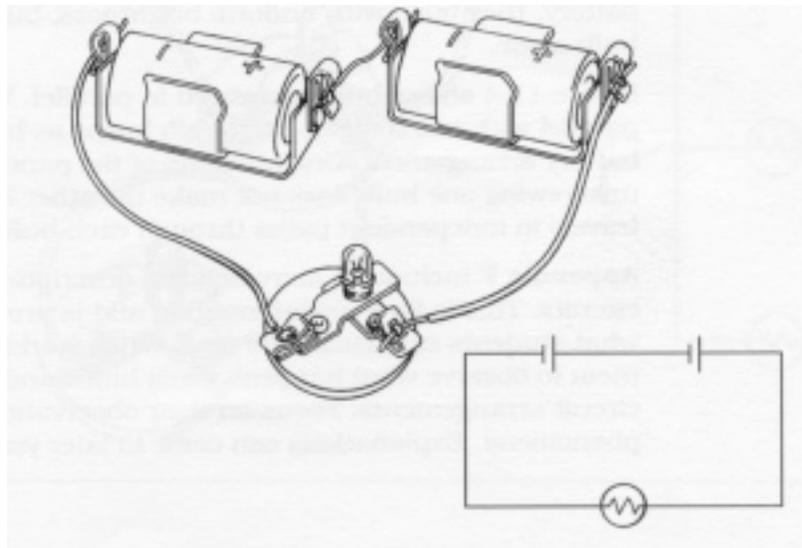


Figure 2

6. Write your observations of what happens when the circuit is completed in the data table below:

Observations:

Data Table: Experiment One, Part A

	Observations
1 battery	
2 batteries in parallel	
2 batteries in series	

Questions:

1. Did you observe changes in the behavior of the light bulb when the second battery was connected in parallel? Explain.
2. Did any properties of the circuit (light bulb and connecting wires) appear to change when the second battery was connected in parallel (Figure 1)? Would you expect them to change?
3. Did any properties of the circuit (light bulb and connecting wires) appear to change when the second battery was connected in series (Figure 2)? Would you expect them to change?
4. Could you tell if any properties of the source of “electron push”(batteries) change when the second battery was added to the circuit in parallel? In series? Explain.

Part B: Introduction:

For Part B you will connect meters to measure the voltage (“electron push”) of the source and the current (see end of lab for definition) through the circuit when one and two batteries serve as sources.

Part B: Procedure:

1. Wire up a complete circuit so that one battery is able to push electrons through the bulb.
2. Connect a voltmeter and current meter as shown below (Figure 3) so that the voltage of the source and the current through the circuit can be measured.

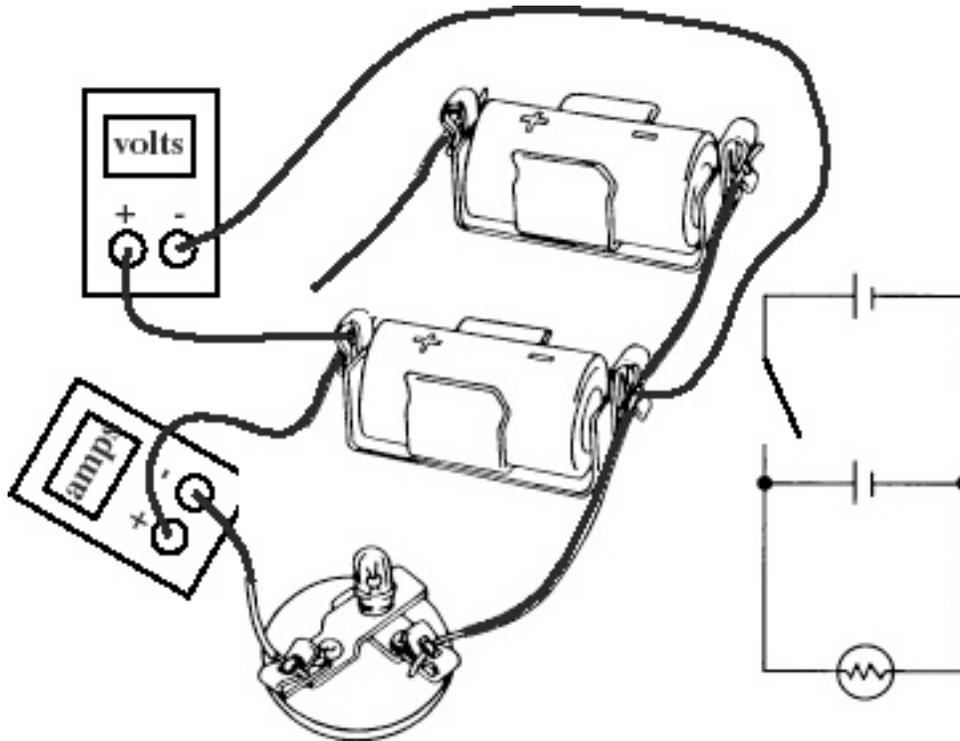


Figure 3

3. Draw on the circuit diagram, above right, the placement of the voltmeter and current meter. Refer to the end of the lab for a description of symbols representing circuit elements and use the proper symbols.
4. With the one battery used as a source and the bulb lit, measure the voltage across the source and the current through the circuit and record your results in the table below.
5. In the manner followed for Part A, attach wires to the second battery in its holder. Connect the - sides of the two batteries together, so they are in parallel.
6. While observing the voltmeter and the current meter, touch the + wires together. Record the voltage and current observed when two batteries are used in parallel as a source below.

7. Reconnect the batteries so that they are in series (+ of one to – of the other... etc, following Figure 2, above.). Leave one wire going to the bulb disconnected.
8. While observing the voltmeter and the current meter, briefly connect the last wire to the bulb to make a complete circuit. Record the voltage and current below.

Observations:

Data Table: Experiment One, Part B

	Voltage (V)	Current (I)	Observations
1 battery			
2 batteries in parallel			
2 batteries in series			

Questions:

1. Did the voltage of the source change significantly (more than 0.2V) when you connected the second battery in parallel? Explain.

2. Did the current through the circuit change significantly when you connected the second battery?

3. Did the voltage of the source change significantly when you connected the second battery in series? Explain.

4. Did the current through the circuit (bulb) change significantly when you connected the second battery in series? Why?

5. Which do you think affects the brightness of the bulb, voltage or current? Describe any evidence from this experiment that supports your thinking.

Part C: Introduction:

What happens when we change the circuit of our two-battery (in series), one bulb system? For example, what happens when we connect another bulb in series with the first, (by disconnecting A and connecting B) as shown below:

Say we connect another bulb **in series with the first**, so that electrons must move through two bulbs in a row? Which will change when the second bulb is connected, current or voltage? Why? Again state your prediction as a hypothesis, and give an explanation, below:

Hypothesis: When I add the second bulb, I will observe that the (voltage, current) will...

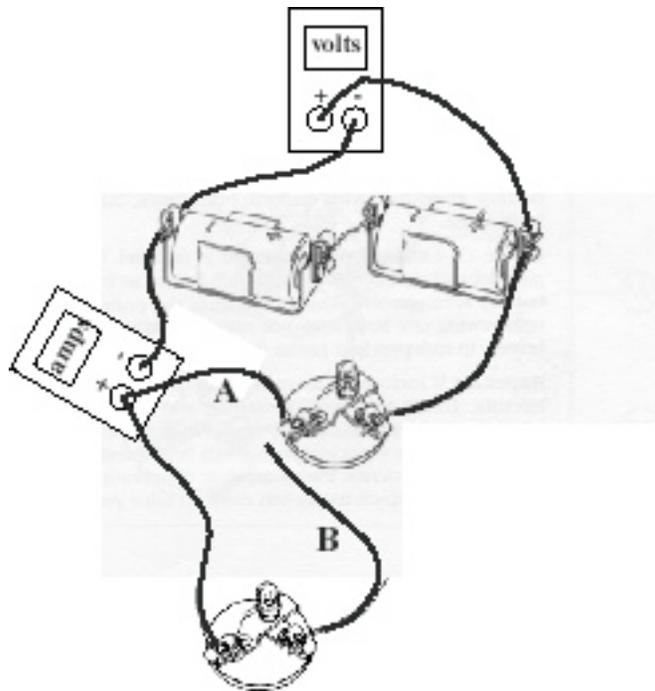


Figure 4

Checkpoint: Have a laboratory instructor check your hypothesis before proceeding.

Part C: Procedure:

1. Wire up a complete circuit so that two batteries are able to push electrons through one bulb.

2. Connect a voltmeter and current meter as shown above so that the voltage of the source and the current through the circuit can be measured.
3. With wire A connected and B disconnected (one bulb), (briefly!) observe the circuit with one bulb connected to the two batteries. Measure the voltage across the source and the current through the circuit. Write your observations in row one, below.
4. Disconnect wire A and connect wire B to the first bulb so that current leaving one bulb must pass through the other bulb before returning to the source. Observe changes in the brightness of bulb one, and the voltage and current, record on line two, below.

Observations:

Data Table: Experiment One, Part C

	Voltage (V)	Current (I)	Observations of bulb one
2 batteries, 1 bulb			
2 batteries, 2 bulbs			

Questions:

1. Did the voltage of the source change significantly when you connected the second bulb in series?
2. Did the current through the circuit change significantly when you connected the second bulb? Explain.
3. When the circuit connected to the source is changed, do the batteries act as a source of constant voltage or constant current? Support your answer using the observations recorded above.

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**Experiment 2: Are two bulbs better than one?**

**Introduction:**

In Experiment 1, you changed your voltage source by adding a second battery “in parallel” and observed the consequences. You also changed the circuit by adding a second bulb “in series.” You are now challenged to construct a circuit using two batteries in parallel and two bulbs so that the brightness of the first bulb doesn’t change when the second bulb is added.

**Challenge:** Plan a circuit that, using a switch, adds a second bulb to two batteries in parallel, so that the brightness of the first bulb doesn’t change. Use the space below to draw your circuit using the circuit symbols depicted at the end of the lab. Be sure to include the voltmeter and current meter so that voltage of the source and current through the circuit can be easily monitored.

**Checkpoint:** Have the lab instructor check your circuit before proceeding with the experiment. Be prepared to explain it to her/him.

**Procedures:**

1. Wire up the circuit you drew, above.
2. With the switch set so that only one bulb is connected, measure the voltage and current, and observe the brightness of the bulb. Record your observations in the table, below.
3. Now set the switch so that the second bulb is connected to the source. Again record your observations below.

**Observations:**

Data Table: Experiment Two

|                      | Source Voltage (V) | Current through circuit(I) | Resistance ( $\Omega$ ) | Observations : |
|----------------------|--------------------|----------------------------|-------------------------|----------------|
| 2 batteries, 1 bulb  |                    |                            |                         |                |
| 2 batteries, 2 bulbs |                    |                            |                         |                |

**Calculations/Questions:**

1. Did your circuit work properly? Why or why not?

2. Assuming your circuit worked (ask your instructor to help you if it did not), did the voltage of the (two battery) source change appreciably when you lit the second bulb?

3. How did the current through the (properly working) circuit change when you lit the second bulb (circle one): Halved Stayed the same Doubled Tripled Explain why you think it did what it did.

4. The **resistance**,  $R$ , of a circuit can be defined in words as its opposition to electrons flowing through it. Using Ohm's Law resistance is defined as:

$$\text{resistance} = \text{voltage} / \text{current}$$

Note that if we maintain a constant battery source, voltage doesn't change. If we double the resistance of a circuit, for example, the current must be halved. Using this information and your observations of voltage and current, fill out the Resistance column in the Observations table.

5. When the second bulb was added to your (properly working) circuit, the resistance must have (circle one): Halved Stayed the same Doubled Tripled Explain why you think this.

6. Looking back at your voltage and current results from Part C of Experiment 1, what happened to the resistance of the circuit when a second bulb was added in series? Did it decrease, stay the same, or increase. Describe evidence to support your thinking.

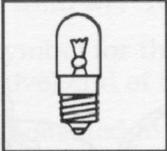
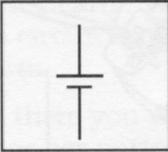
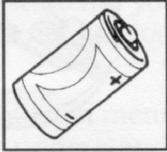
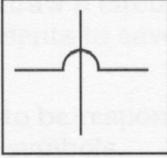
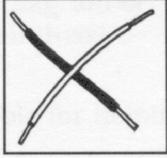
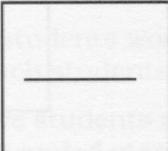
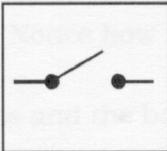
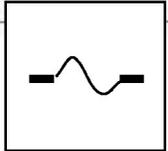
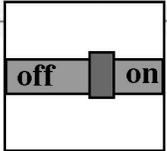
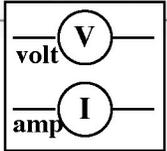
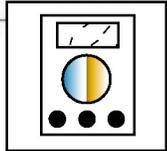
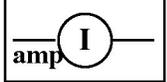
(these questions can be answered after the lab session)

7. Light bulbs in your house are wired in such a way so that turning on an additional light doesn't affect those that are already on. If you were charged with wiring up those lights, would you choose a parallel or a series circuit? Draw a simple circuit diagram showing how you would wire up your household lights and explain how it works. Support your answer by citing results from this lab.
8. During Experiment 2 you added a second bulb in parallel to a first. If you were to add more bulbs in parallel the current through the circuit would be observed to increase. A fuse is a device that will break a circuit when the current gets too large (see the symbol for a fuse, below). Add to your diagram for question 7 a fuse in the proper position so that it will "blow" when too many light bulbs are turned on. Be sure to label your fuse.

**Definitions:**

| Name                        | Symbol              | Definition                                                                                                     | Formula                    |
|-----------------------------|---------------------|----------------------------------------------------------------------------------------------------------------|----------------------------|
| Charge                      | Q<br>(Coulombs)     | A property of particles that can push or pull other charged particles. There are two types of charge, + and -. |                            |
| Voltage                     | V (Volts)           | What pushes or pulls charged particles. Voltage is Electric Potential Energy (difference) per charge           | $V = EPE / Q$              |
| Current                     | I (Amps)            | Charges in motion. The number of charges (Q) passing a point in one second.                                    | $I = Q/t$                  |
| Resistance                  | R (Ohms, $\Omega$ ) | Opposition to current flow. Given a voltage source, more resistance means less current.                        | $I = V / R$<br>(Ohm's Law) |
| Electrical Potential Energy | EPE (Joules)        | Stored energy available to push (or pull) charges. Voltage is EPE per charge, Q                                | $V = EPE / Q$              |
| Electrical Power            | P (Watts)           | For electricity, power is voltage times current (which is used EPE / time)                                     | $P = I \cdot V$            |

**Circuit Symbols:**

|         |                                                                                   |                                                                                   |                 |                                                                                    |                                                                                     |
|---------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Bulb    |  |  | Connected Wires |  |  |
| Battery |  |  | Crossing Wires  |  |  |
| Wire    |  |  | Switch          |  |  |
| Fuse    |  |  | Meter           |  |  |
|         |                                                                                   |                                                                                   |                 |  |                                                                                     |