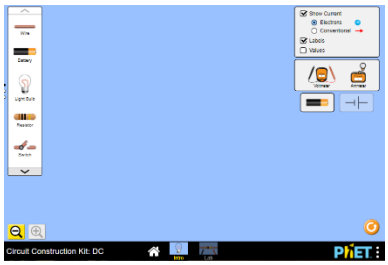
Circuits Module Student Guide

In non-COVID times this is the point in the semester in which you would be building some simple circuits. You would get a box with an ammeter, voltmeter, a 6-Volt battery with a circuit-breaker, three light bulbs, and a whole bunch of red and black wires. Alas, these are probably things you don't have in your bedroom.. So this week, we will try doing the same experiments as you would do at this point in the course, but with the [PhET Circuit Construction Kit: DC](). Click on Intro.



Background

When water flows through a garden hose, we can characterize the rate of flow as the volume of water passing any cross section of the hose per time. Units for this flow could be $\mathrm{m^3/s}$. Similarly, for a conducting wire electric charge can flow down the wire. We call the rate of flow of electric charge the *current*, which is the charge Q passing a cross section of the wire per time t. In SI units this is $\mathrm{C/s}$. $1\ \mathrm{C/s}$ is also called an *ampere*, A. Conventionally the current is given the symbol I, so the definition of current is:

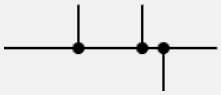
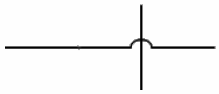
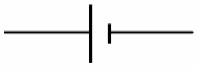
$$I \equiv \frac{\Delta Q}{\Delta t}$$

In order for water to flow in a hose a source of pressure is required. Similarly, for a current to flow in a wire a source of *voltage* is required. Common voltage sources are batteries, electric generators, and power supplies. In this Module we will be using a battery.

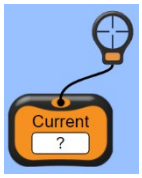
Activity 1: Simple Circuit (15 minutes)

Choose a light bulb from the box of items on the left. There are two metal contacts on the light bulb, one on the bottom, and one on the right, indicated by the dashed red circle. The glass holds a vacuum, and a tiny wire called a filament is connected to these two external contacts. If "Show current" and "Electrons" is selected, you will see little blue circles in the filament, indicating that it is filled with conduction electrons, as is all metal.

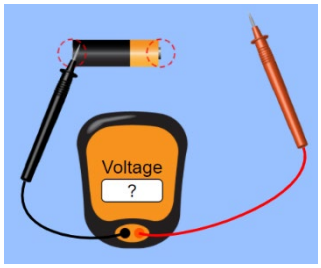
A. Grab two wires and a battery from the box on the left. Hook them up to the light bulb so that it starts to glow. This is a simple circuit. Use a Screen-capture app to copy what you see into your Google Slide. The battery has a plus-side, which is gold, and a black-side, which is negative. Do the electrons going toward the light bulb come from the + side or – side of the battery?
B. With the same circuit, change the Show Current to Conventional, and include an image of this. Does the conventional current going toward the light bulb come from the + side or – side of the battery? [NOTE: Physicists use Conventional current as the "current" so for the rest of the experiments today please leave the Show Current option on Conventional.]
C. Instead of drawing a picture of an electric circuit, we can schematically represent it with a *circuit diagram*. Here are a few elements of circuit diagrams.

Wire	
Wires that are joined	
Wires that are not joined	
Light Bulb	
Battery	

For the Battery shown in the table, the positive terminal is on the left and the negative terminal is on the right . Here is a mnemonic for remembering this: a **+** symbol has more line in it than **–**, and the longer line of the battery is the + terminal. Draw a circuit diagram of the circuit you have constructed, and include your drawing in the Google Slides.



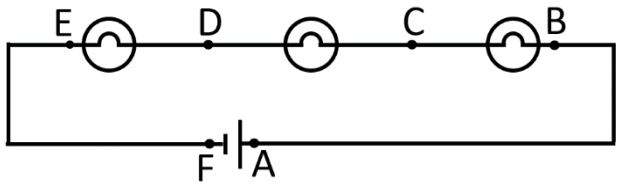
D. Grab the Ammeter from the box on the right. The ammeter has a little cross-hairs circle which tells you the magnitude of the net current is going through the circle, in Amperes. It reads "?" when the net current through the circle is zero. Measure and record the current at various parts of your circuit. You may label certain points on the circuit with letters. For example, the + side of the battery is A, the side-contact of the bulb is B, the bottom-contact of the bulb is C, and the – side of the battery is D. The current then travels A→B→C→D→A … etc.
E. Grab the Voltmeter from the box on the right. This has two metal sticks, called terminals, the black one and the red one. The Voltmeter measures the Electric



Potential Difference, in Volts, between the black and red terminals. This Electric Potential Difference is called the "voltage". The way you use a Voltmeter is that you connect the black terminal to a certain reference spot in the circuit. The standard reference spot is the -side of the battery. We define this as "zero voltage". Leave the black terminal there, and now you can touch the red terminal to various parts of the circuit to determine the voltage at those points. Measure and record the voltage at various parts of your circuit, using the same letters that you used when you measured current.

Activity 2: Series Circuit (25 minutes)

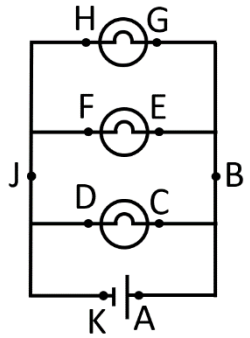
Click the "refresh" icon in the lower-right corner to remove all of your circuit elements. Click "Conventional" again for Show Current. Choose three light bulbs from the box of items on the left, and one battery. Use wires to hook up the three light bulbs to the battery "in series". Here is the circuit diagram, with some points labeled:



A. Once the current is flowing, include an image of your completed series circuit in your Google slides. Click on "Ask For Help", and when the TA arrives, share your PhET animation showing the completed series circuit. The TA will add their initials to your Google Slides to verify that you got it working.
B. Use the Ammeter to measure the current at the labeled points. Do you note anything interesting about the values?
C. Use the Voltmeter to measure the voltage at the labeled points (with point F as your reference for the black terminal). What are the voltage changes when the current goes from one side of a circuit element to the other: F to A, B to C, C to D, and D to E? How are these voltage changes in a series circuit related?
D. If you click on a connection between a wire and a light bulb, you can then click on the scissors icon to "cut" the wire there. Cut one of the wires which is connected to the middle light bulb (near point C). What happens to the brightness of the other two bulbs?
E. Record the current through the battery for these three light bulbs connected in series. Change the circuit and record the current through the battery when there are different numbers of light bulbs connected in series (1, 2, and 4 for example). Make a plot of current through the battery vs number of light bulbs in series, and comment on the relationship.

Activity 3: Parallel Circuit (25 minutes)

Click the “refresh” icon in the lower-right corner to remove all of your circuit elements. Click “Conventional” again for Show Current. Choose three light bulbs from the box of items on the left, and one battery. Use wires to hook up the three light bulbs to the battery “in parallel”. Here is the circuit diagram, with some points labeled:



A. Once the current is flowing, include an image of your completed parallel circuit in your Google slides. Click on “Ask For Help”, and when the TA arrives, share your PhET animation showing the completed parallel circuit. The TA will add their initials to your Google Slides to verify that you got it working.
B. Use the Ammeter to measure the current at the labeled points. There are certain junctions, for example, the current from point A splits so that some goes to C and some goes to B. From your observations, what is the mathematical relationship between the currents going into and out of a junction.
C. Use the Voltmeter to measure the voltage at the labeled points (with point F as your reference for the black terminal). What are the voltage changes when the current goes from one side of a circuit element to the other: K to A, C to D, E to F, and G to H? How are these voltage changes in a parallel circuit related?
D. Cut one of the wires which is connected to the middle light bulb (near point E). What happens to the brightness of the other two bulbs?
E. If a light bulb burns out in your house, do all the other lights also go dark? Do you think the electrical wiring in your house is in series or parallel?
F. Record the current through the battery for these three light bulbs connected in parallel. Change the circuit and record the current through the battery when there are different numbers of light bulbs connected in parallel (1, 2, and 4 for example). Make a plot of current through the battery vs number of light bulbs in parallel, and comment on the relationship.