

Class #1: Wiring Protoboards & Measuring Voltage

Purpose: The objective of this experiment is to introduce you to wiring circuits on protoboards and making voltage measurements.

Background: Before doing this experiment, students should be able to

- Recognize which rows of holes represent connections on a protoboard.
- Know and be able to apply Ohm's Law $V = IR$ to determine any one of the three parameters given the values of the other two.

Learning Outcomes: Students will be able

- Physically wire up circuits on protoboards.
- Troubleshoot and debug wiring mistakes on a protoboard.
- Make DC voltage measures across circuit elements.

Resources Required:

- Resistors: 470Ω , $4.7k\Omega$ (4700Ω), $1M\Omega$ (1000000Ω) (in your parts kit)
- LED (any color) (in your parts kit)
- Battery (or other power supply) (provided, must be returned)
- Voltmeter (or Discovery Board) (provided, must be returned)

Pre-Lab

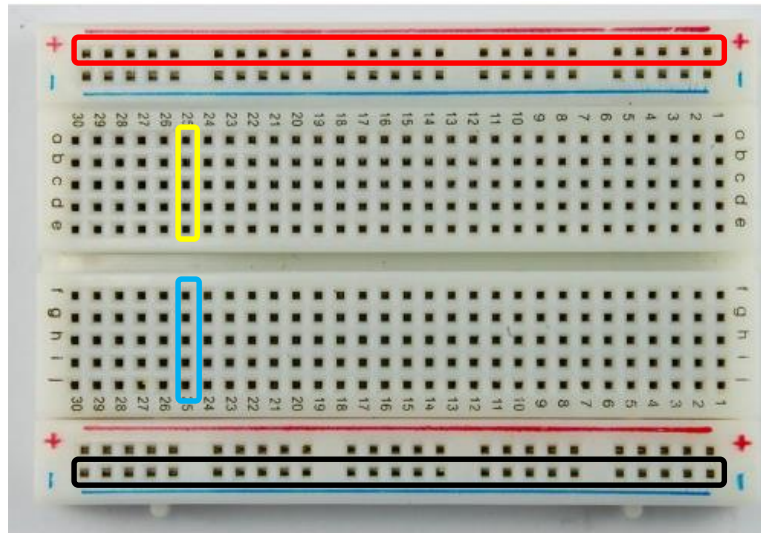
Required Viewing: Before beginning the lab, each team member must watch the video posted for this experiment.

Due: At the beginning of Class #3

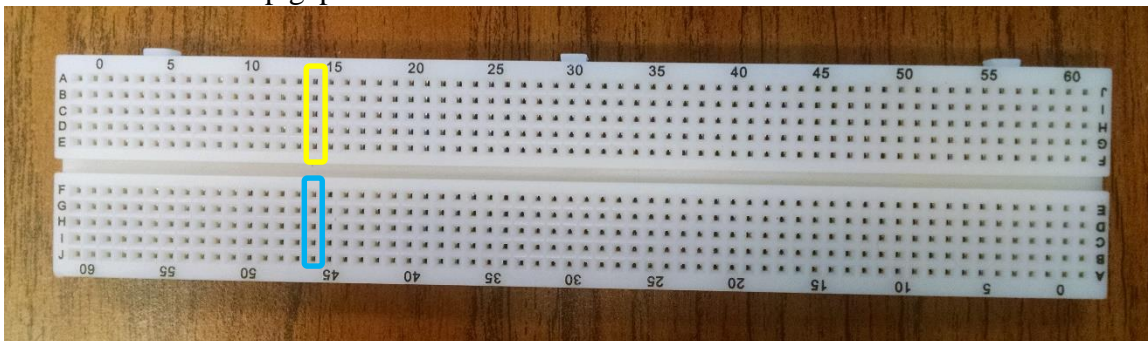
Notes: Every student needs to build their own circuits and verify that the circuit is working correctly. There may be a limited number of resources, so you may need to share equipment with your neighbors/teammates. Once you have successfully implemented a circuit, give your neighbor any tools he/she needs while you build another circuit. If you are having trouble getting your circuit to work, do not hesitate to ask for help.

Background/Review:

Protoboards: On this page, you can see various combinations of holes that are connected together on an example protoboard. You should remember this information from watching the video. A common small protoboard is shown in the figure below. Each circled section is an example of one entire set of connected holes. The long sets on the ‘sides’ are typically called buses and are used for power/ground connections. Note: The yellow and blue sets of holes are not connected, the gap between them is a chip gap. The red circled positive bus at the ‘top’ is **not** connected to the uncircled positive bus at the ‘bottom’. When building circuits, each set of holes represents a shared connection (node) between various components. Note that your protoboard may not have the long sets of holes (buses).

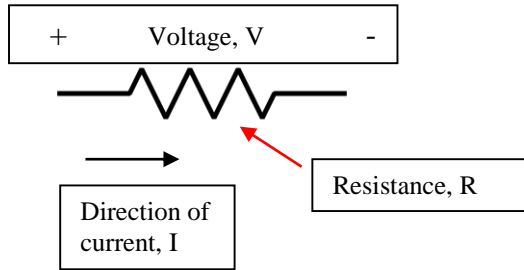


If you purchased the Discovery Board parts kit, the included protoboard is shown below. In this case, the power buses are not part of the board. Only the banks of five holes on either side of the chip gap are available as shared connected holes.

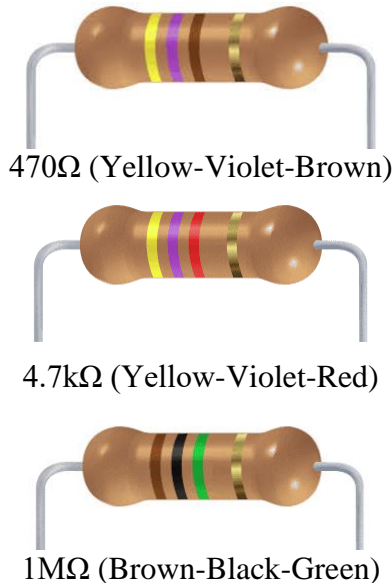


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Resistors: Resistors are devices that drop a voltage and allow current to flow. One of the most important equations in Electrical Engineering is Ohm's Law, which describes the relationship between voltage, current and resistance. This equation is a simple linear relationship, $V = IR$, VOLTAGE = (CURRENT)*(RESISTANCE). These concepts will be discussed in more detail as the course progresses. Resistors are devices that obey Ohm's Law.



In this experiment, you will be using three different resistors. To identify the resistors, check their color code.

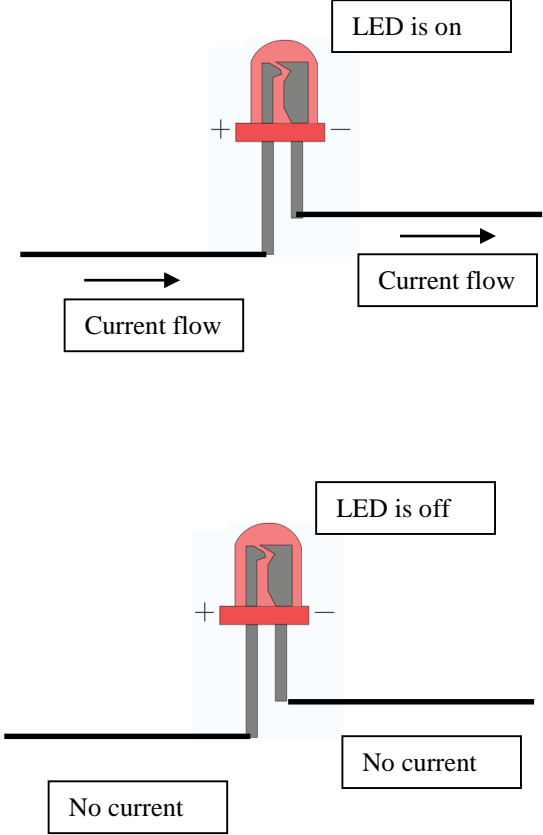


Digi-Key provides an online color code calculator (you can find quite a few by googling). The website has a number of useful web pages and is a resource if you are interested in buying electronics.

<https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code-4-band>

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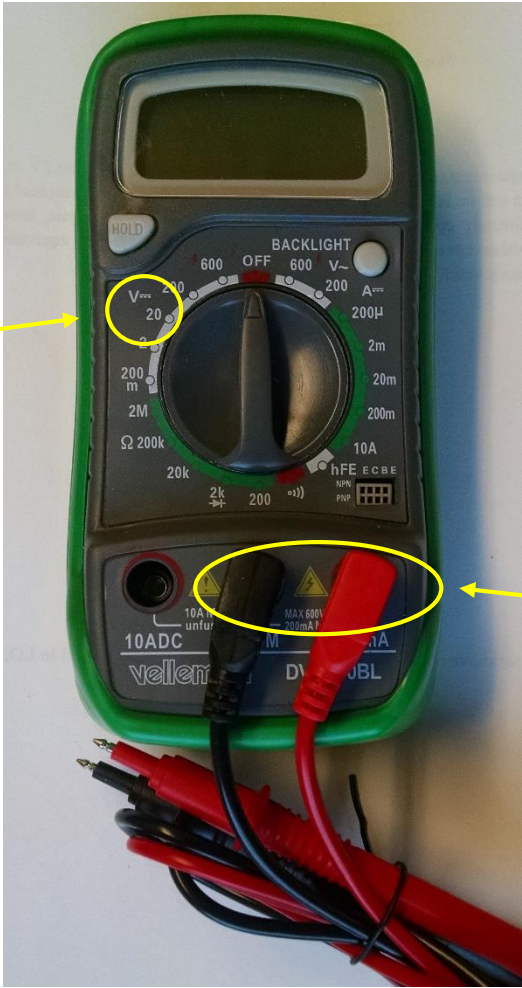
LEDs: Light Emitting Diodes (LEDs) are devices that emit light when current flows through them. An important characteristic is that they only turn on (emit light) when current flows from the anode (positive side) to the cathode (negative side). When no current is flowing, the LED is off (no light is emitted). Current cannot flow in the opposite direction (unless you burn it out). We will see more details about LEDs as the course progresses.



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Multimeters/Voltmeters: Multimeters are devices that are used to measure various circuit characteristics. The multimeter shown below can be used to measure voltage, current, and resistance. It has some other features as well, such as a short circuit test and transistor gain calculation. For this laboratory, we will use the voltmeter feature to measure DC voltage. It is important to make sure the probes are connected to the voltage measurement connections, as shown in the image below. If the probes are connected incorrectly, it is possible to damage the voltmeter. Since we will be making DC voltage measurements in the 0-9V range, we need to select the correct setting. The V with a flat bar indicates DC (direct current) measurements. The V with the 'wavy' bar indicates AC (alternating current) measurements. With our voltage range, we will want to choose the '20' setting which will measure voltages between -20V and 20V. Note, negative voltages are possible measurements.

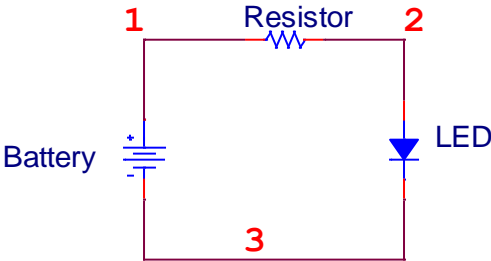
Voltmeter setting for -20V to 20V DC measurements



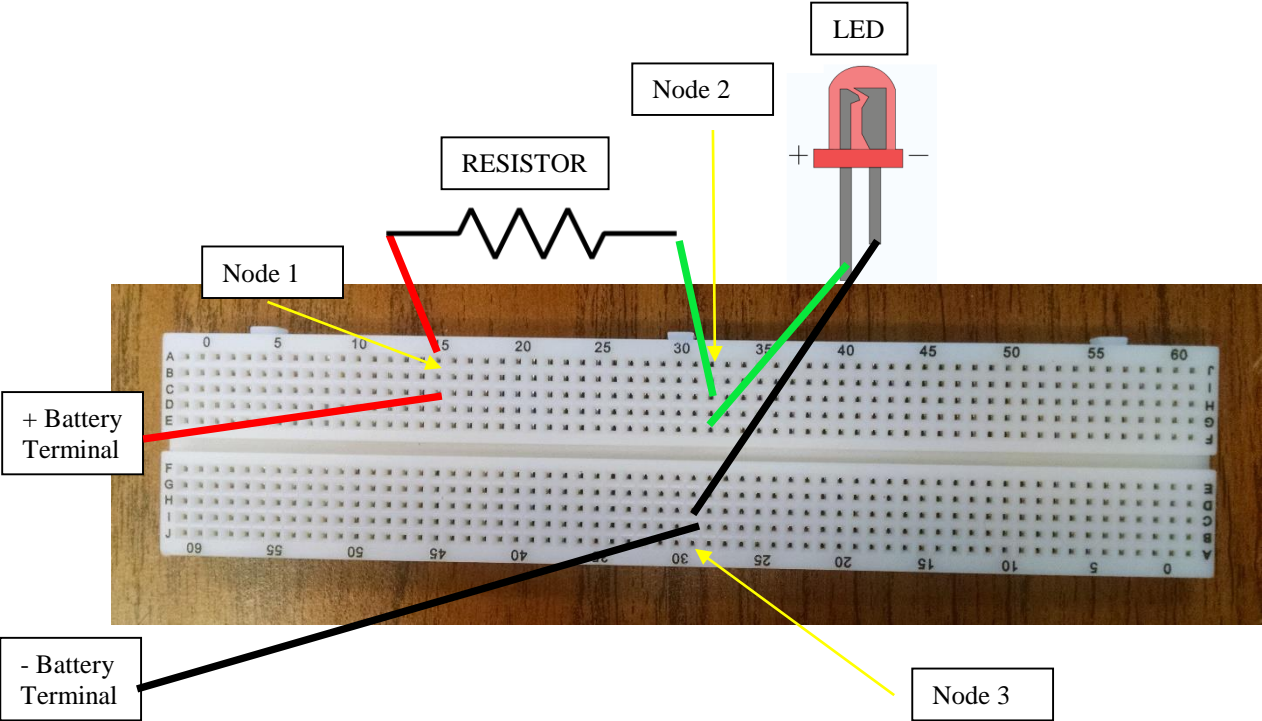
Probe connections for measuring voltage

For This Experiment:

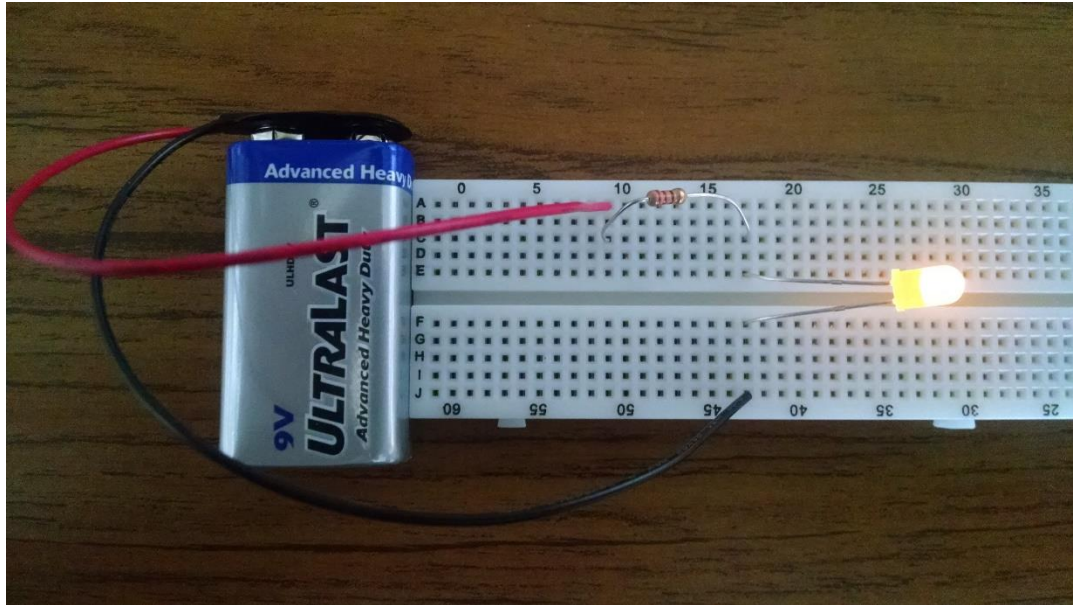
1. We want to build the circuit shown in the schematic below. When the circuit is successfully constructed, the LED will turn on (glow). In the circuit, we have three connection points (nodes), with labels 1, 2, and 3. Using the connected holes on a protoboard, we can connect the various devices. A couple special considerations should be mentioned. The ‘buses’ on the protoboard are typically used for power levels. A battery has two power levels. One is the battery voltage connected at the positive battery terminal. The other is usually ground, connected at the negative battery terminal. A physical layout for this circuit is shown in the following figure. The colored lines are used to indicate where the associated part ‘leg’ should be placed.



LED circuit

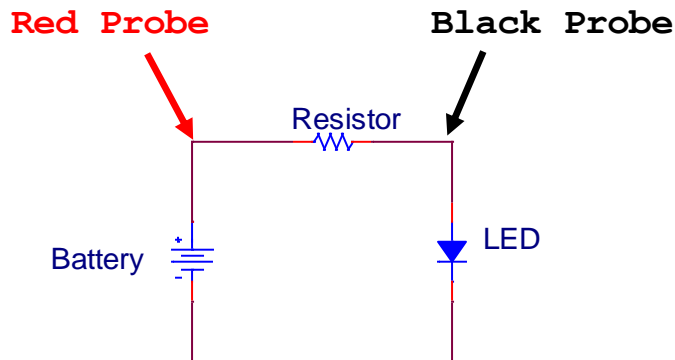


The implemented circuit, with the LED on should look like the following picture.



Implement the circuit using a 470Ω resistor. If the LED does not turn on, you have made a mistake. One possibility is that the LED is in ‘backwards’. If that doesn’t work, double check your wiring to make sure that the connections exist. As a final check, ask the instructor to check the battery voltage.

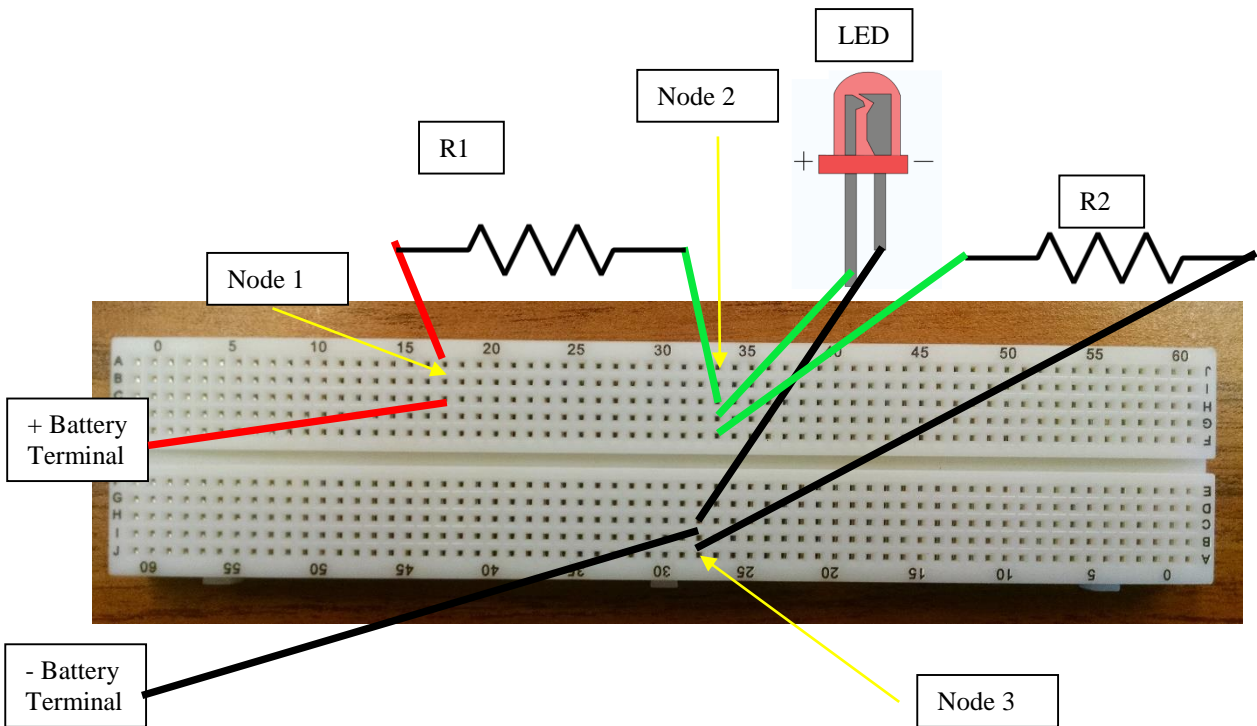
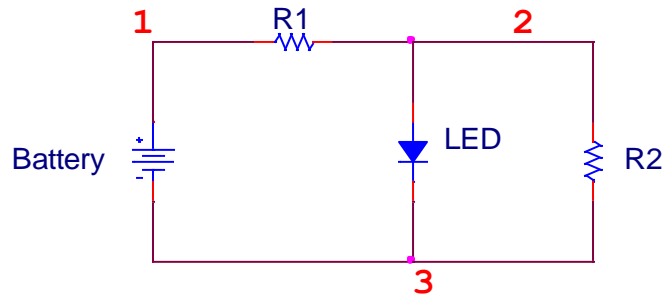
2. Now that the circuit is working, use the multimeter to measure the voltage across the resistor (with the circuit on). Place the multimeter probes on either side of the resistor. Make sure the metal at the end of the probes is in contact with the metal legs on either side of the resistor.



What voltage do you measure across the resistor? The current through the resistor is the same as the current through the LED. Using Ohm’s Law, $V = IR$, what is the current through the LED?

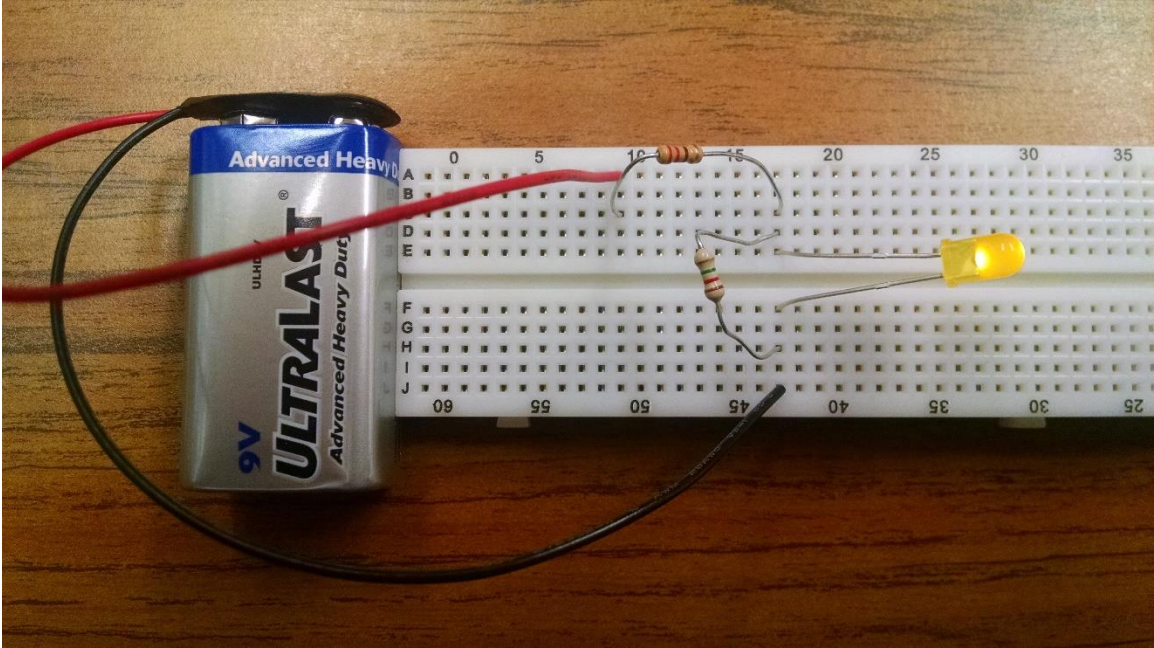
3. Replace the 470Ω resistor with a $4.7k\Omega$ resistor.
Did the LED get brighter or dimmer? Measure the voltage across the resistor and determine the current again? Is the current larger or smaller?

- Replace the $4.7\text{k}\Omega$ resistor with a $1\text{M}\Omega$ resistor.
Did the LED get brighter or dimmer? Measure the voltage across the resistor and determine the current again? Is the current larger or smaller? What trend do you notice between current and LED brightness?
- Implement the slightly more complicated circuit shown below. In this case, the number of nodes has not changed, but nodes 2 and 3 both have three components connected while node 1 still only has two components connected. Build the circuit with $R1 = R2 = 470\Omega$. When successfully built, the LED should be on.



A picture of the implemented circuit is shown on the next page.

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6. Measure the voltage across both resistors.
Why do you think the voltages are different? This question is not necessarily easy to answer and will be discussed later in the course.