Ohm’s Law and Voltage Dividers

Now we will connect a 9V battery to the protoboard and measure the voltages on the circuit to see if they are consistent with the predictions of Ohm’s Law. Before making any connections, verify that your battery is working properly by measuring its voltage.

Turn the dial on the DMM to measure DC Volts (DCV) and select the range that is just larger than 9V (should be 20V). Touch the two probes at the end of the leads to the battery. A new battery should have a voltage near 9V, usually a little larger, but anything close is fine. Next attach the battery connector with the red and black wire leads to the battery. Measure the voltage at the ends of the leads to be sure they are working. Be sure to keep the ends from touching one another or your battery will quickly drain down and be useless.

The wires used in the connector are stranded, so they are a little difficult to attach to the protoboard, but you will be able to do this with a bit of practice. However, it is best to leave them attached, and connect to resistors, etc. using the jumper wires provided.

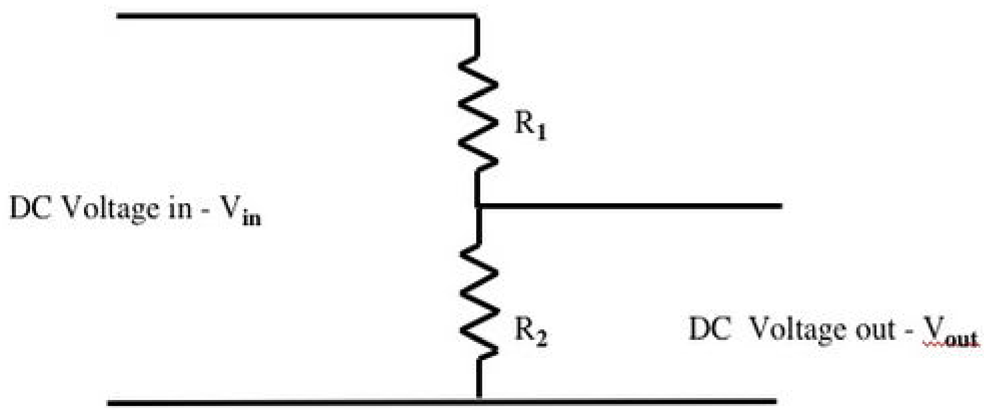
In this activity, you will not be provided with instructions in how to use the protoboards. All circuits will be described with standard circuit diagrams which you will have to interpret when you build your circuits. Ask for help if you have problems.

Ohm’s Law

As a reminder, Ohm’s Law can be written in many forms, but the standard form we will use is $V = IR$ or $I = \frac{V}{R}$ or $R = \frac{V}{I}$ with resistance measured in Ohms, voltage in Volts and current in Amps. (Note that all units should be capitalized because they are based on the names of people were are honoring. Ohm is for Georg Simon *Ohm*, Volts are for Alessandro Giuseppe Antonio Anastasio *Volta*, and Amps are for André-Marie *Ampère.* They are from three different countries. Can you guess which ones? One of the electrical units we will use is named after an American who was born not far from Troy.) In all formulas, Voltage is really ΔV, the voltage difference between one end of a component and another.

The combinations of resistors we worked with in the Resistor activity formed what we call voltage and current dividers. Resistors in series each will have part of the overall voltage and resistors in parallel will carry part of the overall current. Thus, either the voltage or the current is divided between the resistors. Here we will see that Ohm's Law allows us to predict how this division occurs.

Voltage Divider: The simplest voltage divider has only two resistors, as shown below. For our experiments, we will use the 9V battery for V_{in} and use the DMM to measure V_{out}.



Set up this circuit using 1kΩ resistors for both R_1 and R_2. From Ohm's Law analysis, based on the assumption that the current through both resistors must be the same, we know that $V_{out} = V_{in}\frac{R_2}{R_1 + R_2}$. (Wikipedia has a proof at http://en.wikipedia.org/wiki/Voltage_divider)

Calculate and measure V_{out} and see how close the two numbers are. You should first calculate based on the ideal values of 1kΩ and then use the DMM (in resistance measurement mode) to determine their real values and recalculate the value of V_{out}. Do you get better agreement this way? If you search online for 'Voltage Divider Calculator' you will find lots of useful tools to check your results. One that is particularly good is found at http://hyperphysics.phy-astr.gsu.edu/hbase/electric/voldiv.html.

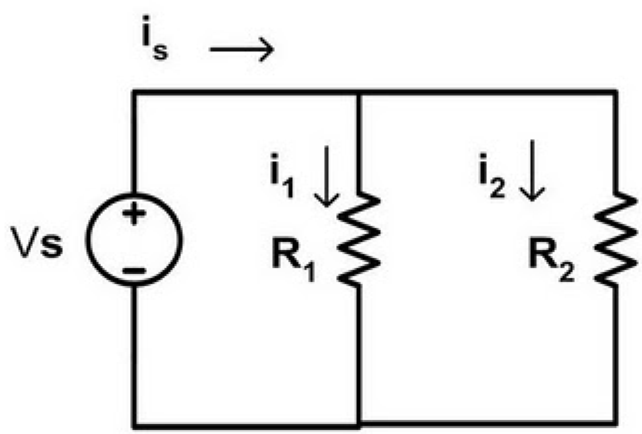
Before we try any other resistor combinations, we must address the issue of power or we may damage some of our components.

Power

The rate at which a resistor converts electrical energy into heat is the power it dissipates. This is given by $P = VI = V\left(\frac{V}{R}\right) = \frac{V^2}{R}$ where we have used Ohm's Law to replace the current with the ratio of voltage to resistance. It is easiest to measure voltage, so we use expressions that do not involve current here. The resistors we are using on our protoboards are rated at ¼ Watt. (Who is this unit named after and where is he from?) If we try to dissipate more power, the resistor will be become very hot and usually will be damaged. For a 1kΩ resistor connected to a 9V battery, the power will be $P = VI = \frac{V^2}{R} = \frac{81}{1000} = 0.081W = 81mW$ which is less than ¼ W = 250mW. If we used a 10Ω resistor, we would have some problems.

Now repeat your analysis and measurement of the resistive divider using 1kΩ, 33kΩ, and 100kΩ resistors in all possible combinations for R_1 and R_2. Sometimes $R_1 > R_2$ and sometimes $R_1 < R_2$. Be sure you do the analysis by hand and only use the online tool to check your calculations. This combination of hand calculations, simulation tools and measurement is a very powerful way to learn new concepts, but you need to do all three.

Current Divider: We will not study this as extensively. For a configuration as shown below (two resistors) the current should divide in a manner similar to the voltage divider $i_2 = i_s \frac{R_1}{R_1 + R_2}$ which expresses the general rule that the current follows the path of least resistance.



Here we will use $R_1 = 1k\Omega$ and $R_2 = 33k\Omega$. From your calculations in the Resistors activity, determine the combined resistance R_T of the two resistors in parallel. Then, determine $i_s = \frac{V_s}{R_T} = \frac{9V}{R_T}$. Use Ohm's Law to find the other two currents and verify that $i_s = i_1 + i_2$

There is no real reason to measure anything in this case since the voltages across both resistors will be the same as the source voltage = 9V. However, you should determine the power dissipated in each resistor.

Voltage Divider Again: Now return to the voltage divider configuration, but consider several resistors in series. Specifically, build a circuit with four resistors in series, calculate and measure the voltages across each one. You can use any resistors you wish from your collection, but they should not all be the same. Use your results to verify Kirchhoff's Voltage Law (KVL). (Who was Kirchhoff and where was he born?) KVL should look like $V_s = V_1 + V_2 + V_3 + V_4$