In this lab you will be making current and voltage measurements within circuits involving the power source, the DMMs, resistors, and wires and will investigate what determines the currents and voltages present. Recall that in voltage mode, the DMMs measure the potential difference between the two terminals and in current mode they measure the rate of charge passing through the meter.

Always draw neat circuit diagrams for every arrangement that you use. Draw arrows representing the path of the current that you measure.

Ohm’s Law

You have already seen resistors. They were used in both previous labs to render a power supply's voltage "safe" by somehow limiting the current. Drawing current from the supply through a resistor reduced the voltage not of the supply itself, but of the new terminal formed by the resistor (with the negative terminal). Another way to view this is that passing current through a resistor creates a voltage difference across the resistor's own terminals. This idea is expressed quantitatively as Ohm’s Law - the voltage across a resistor is proportional to the current through it, with the constant of proportionality being its resistance in Volts per Amp, or Ohms (for which we use the symbol Ω).

Allow a current from the red to black terminals of your power supply to pass through one of the five resistors you have been given. Using the DMMs, simultaneously measure both the current and the voltage. Repeat this for each of your five resistors.

1. Draw the circuit diagram including the meters.
2. Does it matter on which side of the resistor the current is measured?—Check you guess experimentally.
3. Calculate the resistance of each resistor using Ohm’s law.
4. Measure each resistance again using the Ohm function of your DMM.
5. Compare both of your measurements with the resistor’s color code (see the table below).

Test two of your resistors (try the 5KΩ and the 10KΩ) to see how well they obey Ohm’s law. Change the voltage in 6 steps between 0V and 10V, at each step measuring both the current through the test resistor and the voltage across it.

6. Plot voltage vs. current for both resistors on the same graph and check Ohm's law. Use a large plot and do the plot carefully—is there any measurable deviation between your data and a straight line drawn through the data?
Series and Parallel Circuits

String all of the resistors together so that the current from the supply must pass through each one in order to get to the next. This is a series circuit, and the resistances simply add. Measure the current through, and the voltage across each resistor.

(7) Does Ohm's law still hold for each resistor?
(8) What is the measured total resistance across the series? Does your measurement agree the sum of the individual resistances?
(9) Which resistor has the largest influence on the current flowing in the circuit?

Now connect all of the resistors across the power supply so that each one provides an independent path for the current. This is a parallel circuit. Measure the current through, and the voltage across each resistor. Check the current in the power supply lead.

(10) Does Ohms law still hold for each resistor?
(11) Does removing one resistor change the current or voltage across any of the others?
(12) What is the total resistance across the parallel combination?

You can predict the total parallel resistance using Ohm’s law. The voltage across each of the resistors is the same, so the current through the first resistor is \( I_1 = \frac{V}{R_1} \). All of the current has to run through one of the resistors, so \( I_1 + I_2 + I_3 + I_4 + I_5 = I_{\text{total}} \). The total parallel resistance obeys the relation \( V = I_{\text{total}} R_{\text{total}} \).

(12) Derive the equation for \( R_{\text{total}} \) in terms of \( R_1, R_2, R_3, R_4, \) and \( R_5 \). Check if your prediction agrees with your experiment.
(13) Which parallel resistor has the largest influence on the current flowing through the supply lead?

Now put together a combination circuit by first passing current through a single resistor and then into a new resistor formed by two other resistors in parallel. Measure the current through, and the voltage across each resistor. Remove one of the parallel resistors. Replace it and remove the other, checking the currents and voltages each time.

(14) Explain why removing a parallel resistor makes a difference here?
Lead Wire Resistance

The wires we use to connect everything together have resistance, but it is quite small. Try measuring the resistance of one of your banana plug cables with the DMM. Why is this difficult? On your bench you have a board wrapped with a couple of different kinds of wire.

(15) What is the resistance of each of the strands of wire?
(16) What is the resistance per unit length (in Ω/m) of each?
(17) What factors do you think determine the resistance per unit length?

The banana plug cables we use have much lower resistance per unit length than the wires wrapped around the board. The resistance they add to a circuit is less than 1 Ω, and usually comes almost entirely from contact resistance at the connectors.

Resistor Color Code

First three bands give the resistance - two digits followed by the number of zeros:

<table>
<thead>
<tr>
<th>Color</th>
<th>Digit</th>
</tr>
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<tbody>
<tr>
<td>black</td>
<td>0</td>
</tr>
<tr>
<td>brown</td>
<td>1</td>
</tr>
<tr>
<td>red</td>
<td>2</td>
</tr>
<tr>
<td>orange</td>
<td>3</td>
</tr>
<tr>
<td>yellow</td>
<td>4</td>
</tr>
<tr>
<td>green</td>
<td>5</td>
</tr>
<tr>
<td>blue</td>
<td>6</td>
</tr>
<tr>
<td>violet</td>
<td>7</td>
</tr>
<tr>
<td>gray</td>
<td>8</td>
</tr>
<tr>
<td>white</td>
<td>9</td>
</tr>
</tbody>
</table>

Example: orange-gray-red   3800

If there are only three bands, the manufacturing uncertainty in the resistors is +/-20%. If there's a fourth band, it indicates the “tolerance”: silver - 10%; gold - 5%.