Goals:

- Learn how to make simple circuits, measuring resistances, currents, and voltages across components.
- Become more comfortable making “breadboard” connections of electrical components, tracing connection errors, diagnosing problems, and resolving them logically.
- Verify the Ohm’s Law relationship of Voltage and Current through series and parallel resistors.

Background:

The fundamental relationship among the three important electrical quantities, *current, voltage, and resistance*, was discovered by Georg Simon Ohm and first published in 1827. This relationship states that current through a resistor is directly proportional to the voltage “across” the resistor:

\[ I = \frac{V}{R} \]

Another way to see this is to state that the current through a resistor is directly proportional to the electrical “pressure” that pushes charge through the connection that has resistance. Many textbooks also use a “water flow” analogy to help explain the three key variables:

<table>
<thead>
<tr>
<th>Electrical Quantity</th>
<th>Description</th>
<th>Unit</th>
<th>Water Analogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage or Potential</td>
<td>A measure of the Energy difference per unit charge between two points in a</td>
<td>Volt (V)</td>
<td>Water Pressure</td>
</tr>
<tr>
<td>Difference</td>
<td>circuit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>A measure of the flow of charge in a circuit.</td>
<td>Ampere (A)</td>
<td>Amount of water flowing</td>
</tr>
<tr>
<td>Resistance</td>
<td>A measure of how difficult it is for current to flow in a circuit.</td>
<td>Ohm (Ω)</td>
<td>A measure of how difficult it</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>is for water to flow through a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pipe.</td>
</tr>
</tbody>
</table>

Figure 1
This lab activity will challenge you to verify Ohm’s law in a variety of ways, using digital measurement devices and computers to graph quantities. At the end of the activity, you will create your own hypothesis, design an experiment to test it, do the experiment, and document your results.

Write up:

This experimental write up should follow the formal physics laboratory report format (available online at http://www.chabotcollege.edu/faculty/shildreth/physics/updated_lab_report_format.htm ). Make sure that you include the roles that each member of your team played in the activity, clearly labeled graphs, data tables in your appendix, and answers to the QUESTIONS you’ll find within. The lab report is due in one week:

Thursday 10/10/13 (for Thursday’s lab section) or Friday, 10/11/13 (for Friday’s section.)

MATERIALS

Computer running Logger Pro software 6-8 sets of alligator clip wires
LabPro interface Batteries
Vernier Current & Voltage Probe System adjustable low-voltage DC power supply
Additional Vernier Voltage Probes Vernier Circuit Board
Various small bulbs Digital Multimeter w/ (2) voltage probes

PRELIMINARY SETUP AND QUESTIONS

1. Open the file in the Experiment folder of Physics with Computers. A graph of potential vs. current will be displayed. The vertical axis is scaled from 0 to 6 V. The horizontal axis is scaled from 0 to 0.6 A. The Meter window displays potential and current readings.

2. Connect DIN 1 on the Dual Channel Amplifier to Channel 1 on the LabPro. Connect DIN 2 to Channel 2. Connect a Voltage Probe to PROBE 1 on the Dual Channel Amplifier. Connect a Current Probe to PROBE 2.

3. With the power supply turned off, connect the power supply, 10-Ω resistor, wires, and clips as shown in the sample setup. Take care that the positive lead from the power supply and the red terminal from the Current & Voltage Probe are connected as shown conceptually in Figure 1. Note: Attach the red connectors electrically closer to the positive side of the power supply.

4. Click [Zero]. A dialog box will appear. Click [Zero all sensors]. This sets the zero for both probes with no current flowing and with no voltage applied.

5. Ask your professor to check the arrangement of the wires before proceeding. (Bribe him with a doughnut or chip.) Turn the control on the DC power supply to 0 V and then turn on the power supply. Slowly increase the voltage to 5 V. Monitor the Meter window in Logger Pro and describe what happens to the current through the resistor as the potential difference across the resistor changes. If the voltage doubles, what happens to the current? Is what you are seeing consistent with Ohm’s Law?

IMPORTANT NOTES

1. Keep the voltage in this experiment under 5 V at all times; watch the brightness of the light bulbs and be careful not to run the voltage so high that the bulb burns out. Make small changes only at once.
PART A: SIMPLE SERIES CIRCUITS PROCEDURE

1. Make sure the power supply is set to 0 V. Click [p Collect] to begin data collection. Monitor the voltage and current. When the readings are stable click [Keep].

2. Increase the voltage on the power supply to approximately 0.2 V. When the readings are stable click [Keep].

3. Increase the voltage by about 0.2 V. When the readings are stable click [Keep]. Repeat this process until you reach a voltage somewhere between 2.0 – 3.0 V.

4. Click [Stop] and set the power supply back to 0 V.

5. Examine the graph. Are the voltage and current proportional? Click the Linear Regression button, \( y = mx + b \). Record the slope and y-intercept of the regression line in the data table, along with their units.

6. Repeat Steps 1 – 5 using a second 10-Ohm resistor in series with the first. When you click on the [p Collect] button, you can save or erase your previous data to start a new experiment. SAVE your data if you cannot print out your graphs, and email a copy of it to at least two members of your team to include in your lab write-up.

As you vary the supply voltage, use the standalone digital multimeter to measure the voltage drop across each resistor in the circuit separately. What is the sum of the voltages? Does that sum add to the value of the supply voltages in each case?

7. Repeat Steps 1 – 5 using a 51-Ohm resistor in series with the first 10-Ohm. Again, use the multimeter to record the voltage drop across each resistor in the circuit separately. What is the sum of the voltages? Does that sum add to the value of the supply voltages in each case?

**QUESTION TO ANSWER:** Compare the expected value of the resistors to the slopes you obtained. Do your results for these first three experiments, taken together, support Ohm’s law? Was there any uncertainty in your results? How precisely can you fairly report your match between the printed values of the resistors based on their color code bars and your experiment? What could account for the differences you noted (if any)?

8. Change your circuit to route the current through a light bulb. Repeat Steps 2 – 5, but this time very slowly increase the voltage in 0.1 V steps up to 3.0 V. Note specifically on the graph when the slope changes.

**QUESTION TO ANSWER:** What happens to the lightbulb when the slope changes? Develop a hypothesis to explain what happens, and why. How could you develop an experiment to test this out? (You do not have to do this today, but consider what type of experiment might be used to verify or contradict your hypothesis!)

9. To compare slopes of data at different parts of the curve, first click and drag the mouse over the first 3 data points. Click the Linear Regression button, \( y = mx + b \), and record the slope of the regression line in the data table. Be sure to enter the units of the slope.

10. Click and drag the mouse over the last 10 points on the graph. Click the Linear Regression button, \( y = mx + b \), and record the slope of the regression line in the data table.

11. Now change your circuit again to include a second bulb in series with the first. Repeat step 8 (slowly varying the voltage, keeping data points, and graphing the result.

**QUESTION TO ANSWER:** Does adding a second light bulb change the results? Develop a hypothesis to account for what you saw. Can you test that hypothesis? (Try it if you can!)
PART B: SIMPLE PARALLEL CIRCUITS PROCEDURE

12. Set up a parallel circuit using two 10-Ohm resistors. Connect the Ammeter outside of the two resistors (not between them). Before you energize the power source, ask your professor to review your connections. (Bribe him again.)

13. Make sure the power supply is set to 0 V. Click [Collect] to begin data collection. Monitor the voltage and current. When the readings are stable click [Keep]. Use the standalone multimeter to measure and record the voltages across each resistor.

14. Increase the voltage on the power supply to approximately 0.2 V. When the readings are stable click [Keep]. Use the standalone multimeter to measure and record the voltages across each resistor.

15. Increase the voltage by about 0.2 V. When the readings are stable click [Keep]. Repeat this process until you reach a voltage somewhere between 2.0 – 3.0 V. Use the standalone multimeter to measure and record the voltages across each resistor.

16. Click [Stop] and set the power supply back to 0 V.

17. Examine the graph. Are the overall voltage and overall current still proportional? Click the Linear Regression button, $\mathcal{R}$. Record the slope and y-intercept of the regression line in the data table, along with their units. Compare your results with those you recorded earlier (in Step 6) with two 10-Ohm resistors in series. Does adding a second identical resistor in parallel result in more, or less, total resistance? Is the voltage across each resistor the same as the voltage of the supply?

18. Redo the experiment, but put the ammeter in series with one of the resistors. Record the current through that “leg” as you vary the supply voltage.

19. Now set up a parallel circuit using one 10-Ohm and one 51-Ohm resistor, and repeat steps 13-18.

**QUESTION TO ANSWER:** Does adding a second resistor in parallel result in more, or less, total resistance for the circuit as a whole?

20. Create your own circuit, using any of the resistors on the circuit board. Make sure at least two resistors are in series, and that at least one (or more) are connected in parallel. Use as many connectors as you need. Call your professor over to check your circuit before you begin applying voltages! (Yes, you’ll need another bribe most likely.)

Draw a schematic of the circuit you create. Based on your results above, develop a hypothesis for the overall current that will flow in your circuit, and the overall resistance the circuit presents. Develop a hypothesis for the voltage drops you’ll see across each resistor for a fixed initial value of the overall voltage.

**Now TEST your hypothesis!**

Apply voltage slowly, gathering data on the current through each leg, and the voltage drops across ALL resistors. You may have to use multiple voltage probes for this, and repeat your experiment multiple times to measure currents through various legs.
### SAMPLE DATA TABLE

<table>
<thead>
<tr>
<th>STEP</th>
<th>SERIES RESISTOR VALUE(S)</th>
<th>SLOPE OF REGRESSION LINE (VOLTS/AMP)</th>
<th>Y-INTERCEPT OF REGRESSION LINE (VOLTS)</th>
<th>DOES VOLTAGE DROP ACROSS RESISTORS ADD TO SUPPLY?</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10 Ω</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>10Ω &amp; 10Ω</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>10Ω &amp; 51Ω</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>LIGHT BULB 1 (FIRST FEW POINTS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>LIGHT BULB 1 (LAST 10 POINTS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For Experiment Steps 17 – 20, develop your own data table, recording all appropriate information, including the voltages across each component, the currents through separate legs of the circuit (if you measure them separately), and any appropriate notes. Attach one copy of your table to your report in the appendix. IF you create and neatly capture your data in this table, DO NOT spend time recopying it for the report. IF your table is not well-organized nor clear, you’ll need to present it professionally.