Simple Electrical Circuits

Equipment

<table>
<thead>
<tr>
<th>Qty</th>
<th>Item</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AC/DC Electronics Laboratory</td>
<td>EM-8656</td>
</tr>
<tr>
<td>1</td>
<td>Voltage Sensor</td>
<td>UI-5100</td>
</tr>
<tr>
<td>1</td>
<td>Current Sensor</td>
<td>CI-6556</td>
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<tr>
<td>1</td>
<td>Multimeter</td>
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</tr>
<tr>
<td>4</td>
<td>Patch Cords</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Banana Clips</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Resistors: 2x10Ω, 2x100Ω, 200Ω</td>
<td></td>
</tr>
</tbody>
</table>

Purpose

The purpose of this activity is to examine how Ohm’s Law can be applied to simple resistors arranged in simple electrical circuits.

Theory

Ohm’s Law tells us that resistance of an object is proportional to the voltage applied to it, and inversely proportional to the induced current passing through it.

\[ R = \frac{\Delta V}{i} \]

When multiple resistors are arranged in series and a steady stream direct current is flowing through them we have three rules related to the current, the voltage, and the resistance of all of those resistors together. Those three rules are as follows:

1. For resistors in series the current passing through each of them is the same.

   \[ i = i_j = i_1, i_2, i_3 \ldots \]

2. For resistors in series the voltage being applied to all of them is the sum of the voltage passing over all of them

   \[ \Delta V = \sum_j^n \Delta V_j = \Delta V_1 + \Delta V_2 + \Delta V_3 + \cdots \]
3. For resistors in series the equivalent resistance of all of them together is just the sum of all of their resistance.

\[ R_{eq} = \sum_{j}^{n} R_j = R_1 + R_2 + R_3 + \cdots \]

When multiple resistors are arranged in parallel and a steady stream direct current is flowing through them we have three rules related to the current, the voltage, and the resistance of all of those resistors together. Those three rules are as follows:

1. For resistors in parallel the total current passing through all of them is the sum of the current passing through each of them.

\[ i = \sum_{j}^{n} i_j = i_1 + i_2 + i_3 + \cdots \]

2. For resistors in parallel the voltage passing over each of them is the same.

\[ \Delta V = \Delta V_j = \Delta V_1, \Delta V_2, \Delta V_3, \ldots \]

3. For resistors in parallel the inverse of the equivalent resistance of all of them is the sum of the inverses of all of them.

\[ \frac{1}{R_{eq}} = \sum_{j}^{n} \frac{1}{R_j} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \]

When using these two sets of equations it can be best to draw simple circuit diagrams to help determine which circuit components are in series with each other, and which are parallel to each other. Let us start by examining two basic circuit component symbols.

1. A Potential Difference Source - Power supply, battery, fuel cell, or anything that will induce a potential difference to exist in the circuit. The circuit diagram symbol for such a device is two uneven parallel lines.
The longer line represents the positive side of the Voltage Source, and the shorter line its negative side. The lines pointing out of both sides represent the wires that will connect the Voltage Source to the rest of the circuit.

2. Resistors – A component that hinders the flow of current through the circuit. Resistors are represented by few sharp jagged lines right in row.

This is drawn with the connecting wires coming out of both ends.

Setup Part 1 (Resistors in Series)

1. Using the provided multi-meter, measure the resistance of the provided resistors, and record their measured values in the tables.
2. Double click the PASCO Capstone icon to open the Capstone software.
3. On the Tool Bar, on the left side of the main screen, click on ‘Hardware Setup”. This will open the Hardware Setup window, and a picture of the 850 Interface should be showing. (If it is not showing make sure the 850 interface is plugged in, and turned on, then click ‘choose interface’ tab, then ‘automatically detect’.)
4. On the picture of the 850 Interface click on ‘Analog Ch(A)’. A list of sensors will appear.
   • Scroll down, and add ‘Voltage Sensor’.
5. On the picture of the 850 Interface click on ‘Analog Ch(B)’. A list of sensors will appear.
   • Scroll down, and add ‘Current Sensor’.
6. On the picture of the 850 Interface click on ‘Ch(1) Outputs’. (It will be at the top right of the image). A list of sensors will appear.
   • Add ‘Output Voltage-Current Sensor’.
7. At the bottom center of the main screen select ‘common rate’, and set the rate to 1 Hz.
8. At the bottom center of the main screen, right to the right of the ‘common rate’ click on ‘Recording Conditions’. This will open the Recording Conditions window, click on ‘Stop Conditions’.
   • For ‘Condition Type’ select ‘Time Based’.
   • For ‘Record Time’ set to ‘1.0 second’.
   • Click ‘ok’ to close the window.
9. On the Tool Bar, on the left side of the main screen, click on ‘Signal Generator’. This will open the Signal Generator window.
   • Click on ‘850 Output 1’ tab.
   • Set the ‘waveform’ to DC.
• Set the ‘voltage’ to 2.0 V.
• Set to ‘voltage limit’ to 10.0V.
• Set the ‘current limit’ to 1.5A.
• Then click on the ‘Auto’ tab to set the voltage to start and stop when you start and stop collecting data.

10. Close the Tool Bar
11. Plug two patch cords into the Output 1, and then plug those cords into the AC/DC Electronic Laboratory board.
12. Plug the voltage sensor into Analog Ch(A).
13. Plug the current sensor into Analog Ch(B).
   • Plug in two patch cords to the current sensor.
14. One the main window, select the ‘Four Displays’ from the Quickstart Templates.
   • There will be an icon at the center of each display window.
   • Click on one of those icons. That will open a selection menu, which you are to select ‘Digits’. Repeat for the other three display windows.
   • The top left click ‘measurements select’, select ‘Voltage, Ch A (V)’.
   • The bottom left click ‘measurements select’, select ‘Current, Ch B (V)’.
   • The top right click ‘select measurements’, select ‘Output Voltage, Ch 01 (V)’.
   • The bottom right click ‘select measurements’, select ‘Output Current, Ch 01 (A)’.
   • The measurements on the left will be the experimental values for each individual resistor, while the measurements on the right will be the experimental values for the entire circuit.
15. Put the cursor over one of your Current windows and right click. This will open a menu from which you need to click on ‘Properties’.
   • This will open the Properties menu. Click on “Numerical format”, then change “Number of Decimal Places” to 4. Click “ok” to close window.
   • Repeat for the other Current window.
   • You screen should now look like the following.
16. Construct a simple circuit of the 10Ω, the 100Ω, and the 200Ω resistors in series.

- You will also need to use one of the jumper wires provided in the AC/DC Electronics Laboratory to complete the circuit.
- The circuit diagram for three resistors in series connected to a voltage source looks like the following.
Procedure Part 1 (Resistors in series)

1. Put the alligator clips on the ends of the voltage sensor.
2. Attach the Voltage Sensor to the 10Ω resistor, making sure that one end goes on each side of the 10Ω resistor. (The voltage sensor must always be attached in parallel to the circuit component it is measuring the voltage over, otherwise the data will be nonsense. Also, never attach the alligator clips to the connection coils on the AC/DC Electronics Laboratory)
3. Click ‘Record’.
   - In Table 1 record the voltage for the 10Ω, and record the voltage, and current for the entire circuit.
4. Move the voltage sensor to the 100Ω resistor, and then click record.
   - In Table 1 record the voltage for the 100Ω resistor.
5. Move the voltage sensor to the 200Ω resistor, and then click record.
   - In Table 1 record the voltage for the 200Ω resistor.
6. Take the alligator clips off the voltage sensor and put them on the patch cords attached to the current sensor.
7. Using another small wire provided in the AC/DC Electronic Laboratory connect the current sensor directly to the 10Ω such that the current sensor is also in series with the resistor. (The current sensor must ALWAYS be attached in series to the circuit component it is measuring the current over; otherwise the data will be nonsense.)
8. Click on ‘Record’.
   - In Table 1 record the current for the 10Ω resistor.
9. Repeat for the 100Ω, and the 200Ω resistors.
Setup Part 2 (Resistors in parallel)

Do not make any changes to the software or sensor setup from Part 2.

1. Using the small wires provided in the AC/DC Electronic Laboratory and the resistors, construct a simple circuit where the resistors the 10Ω, the 100Ω, and the 200Ω resistors are all in parallel with the voltage source.

   • The circuit diagram for three resistors in parallel, connected to a voltage source looks like the following.

   ![Circuit Diagram](image)

Procedure Part 2 (Resistors in parallel)

1. Put the alligator clips on the ends of the voltage sensor.
2. Attach the Voltage Sensor to the 10Ω resistor, making sure that one end goes on each side of the 10Ω resistor.
3. Click ‘Record’.
   • In Table 3 record the voltage for the 10Ω, and record the voltage, and current for the entire circuit.
4. Now repeat process for the 100Ω, 200Ω, resistors, and record their voltages in Table 2.
5. Take the alligator clips off the voltage sensor and put them on the patch cords attached to the current sensor.
6. Using another small wire provided in the AC/DC Electronic Laboratory connect the current sensor directly to the 10Ω such that the current sensor is also in series with the resistor.
7. Click on ‘Record’.
   - In Table 2 record the currents for the 10Ω resistor.
8. Repeat for the 100Ω, 200Ω and the resistors, and record their currents in Table 2.

**Setup Part 3 (Resistors in a mix series and parallel)**

*Do not make any changes to the software or sensor setup from Part 3.*

1. Using the resistors and the small wires to construct a simple circuit where one of the 10Ω (R₁) and one of the 100Ω (R₂) resistor are in series, and then they are in series with the other 10Ω, and 100Ω (R₃ and R₄) resistors which are in parallel with each other.
   a. The Circuit diagram for this circuit looks like the following.
Procedure Part 3 (Resistors in a mix of series and parallel)

1. Put the alligator clips on the ends of the voltage sensor.
2. Attach the Voltage Sensor to the first 10Ω resistor, making sure that one end goes on each side of the 10Ω resistor.
3. Click ‘Record’.
   - In Table 3 record the voltage 10Ω, and record the voltage, and current for the entire circuit.
   - Also record the current and voltage for the entire circuit board in table 3.
4. Repeat process for the other 3 resistors, and then record their voltages in Table 5.
5. Take the alligator clips off the voltage sensor and put them on the patch cords attached to the current sensor.
6. Using another small wire provided in the AC/DC Electronic Laboratory, connect the current sensor directly to the 10Ω such that the current sensor is also in series with the resistor.
7. Click on ‘Record’.
   - In Table 3 record the voltage for the first 10Ω resistor.
8. Repeat for the other 3 resistors, and record their currents in Table 3.
Analysis of Simple Electrical Circuits Lab

Name______________________________________________  Group#________

Course/Section__________________________________________

Instructor______________________________________________

For each of the three simple circuit boards you will need to calculate the total resistance \( R_{eq} \) for the entire circuit board by using the measured resistances of each of the resistors, and the equations given to you in the theory section. Then using the applied voltage of 2V, as the theoretical voltage \( V_{th} \) for the entire circuit board you can calculate the theoretical current, \( i_{th} \), for the entire circuit board.

**Table 1(Resistors in series)**

<table>
<thead>
<tr>
<th>( R(\Omega) )</th>
<th>( i_{ex}(A) )</th>
<th>( V_{ex}(V) )</th>
<th>( i_{th}(A) )</th>
<th>( V_{th}(V) )</th>
<th>% Error ( i )</th>
<th>% Error ( V )</th>
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<tbody>
<tr>
<td>( R_{eq} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>10( \Omega )</td>
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<td>100( \Omega )</td>
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<tr>
<td>200( \Omega )</td>
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</tbody>
</table>

1. Using the equations for resistors in series calculate the theoretical voltages, and currents for each of the resistors, and the entire circuit. Use the measured values of the resistance in your calculations. Then calculate the % errors. Show work. (20 points)
2. According to our equations, what should be the relationship between the total current and the currents passing through each resistor? Does your data show this relationship? (5 points)

3. According to our equations, what should be the relationship between the total voltage and the voltages passing over each resistor? Does your data show this relationship? (5 points)
<table>
<thead>
<tr>
<th>$R(\Omega)$</th>
<th>$i_{ex}(A)$</th>
<th>$V_{ex}(V)$</th>
<th>$i_{th}(A)$</th>
<th>$V_{th}(V)$</th>
<th>% Error $i$</th>
<th>% Error $V$</th>
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<tbody>
<tr>
<td>$R_{eq}$</td>
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<tr>
<td>$200\Omega$</td>
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</tbody>
</table>

4. Using the equations for resistors in parallel calculate the theoretical voltages, and currents for each of the resistors, and the entire circuit. Use the measured values of the resistance in your calculations. Then calculate the % errors. Show work (20 points)
5. According to our equations what should be the relationship between the total current and the currents passing through each resistor? Does your data show this relationship? (10 points)

6. According to our equations what should be the relationship between the total voltage and the voltages passing over each resistor? Does your data show this relationship? (10 points)
Table 3 (Resistors in both series and parallel)

<table>
<thead>
<tr>
<th></th>
<th>$R(\Omega)$</th>
<th>$i_{ex}(A)$</th>
<th>$V_{ex}(V)$</th>
<th>$i_{th}(A)$</th>
<th>$V_{th}(V)$</th>
<th>% Error $i$</th>
<th>% Error $V$</th>
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<td>$R_1$</td>
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<td>$R_2$</td>
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<tr>
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<tr>
<td>$R_4$</td>
<td>10Ω</td>
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</tbody>
</table>

7. Using the equations for resistors in series and in parallel, calculate the theoretical voltages and currents for each of the resistors, and the entire circuit. Use the measured values of resistance in your calculations, then calculate the % errors. Show work. (20 points)
8. Do the results of the experiment confirm theoretical predictions for resistors in series and parallel? Explain your answer. (10 points)