Ohm’s Law  
Spring 2017

Introduction

In this experiment, you will practice connecting simple circuits, measuring the voltage across and the current through an element of the circuit, and examine the current-voltage relation for a resistor, a light bulb, and a LED. Before beginning this experiment, you should again read the “Using a Digital Multimeter” document you printed last week.

IMPORTANT NOTES ABOUT THE POWER SUPPLY:
- Always connect your wires to the + and – terminals of the power supply after your elements are connected; never leave bare wires hanging from the power supply.
- Turn the voltage knob on the power supply, but not the current knob!
- Don’t use the GND connector on the power supply
- Never pull on the wire, only on the end connector

Experiment

1. Setting up the voltmeter and ammeter: You will be using two identical multimeters, one labeled as an ammeter (for measuring current), the other a voltmeter (for measuring voltage). It is important that you connect each meter correctly to the circuit, to prevent blowing a fuse in the meter or power supply.
   a. The ammeter measures the current through the circuit, and gets inserted into the circuit just like another element. Insert one wire into the ammeter in the “A” port, and be sure that the dial is set to a “DCA” setting. This will remind you that the circuit needs to be opened up in order to measure current (the “free” wire from the opened circuit will be connected to the “COM” port).
   b. The voltmeter measures the voltage across an element (light bulb, battery, etc.); insert two wires into the voltmeter, one in the “COM” port, the other in “V/Ω”, and set the dial to a “DCV” setting. This will remind you that the voltmeter is used to “touch” both sides of an element. The voltmeter should always be connected to the circuit after the ammeter.

2. Direct measurement of resistance: Before connecting the circuit, use the multimeter labeled as a voltmeter to measure the resistance of each element. Set the dial to measure resistance (“Ohm”) – your voltmeter is now an ohmmeter! Record the resistance of the incandescent bulb. You also have a black box with a resistor and an LED; its contents are described on the next page. Measure the resistor and the LED in the black box using the connections shown below (you won’t be able to measure the resistance of the LED with the meter.) Be sure to reset the meter to be used as a voltmeter before measuring voltages.

3. Assembling the circuit: Be sure to turn the voltage knob on the DC power supply counterclockwise to zero, and turn the power off with the switch each time you make a change to your circuit. You needn’t adjust the current knob.
   a. Sketch the circuit at right in your report. The symbols that will be used in circuit diagrams are found below.
b. Create the circuit above using two wires to connect the socket containing the incandescent light bulb to the + and – terminals of the power supply (don’t use the GND terminal). Turn the variac on and slowly turn the voltage knob clockwise. The bulb will slowly increase in brightness; if not, have your instructor check your circuit. Do not exceed 6.0 volts at this time, as shown on the power supply’s “voltage” meter.

c. Turn the voltage off by turning the power supply knob counterclockwise all the way and pressing the button. To measure I, the current through the incandescent bulb, disconnect the wire from the + terminal of the power supply, and insert it in the “COM” port of the ammeter; the free end of the wire previously inserted in the “A” port of the ammeter is then connected to the power supply to complete the circuit. Set the ammeter to ‘2’ DCA. (Keep the supply turned off!!)

d. You will measure V, the voltage across the light bulb, by plugging the wires from the voltmeter into the connectors on both sides of the light bulb – don’t remove the wires connected to the bulb. Set the voltmeter to ‘200’ DCV. (The power supply is still off!!). Sketch the circuit at right in your report.

e. When both meters are connected, turn on the switch, and raise the voltage slowly until the voltmeter reads 7.5 V. Record the voltage and current you measure in your report.

f. The power output of the bulb, in Watts, is the product of the voltage across the bulb (units: volts) and the current through it (units: amperes): P = I·V. Calculate the power of the bulb, and calculate the % difference with the published value (1.65 W).

4. Ohm’s Law: Ohm’s Law states that certain types of circuit elements exhibit a linear relationship between current and voltage: \( V = I \cdot R \). Elements that obey Ohm’s law will produce a straight line through the origin when plotting I vs. V, and the resistance of the element can be determined from the inverse-slope of the line. If an element produces a non-linear graph, than its resistance cannot be accurately determined with this method, so you will not need to apply a linear fit to non-linear Excel data.

Bulb:

a. Create a data table in your report to record measurements of I and V. With the light bulb still connected, adjust the power supply so that the reading on the voltmeter is 7 V (the maximum you will use). Decrease the voltage in 1.0 V increments as read on the voltmeter and measure the current on the ammeter. Also take a current measurement when the voltage is 0.5 V. In Excel, create a graph of current as a function of voltage as you collect your data. (Excel notes: Recall that in Excel you can create an x-y scatter plot after you have entered 3 data points; be sure to put voltage in the first column, then current in the second column, and be sure to include {0,0} as a data point!)

You will next examine two other circuit elements using a black box containing a resistor and an LED. The box allows you to easily connect these elements to your circuit. The figure at right is a top view of the box; note that terminal A has a large resistor, terminal B a plain wire, and terminal C has an LED and a small resistor in series (the small resistor is in place to protect the LED from high currents if the box is connected incorrectly, so we can pretend it’s not there). The wires from the power supply and the voltmeter will be attached to different connectors, depending on which element is to be measured as part of the circuit.

Resistor:

b. Turn off the power supply, and replace the incandescent bulb in the circuit with the black box: connect the wires from the power supply and ammeter that were attached to the light bulb to terminals A and B on the box (blue wires, at right); also connect the wires from the voltmeter (green, at right) to A and B. Change the ammeter setting to ‘20m’ DCA, and the voltmeter to ‘200’ DCV. Your circuit now has the large resistor connected in place of the light bulb. Draw a new circuit diagram, using the symbol for a resistor found on page 1.

c. Adjust the power supply so that the reading on the voltmeter is 10 V, and measure and plot I vs. V (on a second graph), decreasing the voltage in 1.0 V increments, as read on the voltmeter. Keep the current units in mA, and be sure to include {0,0} as a data point as before.
**LED:**

d. Now connect the wires from the ammeter and power supply to the A and C terminals on the box in your circuit; this will replace the large resistor with the large resistor-LED combination. Move the wires from the voltmeter to the B and C terminals so that you are only measuring the voltage across the LED. Draw a new circuit diagram, using the LED symbol on the first page.

e. Switch the ammeter to ‘20m’ DCA, and set the voltage on the power supply (as read from the power supply’s ‘voltage’ meter) to 12.0 V. You will decrease the voltage that is displayed on the power supply in 1.0 V increments. For each setting on the power supply, measure I and V from the ammeter and voltmeter, respectively. It will be easier to keep track of your measurements if you copy the following table in your report:

<table>
<thead>
<tr>
<th>V (volts) As read on power supply</th>
<th>V (volts) Measured on voltmeter</th>
<th>I (mA) Measured on ammeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

f. Create a third graph of I vs. V for the LED, using the values measured on the multimeters (columns 2 and 3 of the table). Again, keep the current units in mA.

**Analysis**

a. Look at your three I vs. V graphs: which element(s) obeys Ohm’s Law (linear points *through the origin*)? If you haven’t yet done so, apply a liner fit to the graph(s) that follows Ohm’s Law, and calculate the value of resistance from the reciprocal of the slope (*explain why the resistance calculated from the reciprocal of the slope!*)

b. Calculate the % difference between the resistance calculated from the graph of this element to the resistance as measured using the ohmmeter in step 2. How well do these values agree with each other?

**Discussion**

- Comment on the measured power output of the incandescent bulb as compared to its expected value – meaning you should have calculated the percent difference!
- Summarize your resistance measurements and calculations, and comment on the elements that did or did not behave as predicted by Ohm’s Law (support your argument by discussing your graphs).

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**PLEASE UNPLUG ALL THE WIRES FROM YOUR CIRCUIT, AND TURN OFF THE POWER SUPPLY & MULTIMETERS.**