Ohm's Law, Resistance and Resistivity

Objective

The purpose of this experiment is to use graphical analysis to determine whether various circuit elements obey Ohm's Law, and to determine the resistance for some that do.

Materials

1. 2-ohm resistor
2. Board with five spools of wire
3. Long (banana to spade) wires
4. Pasco 550 Interface
5. Small aluminum component box
6. Fluke Digital Multimeter

Introduction

Dual Trace Oscilloscope

By definition, the resistance (in ohms) of a circuit element is given by

$$R = V/I$$

Where V is the potential difference (in volts) across the element, and I is the current (in amperes), through the element. For some devices current may vary in a complicated way with voltage. But for certain devices, which we call resistors, at least ideally, the resistance is constant. Therefore, resistors fall in the class of conductors that are described by Ohm's Law. (The word "Law" is really a bit too strong here.) Ohm's Law is the assertion that the current "flowing" through a device is directly proportional to the potential difference applied to the device. Conductors obeying Ohm's Law are said to be *ohmic*. For such conductors, a graph of a graph of V vs I will be a straight line of slope R. (Note that I vs V will be a straight line with slope $1/R$.) In this experiment we will use V vs I graphs to determine whether various circuit elements obey Ohm's Law, and for some that do we will determine the resistance.

Procedure

Preparation of the Experiment

Double-click the Pasco Capstone icon on your computer desktop to open the program (and make sure that your Pasco 550 Interface is turned on). In the "Tools" windows panel on the left side of the screen, click on "Hardware Setup". Click on the yellow circle at the top far-right of the PASCO interface and select "Output Voltage Sensor". From that same dropdown menu, select "Output Current Sensor" as well. Now click on the "Signal Generator" in the "Tools" panel and select "550 Output". Change the "Waveform" to "Triangle". Change the frequency to 0.1Hz and the amplitude/voltage to 1V. Click "On" at the bottom of the panel.

Under the "Displays" window panel, double-click on "Graph" and change the y and x axes to "Output Voltage" and "Output Current" respectively by clicking on "Select Measurement" on each axis and choosing the respective quantity.

You will connect two wires to run from your 2- ohm resistor[1] to the output connections on the Interface (this is the signal generator for the Interface).

Data Collection and Representation

You will use the following data collection procedure for most of the rest of the experiment. Click the "Record" button, let it run for about 10 seconds, then click "Stop". (Run it for 10 seconds, because the frequency, as noted in the small window panel for the signal generator, is set to 0.10 Hz, so it takes 10 seconds to complete one full cycle of the triangular wave.) You should have obtained a graph of voltage vs current (V vs I). For any circuit element that is an ohmic conductor the graph will be a straight line.

For devices that prove to be ohmic we can have the computer give us the resistance as the slope of a graph of voltage vs current. Let's confirm the resistance for this first 2-ohm resistor. First, notice the noise for the voltage near 1.0 V. To ignore this noise for the purpose of fitting, highlight (in the intuitive way) the linear portion of the data by using the "Data Highlighter" tool to select the data region. Then on the top of the graph click on the "Curve Fits" tool, and choose "Linear" from the drop-down. This will ask the computer to draw the best straight line through the highlighted data and compute its slope. Is the slope approximately 2? The "r" value in the linear fit box is not the resistance; this is a correlation coefficient that gives a measure of how well your data fits a straight line. The closer the coefficient "r" is to 1, the better the fit.

Checking for Ohmic Devices

Use the above procedure to examine the voltage vs current behavior of the devices in the small aluminum box. You will first want to delete your previous data. The easiest way to do this is to click on the arrow next to the "Delete Last Run" tool at the bottom of the screen, and select the specific run or "Delete All Runs". You should also delete your Linear Fit box. To do so, click on the "Linear Fit" box, and hit the backspace or delete key to delete (this should remove it from your graph). A note on *terminology*: In this activity, the "voltage across" a device is displayed as "Output Voltage"; likewise the "current through" a device is displayed as "Output Current".

One by one connect each of the four loads in the aluminum box to your interface, with the red wire on the single, white terminal on top of the aluminum box, and the black wire to each (black) device

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[1] You should use the digital multimeter to verify the resistance of the resistor.

terminal in turn. You are to sketch what each of these four loads looked like in your lab write-up. Each time that you finish checking a load, make sure you delete the last data run.

Which devices were ohmic? Which devices were not ohmic? For the ones that were not ohmic, try to explain why the resistance is not constant.

Determining the Resistivity of Wires

First you will need to go to your signal generator box again and change the output voltage to 0.1-volt. You will use the "Curve Fits" method from earlier to determine the resistances of the five wire spools. (Four of the spools are copper.)

Considering the information in Table 1, do the ratios of their resistances make sense? Explain.

Spool	Material	Length (m)	B&S Size	Diameter ($\times 10^{-4}$ m)
A	Copper	10	22	6.44
B	Copper	10	28	3.21
C	Copper	20	22	6.44
D	Copper	20	28	3.21
E	Nickel-Silver	10	22	6.44

Table 1: *Wire Spool Data*

From the equation,

$$R = \rho L/A$$

where is L length and A is cross-sectional area. Determine the resistivity, ρ, of the two materials. The result should be in ohm-meters. Later you can compare these values of resistivity to the theoretical values in your textbook.

Last Modified: October 15, 2019