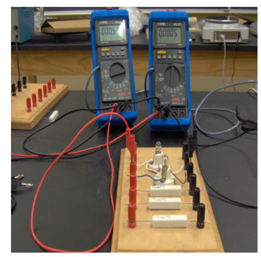
Series and Parallel Resistances and Ohm's Law Revised 2012

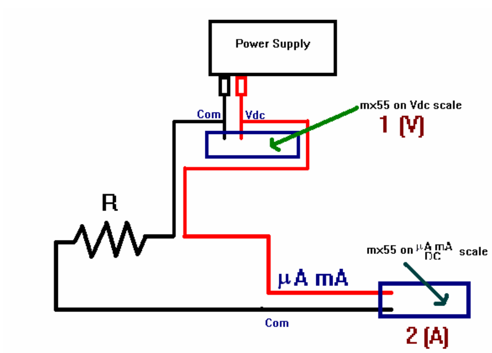
Please refer to the instructions regarding mx55 interface initialization on the lab website before starting the experiment. You will acquire data with the program "OhmsLaw" which you will see a script link to on your unix desktop. The data will be written to your I directory (under /root/I) with a file of your choosing (use less than 9 characters, no spaces or unusual characters) in ".csv" format. The data will need to be copied into the spreadsheets shown on the web to do the analysis. Be sure to read the instructions in the program when you start it.

In this lab, you will verify several aspects of resistance and capacitance. As far as resistance goes, you will investigate several Ohmatic and non-Ohmatic resistors. You will then verify the addition formulas that we will obtain in class for resistances in series and parallel.



Part I: Resistances.

The fundamental circuit diagram for this portion of the lab is shown below.



Here, we will use a variable voltage supply to vary the applied voltage to a resistance. You need to be a bit careful when making connections with analog meters (such as the voltmeters we are using) since you need to observe polarity. Basically, you want to connect red terminals to each other and black terminals to black terminals. Connections for the ammeter can be more complicated. Here, you need to connect the red end to the higher potential and the black (or common) to the lower potential. As a general rule, current flows through an ammeter but across a voltmeter: if a voltmeter were removed, the circuit will function. If an ammeter is removed, the circuit will not function. As a note, if you sometime pick up an ammeter which does not seem to function properly than a good guess is that a fuse across the lead has been blown.

Here is a picture of the power supply you'll use:

In DC operation, the black switch should be set to Volts or Amperes. This refers to the reading that is present on the meter above the word "Power". Use the black and red terminals for DC operation and green terminals for AC operation. We use black and red today.

Warning: some of the resistors can become warm. Do not touch hot resistors!

Please note: an important part of this lab is to make completed circuit diagrams for your experiments which you show to me. You will have to sketch a total of about 4 diagrams which you will need to show to me (but not hand in). Also make sure that I confirm proper connections before you switch on your circuit. And if you are in doubt about something, especially with regard to electrical connections, be sure to ask. I will sign off on your diagrams when I check your circuit.

Experiment I: Ohmatic resistances.
Note: do not exceed 5A of current in this lab.

In class, we defined the fundamental definition of resistance as R=V/I where V is voltage and I is current. Further, we said that if a resistor is Ohmatic, a plot of V vs. I will produce a straight line. Now, the truth is that rarely does one find a true Ohmatic resistor, and then only for a narrow range of currents. Never-the-less, it is useful to say that resistances are Ohmatic although in exacting applications, problems may arise.

I have provided you with a set of standard resistances. You should connect resistor A into your circuit now. Vary the voltage from 0 to 10 volts in steps of about 1 volt. Then, measure and record your current at each voltage.

You will, in your analysis plot a graph in OpenOffice with current on the x-axis and voltage on the y-axis. Be sure to delete my data and replace it with your data. A fit to a linear trend line to your data will automatically happen. You can determine your percent deviation by entering the expected values of your resistance. The slope of your graph will be the value of the resistance of an Ohmatic resistor. If the data is linear, then your resistor is Ohmatic.

The percent deviation is calculated by:

$$\%deviation = 100 \frac{R_{measured} - R_{Expected}}{(1/2)(R_{measured} + R_{Expected})}$$

Repeat this procedure for resistor B and C. You will find that each of these resistors are Ohmatic and for a good reason: they are called power resistors and they are specially designed to not be affected strongly by IR heating.

A series resistance

Now, connect resistance A and B in series and repeat the same analysis. You can now check the accuracy of the addition formula for series resistance by the following: Suppose you measured for the series resistance $R_{measured}$ and here $R_{calculated}$=A+B. The percentage deviation in this measurement is given by

$$\%deviation = 100\frac{R_{measured} - R_{calculated}}{(1/2)(R_{measured} + R_{calculated})}.$$

Find your percentage error by entering the correctly calculated series resistance in the spreadsheet helper. Your values should be in good agreement.

A parallel resistance

Now, connect resistance A and B in parallel and repeat the same analysis. You can now check the accuracy of the addition formula for parallel resistance. Be sure to report the percentage error. **And, I have a warning**: students I have taught have almost always shown themselves to have problems working with the parallel resistance addition formula. Make sure you are not one of them!! How the resistance add:

$$\frac{1}{R_{eq}} = \frac{1}{R_A} + \frac{1}{R_B}$$

Again, enter the correctly calculated equivalent resistance into the spreadsheet helper to obtain your % deviation. Your values should be in good agreement.

Non-Ohmatic resistances

As you now know, rarely are resistances Ohmatic. Indeed, if you had taken very precise data on the resistances above, you would have seen a departure from linearity. Just because a resistor is not Ohmatic, however, does not mean that it can not be used. Indeed, quite the contrary! You are pretty much limited to a space of only non-Ohmatic resistors. Let's look at a non-Ohmatic resistor.

The light bulb

Note: do not exceed about 5 Volts across the light bulbs. They easily burn out and will if you go higher than 5 Volts.

Light bulbs are good examples of non-Ohmatic resistances. The rating on light bulbs (in W) is given at the normal operating temperature. But, the resistance can vary significantly before the bulb reaches its operating temperature. Connect one of your light bulbs in the circuit and repeat the analysis above. This time, however, you will not be able to fit a linear trend-line to the I-V curve. In the light bulb helper, I have plotted log(V) vs log(I) and done a linear fit to this. The resulting fit will be then:

$$V = e^{intercept}(current)^{slope}$$

where the intercept and slope come from your graph. There is, however no further analysis required. **However, if you have zero voltage or zero current, you need to delete these from your data. Also make sure you delete my example data and calculations on the helper.**

The various parameters of this I-V fit tell us what the resistance will be at a specified voltage. You will note that the light bulb starts out with a low resistance which increases. This is a characteristic of metals: the resistance increases as temperature increases. Bulb manufactures know this and sell more bulbs than they should because of this Here is how it works. When you first switch on a light bulb, there is little resistance in the circuit. This means that the current is quite high through the circuit. But a high current through the circuit is exactly what is needed to cause the filament to burn out. Thus, the likelihood of failure in a light bulb is as soon as it is switched on. My light bulbs have almost always burned out when I cut them on. When do your light bulbs burn out? It is also interesting to note that glasses, by contrast to metals, show a decrease in resistance as temperature increases.

Parallel vs. Series wiring.

Connect your two light bulbs in series and perform the same analysis. This time, however, be sure to make notes about how bright the light bulb is at 10 V. I know this is a hard thing to ask: I am asking you to force your eye to remember brightness. Be sure to see what happens when you unscrew one of the bulbs.

Now, connect your two bulbs in parallel and perform the same analysis. Compare the brightness at 10 V to the series arrangement. You should see that the parallel combination produces brighter lights. The reason for this is that the voltage drop is the same across both bulbs in the parallel arrangement. More current is delivered to each bulb in the parallel arrangement. For this reason, circuits in your home are wired in parallel, not series. It used to be that Christmas tree lights were wired in series and if one burned out, you had to trace through the entire circuit, changing bulb after bulb trying to find the one bulb that is bad.

But how can lots of things plugged into the socket cause a fuse to blow? If you assume that you have N resistances in parallel then you can (and perhaps should) show that the equivalent resistance is given by $R_{eq}=R/N$ where R is the resistance of any one resistor. The power dissipated in this circuit is given by $P=IV$. Now if N approaches infinity, then the equivalent resistance approaches zero. The voltage supply does its best to keep the voltage constant under these conditions so the only thing that can happen is the current must go to infinity. As a consequence, you can see that the power dissipated in your circuit increases greatly. If the current exceeds what a fuse can handle, then the fuse blows. This, however, is a good thing. If the fuse does not blow, the wires can always heat up and set your house on fire. So the moral to this story is use the correct fuse for your circuits and if the fuse blows, don’t fix the problem by putting in a larger fuse.

Your write up for this lab consists of plots showing the slope for each of the Ohmatic resistances, along with the normal required elements of your lab report. Below each plot, you should type a sentence (or two) which discusses what the resistance is, if the material is Ohmatic and why.