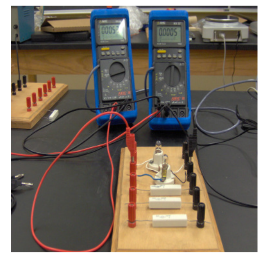
Series and Parallel Resistances and Capacitances

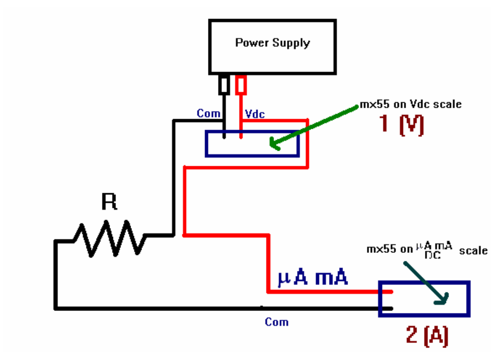
Please refer to the instructions regarding mx55 interface initialization on the lab website before starting the experiment. You should also note where files are written in these same instructions. You will acquire data with the website program “ohmslaw.exe”. If you access this program through internet explorer, you can run it directly from the website. The data will be written to your I drive with a file of your choosing in “.csv” format. The data will need to be copied into the spreadsheets shown on the web to do the analysis. I have provided a maximum of 200 data pairs on these spreadsheets. 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 obtained in class for capacitances.



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!

Experiment I: Ohmatic resistances.
Note: do not exceed 500 mA 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 1 volt. Then, measure and record your current at each voltage. Don't forget that 0,0 is a data point.

You will, in your analysis plot a graph in Excel with current on the x-axis and voltage on the y-axis. Fit a linear trend line to your data with the option of displaying the equation on the graph and force your trend line to pass through the origin (an intercept at (0,0)). 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. In the spreadsheet helper, if you do not have as many points as the helper provides for, simply delete the points that are not part of your data.

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 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: lets say that the last resistance is R. Then R=A+B from class. So the percentage error in this measurement is given by $\%\text{error} = 100\frac{R-A-B}{R}$. Find your percentage error.

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:

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

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

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. You can probably fit your data with a 2nd order polynomial, but be sure to force the curve to pass through the origin. 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. Glasses, by contrast, show a decrease in resistance 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?

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.

Part II: parallel vs. series capacitances

I have provided you with multimeters capable of measuring capacitance. First, measure each of the capacitances and try to get some rough agreement between the meter reading and what is printed on the side of the capacitor. After you have done this, use the clip provided to connect one leg of the capacitances in series. Measure this capacitance. Then, place both of the capacitances into the slot of the meter and then measure the parallel capacitance. Determine the percentage error in each of the measurements. You will probably find that the error is higher than it was for the resistance. Part of the reason for this is that it is simply harder to measure capacitance than resistance.

You may have noticed that the capacitor has markings on its side. There is not really only one standard for capacitance rating through markings. If you are diligent enough, you will find that there are some systems in wide use today but my absolute best advice to you is if you are going to use a capacitor, either measure the capacitance or get one that has the values printed on the side. While I am at it, I need to mention something about the polarity of capacitors. Modern capacitances require you to respect polarity, keeping + sides with the higher potentials. If you fail to connect your capacitor in many circuits properly, you will sooner or later get a big surprise. The surprise will be the failure of the capacitor. This is accompanied by an enormous pop and a release of energy. More annoying, however, is that it will scare you without warning. The moral to this story is to get your capacitor polarities correct.

You may have also noticed that many resistors have color bands marked on them. There is a standard method for marking resistances (and some resistances must have polarity respected if they are very high). The color coding is useful if you are looking at a resistance in a circuit and want to know its value. However, for my time, I would much rather use an Ohmmeter to measure the resistance and leave the color bands up to someone else with more time on their hands. Although the bands are useful in circuits, you are usually looking at a burned out resistor and the color bands are usually already burned off of these things. Your mileage may vary and you should feel free to learn the color coding for resistances if you like.