Notes on Experiment #6

We will do experiment #6 AS IS. Follow the instructions as given.

**Analog Meters**

When attaching a meter to a circuit to make a measurement we would hope that the presence of the meter does not cause voltage and current values in the circuit to change. Analog meters, in order to operate, generally borrow energy from the circuit to which they are attached. This is called "loading the circuit." If the meter uses a very small amount of energy and does not cause voltages or currents to change then we say the meter is a "light load." If the meter draws a great deal of energy and current and voltage values in the circuit change dramatically then then meter is "loading down the circuit" or is "a heavy load."

The Simpson multi-meter is an analog meter and will load a circuit when making a measurement. The DMM is almost an "ideal meter" and as such will be an extremely light load on a circuit. (There are cases when the DMM could load down a circuit however.) We will be using the DMM to observe the loading effect of the Simpson meter on a circuit.

**Current Meters**

All current meters can be modeled as a resistor $R_m$. An ideal current meter has $R_m=0$. A practical current meter has $R_m$ equal to "a very small resistance." The circuit in Figure_1 has a current meter in series with a voltage source and a resistor. The current in the circuit without the meter is

$$I = \frac{V_S}{R}$$

If the meter is "in circuit" then the current becomes

$$I = \frac{V_S}{(R + R_m)}$$

which is clearly a lower value than the original current. You will notice that this new current will actually be the current that the meter displays!
Voltage Meters

All voltage meters can be modeled as a resistor $R_m$. An ideal voltage meter has $R_m=$infinite resistance. A practical voltage meter has $R_m$ equal to "a very large resistance." The circuit in Figure_2 has a voltage meter in parallel with a resistor. The voltage $V_2$ in the circuit without the meter is (by voltage division)

$$V_2 = \frac{R_2}{(R_2 + R_1)} \cdot V_S$$

If the meter is "in circuit" then the voltage becomes

$$V_2 = \frac{\{R_2 \parallel R_m\} / \{R_2 \parallel (R_m + R_1)\}}{\{R_2 \parallel R_m\} + R_1} \cdot V_S$$

which is clearly a lower value than the original voltage. You will notice that this new voltage will actually be the voltage that the meter displays!

The internal resistance $R_m$ of the Simpson meter as a current meter is not available. If there is time, see if you can calculate it using your data from part 1 of the experiment.

The internal resistance $R_m$ of the Simpson meter as a voltage meter is $20K \times$ the scale setting. So, if the scale is on the 10 volt setting then

$$R_m = 20K \times 10 = 200K$$

On the 2.5 volt setting

$$R_m = 20K \times 2.5 = 50K$$
Note that this is the scale setting used here and not the voltage value measured at this setting.

For your circuit analysis in part 2. Calculate $V_1$ and $V_2$ with no meter and then again with the meter attached appropriately. Consult your lab manual for available voltage scales on the Simpson meter. Choose an appropriate scale for each measurement.

Have fun.
ECE 210 Experiment #6

Analog Meters

Purpose: To illustrate use and pitfalls of analog meters

Equipment: Agilent 34401A Digital Multimeter (DMM), Agilent E3631A Triple Output DC Power Supply, Universal Breadbox, Simpson Multipurpose Analog Meter

I. Using an analog meter to measure current, voltage, and resistance

CAUTION: with the Simpson meter, as with all analog meters, care must be taken to put the meter in the circuit with the proper polarity and on the proper range, or the meter can be easily damaged. Current must flow into the meter terminal which on analog meters such as this is usually labeled "+" or "V-A" or some such thing and is often colored red, and out of the terminal which is usually labeled "COM" or "GROUND" or ",-", etc. and is often colored black. Ammeters should always be set initially to the least sensitive scale (labeled with the largest values of current) and then turned to more sensitive ranges until a good needle deflection is obtained. Similar precautions hold when using the Simpson as a voltmeter; polarity must be observed and you should start on the least sensitive scale, then switch to more sensitive ranges to get a good reading. These precautions are largely unnecessary for our digital multimeters (DMM), which if used wrong merely announces that fact by an overload indication.

Taking these precautions, set up the circuit below. Throughout this part, leave the DMM in the circuit, operating as a current meter.

![Circuit Diagram]

Use DMM as an Ammeter

Figure 1.
Put the Simpson in the circuit as a current meter (in series with the DMM) and adjust the DC voltage supply until the current is 1 mA. Do the DMM and the Simpson agree? Then remove the Simpson from the circuit. Does the current (as measured by the DMM) change as a result of removing the Simpson? Now use the Simpson as a voltmeter to measure the voltage across the resistor. Pay close attention to the current (measured on the DMM): does the current change when the Simpson is attached to measure the voltage? Last, disconnect the resistor from the circuit and use the Simpson to measure its resistance. Do the readings of V, I, and R verify Ohm's Law? Record the measurements and the percent error observed in \( V = I \times R \), with readings taken on the Simpson. Measure the same three quantities with the DMM and calculate the error in \( V = I \times R \) again. Comment on your observations.

II. Meter "loading" of a circuit

A meter is said to "load" a circuit if attaching it changes the voltages or currents in the circuit being measured. In principle this loading should be zero. Set up the circuit below. Attach the DMM to measure \( V_1 \).

![Figure 2](image.png)

Leaving the DMM attached, connect the Simpson to measure \( V_1 \) also. Does the addition of the Simpson affect the circuit? Record your observations.

The degree of loading by the Simpson can be calculated. Its effect on the circuit is the same as if a resistor were attached, with a value of "20,000 ohms per volt" where the "volt" refers to the range used. For example, on the 10 volt scale it affects the circuit like connecting a resistor of 200K (= 20K ohms/volt x 10 volt scale.) Calculate the expected loading, that is, how much you would expect \( V_1 \) to change when the Simpson is attached. Compare this with your observations.

Now repeat this experiment for \( V_2 \). Explain why the loading is less in this case.