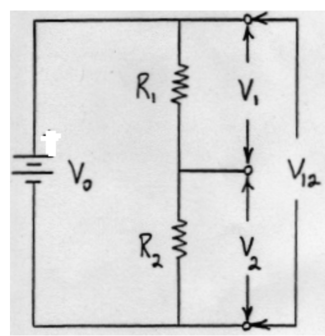
EXPERIMENT 1: DC INSTRUMENTS AND MEASUREMENTS 9/4/03

In this experiment we will learn about some of the laboratory instruments which will be used during the semester, and gain experience with measuring DC currents and voltages. We will also see that voltmeters and ammeters can sometimes have a non-negligible effect on the behavior of a circuit.

Note that sections (a) and (c) of part 2 involve deriving some simple formulas. This should be done prior to the lab period.

Before you begin, clean the selector switches on the Volt-Ohm-Milliammeter (VOM), the Electrometer, and the resistance boxes by slowly rotating them full circle clockwise and counter-clockwise several times. Also clean the inputs of all meters and resistance boxes and the outputs of the power supply by inserting and removing a snugly fitting banana plug several times. The wiping action helps to remove insulating films from the switches and connectors. This procedure should be followed whenever you encounter a circuit that "drifts" or appears to be noisy or unreliable.

1. First, we will investigate the effect that various DC voltmeters have on a simple voltage divider circuit. Construct the circuit shown at the right. Use the Lambda DC power supply for V_0 (do not ground either terminal), and use the Digital Multimeter (DMM) to set $V_0 = 8.0$ V. Use 10% resistance boxes for R_1 and R_2.



(a) Use one of the Simpson Volt- Ohm-Milliammeters to measure the voltages V_1, V_2 and V_{12} for $R_1 = R_2 = 100\ \Omega$, $10^5\ \Omega$, and $10^7\ \Omega$. Make a table giving R_1, R_2, V_1, V_2, V_{12}, and the % difference between the measured values of V_{12} and $V_1 + V_2$.

(b) Repeat part (a) using a DMM instead of the VOM.

(c) Repeat the measurements once more, this time with a Keithley electrometer.

(d) For an ideal voltmeter you would expect to obtain $V_{12} = V_1 + V_2$, but for real voltmeters you see that this is sometimes not the case. Look up the input impedances of the various voltmeters in Appendix C and briefly explain the reason for the discrepancies you observed.

2. Next, we will use a pair of VOM's (one used as a voltmeter and the other as an ammeter) to measure the resistance of a resistor R. In principle we could use either circuit A or circuit B (shown below) and the resistance would be given by R = V/I, where V and I are the voltage and current read on the meters. In practice, however, things are not quite so simple. Note that in circuit A (for example) the ammeter reads the current through R (as desired), but the voltmeter reads the voltage across both the resistor and the ammeter. Thus, R should be calculated from $R = V_C/I$, where $V_C = V - V_A$ and where V_A is the voltage across the ammeter. In circuit B, V is just the voltage across R, but I includes the current through the voltmeter (I_V) as well as the current through R, and thus we want $I_C = I - I_V$. Often these corrections are small enough to be ignored, but this is not always the case.

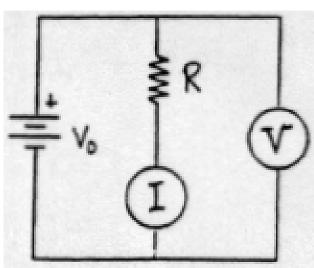
(a) Sketch the two circuits in your notebook. Next, write down the equations needed to correct your measurements for the finite input resistance of the meters. For example, for circuit B, you need a formula that gives I_C in terms of I, V, V_{FS} (the full scale voltage setting of the voltmeter), and S_V, (the sensitivity of the voltmeter). Similarly, for circuit A you want to express V_C in terms of I, V, I_{FS} and S_A. Note that the meter sensitivities are given in Appendix C.

(b) Set up the circuits using the $\pm 10\%$ resistance boxes for R. Be careful not to connect the ammeter directly across the output of the power supply. Use the DMM to set V_0 to the values given in the table at the right, and then read the values of V and I. For each circuit, construct a table giving V_0, the nominal value of R, V, V_{FS}, I, I_{FS}, V_C (I_C for circuit B), V/I, and V_C/I (V/I_C for circuit B).

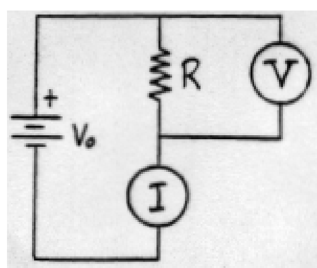
V_0	R	V_{FS}	I_{FS}
1.9 V	220 Ω	2.5 V	10 mA
1.9 V	2.2 kΩ	2.5 V	1 mA
0.9 V	22 kΩ	2.5 V	50 μA

(c) Now remove the resistance box from the circuit and use the Ω function on the DMM to make a direct, accurate measurement of R for each resistance value used in part (b). Make a table that summarizes the values of R you

CIRCUIT A



CIRCUIT B



obtained (including the corrections) with Circuit A, Circuit B, and the DMM. Approximately how close to the correct value did you get by using the VOM's?

Question: Normally we like to be able to measure R without the need for making any corrections. In particular, suppose we want to keep the corrections below 1%. What condition must hold in order that the correction V_A for circuit A be less than 1% of V? You should be able to write the answer in the form of an equation that involves R, I_{FS} and the meter sensitivity. Similarly, find a formula (involving R, V_{FS} and S_V) that expresses the conditions under which the correction I_V in circuit B is less than 1% of I. These results will be used in Parts 3 and 4 below.

3. In this section you are to use VOM's to check the linearity of a 100 kΩ, 10% resistor, by measuring V and I as a function of V_0. Choose the appropriate circuit (A or B) and use full scale settings which lead to at most a 1% correction to the measured value of R (you may ignore this correction). Measure and tabulate about 10 points from V_0 = 1 to 20V. Plot the measured values of I vs V and determine whether the resistor is linear. Calculate the value of R for each measurement of V and I and include the results in your table. Then calculate the average value of R, and estimate the uncertainty in any individual value of R by calculating the standard deviation of the measured values.

4. Measure and tabulate V and I for an incandescent light bulb filament. As in part 3 you should choose the appropriate circuit and use full scale settings to keep the errors below 1%. Your measurements should include several below 20 mA, and should increase until you reach currents that cause the filament to glow brightly. For each point, calculate the resistance (R = V/I) of the filament. What happens to the resistance of the filament as the temperature increases?

5. In this section we will measure the input impedance (R_I) of a Model 175 DMM. First, connect the DMM across the output of the power supply and measure the output voltage. Then insert a resistance box in series with the DMM and adjust R until the reading of the DMM drops by a factor of two. Since the meter measures the voltage drop across its input terminals and since the power supply produces a constant voltage, we conclude that at this point the voltage drop across R is equal to the voltage drop across the meter, and thus R_I = R. Measure R_I for three different scales (2V, 20V, 200V) to determine whether the input impedance depends on the range setting of the DMM. Record in your notebook the model number of the DMM you are using. This method is useful for measuring the input impedance not only of voltmeters but of other circuits as well.