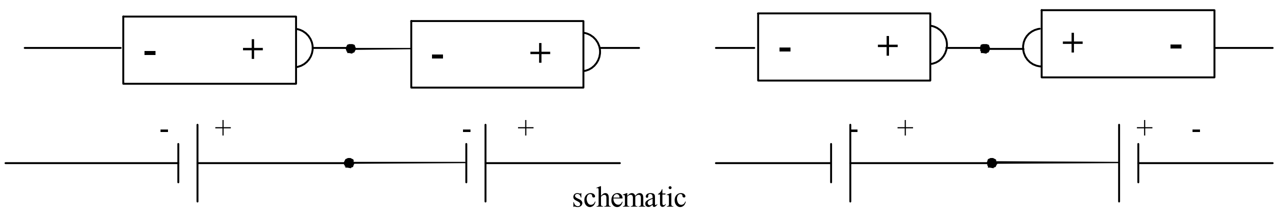
MEASUREMENTS IN SIMPLE CIRCUITS

Refer to the "Simple D.C. Circuits and Measurements" lab handout and your textbook for reference material.

1. Select the voltmeter function on the portable multimeter and use the meter to measure the potential difference between the terminals of one of the batteries you have. Make sure that the polarity of the leads is correct. Check it on several scales. Now measure the potential difference of the second battery.

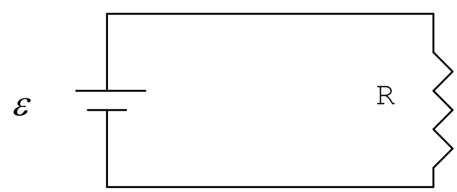
2. Connect your two batteries together first with the "+" of one to the "-" of the other and secondly with the "+" of one to the "+" of the other. See the drawing.



schematic

For each combination measure the potential difference across the combination with the voltmeter. Use as sensitive a scale as possible. Do the combined values agree with the sum of the individual values (be careful with signs)?

3. Make the circuit shown, where the battery EMF, $\mathcal{E}$, is provided by an alkaline battery and the resistance R by a large size red-red-brown (or red-violet-brown) resistor.



(a) Measure the potential difference (drop), V, across the resistor using one of your meters as a voltmeter. Draw a schematic showing the placement of your voltmeter.

(b) Measure the current in the circuit using one of your meters as an ammeter. Remember to "open the circuit" and to insert your ammeter in the circuit. Draw a schematic of the meter placement.

(c) Using the measured values of V across the resistor and I through the resistor, calculate the resistance of the resistor using Ohm's Law.

(d) <u>Disconnect</u> the resistor and measure its resistance with a multimeter used as an ohmmeter. Compare with the calculated value.

4. Replace the battery with a 0-20 V power supply. Connect both a voltmeter and an ammeter in the circuit to <u>simultaneously</u> measure the voltage drop across the resistor and the current through the resistor.

(a) Vary the output of the power supply and record values for the voltage drop, V, across and the current, I, through the resistor (as measured by your meters) for five to ten settings of the power supply. <u>Do not exceed 10 V.</u>

(b) Graph I vs. V. Deduce the resistance of the resistor from the slope of the line on the graph.

5. Series connections:

Connect numbered resistors R_3 and R_4 in a series combination with the power supply. Set the power supply to a convenient value and keep it at this value for this part.

(a) Measure (easiest to use just one meter at a time). Do a diagram for each measurement showing the placement of your meter:
   (1) current through the combination
   (2) current at different places in the circuit
   (3) potential difference across combination
   (4) potential difference across each resistor

(b) Using your measured values of I and V:
   (1) calculate the resistance of the combination
   (2) calculate the resistance of the individual resistors.

(c) Measure with the ohmmeter (**Remember to remove the power supply!**)
   (1) the resistance of combination
   (2) resistance of the individual resistors
   Compare these measured values to those calculated in (b).

(d) Questions:
   (1) Do you get what you expect for the combination values of V, I, R with a series combination? Explain.
   (2) How does the ratio of the resistor values compare to the ratio of the potential differences across them?

6. Parallel Connection:

Connect numbered resistors R_3 and R_4 in a parallel combination with the power supply. Set the power supply to a convenient value and keep it at this value for this part.

(a) Measure. Do a diagram for each measurement showing the placement of your meter:
   (1) potential difference across combination
   (2) potential difference across each resistor
   (3) current through the combination
   (4) current through each resistor
   (5) with the ohmmeter (**remove power supply!**), the resistance of the combination

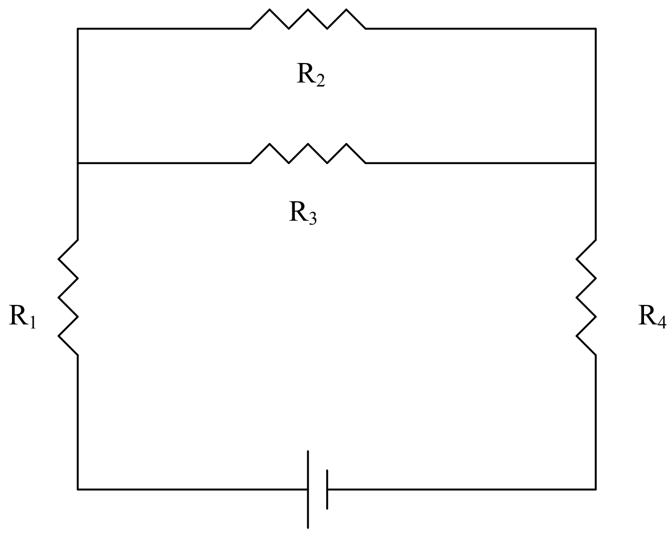
(b) Using your values of I and V, calculate the resistance of the combination and compare to that measured with the ohmmeter in (a) above.

(c) Calculate the equivalent parallel resistance using the individual values of R_3 and R_4 as measured in part 5 (series connections). Compare to the measured combination value.

(d) Questions:
   (1) Do you get what you expect for the combination values of V and I for a parallel connection? Explain.
   (2) How does the ratio of the currents compare to the ratio of the resistor values?

7. Combination of series and parallel:

Connect the four numbered resistors in the circuit as shown. Set a convenient value for the power supply and leave it. Use a single multimeter to make these measurements.



(a) Measure the potential difference across the combination and the potential drop across each resistor. (Draw a schematic showing the placement of the meter to measure V_3.)

(b) Measure the current in the total circuit and the current through each resistor. (Draw schematics showing the placement of the meter to measure I_1 and I_3.)

(c) Do these measured values of potential differences and currents agree with what you know about the relationships in series and parallel connections of resistors? Explain.

(d) Measure the resistance of the entire combination with the ohmmeter. (Remember to remove the power supply.) Compare this to the value for the resistance of the combination obtained using Ohm's Law with the measured values of V and I for total circuit.

(e) Calculate the individual resistances from the measured values of V and I using Ohm's Law and compare to values obtained with the ohmmeter.

(f) Calculate the equivalent resistance of the combination using the individual values of resistance (either set of values from (e)) and compare to values you have from (d) above.

Sections 8-10 are optional depending on time.

8. Internal Resistance of a battery

To determine the internal resistance of a battery, we will connect a small resistor to the non-alkaline battery and look at the effect on potential difference at the terminals of the battery (the terminal voltage of the battery). If there is internal resistance, then, when the battery delivers current, there will be a potential difference across the internal resistance, thereby reducing the potential difference at the terminals of the battery.

(a) Arrange a set up that allows you measure the potential difference at the terminals of the battery while easily connecting and disconnecting an approximately 110 ohm (brown-brown-brown) resistor across the terminals of the battery. Observe the voltmeter reading with and without the resistor across the battery. If there is a decrease when the external resistor is attached, then that decrease is the potential drop across the internal resistor.

(b) Using the known value of the external resistor (measure with ohmmeter) calculate the value of the internal resistance from the observations in (a).

(c) Now use R_4 for your external resistor. Look at the effect on the terminal voltage of the battery as you connect and disconnect it to the battery. Compare its effect on the terminal voltage to that of the 110 ohm resistor in part (a) and explain. (Remember that you know the value of R_4 from an earlier part.)

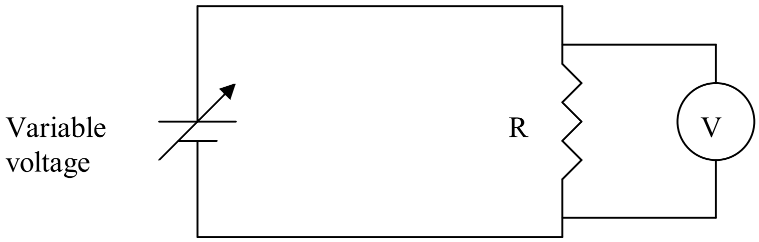
(d) Return to using the approximately 110 ohm resistor and check out your other battery to see the effect on the terminal voltage as it is connected and disconnected. Based on your observations, which battery has the larger and which has the smaller internal resistance? Explain.

9. Resistive Transducers

A transducer converts one form of signal (information, energy, etc.) into another. A resistive transducer converts signals into resistance changes. These are very valuable in measurements. You have a photocell and thermistor. Investigate in a qualitative way how their resistance (connect them to the ohmmeter) changes in response to light and temperature.

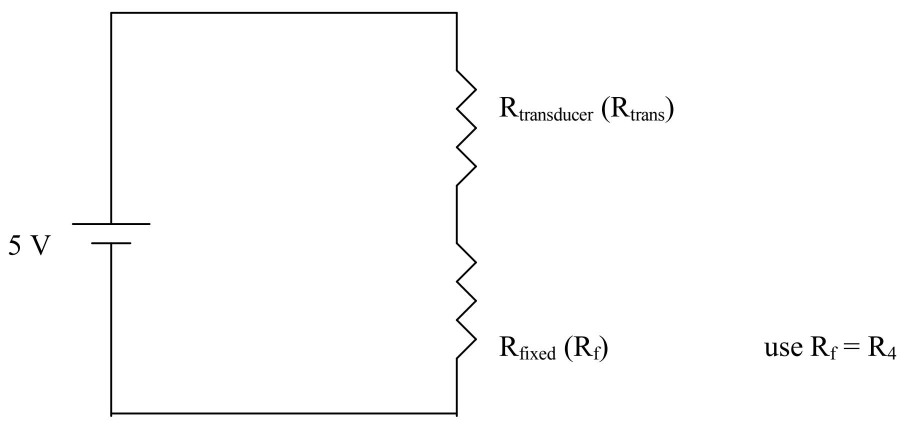
10. Using the Transducer in a Simple Measurement Circuit

Suppose you wish to use the resistive transducer. Typically, it is not convenient to directly measure the resistance. Consequently you would use a source and make a circuit which includes the transducer. One simple way you could detect changes in the resistance would be to put an ammeter in series with the transducer. As the transducer's resistance changes, the current in the circuit would then change (more R, less I, etc.). This is the method used in simple light meter circuits. Often, however, a voltage measurement is better or more convenient (as with an oscilloscope or in computer interfacing, for example). So how can you measure current with a voltmeter? If a known resister is placed in the circuit, then by measuring the voltage drop across it, you are measuring the current ($I = V/R$). As an example consider the following simple circuit (like the first(!) in this lab).



If R is known, then the voltmeter reading is an indication of the current. If the current increases, V increases and vice-versa. If the value of the current is needed, you can calculate it from the V and R.

Related to this is using two resistors in series to "divide" the voltage. In series the voltage is divided in proportion to the ratio of the resistors (check your results in part 5). If one resistor changes and the other stays fixed, the ratio of the potential differences changes and since the total potential difference stays the same, the potential difference across the fixed resistor will change (it is "divided" differently). Make sure you understand what happens to the current in the series combination if one of the resistors increases and from this what happens to the potential difference across the other fixed resistor. To see this, and how it can be used in a detection circuit, construct the following, using either of your transducers.



Now place the voltmeter across R_f. Experiment with changing the value of R_{trans} by changing the stimulus. Can you detect the changes with your voltmeter? Qualitatively relate the meter reading changes to the stimulus. (For example, does it go up or down with increased light? How much does it change from dark to room light?)

Make sure you understand why you get the observed direction changes when you change the stimulus, using your knowledge of how the resistor changes with the stimulus.

Try to stabilize your circuit by keeping the stimulus fixed. Record the reading of the voltmeter which is across R_f and the V across the entire series combination. Using these values and the known resistance of R_f, determine the value of R_{trans}.

In a careful experiment, you could "calibrate" the system so that the voltmeter readings could be converted to light level or temperature or whatever the stimulus of the transducer.