LAB D4: *SIMPLE ELECTRIC CIRCUITS*, *RESISTANCE AND OHM'S LAW*

January 29, 2003

In this lab you will:

a) Learn to use a multimeter to measure DC voltage differences, resistances, and currents. The associated five-page ***Guide to Building Circuits*** contains all necessary instructions. Read it and this page carefully before coming to lab. Please follow the guide carefully the first time you do each different measurement and then until you have mastered the technique.

b) Investigate the behavior of a simple circuit. A simple circuit is one that contains only one resistor and one battery (or source of voltage difference) connected in a single loop (see the diagram in Part A of the ***Guide to Building Circuits, etc***.).

c) Determine whether a small, cylindrical piece of carbon (a "resistor") obeys Ohm's Law (read section 20.2 of Walker to find out what this means).

You will be given a selection of D batteries (if you are unsure how to combine batteries to make voltages larger than 6 volts, ask the instructor or lab assistant) and resistors (use $150\,\Omega \leq R \leq 15{,}000\,\Omega$), a multimeter, and a breadboard. We suggest that you acquire at least 6 sets of data for each of the two parts of the lab (parts 2 and 3 below).

1) LEARNING TO MEASURE RESISTANCE, CURRENT AND VOLTAGE

Choose one resistor and one battery voltage. Follow completely the directions in parts C, D, and E of the ***Guide to Building Circuits***. You will then be ready to carry out the necessary measurements with the multimeter in the lab. *In the remainder of the lab, make sure that you measure all battery voltages and all resistances with the multimeter! Do not assume they have the values listed on them. Record in your lab book all measurements you make.*

2) MEASURING CURRENT AS A FUNCTION OF VOLTAGE

Your goal in this part is to use a simple circuit to measure the current through a resistor as a function of voltage difference across the resistor and to discover the algebraic relationship between these two quantities. <u>Design a method for doing this and write a brief but clear description of it in your lab book</u>. Do NOT assume that the batteries provide 1.50 volts of voltage difference!! Measure each voltage difference used.

3) MEASURING CURRENT AS A FUNCTION OF RESISTANCE

Your goal in this part is to use a simple circuit to measure the current through a resistor as a function of its resistance and to discover the relationship between these two quantities. <u>Design a method for doing this and write a brief but clear description of it in your lab book.</u> Hint: is there a quantity that should remain constant during this part? You might choose to measure all your resistances first, and then measure each of the resulting currents, in order to save switching the multimeter back and forth. Be especially careful about measuring the current properly.

4) ANALYSIS

For each part above,

1) Look at your data in order to decide how to plot the data so that they can be fit by a straight line; you may have to re-express your data in order to obtain a linear relationship.

2) Graph the dependent variable (current, in AMPS in each case) on the vertical axis versus the independent variable. Use either Graphical Analysis or your TI calculator; you will need to print a copy to turn in. (Graphs must have titles, labels and units on axes, correct sig. figs. and units on fit parameters.)

3) Compare your graphical results (slope and intercept for each of the two cases) with those expected. Read Walker [section 20(2)] for help on what to expect.

5) CONCLUSION

Summarize what you did, how you did it, and your results. Describe how your results support or do not support Ohm's Law.

A GUIDE TO BUILDING CIRCUITS
and
USING A MULTIMETER TO MEASURE RESISTANCE, VOLTAGE, AND CURRENT

PART A: *USING THE BREADBOARD TO BUILD A CIRCUIT*

The "breadboard" consists of a block of white plastic with two sets of five rows of holes. Each set of rows looks like

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.   .   .   .   .   .
.   .   .   .   .   .
.   .   .   .   .   .     etc.
.   .   .   .   .   .
.   .   .   .   .   .
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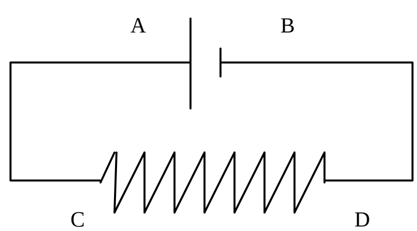
where each dot represents a hole. These holes are receptacles in which the ends of a resistor can be placed to construct a circuit.

Each of the 5 holes in a vertical column is connected to the others in that same column by a wire inside the white plastic, so you don't see it. Each of the 5 holes in a vertical column is therefore electrically connected.

There are two distinct sets of these rows of 5-hole columns. The upper set is NOT connected to the lower set.

Suppose that we want to use the breadboard to construct the circuit diagrammed below:



The symbol | in the circuit diagram represents a battery; the longer line represents the positive terminal, the smaller line the negative terminal. The symbol /\/\/\/\/\/\ represents a resistor.

Place the wire connected to one end of the resistor (labeled "C" above) in any hole -- say the top hole (i.e., row 1) of column 5. The wire connected to the other end of the resistor (labeled "D") can be placed in any hole <u>except</u> those in column 5. (Placing the opposite ends of a resistor in holes of the same column is the same as directly connecting the two ends of the resistor, because of the wire connecting all holes in a vertical column. This is called "shorting out" or "short-circuiting" the resistor. When this happens, the circuit will behave as if the resistor were not there.)

Now connect a clip lead from the positive end of the battery (labeled "A" above) to the wire at one end of the resistor (labelled "C" above). Connect a second clip lead from the negative end of the battery (labeled "B" above) to the other end of the resistor ("D"). The circuit is now complete.

PART B: *INTRODUCTION TO THE USE OF THE MULTIMETER*

The Fluke (brand name) multimeters are capable of measuring AC voltage differences, DC voltage differences, resistances, AC current, and DC current. The top section of the multimeter allows the user to choose the measuring function. The multimeter face looks like the diagram on the left; the corresponding function symbols are described on the right. Some multimeters may have the symbols in a slightly different order.

Turn the dial to this position	*in order to*
OFF	turn the multimeter off
V ~	measure AC voltage difference
V $\overline{- - - - -}$	measure DC voltage difference
dial Ω	measure resistance
--> +)))	test diodes
μA	measure current when in microamps
mA	measure current when in milliamps
A	measure DC current

The bottom portion of the multimeter contains the two plug-in leads (one is red, the other is black) that will be used to measure voltage, current, and resistance. The bottom of the multimeter face looks like the diagram below; the symbol "•" has been used to represent a hole via which the leads are connected to the instrument.

A	μA mA	COM	V Ω
•	•	•	•

Always plug the black lead into the hole below COM (which stands for "common" or ground; in this context, "ground" means the place of zero voltage, i.e., wherever you place the black lead is defined to be zero voltage; the multimeter then reads how much higher or lower the voltage is at the place where you put the red lead).

Where the red lead is plugged depends on what you are measuring. If you wish to measure voltage or resistance, plug the red lead into the hole below the "V Ω" symbol. If you wish to measure current, the red lead is plugged into either of the other two holes. Since we will be using large resistances (greater than 100 Ω) and small voltages (less than 10 volts), the resulting currents will be less than 300 mA (milliamps); therefore, plug the red lead into the hole below the μA/mA symbol when measuring current.

PART C: *USING THE MULTIMETER TO MEASURE RESISTANCE*

1) Choose a resistor that falls in the range given in the lab instructions.

2) Now measure the resistance with the multimeter:

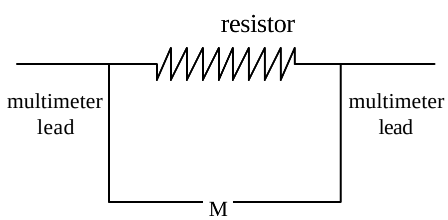
NEVER HAVE A BATTERY CONNECTED TO A RESISTOR WHEN YOU ARE MEASURING THE RESISTOR'S RESISTANCE

a) turn the multimeter dial to the appropriate setting (see Part B)

b) plug the red and black leads into the appropriate multimeter holes

c) touch one lead from the multimeter to one end (it doesn't matter which) of the resistor, and touch the other lead of the multimeter to the other end of the resistor.

Schematically, what you are doing looks like

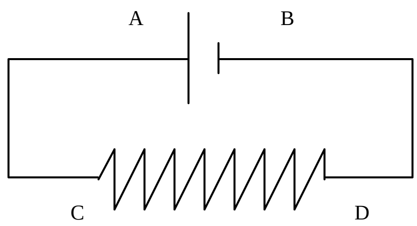


3) Record the value of the resistance measured with the multimeter in your lab book.

4) Do this part only for the first resistor you use: Use the resistance color code (found on the chart on the lab wall) to read the value of the resistance. Record the color code and the resistance value in your lab book. How does the measured value compare with that read from the color code?

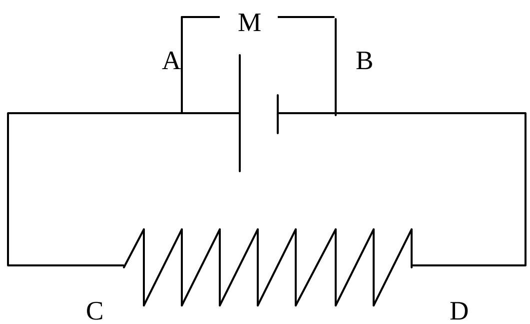
PART D: *USING THE MULTIMETER TO MEASURE VOLTAGE DIFFERENCES*

1) Construct the simple circuit shown below on the breadboard with one 1.5-volt battery and the resistor whose resistance you measured above. Refer back to Part A, if necessary.



2) Turn the multimeter dial to the appropriate (voltage) setting (see Part B).

3) Suppose that we want to measure the voltage difference $V_A - V_B$ (refer to the figure above). Notice that since A is at the positive end of the battery and B is at the negative end, we expect a measured voltage difference of about 1.5 volts. To actually make the measurement, touch the black lead to point B (the wire emerging from the negative end of the battery pack or any piece of metal touching it) and touch the red lead to point A (the wire emerging from the positive end of the battery pack or any piece of metal touching it). Schematically, what you have done with the multimeter looks like



4) Record the measured battery voltage in your data table.

The important lesson here is that if you want to measure any voltage difference, $V_1 - V_2$, the red lead touches point 1 and the black lead touches point 2. Always think "red minus black."

5) Perform and record the following measurements in your lab book ONLY for the very first circuit you build; you may assume the results apply to all your other circuits.

a) $V_C - V_A$; why is this voltage difference zero?

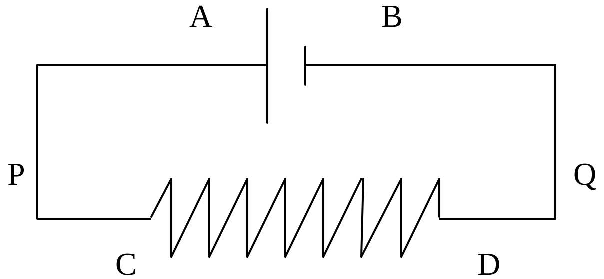
b) $V_B - V_A$; why is this voltage difference negative?

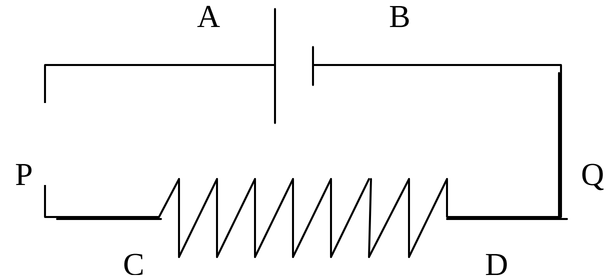
c) $V_D - V_C$; why is this voltage difference negative?

PART E: *USING THE MULTIMETER TO MEASURE CURRENT*

The multimeter is used in a very different way to measure current. Unlike the method for measuring voltage difference (where the multimeter was placed in the circuit "in parallel"), the method for measuring current requires the multimeter to be placed in the circuit "in series". More about series and parallel later.

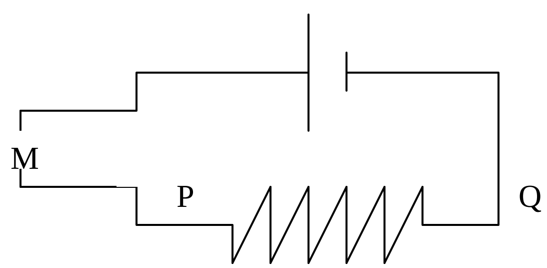
Suppose that we want to measure the current at point P in the circuit shown below, left.





To do so, the circuit must be "broken" (or opened up at P) as shown in the diagram above, right. This is best done by removing both the battery wire connected to A and the C end of the resistor from the breadboard.

1) Break the circuit at point P
2) Now connect the multimeter in series at point P as shown below; turn the multimeter dial to the appropriate current setting. Did you remember to plug the red lead into the 300 mA port?



Do you see the difference between using this diagram and the second diagram on the previous page? If not, stop and ask for help.

IT IS VERY IMPORTANT THAT THE MULTIMETER BE USED IN SERIES WHEN MEASURING CURRENT AND NOT IN PARALLEL AS IT WAS WHEN MEASURING VOLTAGE DIFFERENCES ON THE PREVIOUS PAGE. IMPROPER USE WILL DAMAGE THE METER & BLOW THE FUSE (THEREFORE MAKING THE MULTIMETER INOPERABLE). THIS MAY MEAN THAT YOU WILL HAVE TO COME BACK AT NIGHT TO FINISH THE LAB AND THAT YOU WILL HAVE TO PAY FOR A NEW FUSE. WE THEREFORE REQUIRE EACH GROUP TO MEASURE THEIR FIRST CURRENT IN THE PRESENCE OF A TEACHER OR SENIOR LAB ASSISTANT.

3) Record the measured current in your data table.
4) Do this part only for the very first circuit that you build; assume others behave the same.
   Is the current the same everywhere in a simple circuit like this? To find out, measure the current at point Q, using the method above. Record the measured value of the current at Q in your lab book. Is it the same as the current at point P?
   Later we will learn that current can only change when there is a branch in the circuit. Since this circuit has no branches, the current is the same everywhere in the circuit.