COMPLEX CIRCUITS

(L-21)

As you know, there are circuits that cannot be simplified using equivalent series and parallel combinations. In such cases, Kirchoff's Laws must be used to analyze the situation. This lab will allow you to work with such a circuit.

PROCEDURE--DATA

Part A: (the circuit)

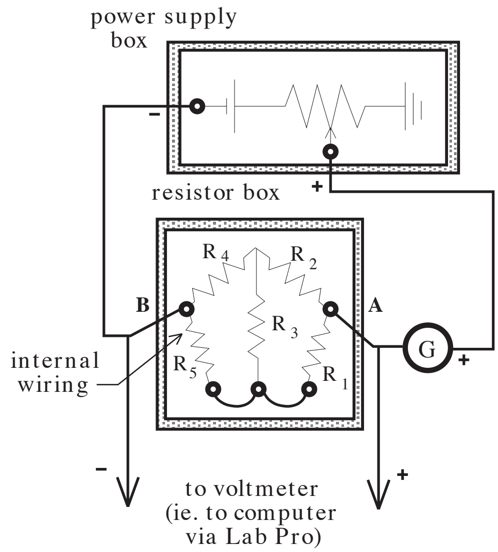
a.) With the exception of the fact that the circuit box is different, the setup for this lab is exactly the same as that used in the Ohm's Law lab.

1.) Plug your *voltage probe* into the Lab Pro and open up the Logger Pro program. You should see a *voltage vs. time* graph.
2.) Go to EXPERIMENT (this is a pull-down on the top ribbon), then DATA COLLECTION (this is a pull-down). From MODE, select the EVENTS WITH ENTRY option. When the window opens, write CURRENT, then "I," then AMPS in the appropriate boxes.
3.) Double click on the graph window (not the axis). Click on the GRAPH TITLE option, then put your name and your partner(s) name(s).
4.) On the AXIS OPTIONS, click AUTOSCALE FROM ZERO for the y-axis.
5.) Double click on the CURRENT DATA TABLE (on the header). In that pop-up window, click OPTIONS then DISPLAY PRECISION. In that box, put a 4 (so the data comes out like 0.0001).

b.) Calibrate your voltage probe by going to EXPERIMENT and clicking on ZERO.

c.) Wire the circuit shown on the next page. As always, the dark-line connection *you* have to make--the light-line connections are internally wired.

Note 1: External wires must be used to connect the "unlabeled terminals" on the circuit box (i.e., resistors R_1, R_3, and R_5 must be connected to one another). The voltage leads from the computer must be connected to terminals *A* and *B*.



After I have checked the circuit, increase the voltage across the POWER SUPPLY until the current through the circuit box is "1" (x10^{-4} amps--remember, the galvanometer is calibrated in 10^{-4} amps). When the voltage readings from the computer stabilize, hit the SPACE BAR to select that reading, then enter the current (i.e., .0001). Continue this for 2, 3, 4, and 5x10^{-4} amp settings.

d.) Once you have all your data, exit back to the MAIN MENU and HIGHLIGHT the current interval of 2.9x10^{-4} amps to 3x10^{-4} amps, then zoom in (the magnifying glass icon in the toolbar). You should get a full-screen view of that portion of the graph. PRINT a copy of the graph for each member of your group.

Part B: (additional info)

e.) With the UNLABELED terminals *connected*, use the IMPEDANCE BRIDGE provided to determine values for:

--The *equivalent resistance* for the entire resistor complex (call this R_{imp}), and

--The resistance across resistor R_3 (call this $R_{3,whoops}$).

f.) With the UNLABELED terminals *disconnected*, use the IMPEDANCE BRIDGE provided to determine values for:

--Individual resistance values for R_1, R_2, R_3, R_4, and R_5.

g.) Have me check your resistance values *before leaving lab*.

<u>CALCULATIONS</u>

<u>Part A:</u> (the *experimental* equivalent resistance of the complex ckt.)

1.) Using the information available on your graph:

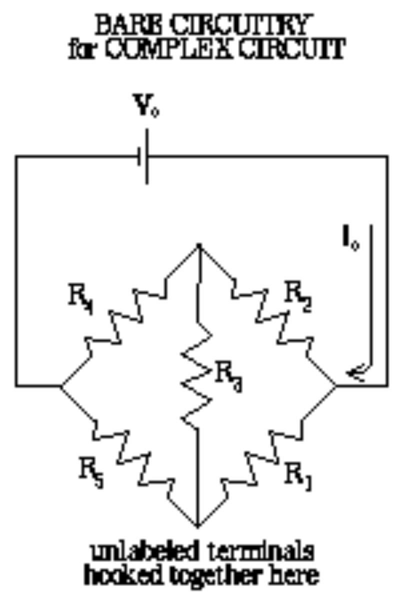
a.) Pick a point and use it to determine the *net resistance* of the complex circuit. Call this value R_{exp}.

b.) Pick a second point on your graph and repeat the calculation requested in *Part 1a*. If the two values are close, average the two and continue on (use the average whenever asked to deal with R_{exp}). If they aren't close, COME SEE ME!

2.) Do a % comparison between R_{exp} and the equivalent resistance's actual value (i.e., the Impedance Bridge value R_{imp}). Comment.

<u>Part B:</u> (the *theoretical* equivalent resistance of the complex ckt.)

3.) <u>BACKGROUND</u> (i.e., there are no calculations in this part): Examine the sketch on the next page. It is simply our circuit minus the extraneous boxes, etc. If we use Kirchoff's Laws to derive a theoretical expression for the current i_o (i.e., the current that flows *into* the complex-resistor combination), our final expression will be in terms of the battery voltage V_o and a group of resistance variables (i.e., *R-type* terms linked by multiplication and division--we will collectively call this group *K*). The result would look something like:



$i_o = (K)V_o$ (Equation A).

What is interesting here is the following: From Ohm's Law we know that the voltage across the complex circuit--the battery voltage V_o in this case--will be related to the current i_o through the complex circuit by the relationship $V_o = i_o R_{th}$, where R_{th} is the theoretical equivalent-resistance of the entire resistor-system. When we compare this expression with the i_o expression derived using Kirchoff's Laws (i.e., Equation A above) it becomes clear that K must equal $1/R_{th}$. In other words, if you can determine K by deriving an expression for i_o, you can determine R_{th}. To make life even easier, if we assume $V_0 = 1$ V, then your result for i_0 is all you need to invert to get R_{th}.

4.) To derive an expression for i_o, begin by making a **FULL PAGE** sketch of the circuit shown above. In that sketch:

- --Label each resistor with its algebraic symbol (e.g. R_1, R_2) *as well as its* *Impedance Bridge value*;
- --Define *current directions* through all branches; and
- --Define *current variables* (i.e., we have already defined the current from the battery as i_o, define the rest of the currents algebraically). SEE NOTE BELOW BEFORE PROCEEDING WITH THIS.

BIG NOTE: When defining algebraic variables for the currents, be clever. You should be able to define all the currents in terms of i_o and only TWO other current variables (i.e., you should end up with only THREE unknowns). If you *cannot* accomplish this, COME SEE ME!

5.) Using numerical values of all resistors (instead of using the general variable form--R_1, R_2, etc.):

a.) Write out three LOOP EQUATIONS. Note that at least one (and, I'd suggest, *only* one) loop must include the POWER SUPPLY.

b.) Re-write the three LOOP EQUATIONS from above in DETERMINATE FORM.

6.) Use a MATRIX APPROACH to derive an expression for i_o. You may choose to solve by hand, or to use your TI calculator's built- in functions. If you choose to use the calculator, please show the matrix or matrices you input in your calculator and explain briefly how you calculated the result (e.g. give what you typed into the calculator screen and the resulting matrix). Remember to put in values for all coefficients and constants ($V_0 = 1$).

7.) From the expression derived in Calculation 6, determine the *theoretical equivalent resistance* of the complex circuit. Call this R_{th}.

8.) Do a % comparison between R_{th} and your IMPEDANCE BRIDGE value for the equivalent resistance, R_{imp}. Comment.

QUESTIONS

I.) In *Part B-e* you measured the Impedance Bridge value for R_3 when the circuit was completely hooked together (we called this $R_{3,whoops}$). In *Part B-f* you measured the Impedance Bridge value for the resistance across R_3 when R_3 was isolated (we called this R_3).

a.) What were those two values (i.e., write them out)?
b.) Why were they different (after all, it is the SAME resistor).