Physics 310
Lab 1: DC Circuits

Equipment:
Digital Multimeter, 5V Supply, Breadboard, two 1 kΩ, 2.7 kΩ, 5.1 kΩ, 10 kΩ, two 10 MΩ, Decade Resistor Box, potentiometer, 10 kΩ Thermistor, Multimeter Owner's Manual

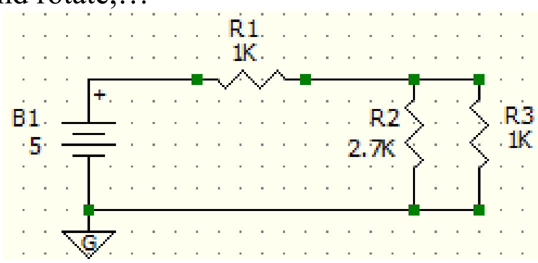
General Lab Notebook instructions (from syllabus)

You should be sure to write down enough so that you can recall what you did several weeks later (it may come in handy when you're working on your final project.) See the checklist in the inside cover of your lab notebook.

General Procedures:
- Do not assume that the values of the resistances are exactly those that appear in the diagrams. Measure the resistances and record them before constructing a circuit. The one exception is that you may use the value from the dials of the decade resistor box. Also, use a voltmeter to find the actual voltage provided by the power supply.
- Be sure to show all of the work used to arrive at theoretical predictions. Unless you are told to use a specific method, you may choose which one to use.

1-1. Kirchoff's Laws

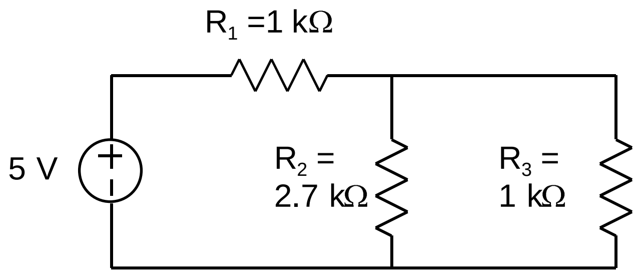
Pre-Lab:
A. In 5Spice, construct the circuit shown below. The program mostly works as you'd expect – click an icon to select, click on the page (inside the yellow lines) to deposit, right click to change properties and rotate,…



B. Once you've drawn the circuit, under "Analysis" select "run." Now, if you place the cursor on wire, a pop-up box will display the voltage at that point.

Question: In your notebook, record the voltages across R_1, R_2, and R_3 according to 5Spice *and* show that an analytic analysis yields the same results (clearly show your work.)

C. In lab, construct the circuit shown below (with real components, not in 5Spice.)

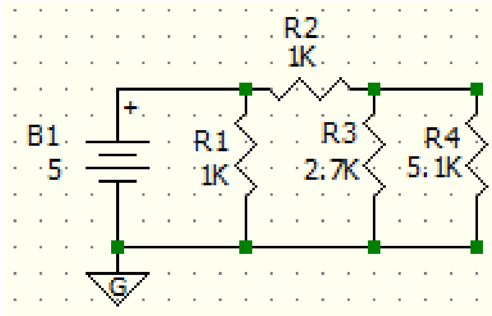


D. Measure the voltage across each resistor (label them V_1, V_2, and V_3). As an example, sketch the set up used to measure V_1 (i.e. – draw where the meter is placed).

Question: How do the measured values compare with what you expect theoretically (use measured V_{supply} and resistance values)?

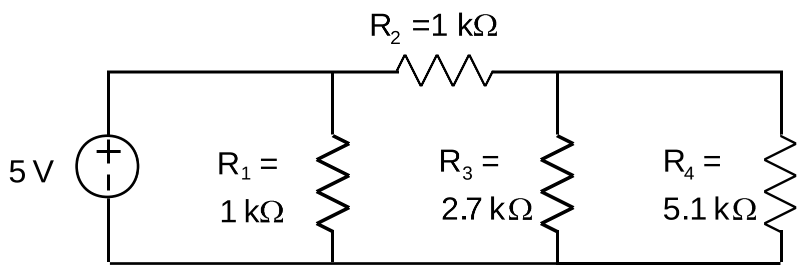
Pre-Lab:

E. In 5Spice, construct the circuit shown below.



Question: In your notebook, record the voltages across R_1, R_2, R_3, and R_4 according to 5Spice *and* show that an analytic analysis yields the same results (clearly show your work.)

F. In Lab, construct the circuit shown below.



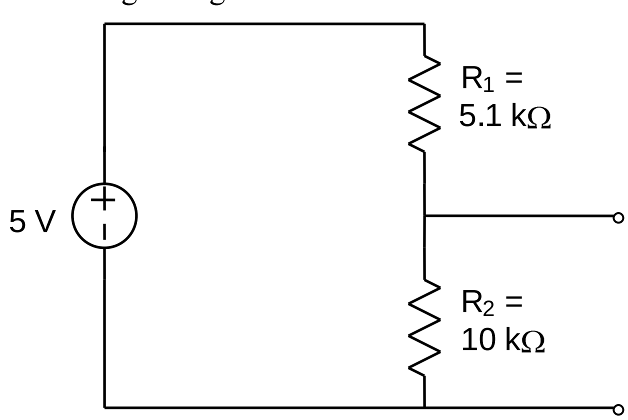
G. Measure the current through each resistor (label them I_1, I_2, I_3, and I_4). As an example, sketch the set up used to measure I_1 (i.e. – draw where the meter is placed).

Question: How do the measured values compare with what you calculate theoretically (given the measured values of the resistances and the supply voltage)?

1-2. Voltage Divider / Thévenin's Theorem

Pre-Lab:

A. For the circuit illustrated below, draw the Thévenin equivalent of the voltage divider.
B. Imagine attaching a load resistor, R_L, parallel to R_2, and use the Thévenin equivalent circuit for the voltage divider to find a theoretical expression (a symbolic equation) for V_L as a function of the supply voltage, V_{sup}, as well as R_L, R_2, and R_1.
C. Construct the following voltage divider circuit.



D. Experimental determine the Thévenin equivalent of this circuit by doing the following:
   1. Find V_{TH} by measuring the open terminal voltage across the output terminals.

2. Measure the short-circuit current (I_{SHORT}) by connecting an ammeter between the output terminals. The equivalent resistance is found using:

$$R_{TH} = \frac{V_{TH}}{I_{SHORT}}$$

E. Draw the Thévenin equivalent of the voltage divider.

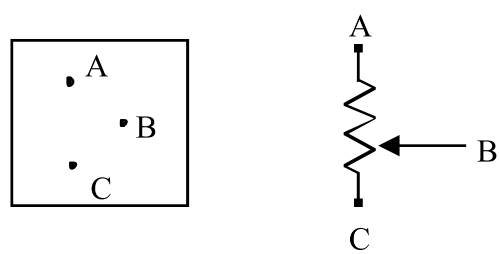
F. Connect a decade resistor box as a load resistor across the output terminals of the voltage divider. Measure the voltage across the load resistor (V_L) as a function of the load resistance (R_L) for several values from 1 kΩ to 1 MΩ.

G. Make a plot of V_L vs. R_L for your data. Add the theoretical curve to your plot; for this, use the actual values of R_1 and R_2 to set R_{TH} and the actual supply voltage.

Question: How does V_L change as the load resistance is increased? Approximately how large should R_L be compared to R_2 so that V_L does not change by more than 10% from its value with no load? (In other words, when does the voltage divider work well?)

1-3. Bridge Circuit

A. Potentiometers have three terminals. The arrangement for a typical potentiometer is shown below along with a schematic representation. Turning the small screw, called the "wiper knob" moves contact B up and down between contacts A and C.

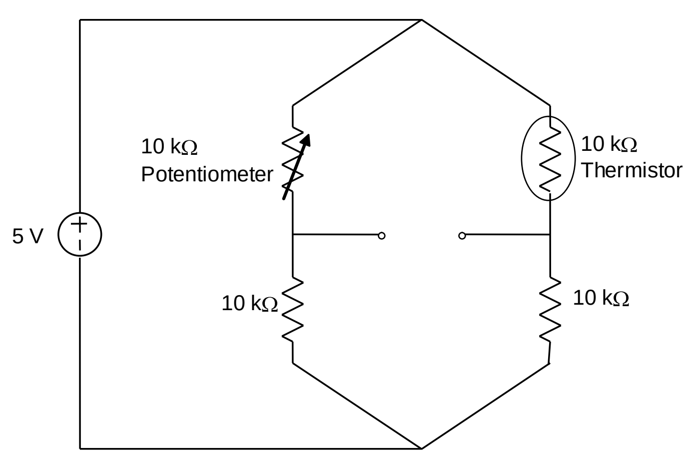


B. Using a DMM as an ohmmeter, measure the resistance between terminals A and C. Note any change as the wiper knob is turned. Repeat for terminals A and B noting which direction the resistance changes as the knob is turned clockwise and counterclockwise. Repeat for terminals B and C.

Note: If you are just using terminals A and B of a potentiometer, it is a good idea to connect the unused terminal (C) to the wiper (terminal B).

C. Attach an ohmmeter to a 10-kΩ thermistor. Warm the thermistor with your fingers and note what happens to its resistance.

D. Construct the following bridge circuit. The potentiometer should be wired as a variable resistor.

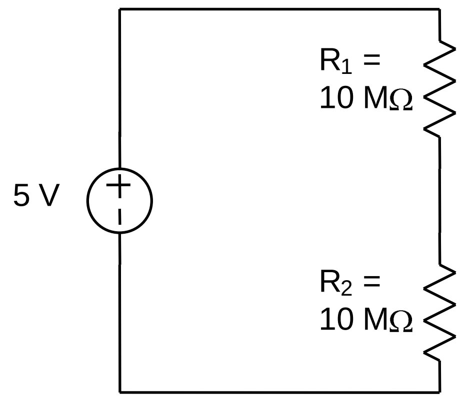


E. Connect a voltmeter across the middle of the bridge and adjust the potentiometer so that it reads very close to 0 Volts at room temperature.

Question: How should the voltmeter be connected (which terminal where) so that it gives a positive reading when the temperature increases and a negative one when the temperature drops? Experimentally check to make sure you're right.

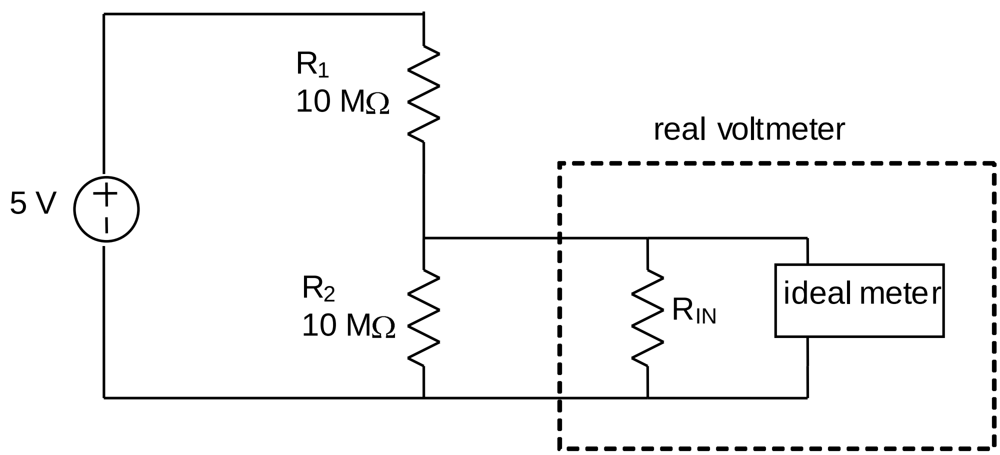
1-4. Input Resistance of a Voltmeter

F. Construct the following circuit. Use a DMM to measure the voltage across R_2.



Question: Is the voltage what you expect for an "ideal meter"?

G. Use the following circuit diagram as a model for the voltmeter. Note that a real meter has a resistive load referred to as the input resistance (R_{IN}). Use DMM's reading to determine its input resistance.

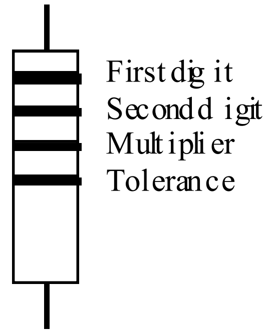


Question: How does the measured input resistance compare with the value given in the manual for the DMM?

Lab 1 Supplement

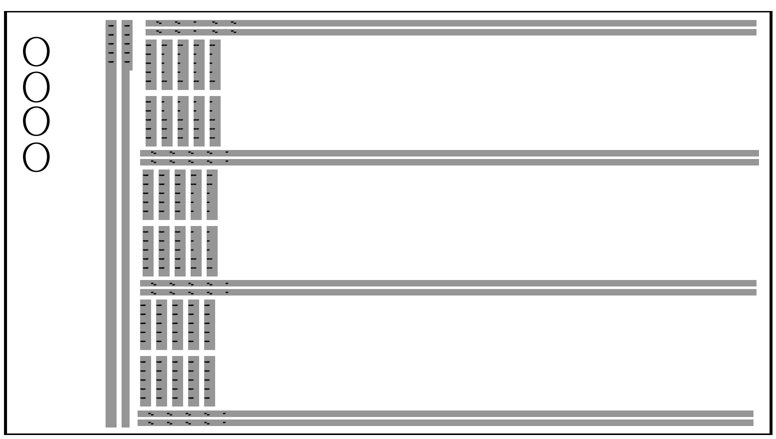
Resistor Color Code: (The colors from red to violet are those of the rainbow, excluding indigo.)

Color	Digit	Multiplier	Tolerance
Silver		$10^{-2} = 0.01$	±10%
Gold		$10^{-1} = 0.1$	±5%
Black	0	$10^{0} = 1$	
Brown	1	$10^{1} = 10$	
Red	2	$10^{2} = 100$	
Orange	3	$10^{3} = 1$ k	
Yellow	4	$10^{4} = 10$ k	
Green	5	$10^{5} = 100$ k	
Blue	6	$10^{6} = 1$ M	
Violet	7	$10^{7} = 10$ M	
Gray	8		
White	9		



Breadboard layout: The shading on the diagram below shows the connections between the "holes" in the breadboards that you will use.

- The four connectors on the side for banana cables are not linked to any of the holes on the breadboard. You must run wires to them if you want them to be linked.
- There are some variations for different brands of breadboards, so don't assume they are all like this! Often the longer "bus" strips have a break in the middle.



Hints about circuit construction:

1. Connect the ground to a bus strip below your circuit and the positive supply to a strip above it. When you get to circuits that include a negative supply, connect that to another row on the bus strip below the circuit.
2. When possible, try to build circuits so that they look like the circuit diagrams that you are following.
3. Connect meters after completing a circuit, but remember that an ammeter must be inserted "into" a circuit.
4. Use color-coding to help you keep track of your wiring: black for ground, red for positive, green for negative. This will become more important as circuits get more complicated, but it is a good habit to develop with simpler circuits.

Hints about using a digital multimeter (DMM):

1. Be sure the leads are connected correctly for the mode that you are using.
2. When using a DMM as an ohmmeter, only make measurements for a single resistor that is not in a circuit. Do not try to measure the resistance with current running through a resistor.
3. The most common ways to damage a digital multimeter are:

    a. Placing the meter in parallel with a power supply when it is in current-measuring mode will blow a fuse. If the reading in current mode is zero, the fuse may be blown.

    b. Trying to measure a voltage out of range for the meter can permanently destroy a meter.