Physics 313 Lab 1: DC fundamentals

Objectives:

- look at the current-vs.-voltage characteristics of some ohmic and non-ohmic devices
- investigate the effect meters have on a circuit
- use and design voltage dividers
- see how Thévenin equivalents work
- use the voltage divider technique to determine unknown impedances
- develop good breadboarding technique

1-1. Ohm's Law

You will be given a black box, inside of which is a two-terminal device. Your goal is to determine the current as a function of applied voltage (DC) for the device over a voltage range of about +/- a few Volts. Use a variable DC power supply to apply the voltage, and two digital multimeters (DMM), one used as an ammeter and one as a voltmeter. Note that you have a choice of how to connect the meters; either the voltmeter can measure what you want (V across the device only), or the ammeter can measure what you want (I through the device only), but it's not possible to have both simultaneously measuring what you want. Therefore, be sure to sketch (schematically) how you have them hooked up. In the next section, we'll explore what effect the presence of one meter in the circuit has on the other.

Take a number of measurements between few volts on either side of zero (+/- 5 V is good unless the box is marked with a lower value). Make a rough graph of your data (I vs. V) in your logbook **as you go along**, so that you know if there are regions where more data would be helpful.

Summarize: Is the component in your black box described well by Ohm's Law, at least over the range you've measured? Why/why not?

Discuss the results as a class, and then open up the black boxes to see what's inside.

1-2 Effect of test instruments on measured values

Remember that an ideal ammeter has zero internal resistance and an ideal voltmeter has infinite internal resistance. Because our meters are not ideal, we need to have some idea of how much their internal resistance might affect measurements made with them.

To investigate this question, we're going to use Ohm's Law to determine the resistance of a 10k resistor by measuring current and voltage with different configurations of the meters. Before you start, you might want to use the appropriate functions of one of your DMMs to determine the resistance of your particular 10k resistor more precisely than you can by reading the color code.

Start with one meter measuring voltage across **only** the resistor, with the other meter measuring the current (does it matter whether the current meter is placed before or after the resistor?). Use the breadboard to lay out your circuit. Set the output of the variable power supply to about 1 V.

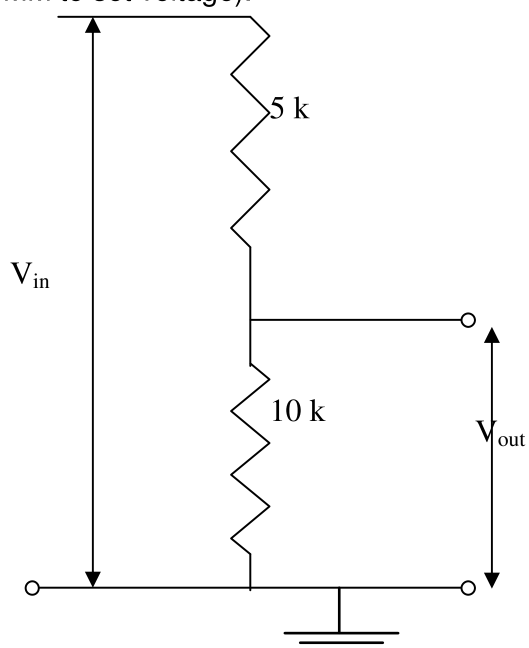
Record the measured current and voltage, as well as the scales the meters are on. Now change the voltmeter scale and record the values again. Change the voltmeter scale back to the original one, and try a different current scale; record the values.

Repeat with the voltmeter across both the resistor and the ammeter, so that the ammeter is now measuring the current through only the resistor. Use several different scales for both meters.

Figure out R in each case (no need to do a formal error analysis, but round your results reasonably). Compare each result to the known value of R.

Summarize: Summarize your findings.
How would you arrange the meters if you wanted your measurements to be as accurate as possible?
Why might it be a good idea to record the scale a meter is on when making a careful measurement?

1-3 Voltage dividers
Construct the voltage divider shown below. Use the breadboard +15 V supply to supply V_{in}. (use DMM to set voltage).



Measure the open-circuit output voltage V_{oc}. Attach a 10k load across the output and measure the output voltage again. Compare the results with what you expect (be quantitative).

What do you predict will happen if a larger load resistance is used? Choose a larger resistor and try it. Do the results agree with what you expect? Make sure this makes sense before going on.

Summarize: What's the relationship between V_{out} and V_{in} for a voltage divider with no load? How does V_{out} change when a load is attached? Does a load with large resistance (as compared to R_1 and R_2) affect V_{out} more, less, or the same as a load with small resistance?

1-4 Thévenin equivalent circuits
Now let's find the Thévenin equivalent of the circuit in the previous section (the unloaded voltage divider). That means we need to find V_{TH} and R_{TH} for that circuit. You know V_{TH} (the open-circuit) voltage already (right?). To find R_{TH}, we need the short-circuit output current I_{SC}. To find it, remove the load resistor from the voltage divider and measure the I_{sc} by "shorting" the output to ground through a current meter. This isn't a true short, but a good current meter is supposed to have very small resistance (and we'll check that in the next section). (Aren't short circuits always bad?? Why is shorting the output ok here?)

From V_{TH} and I_{sc} you can calculate the Thévenin equivalent circuit. Build that equivalent circuit, using a variable power supply or the variable +V supply on the breadboard as the voltage source, and whatever other components you need. Measure the open-circuit voltage and the short-circuit current of the equivalent circuit. Are they the same as those of the original circuit?

Now attach a 10k load and measure the voltage across it. Does the Thévenin equivalent act the same as the original circuit under load?

Summarize: What specifically does it mean to say that the Thévenin equivalent circuit is the equivalent of the voltage divider?

1-5 Impedances of test instruments

In 1-3, you constructed a voltage divider and used the known resistances to predict V_{out}. The same type of circuit can be used to determine an unknown resistance, by making the unknown resistance part of a voltage divider with a known resistance and then measuring V_{out}. Will this type of measurement be most accurate if you use a known resistance much larger than, about equal to, or much smaller than the unknown resistance? Why?

Use this idea to determine the resistance of the BK meter in voltage mode on a given voltage scale (be sure to explain how you're doing this, and record the raw data as well as the results). Change scales and repeat. If there's time, do it again for the BK meter in current mode.

Summarize: Summarize and explain why your results do or do not make sense, given what you know about the properties of ideal meters and the documentation for the BK meter.

1-6 Design problem: voltage divider

Design a voltage divider that will produce 3.5 V from a 15 V supply, and that will maintain that output voltage to within 3% when loads with resistance in the range 10k to 100 k are attached.

Set up your circuit. Before hooking up the power, calculate the power you expect to be dissipated in each resistor and make sure that you won't exceed the ¼ watt rating for any of the resistors. See me if you think you will.

Test your circuit to make sure it works as you expect. Be sure that you take and record appropriate data to verify that it meets the specifications you were given.