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EECS40 Lab
Introduction to Lab: Guide

Objective
The student will use the following circuit elements and laboratory equipment to make basic circuit measurements: Resistors, Breadboards, multimeters (DMM), and Power supplies.

Theory
a. Resistor

A resistor is schematically shown in Fig. 1. Its characteristic equation or "terminal relation" is given by Ohm's Law:
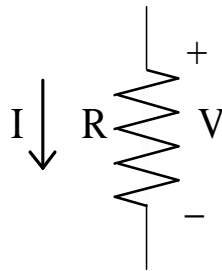
$$V = IR$$

Figure 1

A potentiometer (pot) is a 3-terminal variable resistor. It has a constant resistance between pins 1 & 3 (see Figure 2) and the knob controls the resistance between pins 1 & 2 and 2 & 3.
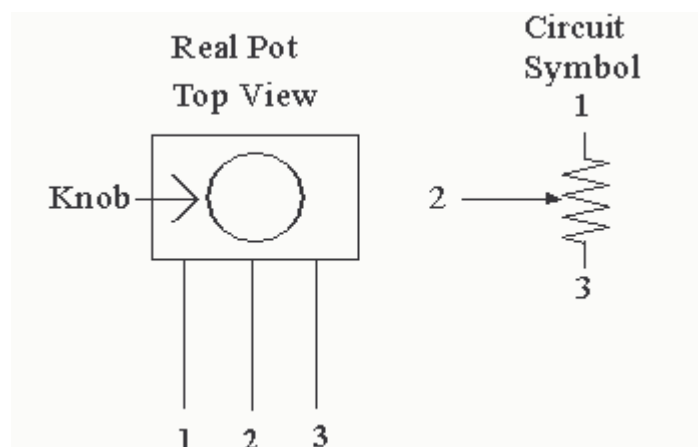
Figure 2

b. Voltage source: Its one characteristic is that the voltage across its terminals is always *V* volts, no matter what the current going through it is.

c. Current source:. Its one characteristic is that the current through it is always *I* amps, no matter what the voltage across it is.

d. Series and Parallel connection (see Figure 5 and Figure 6 respectively)

This is when the devices are connected in such a way that both devices have the same current flowing through them.
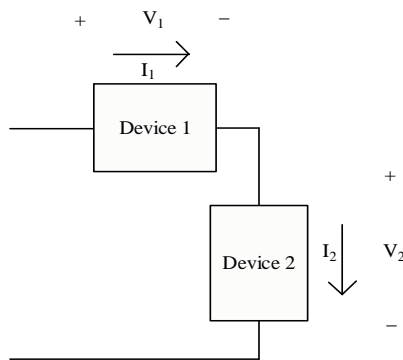

Figure 5

$$I_1 = I_2$$

Parallel connection is when the devices are connected in such a way that they have the same voltage across them.
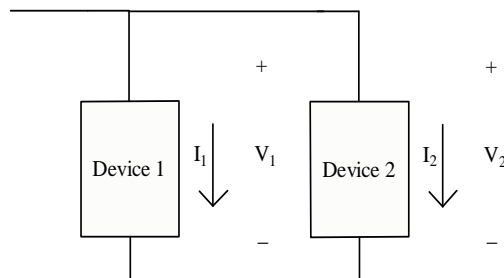

Figure 6

$$V_1 = V_2$$

e. Resistors connected in series (see Figure7)
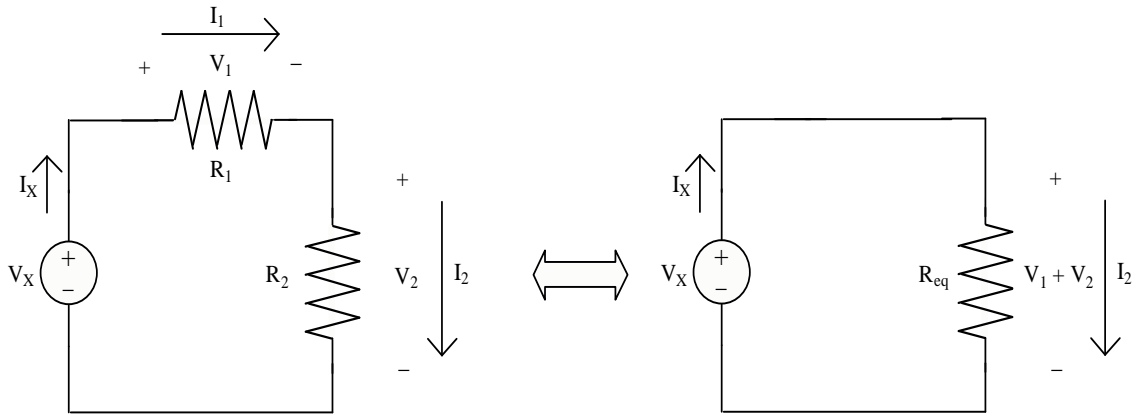

Figure 7

$$I_x = I_1 = I_2$$

$$V_x = i_x R_1 + i_x R_2$$

$$\frac{V_x}{i_x} = R_{eq} = R_1 + R_2$$

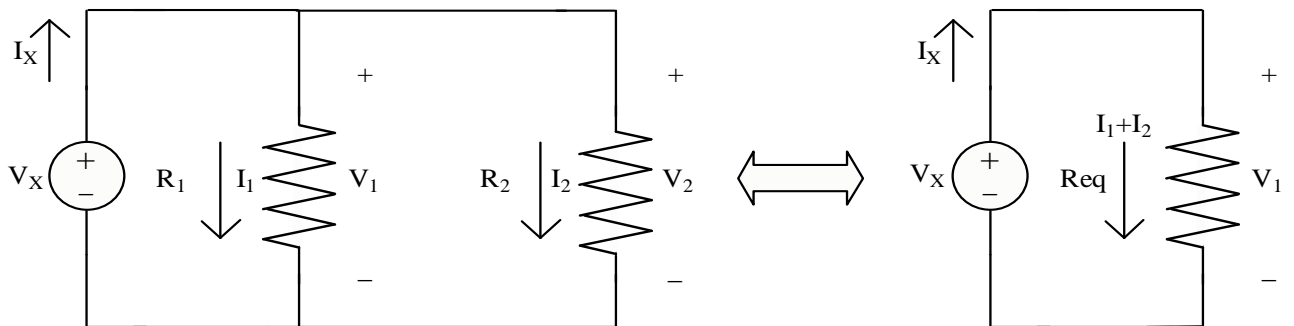f. Resistors connected in parallel (see Figure8)

Figure 8

$$i_1 = \frac{V_x}{R_1}, i_2 = \frac{V_x}{R_2}$$

$$i_x = i_1 + i_2$$

$$i_x = \frac{V_x}{R_1} + \frac{V_x}{R_2}$$

$$\frac{1}{R_1} + \frac{1}{R_2} = \frac{i_x}{V_x} = \frac{1}{R_{eq}}$$

g. Voltage divider (see Figure 7)

$$V_x = i_x R_1 + i_x R_2$$

$$V_1 = i_x R_1, V_2 = i_x R_2$$

$$\frac{V_2}{V_x} = \frac{i_x R_2}{i_x (R_1 + R_2)}$$

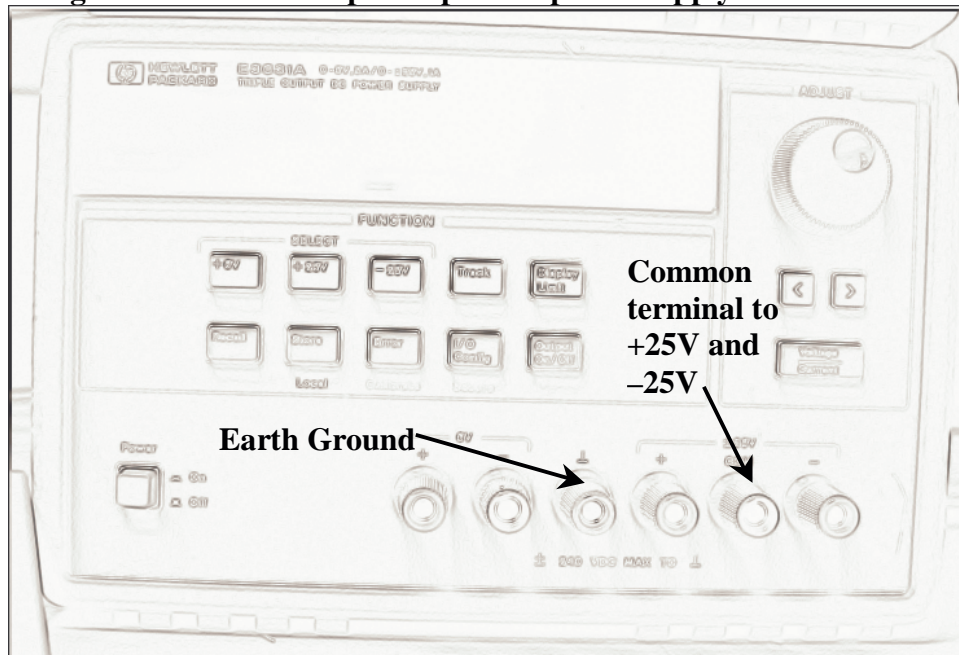$$V_2 = V_x \frac{R_2}{R_1 + R_2}$$

$$V_1 = V_x \frac{R_1}{R_1 + R_2}$$

Experiment

First, pick up the following small items:
1. Wires for the breadboard
2. Wires with Alligator clips and Banana plugs
3. Two 1 k resistors
4. One 10 k potentiometer

Using the HP E3631A triple output DC power supply

Like a battery, a DC power supply provides a constant voltage for powering electronic circuits. But, unlike a battery, the power supply will provide continuous power as long as it is connected to a wall outlet. Furthermore, you can set the voltage of the supply and set the maximum current (the current limit feature) that can be drawn from it. The DMM will NOT output a value of current greater than the set limit. It may adjust the output voltage to match this maximum value of current. This is useful when you know beforehand that your circuit cannot tolerate more than a certain current or power. Setting current limits is described further below.

The HP E3631A triple output DC power supply contains three variable voltage sources, with maximum voltage values of +6V, +25V, and -25V. The 6V supply operates independently of the +25V and –25V supplies, which share a common terminal. (Look at figure 8 and try to spot the buttons for the three voltage settings). To a certain limit, all three voltage sources can be connected independent of earth ground, which is actually connected through the building wiring to the earth.

The concept of ground is **VERY IMPORTANT.** A ground node is a piece of wire designated by a human to be the voltage reference for other nodes. Thus, with reference

to itself, the ground node is at 0 volts. If a node is at "236 volts", we must assume it is 236 volts above the ground node. On the power supply, there is only ONE ground terminal by default: the green "earth ground" terminal. None of these terminals is automatically functioning as a your circuit ground unless you explicitly connect one of these to all the ground connections indicated in your schematic. Schematics often use implied ground references, so until you become accustomed to them, you may redraw the schematic with all wiring explicitly shown by lines. A schematic view of the terminals of the DC power supply is shown below.
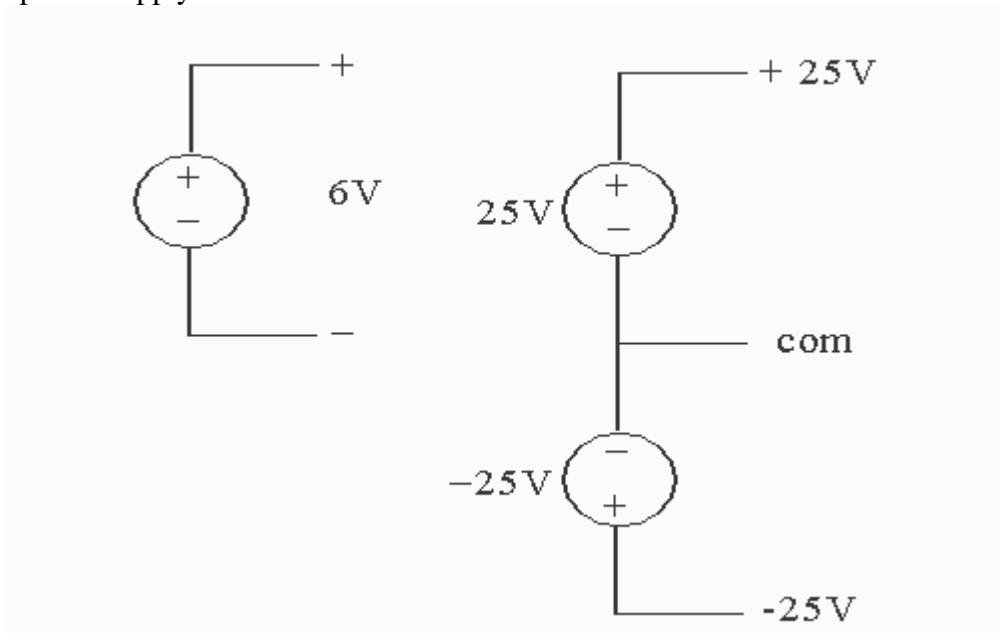

Figure 10

Try using the triple-output power supply:
1. Disconnect the power supply from a circuit and turn it on.
2. The supply will startup with outputs off. You can toggle the output by hitting the output on/off key. The display will say OUTPUT OFF when all outputs are off, otherwise it will display the output voltage and current of an output.
3. Select which source you would like to set, the +25V, the –25V or the +6V by hitting the corresponding key on the supply. The supply you have selected will be displayed along the bottom of the display screen.
4. Now, set the voltage and current limits. Hit the display limit key. You will know that you are changing the limit because LMT will be displayed along the bottom of the display.
4. Select to set the voltage or current limit by hitting the voltage/current key. The one that is blinking is the one that you are editing.
5. When done setting the limits, hit the display limit key again to return to displaying the actual output.
6. Turn the output on once you have connected the supply to the circuit.

Follow the above steps to power a very simple circuit: a short circuit. Take a wire with banana plug ends and put end into the +25 V output; put the other into Common. Set the voltage limit to 5 V and current limit to 100 mA. Turn the output on and explain why the current and voltage are limited.

Using the Digital Multi-meter (DMM)

The HP 3401A is a digital multi-meter (DMM) that will be extremely handy in making basic electrical measurements including voltage, current, resistance, and continuity.

When you first turn on the DMM, it is set to measure DC voltage across the two input terminals labeled V (figure 12). Other measurement functions are accessed from the front panel buttons and many functions are available using the blue-gray shift key (figure 12).
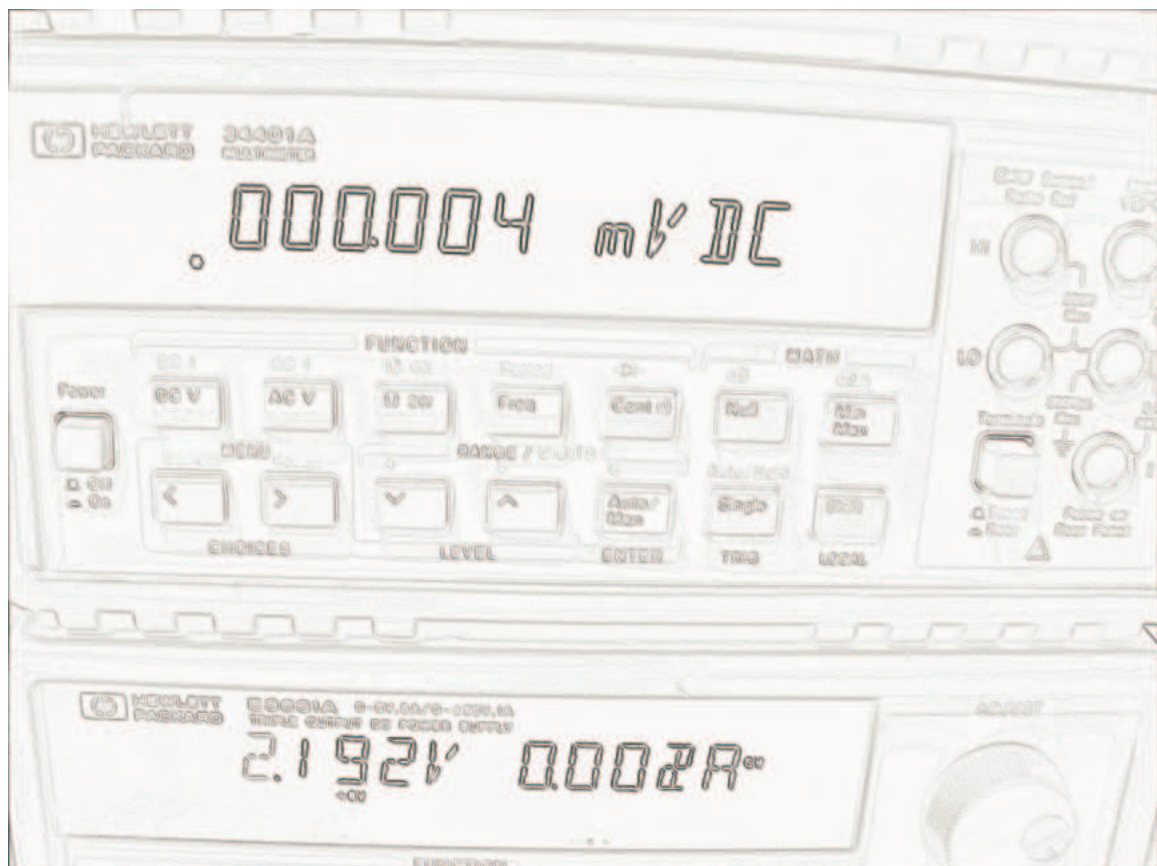

Figure 12

Here are some rules on how to use the DMM (also refer to the DMM User's Guide). So, while you might be able to figure out how to use most features of the DMM yourself, the User's Guide will come in handy for understanding some of its other less-known capabilities.

1. When measuring voltage (DC and AC) across an item, the measurement is made with the meter in PARALLEL with the item (Device Under Test (DUT) in figure 12(b) below). The DMM is said to be acting as a "voltmeter" (see figure 12(b) below). Put the DMM probes in parallel with a voltage source and note whether the DMM measurement agrees with the source display.
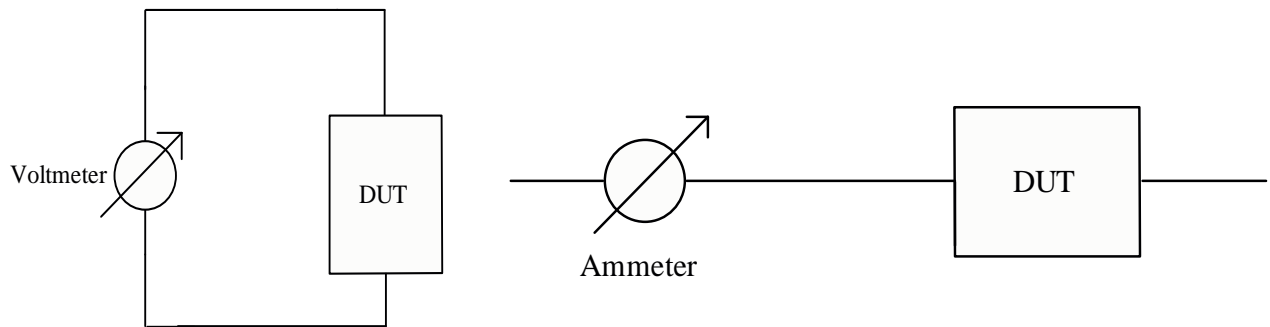

Figure 12 (b)

2. When measuring current (DC and AC) through a circuit wire, the wire must be replaced by the DMM in ammeter mode. Ideally, ammeters have zero resistance and the exact current you want to measure flows through it. Some ammeters measure the voltage across a known near-zero internal resistor and use Ohm's law to compute current. Since ammeters have low-resistance, please do not put an ammeter in series with a voltage supply.

3. When measuring resistors (or pots), you must first unplug the component from the circuit. Otherwise, some of the DMM probe current will also run through circuit paths other than the resistor.

4. The DMM also has a continuity tester mode. It checks if two nodes in your circuit are connected (short circuit) or not. Your DMM will beep if the resistance between the two nodes falls below 50 ohms indicating a potential short circuit. To access this feature, hit the "Cont" button. Try touching the probes together.

The breadboard

A photograph of a section of the breadboard (or protoboard) is shown below.
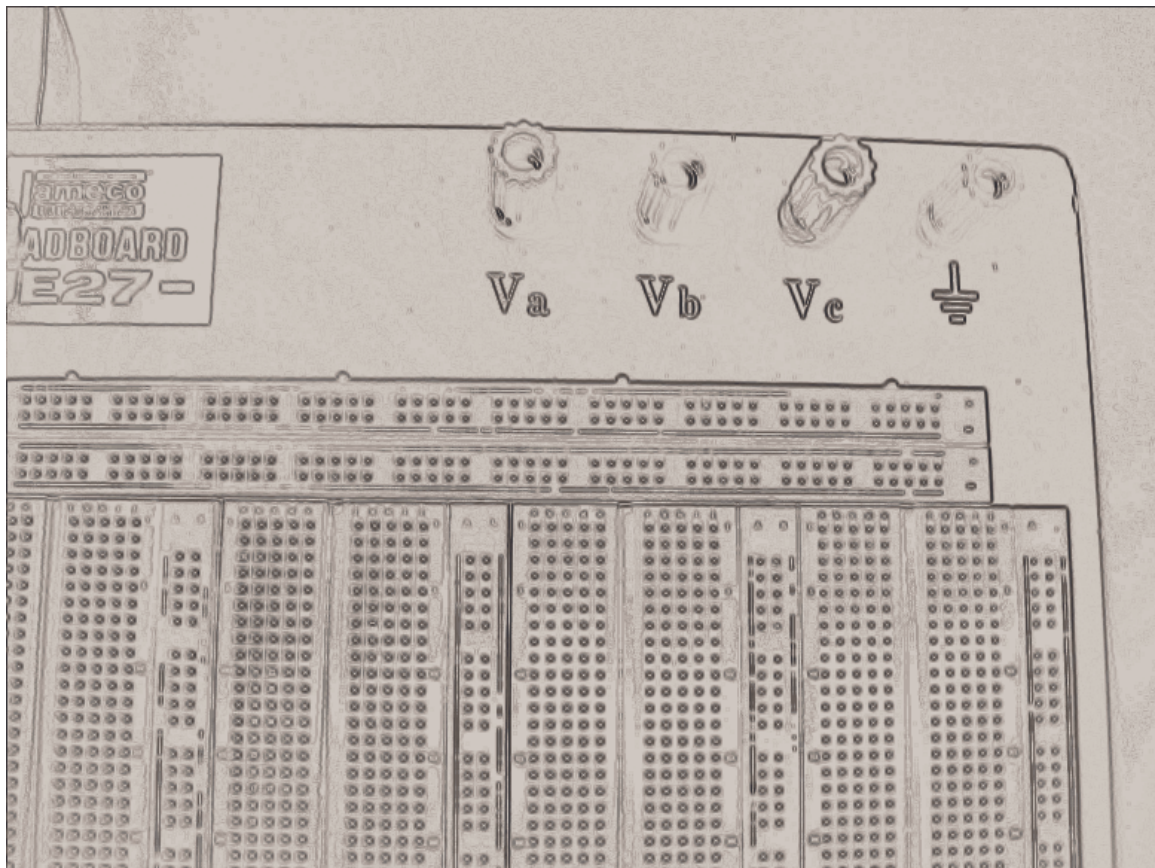
This type of breadboard is very useful for prototyping circuits that use integrated circuits in DIP packages. The IC will straddle the white line between columns e and f. Underneath the breadboard are pieces of metal that will serve as wires in your circuits. In the main section, these wires connect rows of five: from columns a through e, and separately columns f through j. The other useful type of wiring is called "bus wiring". A bus wire runs the whole way along the blue line (A) and another separate wire runs the whole way along the red line (B). Use these "buses" for ground, power, and any other signal that must be accessed from many parts of the circuit.

There are also four binding posts at the top of the board that are not connected to anything yet; you must route a wire from the breadboard to the post and use the post to connect that node to other devices like the power supply, meters, or signal generator. These are provided for your convenience; always look for ways to make your life easier in the lab by using the available connectors, probes, and equipment.
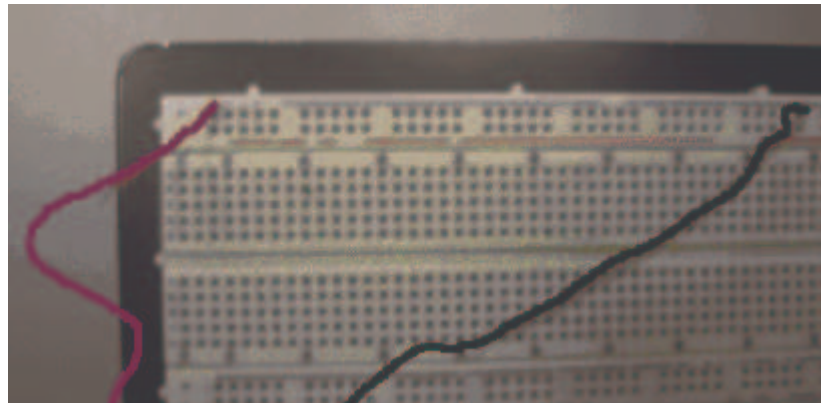
a. Stick two wires into the breadboard as shown. You may need to strip them using the wirestrippers on your workbench. Use the continuity tester in the DMM to determine if the two wires are connected.
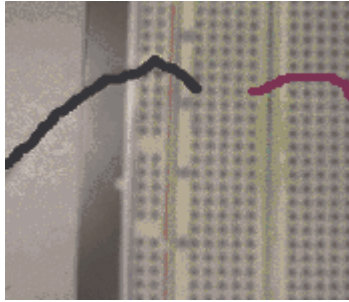
b. Repeat part (a) for the following wiring.
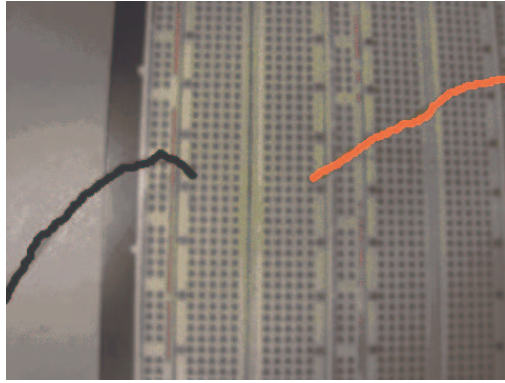
c. Repeat part (a) for the following circuit.

Now use the DMM to measure power supply voltages:
   a. Turn on the power supply and the DMM. Set the DMM to measure DC voltage. Adjust the 6 V output to 5 V, then adjust the +25 V output to 14 V.
   b. Measure the two voltage values using the DMM.

Use DMM and breadboard to measure some resistors:

a. Plug the ends of the resistor in the breadboard such that the resistor is not shorted. Measure the resistance of the 1 k resistor using the DMM.
b. Plug the wires of the pot anywhere into the breadboard where they will not be shorted. Measure the resistance between the outer two legs of the pot.
c. Measure the resistance between the middle leg and any of the outer two legs of the potentiometer using the DMM.

Make some measurements on a series resistor circuit:
a. Build the circuit below on your breadboard. Set V_x to be 5 V and $R_1 = R_2 = 1$ k.
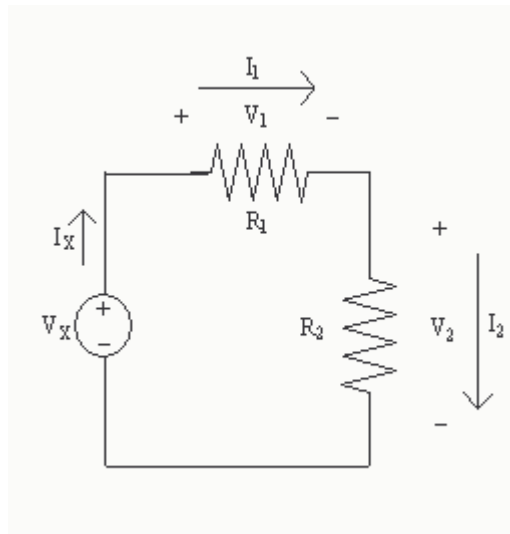
b. Measure the voltage across R1. Then replace the wire comprising the node shared by Vx and R1 with the DMM as ammeter. Measure the current through R1.

Now for some measurements on a simple parallel circuit:
a. Build the circuit shown below. Set V_x to be 7 V and $R_1 = R_2 = 1$ k.
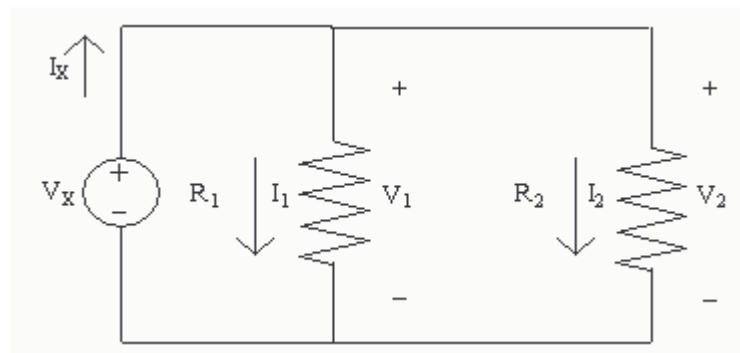
b. Measure the voltage across R2. Then measure the current through R2 using the DMM. Remember to insert the DMM in series with R2.