Meters, DC sources, and DC circuits with resistors

0. Prior to lab
Read through the lab and do as many of the calculations as possible. Then, learn how to determine resistance values using the color codes. There are dozens of web sites that show how to determine resistor values (or do it for you). Here are two, but feel free to use others.

http://en.wikipedia.org/wiki/Electronic_color_code
http://www.dannyg.com/examples/res2/resistor.htm

1. Source and meter tutorials
The lab instructors will give short tutorials on the use of the DC voltage sources and multi-meter, as well as tips and techniques for wiring circuits on the breadboards.

2. Resistance measurements
Remove 20 resistors at random from your kit. Read the value of each from its color codes. Then measure the resistance of each with the multi-meter. Make a table listing the expected resistor value as given by the color code, the measured value, and the percentage difference. (It’s OK to use some resistors that have the same nominal value.) Hint: To work efficiently, put all 20 resistors into the breadboard. Then go down the line reading the color codes and measuring the values.

3. Some resistor destruction
Now, we will participate in bit of component vandalism. The lab instructors will hand out some resistors. These are rated for \( \frac{1}{4} \)-watt of power dissipation (as are most of the resistors in our lab kit). Read the nominal values from the color codes, and measure the value with the ohm-meter. Connect the resistor directly to the 25-V supply using your circuit board. Start with the supply at zero volts and begin increasing the supply in 1-V increments. At each step, calculate the current flowing through the resistor (using Ohm’s law) and the power being dissipated by the resistor. As you increase the power dissipation, note the following: (a) the point at which you can feel the resistor becoming hot with your finger (BE CAREFUL: You can burn yourself on a hot resistor. Once you feel it becoming hot, do not touch it again!), (b) the point at which you can smell it becoming hot, and (c) the point at which it burns out. Remember the heat and the smell. In the future, when you feel hot components or can smell melting plastic, bad things are probably happening, and it might be wise to turn off the power supply to your circuit as quickly as possible. If you need to dissipate higher powers in resistors, you must use components with higher power ratings. Of course, higher power resistors are more expensive. Controlling thermal energy is a big part of practical electronic circuit design. (Note the big heat sinks attached to the microprocessors on your computer’s motherboard.)
4. Equivalent resistances
For each of the simple resistive circuits shown below in Figures 1 and 2:

a. Build the resistor network as shown in the first part of each figure.

b. Calculate the equivalent resistance of the network with respect to the two terminals. Use the nominal values of the resistors.

c. Use the ohm-meter to measure the equivalent resistance at the two terminals.

d. Connect the voltage source to the resistor network as shown, with the voltage set to the listed value. Connect the ammeter in series with the source.

e. Turn on the voltage source and measure the source current with the ammeter.

f. Turn off the source and remove the ammeter from the circuit. Reconnect the source to the circuit.

g. Turn the source on again. Use the voltmeter to measure the voltage across resistor $R_1$, and calculate the current through $R_1$. Of course, this is the source current and should have the same value as measured above using the ammeter.

h. Calculate the expected value of the source current and compare to the measured values. Calculate the power being generated by the source, which is the same as the power being dissipated in the resistors.

Figure 1.
(a) Resistor network to be measured with ohm-meter. (b) Same network with voltage source attached.

Figure 2.
(a) Resistor network to be measured with ohm-meter.

(b) Same network with voltage source attached.
5. Dividers

Build the simple voltage divider circuit shown in Fig. 3. Using the voltmeter to measure the voltages across the source and across each of the three resistors. Use a voltage divider calculation to determine the expected voltage across each resistor. Compare the expected values to the measured values.

![Figure 3. Voltage divider circuit.](image)

Next, build the simple circuit shown in Fig. 4, which contains a three-branch current divider.

Use the ammeter to measure the current from the source and the current through each of the resistors $R_2$, $R_3$, and $R_4$.

Then use the voltmeter to measure the voltages across each of the four resistors, and use Ohm’s law to calculate $i_S$, $i_{R2}$, $i_{R3}$, and $i_{R4}$.

Calculate the equivalent resistance of the entire resistor network, and use the result to calculate the expected source current. Use a current divider calculation to determine the expected current through each resistor. Compare the expected values to the measured values.

![Figure 4. Current divider circuit.](image)
6. Limitations in using the voltmeter

Build the simple two-resistor voltage divider shown in Fig. 5. Note the very large values of the resistors being used.

![Figure 5](image_url)

Measure the voltage across each of the resistors. Use a voltage-divider calculation to determine the expected values. (It should be a trivial calculation.) In comparing the measured results to the expected results, you should see an obvious discrepancy.

What is going on? You are seeing an non-ideal effect of the meter. When you connect a meter (voltmeter, ammeter, ohm-meter, or whatever) into a circuit, you are adding another component to the circuit — the presence of the meter changes the circuit. If the meters were ideal, they would have no effect. But they are not ideal, and in some circumstances, those non-ideal aspects show up in your measurements. An ideal voltmeter or ohm-meter should behave like a true open-circuit (infinite resistance), with no current flowing into the meter itself, but, in practice, there will be a small trickle of current. So when we use the meter to measure a voltage, a tiny bit of current is drawn off from the rest of the circuit. We can represent this as an effective resistance (or input resistance) of the meter, and it is usually in the range of several mega-ohms.

Use the results of the measurements from the divider circuit to Fig. 5 to calculate the effective resistance of the voltmeter.

7. Limitations in using the ammeter

Build the simple current divider circuit shown in Fig. 6.

![Figure 6](image_url)

Use the ammeter to measure \( i_S \) and then the currents in \( R_1 \) and \( R_2 \). The measurements won’t seem to make much sense with Kirchhoff’s current law. Again, this happens because the ammeter is not ideal. In the case of the ammeter, which must be connected in series with a
branch of the circuit, the ideal behavior would be that of a perfect short circuit – current would flow through with no voltage drop. However, in a real ammeter, there will be a small voltage developed across the terminals, and so the ammeter acts as if you connected a small value resistor in series with the other components in the branch. The effective resistance of a typical ammeter is in the range of a few tens of ohms.

Use the measurements from Fig. 6 to calculate the effective resistance of the ammeter.

Measure the current in each branch again, using the “voltmeter + Ohm’s law” method. The measurements should make sense this time. Explain why the indirect method of measuring the voltage seems to work, when the direct method of measuring the current did not.

8. Potentiometers
At the beginning of second lab period, the instructors will explain the operation and use of potentiometers (variable resistors). Let’s play with them a bit.

a. Plug a 10-kΩ potentiometer into your breadboard. Note carefully the position of the 3 pins.

b. Use the ohm-meter to measure the resistance \( R_T \) between the outer two pins.

c. Use the trimming screwdriver to set the potentiometer dial about half-way between the two extremes. Measure the resistance between the left-hand pin and center pin \( (R_1) \). Then measure the resistance between the right-hand pin and the center pin \( (R_2) \). Confirm that \( R_1 + R_2 = R_T \).

d. Repeat the measurements / calculations of part c for three other settings of the potentiometer dial.

e. Connect a 5 V DC voltage across the outer two pins of the potentiometer. Set the potentiometer dial so that it is about half-way between the two extremes. Use the voltmeter to measure the voltage across \( R_1 \) and \( R_2 \). Add the voltages to confirm that the potentiometer is functioning as a voltage divider.

f. Repeat the measurements of part e for three other settings of the potentiometer dial, showing that the potentiometer can be used as a variable voltage divider.

Reporting
Each lab group should prepare a written for the work done in this lab. A template for the report can be downloaded from the web site. Be sure to include all of the measured data, calculated values, and answer all of the questions. To complete the report, add an introduction and a conclusion (about one paragraph each).