Chapter 1

DC circuits

1.1 Objectives

- Practice putting together simple electronic circuits.
- Learn to use voltmeters, ammeters, and ohmmeters.
- Quantitatively establish the relationship between current and applied voltage for an ohmic resistor and a light bulb.
- Measure the resistance of a number of resistors connected in series and in parallel.

1.2 Equipment

- DC power supply (0-6 V, 1 Amp)
- light bulb and assorted resistors
- 2 hand-held digital multimeters

1.3 Circuit diagrams

Before actually connecting the components of your circuit, draw a diagram indicating the current flow and polarities in your notebook. Draw it in the style of the diagrams in your textbook, and using the same symbols for the power supply, resistors, and meters. For the measurements in parts A and B of this lab, the main circuit is shown in Fig.1.1. You will want to put meters in this circuit, in order to measure the current through the resistor R and the voltage across it. Include them in your drawing now, as in Fig.1.2.

The + and - signs in the diagram indicate how the terminals of the meters have to be connected. Current has to flow from + to - within the meters

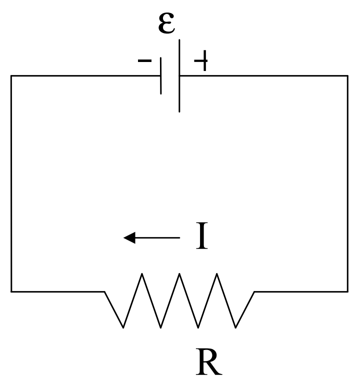

Figure 1.1: Schematic diagram of a simple circuit.

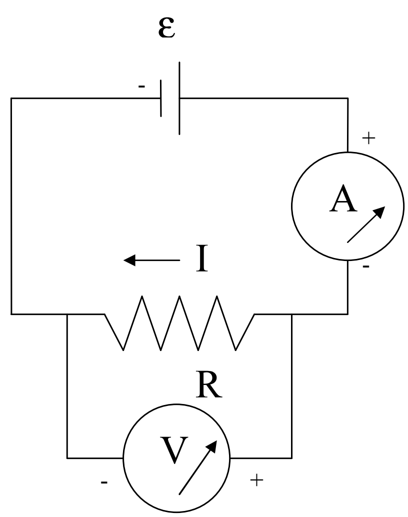

Figure 1.2: Simple circuit with voltmeter and ammeter.

when measuring current. Therefore the positive terminal of the multimeter is connected to the positive terminal of the power supply. The current in the multimeter runs parallel to the current in the resistor, and the meter is connected accordingly.

How would the multimeter be connected if you decided to insert it in the left-hand side of the circuit in Fig.1.2? Make a sketch in your notebook.

1.4 Part A

Circuit setup

Make sure that the power supply is unplugged or turned off and the voltage knob is turned all the way counterclockwise. Get a supply of leads from the test lead holder and connect the main circuit as outlined in Fig. 1. The resistor should have a value of nearly 50,000 Ohms-that is: the third band should be yellow or orange. For help in selecting the proper resistor, see the section on resistor color codes. Then connect the multimeters as shown in Fig. 2. Make sure that the function selection switches are properly set. For the multimeter with which you will measure the voltage across the resistor, you should turn the knob on the front face so that it reads DC volts, as opposed to AC volts. For the multimeter with which you will measure the current through the circuit, you should turn the knob on the front face so that it reads DC milli-amperes or microamperes. For both devices, you may need to adjust the range setting so that it does not go off scale while reading. Also, for both devices, you need to be sure that the leads are plugged into the correct jacks on the front of the device.

Now turn on the power supply and slowly raise its output voltage up to the maximum desired value by turning the voltage selection knob clockwise. You will want to set your multimeters so that they have maximum sensitivity but so that they do not go off scale. If a meter goes off scale, change the range setting. Now you are ready to begin your measurements. The value of the voltage setting on the power supply may not exactly match that read by the multimeter; trust the multimeter rather than the power supply.

Measurements

Record the resistance value from the color bands of the resistor. Measure the current through the resistor at 6 voltage values between 0 and 15 volts. Again, be sure the multimeter is set to measure voltage!

Analysis

According to Ohm's law, the resistance of a resistor is given by the formula $V = IR$. So make a plot of V vs I and determine the resistance of the resistor from the slope of the graph (R_{slope}). You should make sure that you convert to volts and amperes before plotting your data, so that the slope gives your resistance in Ohms. Be sure to label the axes correctly, including units.

There is one complication here. The current measured by the multimeter does not all flow through the resistor; it is divided up between the parallel combination of the resistor and the voltmeter, whose resistances are R and respectively. Thus, we have been overestimating the current which is flowing through the resistor. Assume the resistance of the voltmeter is 10 MΩ. Use your value of R_{slope}, which you measured, and the formula $R_{slope} = R_v R/(R + R_v)$ to calculate a corrected value of R. You will need to do some rearranging of the above formula to solve for R in terms of R_{slope} and R_v. Does your value of R agree with the resistance indicated by the color bands on the resistor within the tolerance of the resistor?

1.5 Part B

Circuit setup

Circuit B is identical to circuit A, except that the resistor is replaced by a light bulb. The light bulbs we are using have a very small resistance, so they will probably draw too much current from your power supply. To prevent this, you should insert a small (*e.g.* 10 Ohm) resistor *in series* with the light bulb as a current-limiting resistor.

Measurements

Using a galvanometer and a multimeters, measure the current through the light bulb and the voltage across the light bulb for about 8 voltage values between 0 and 4 volts. Be careful to not use too much current, or you are likely to burn out the bulb.

Analysis

Again, plot V vs I. Add two more columns to your data table. In the third, calculate V/I, which is the resistance; in the fourth, calculate the power dissipated in your light bulb, which is given by the formula $P = IV$. What trend do you observe in the resistance? Is the resistance constant? Why or why not? In the dissipated power?

1.6 Part C

Circuit setup

In this section, you will use the multimeter as an ohmmeter. When you turn the function switch to Ω, the terminals of the meter are connected to a battery which is inside the meter. Touch the test leads together; it should read zero.

Various sensitivities for measuring resistances are provided. When using any of these, you have to always check the zero first. When you place a resistor across the test leads, you have effectively constructed the circuit shown in Fig.1.3. The components within the dotted line are within the multimeter, where is a current limiting resistor selected by the range selection switch. It should be obvious that changing scale (i.e. changing) necessitates a readjustment of the meter.

Measurements

You should measure the resistance of series and parallel combinations of three small resistors. Select three carbon resistors, labelled in color code, between 10 and 90 Using the proper sensitivities of the multimeter and calibrating the meter each time for , measure:

1. The resistance of each of the 3 resistors by itself.
2. The resistance of the series combination.
3. The resistance of the parallel combination.

Please turn off the multimeter when you are finished with it so that the batteries are not depleted.

Analysis

Calculate the expected resistance of the series and parallel combination of the three resistors and compare with your measured values.

1.7 Resistor Color Code

Commercial resistors for use in electronic circuits look like tiny solid cylinders with a wire at each end. They are usually labelled with colored bands that tell the approximate value of the resistance. The rules for reading this color code are as follows:

- First band (nearest the end) gives the first digit
- Second band tells the second digit
- Third band tells the number of zeros following the second digit
- Fourth band tells the tolerance

For instance, if the bands are successively green, brown, red, and gold, the resistance is presumably 5100 250 ohms. If the colors are gray, red, black, and silver, it is 82 8 ohms. If the colors are orange, white, green and gold, it is 3.9 million ohms 5

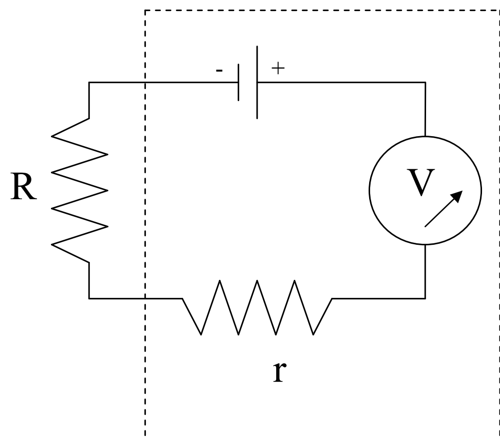

Figure 1.3: Circuit diagram for measuring resistance.

black	0	blue	6
brown	1	violet	7
red	2	gray	8
orange	3	white	9
yellow	4	silver	±10%
green	5	gold	±5%

Table 1.1: Resistor color codes