Experiment 6: Simple Circuits

OBJECTIVES

To use the multimeter and AC/DC circuit board for simple circuits.
To set up a simple circuit using batteries, resistors and wire leads, and explore its basic properties.

APPARATUS

A. AC/DC Electronics Lab Circuit Board

You have already used the Circuit Board in a particularly simple setting, passing an AC voltage through an Ohm’s Law resistor to obtain and measure an AC current. Clearly, the Circuit Board can be used for more interesting investigations.

Throughout the AC/DC Electronics Lab Circuit Board (Figure 6.1) there are springs. These springs are of such low resistance that their resistance can and will be neglected. The springs allow you to easily connect wires or various circuit elements:

- In order to maintain two different springs at the same voltage, connect the two springs with a wire lead.
- In order to connect a circuit element (for example, a resistor), insert the element between a pair of springs to ensure contact.
- Each pair of springs in the bottom rows in Figure 6.1 are connected by a contact that we will assume to be resistanceless, as suggested by the white connecting lines.

The circuit board has some mountings or elements already wired into place. In this experiment you will use:

- On the left side of the circuit board: two mountings for batteries with + (positive) and – (negative) terminals indicated (see “A” in Figure 6.1).
- On the top left of the board: three 3-volt bulbs with two springs on each side (see “B” in Figure 6.1).
- On the bottom of the board: two rows of four spring pairs with a “banana jack” at the end of the row on the right side (see “C” in Figure 6.1). Each pair of springs in a row is wired together.
B. Multimeter

See “Multimeter Overview” for a description of the design and use of the multimeter. For this experiment, we will use the meter as an Ohmmeter (on the R×1 range), as an ammeter (on the 250 mA DC range) and as a voltmeter (on the 5 DC V range).

EXPERIMENT

Part 1: Measuring Resistance with the Multimeter

First, zero the meter as described in the Multimeter Overview, Page 4.

Set the range selector switch on the multimeter to the R×1 range. Connect the test leads to the resistor. Measure the resistance of each of the three 33-Ω resistors. Record your results.

Note: You may want to make other resistance measurements. For example make a thick line with a lead pencil and measure the resistance of the mark. Grasp the clips firmly and see what your resistance is. Touch the clips to your tongue and measure the resistance. Find the resistance of one of the light bulbs.

It can’t hurt to re-zero the meter between resistance measurements.

Part 2: Measuring Resistance for Resistors in Parallel and Series
• Measure the equivalent resistance of two 33-Ω resistors connected in parallel. The equivalent resistance of two resistors \( R_1 \) and \( R_2 \) in parallel is

\[
R_{eq} = \frac{R_1 R_2}{R_1 + R_2}
\]  

(6.1)  

(see the 8.02T Study Guide, Section 7.3 for a derivation of the above expression).

• Measure the equivalent resistance of two parallel 33Ω resistors connected in series to a third 33Ω resistor. The equivalent resistance of two resistors \( R_1 \) and \( R_2 \) in series is

\[
R_{eq} = R_1 + R_2
\]  

(6.2)  

(see the 8.02T Study Guide, Section 7.3 for a derivation of the above expression).

You should now connect two 33-Ω resistors in parallel, labeled \( R_1 \) and \( R_2 \), and the third 33-Ω resistor, labeled \( R_3 \), in series with the other two as shown in Figure 6.2:

![Figure 6.2 Resistors in parallel and series](image)

**Question 1:**

a) Calculate the equivalent resistance of a pair of 33-Ω resistors that are in parallel.
b) Measure the equivalent resistance between the points A and B in Figure 6.2 using your multimeter (across the parallel combination \( R_1 \) and \( R_2 \)) and record your result.
c) Does your measured resistance agree with the value you calculated above?
d) Measure the resistance between the points B and C in Figure 6.2 using your multimeter (across the resistor \( R_3 \)) and record your result.
**Question 2:**

a) Calculate the total equivalent resistance of the three resistors.
b) Measure the resistance across the entire combination of resistors between the points A and C in Figure 6.9 and record your result.
c) Does your measured resistance agree with the value you calculated above?

**Part 3: Measuring Current in a Closed Circuit**

You will next measure the current in each branch of a closed circuit containing a resistor network and batteries.

**Connecting the Batteries:**

You will now make a closed circuit consisting of two 1.5-V batteries in series with your combination of resistors (Figure 6.3).

![Figure 6.3 Closed circuit with batteries and resistors](image)

Insert the two 1.5-V batteries in the plastic battery mounts on the AC/DC Electronics Lab circuit board. Use the long white wire lead to connect the positive terminal of the battery on the upper left corner of the board to a component spring pair on the left side of the upper row. Use a short white wire lead to connect the negative terminal of the upper battery to the positive terminal of the lower battery. Use another white wire lead to connect the negative terminal of the lower battery to a component spring pair on the lower row. If you want to disconnect the battery, disconnect any of these connections.
Measure the current that flows in the branch of the circuit between the batteries and the resistors, as follows.

![Figure 6.4 Multimeter in series in the closed circuit](image)

Always set the multimeter to the proper scale (voltage, current, etc) before you connect it. In order to measure the current, rotate the range selector switch on the multimeter to the 250 mA DC setting. Place the multimeter in series in the circuit (Figure 6.4). You can do this by removing the wire lead from the negative terminal of the lower battery. Then connect the black clip lead from the multimeter to the negative terminal and the red clip from the multimeter to the spring pair on the lower row that also connects the end of the resistor $R_3$ (this is the point C in Figure 6.4).

**Question 3:**

a) When the batteries are connected, calculate the total current that flows in the circuit.

b) With the batteries connected measure the current that flows in the circuit and record your result.

c) Does your measured current agree with what you calculated above?

**Question 4:**

a) Calculate the current that flows through each resistor in the parallel pair.

b) With the batteries connected measure the current that flows through one of parallel pair of 33-Ω resistors and record your result.

c) Does your measured current agree with what you calculated above?

**Part 4: Measuring voltage difference**

You will now measure the voltage difference across different resistor combinations for a closed circuit containing batteries.

Remove the multimeter from your circuit and close the circuit again.

In order to measure the voltage difference across a circuit element with your multimeter, rotate the range selector switch on the multimeter to the 5 DC V setting. Use the red and black clips across any element to measure the voltage difference (this puts the multimeter in parallel with the circuit element Figure 6.5).
Figure 6.5 Multimeter in parallel with a circuit element to measure voltage difference

Question 5:

a) Calculate the voltage difference across the parallel resistors $R_1$ and $R_2$.
b) Measure the voltage difference across the parallel resistors and record your result.
c) Does your measured voltage agree with what you calculated above?

Question 6:

a) Calculate the voltage difference across the resistor $R_3$.
b) Measure the voltage drop across the series 33-$\Omega$ resistor and record your result.
c) Does your measured voltage agree with what you calculated above?

Question 7:

a) If you now try to measure the resistance of any resistor, will you get the same resistance measurements as you did when the batteries were disconnected?
b) Try this out and see what you get. Can you explain your result? What is the source of the current when the batteries are disconnected?
Experimental Summary 6: Simple Circuits

Group __________________________________
Names __________________________________

Part 1: Measuring Resistance with the Multimeter

Set the range selector switch on the multimeter to the RX1 range. Connect the test leads to the resistor. Measure the resistance of each of the three 33-Ω resistors. Record your results here:

1. __________________ Ω
2. __________________ Ω
3. __________________ Ω

Part 2: Measuring Resistance for Resistors in Parallel and Series

Question 1:

a) Calculate the equivalent resistance of a pair of 33-Ω resistors that are in parallel.

b) Measure the equivalent resistance between the points A and B in Figure 6.2 using your multimeter (across the parallel combination \( R_1 \) and \( R_2 \)) and record it here:

_________________ Ω

c) Does your measured resistance agree with the value you calculated above?
d) Measure the resistance between the points B and C in Figure 6.9 using your multimeter (across the resistor $R_3$), and record it here:

____________________ Ω

**Question 2:**

a) Calculate the total equivalent resistance of the three resistors (Figure 6.2).

b) Measure the resistance across the entire combination of resistors between the points A and C in Figure 9 and record it here:

____________________ Ω
c) Does your measured resistance agree with the value you calculated above?

**Part 3: Measuring Current in a Closed Circuit**

**Question 3:**

a) When the batteries are connected, calculate the total current that flows in the circuit.

b) With the batteries connected measure the current that flows in the circuit and record it here:

____________________ amps.
c) Does your result agree with what you calculate above?

**Question 4:**

a) Calculate the current that flows through each resistor in the parallel pair.

b) With the batteries connected measure the current that flows through one of parallel pair of 33-Ω resistors and record it here:

____________________ amps.
c) Does your measured current agree with what you calculated above?
Part 4: Measuring voltage difference

Question 5:

a) Calculate the voltage difference across the parallel resistors \( R_1 \) and \( R_2 \).

b) Measure the voltage difference across the parallel resistors and record it here:
   _________________ volts.

c) Does your measured voltage agree with what you calculated above?

Question 6:

a) Calculate the voltage difference across the resistor \( R_3 \).

b) Measure the voltage drop across the series 33-\( \Omega \) resistor and record it here:
   _________________ volts

c) Does your measured voltage agree with what you calculated above?

Question 7:

a) If you now try to measure the resistance of any resistor, will you get the same resistance measurements as you did when the batteries were disconnected?

b) Try this out and see what you get. Can you explain your result? What is the source of the current when the batteries are disconnected?
READING QUESTIONS

1: What should be the colors of the first three bands of each of the 33-Ω resistors that you use? You may want to consult Section 7.5 of the 8.02T Study Guide.

2: Draw a circuit diagram that would correspond to the situation you are asked to investigate in Question 7. You may want to consult the Multimeter Overview for an explanation of how the multimeter measures resistance. Consider which of the test leads is connected to which side (higher or lower potential) of the resistor.