Experiment 2- 2
DC Circuits

1 Purpose

The purposes of this lab will be:

1.1 to investigate the three variables involved in a mathematical relationship known as Ohm's Law;
1.2 to experiment with the variables that contribute to the operation of an electrical circuits; and
1.3 to experimentally demonstrate Kirchhoff's Rules for electrical circuits.

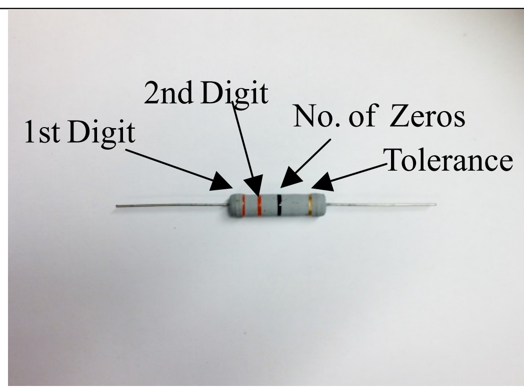
2 Procedure

2.1 Ohm's Law

① Choose one of the resistors that you have been given. Using the chart below, decode the resistance value and record that value in the first column of Table 1.

Reference

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9



Fourth Band	
None	20%
Silver	10%
Gold	5%
Red	2%

Chart 1

Example: brown red red gold = 1200 +/-5%

② **MEASURING CURRENT:** Construct the circuit shown in Figure 1a by pressing the leads of the resistor into two of the springs in the Experimental Section on the Circuits Experiment Board.

③ Set the multimeter to the 200 mA range, noting any special connections needed for measuring current. Connect the circuit and read the current that is flowing through the resistor. Record this value in the second column of Table 1.

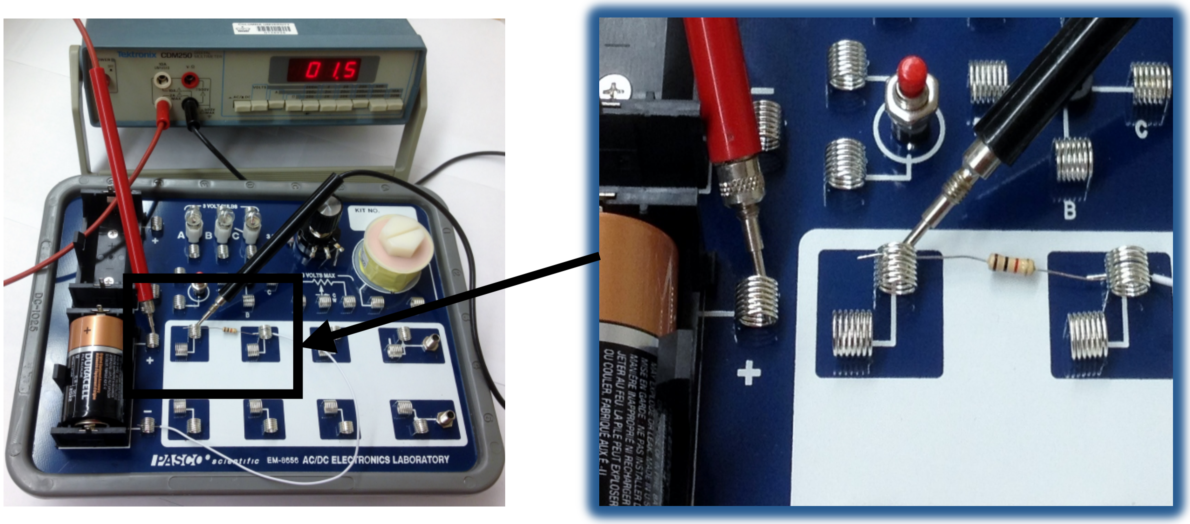


Figure 1a Measuring Current

④ Remove the resistor and choose another. Record its resistance value in Table 1 then measure and record the current as in steps 2 and 3. Continue this process until you have completed all of the resistors you have been given. As you have more than one resistor with the same value, keep them in order as you will use them again in the next steps.

Note: Always disconnect the circuit whenever you are done with your measurements.

⑤ **MEASURING VOLTAGE:** Disconnect the multimeter and connect a wire from the positive lead (spring) of the battery directly to the first resistor you used as shown in Figure 1b. Change the multimeter to the 2V DC scale and connect the leads as shown also in Figure 1b. Measure the voltage across the resistor and record it in Table 1.

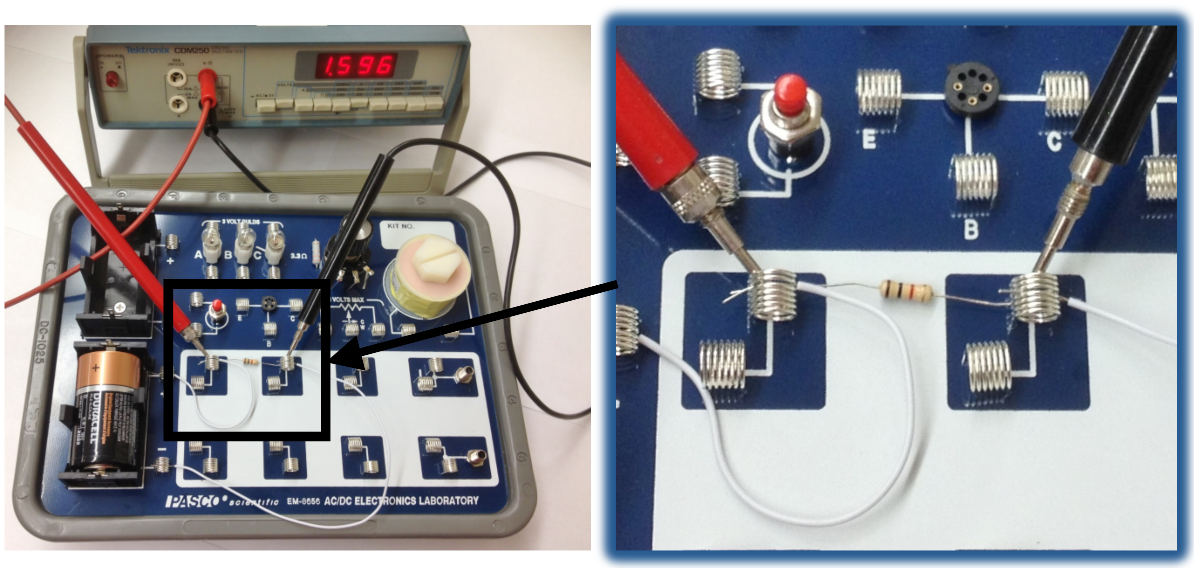


Figure 1b Measuring Voltage

⑥ Remove the resistor and choose the next one you used. Record its voltage in Table 1 as in step 5. Continue this process until you have completed all of the resistors.

Resistance, Ω	Current, amp	Voltage, volt	Voltage/Resistance

Table 1

Data Processing

① Construct a graph of Current (vertical axis) vs Resistance.

② For each of your sets of data, calculate the ratio of Voltage/Resistance. Compare the values you calculate with the measured values of the current.

Discussion

① From your graph, what is the mathematical relationship between Current and Resistance?

② Ohm's Law states that current is given by the ratio of voltage/resistance. Does your data concur with this?

③ What were possible sources of experimental error in this lab? Would you expect each to make your results larger or to make them smaller?

2.2 Resistances in Circuits

Procedure

① Choose three resistors of the same value (330Ω or 1000Ω). Enter those sets of colors in Table 2 on the next page. We will refer to one as #1, another as #2 and the third as #3.

② Determine the coded value of your resistors. Enter the value in the column labeled "Coded Resistance" in Table 2. Enter the Tolerance value as indicated by the color of the fourth band under "Tolerance."

③ Use the multimeter to measure the resistance of each of your three resistors. Enter these values in Table 2.

④ Determine the percentage experimental error of each resistance value and enter it in the appropriate column.

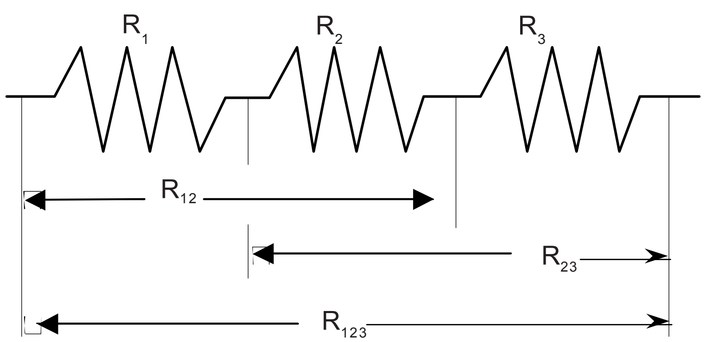
$$\text{Experimental Error} = [(|\text{Measured} - \text{Coded}|) / \text{Coded}\,] \times 100\%.$$

	Colors 1st 2nd 3rd 4th	Coded Resistance	Measured Resistance	% Error	Tolerance
#1					
#2					
#3					

Table 2

⑤ Now connect the three resistors into the SERIES CIRCUIT, Figure 2a using the spring clips on the Circuits Experiment Board to hold the leads of the resistors together without bending them.
Measure the resistances of the combinations as indicated on the diagram by connecting the leads of the multimeter between the points at the ends of the arrows. Use the 20K range if using 1000Ω and 2K if using 330Ω.

Series



R_{12} = ____________

R_{23} = ____________

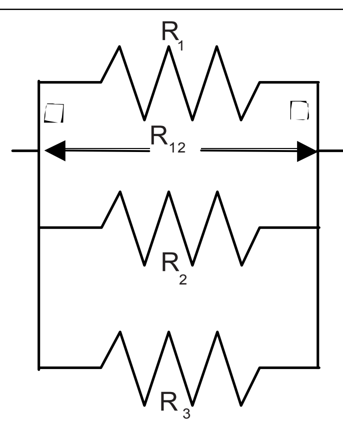
R_{123} = ____________

Figure 2a

⑥ Construct a PARALLEL CIRCUIT below, first using combinations of two of the resistors, and then using all three. Measure and record your values for these circuits.

Parallel

⑦ Connect the COMBINATION CIRCUIT and measure the various combinations of resistance. Do these follow the rules as you discovered them before?



R_{12} = ____________

R_{23} = ____________

R_{123} = ____________

Figure 2b

Combination

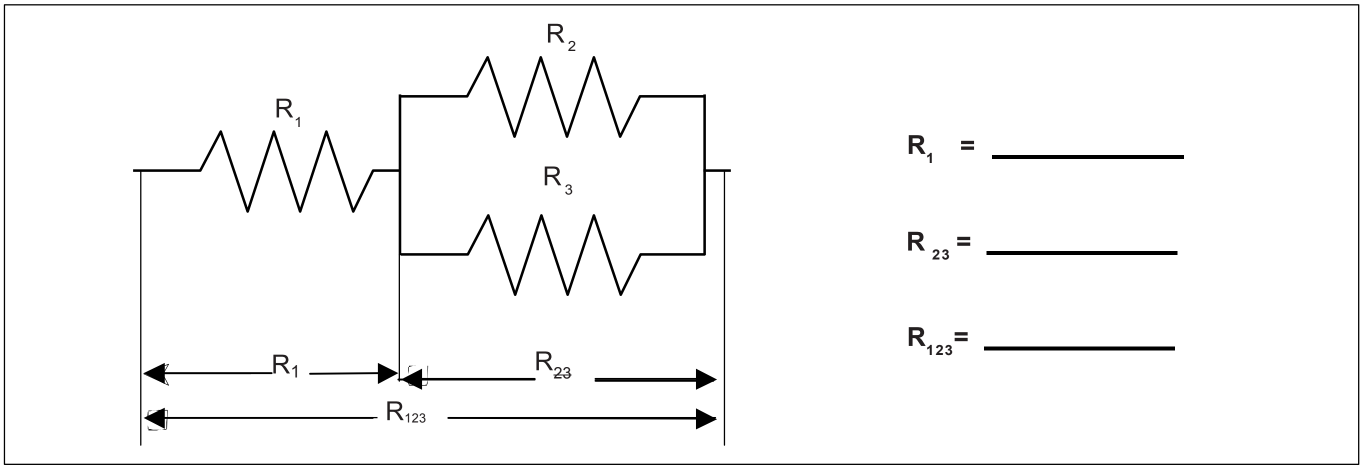


Figure 2c

Discussion

① How does the % error compare to the coded tolerance for your resistors?

④ What is the apparent rule for the total resistance when resistors are added up in series? In parallel? Cite evidence from your data to support your conclusions.

2.3 Voltages in Circuits

Procedure

① Connect the three equal resistors that you used in the previous section into the series circuit shown below, using the springs to hold the leads of the resistors together without bending them. Connect two wires to the D-cell, carefully noting which wire is connected to the negative and which is connected to the positive.

② Now use the voltage function on the multimeter to measure the voltages across the individual resistors and then across the combinations of resistors. Be careful to observe the polarity of the leads (red is +, black is -). Record your readings on the next page.

Series

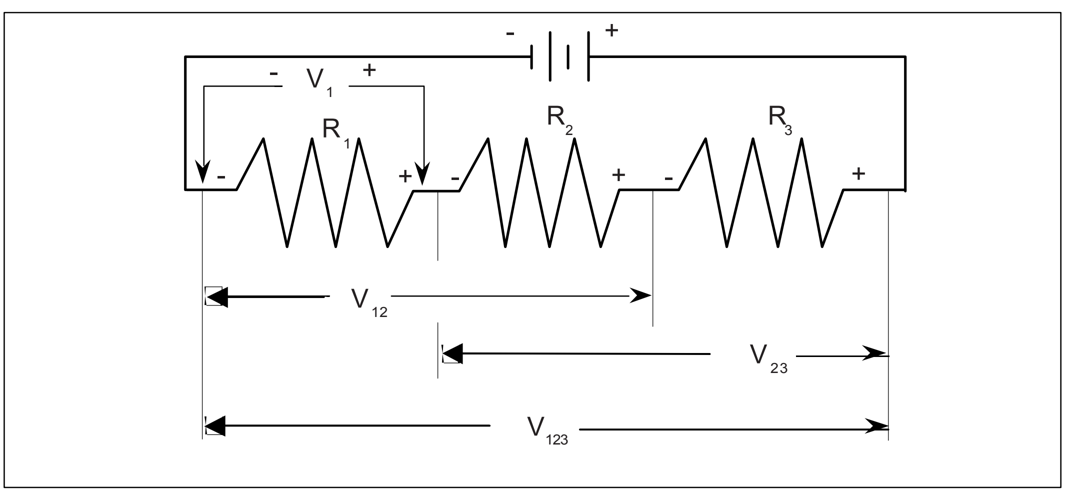


Figure 3a

R_1 = ____________ V_1 = ____________

R_2 = ____________ V_2 = ____________

R_3 = ____________ V_3 = ____________

R_{12} = ____________ V_{12} = ____________

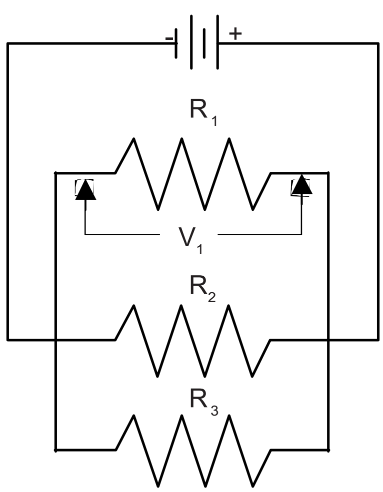
R_{23} = ____________ V_{23} = ____________

R_{123}= ____________ V_{123}= ____________

③ Now connect the parallel circuit below, *using all three resistors*. Measure the voltage across each of the resistors and the combination, taking care with the polarity as before.

> ➤ **NOTE:** Keep all three resistors connected throughout the time you are making your measurements. Write down your values as indicated below.

Parallel



R_1 = ________ V_1 = ________

R_2 = ________ V_2 = ________

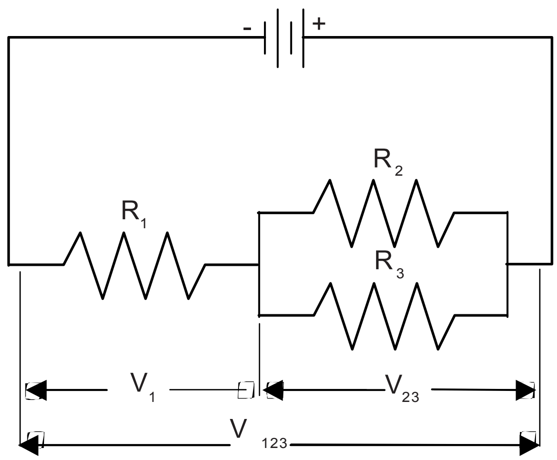
R_3 = ________ V_3 = ________

R_{123}= ________ V_{123}= ________

Figure 3b

④ Now connect the circuit in Figure 3c and measure the voltages. You can use the resistance readings you took in Section 2.2 for this step.

Combination



R_1 = ________ V_1 = ________

R_{23} = ________ V_{23} = ________

R_{123} = ________ V_{123} = ________

Figure 3c

Discussion

1. On the basis of the data you recorded on the table with Figure 3a, what is the pattern for how voltage gets distributed in a series circuit with equal resistances? Is there any relationship between the size of the resistance and the size of the resulting voltage?
2. Utilizing the data from Figure 3b, what is the pattern for how voltage distributes itself in a parallel circuit for equal resistances? Is there any relationship between the size of the resistance and the size of the resulting voltage?
3. Do the voltages in your combination circuits (see Figures 3c) follow the same rules as they did in your circuits which were purely series or parallel? If not, state the rules you see in operation.

2.4 Currents in Circuits

Procedure

① Connect the same three resistors that you used in Section 2.1 and 2.2 into the series circuit shown in the next page, using the springs to hold the leads of the resistors together without bending them. Connect two wires to the D cell, and carefully note which lead is negative and which is positive.

Series

② Now change the leads in your multimeter so that they can be used to measure current. You should be using the scale which goes to a maximum of 200 mA. Be careful to observe the polarity of the leads (red is +, black is -). In order to measure current, the circuit must be interrupted, and the current allowed to flow through the meter. Disconnect the lead wire from the positive terminal of the battery and connect it to the red (+) lead of the meter. Connect the black (-) lead to $\mathbf{R_1}$, where the wire originally was connected. Record your reading in the table as $\mathbf{I_0}$. See Figure 4b.

③ Now move the multimeter to the positions indicated in Figure 4c, each time interrupting the circuit, and carefully measuring the current in each one. Complete the table on the top of the next page.

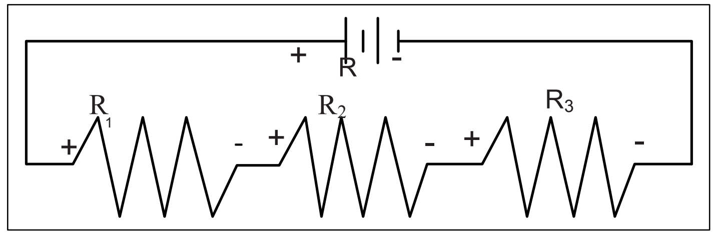


Figure 4a

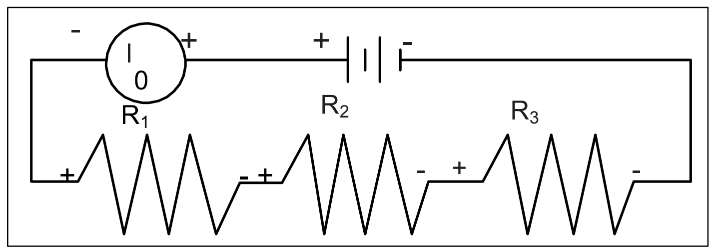


Figure 4b

> ➤ **NOTE:** You will be carrying values from Section 2.1 and 2.2 into the table below.

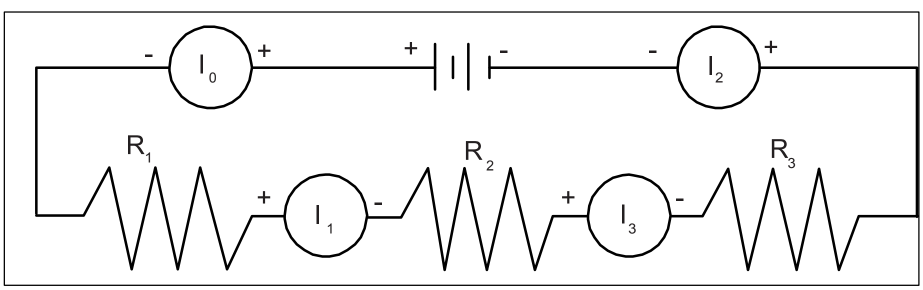


Figure 4c

R_1 = ______	I_0 = ______	V_1 = ______
R_2 = ______	I_1 = ______	V_2 = ______
R_3 = ______	I_2 = ______	V_3 = ______
R_{12} = ______	I_3 = ______	V_{12} = ______
R_{23} = ______		V_{23} = ______
R_{123} = ______		V_{123} = ______

④ Connect the parallel circuit below, using all three resistors. Review the instructions for connecting the multimeter as an ammeter in step 2. Connect it first between the positive terminal of the battery and the parallel circuit junction to measure $\mathbf{I_0}$. Then interrupt the various branches of the parallel circuit and measure the individual branch currents. Record your measurements in the table below.

Parallel

R_1 = ________	I_0 = ________	V_1 = ________
R_2 = ________	I_1 = ________	V_2 = ________
R_3 = ________	I_2 = ________	V_3 = ________
R_{123} = ________	I_3 = ________	V_{123} = ________
	I_4 = ________	

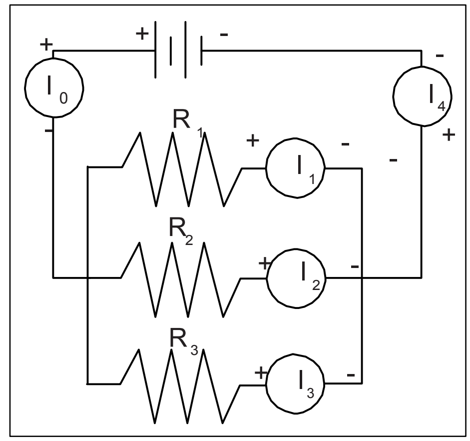


Figure 4d

Discussion

1.On the basis of your first set of data, what is the pattern for how current behaves in a series circuit? At this point you should be able to summarize the behavior of all three quantities - *resistance, voltage and current* - in series circuits.

2. On the basis of your second set of data, are there any patterns to the way that currents behave in a parallel circuit? At this time you should be able to write the general characteristics of currents, voltages and resistances in parallel circuits.

2.5 Kirchhoff's Rules

Procedure

① Connect the circuit shown in Figure 5a using any of the resistors you have **except the 10Ω one**. Use Figure 5b as a reference along with Figure 5a as you record your data. Record the resistance values in Table 3 on the next page. With no current flowing (the battery disconnected), measure the total resistance of the circuit between points **A** and **B**.

② With the circuit connected to the battery and the current flowing, measure the voltage across each of the resistors and record the values in the table on the next page. On the circuit diagram in Figure 5b, indicate which side of each of the resistors is positive relative to the other end by placing a "+"at that end.

③ Now measure the current through each of the resistors. Interrupt the circuit and place the multimeter in series to obtain your reading. Make sure you record each of the individual currents, as well as the current flow into or out of the main part of the circuit, I_T

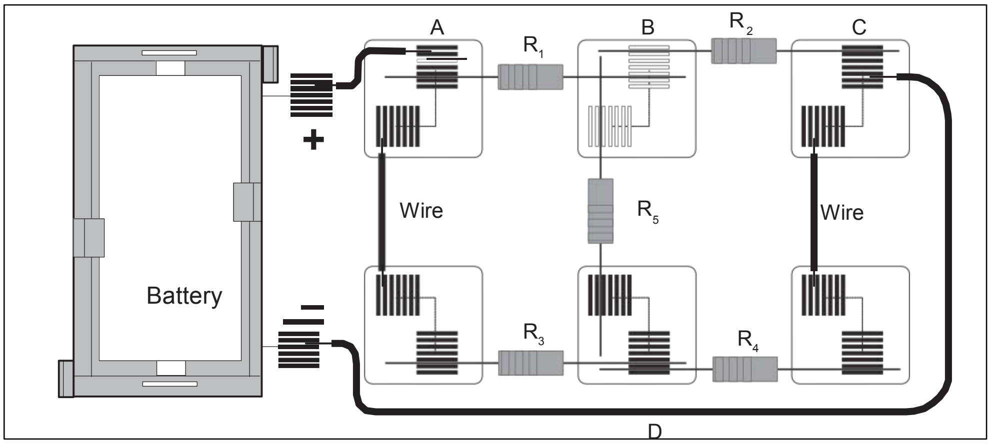


Figure 5a

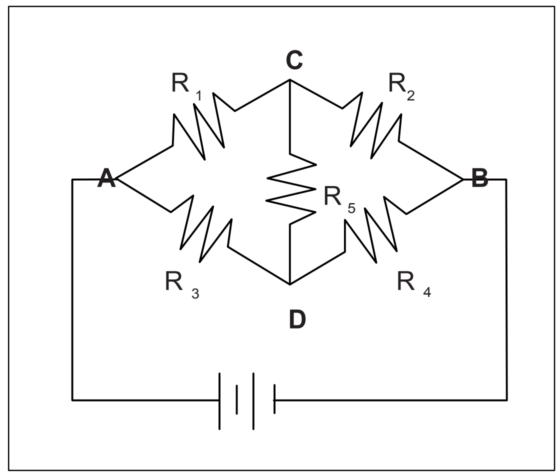


Figure 5b

Table 3

Resistance, &	Voltage, volts	Current, mA
R_1	V_1	I_1
R_2	V_2	I_2
R_3	V_3	I_3
R_4	V_4	I_4
R_5	V_5	I_5
R_T	V_T	I_T

Analysis

① Determine the net current flow into or out of each of the four “nodes” in the circuit.

② Determine the net voltage drop around at least three (3) of the six or so closed loops. Remember, if the potential goes up, treat the voltage drop as positive (+), while if the potential goes down, treat it as negative (-).

Discussion

Use your experimental results to analyze the circuit you built in terms of Kirchhoff's Rules. Be specific and *state the evidence* for your conclusions.