**EXPERIMENT: SERIES AND PARALLEL CIRCUITS – KIRCHOFF’S LAWS**

[Equipment list: Circuit Board with various Resistors, AA-cell Batteries (2), Digital Multimeters (2), Various Wires]

**Overview:**

Resistors are printed with colored bands to indicate their resistance value and tolerance. In figure 1 a 4-band scheme is used. This is typical and is used by the manufacturer of the resistors on the circuit board.

figure 1

A metallic band, painted gold (± 5%) or silver (± 10%) is printed away from the colored bands and is the percent tolerance of the resistor value. To read the value of the resistor look to the 3 colored bands away from the metallic tolerance band. The colored band farthest away from the tolerance band represents the first number, while the second band represents the second number. These are then multiplied by 10 to the power of the value for the third band.

The coding for these colored bands goes like this:

|  |  |
| --- | --- |
| Band color | Numerical value |
| Black | 0 |
| Brown | 1 |
| Red | 2 |
| Orange | 3 |
| Yellow | 4 |
| Green | 5 |
| Blue | 6 |
| Violet | 7 |
| Gray | 8 |
| White | 9 |

In figure 1 the first band is colored brown and represents a 1; the second band is colored orange and represents a 3. Finally the third colored band is green and represents a 5 for the power.

1

3

5

X 10

This makes the resistor in figure 1 equal to 1300 Kilo-ohms, or 1.3 Mega-ohms. The tolerance of this resistor is equal to 65 Kilo-ohms.

Use the Digital Multi-Meter (DMM) as an Ohmmeter to measure the resistances of all the resistors on the circuit board and record them in Table 1 on the Excel worksheet associated with this experiment, along with calculating their tolerance values.

**Answer all numbered questions in the Results section of your lab report. Number your answers to correspond with the question numbers.**

**Question 1:** Do the measured values of the resistors fall within the range of tolerance for each of the resistors? If some do not, which ones are they? They all do.

**Resistors in Series Combination**

Connecting resistors in series effectively increases the total resistance by an amount equal to the sum of the resistance values of the resistors.

The symbol for a resistor when drawing a circuit diagram is represented like this:

When two, or more, resistors are connected in series they are connected end-to-end, like so:

R1

R2

R3

A

B

figure 2

Connect the series combinations of resistors shown in Table 2 on the Excel worksheet using the alligator wires and measure across the total resistance using the DMM. Be sure to measure from one end (point A) to the other end (point B) of the series combination. Enter these measured values into Table 2. Also, add the individual measured resistances (Equation value of Rtotal) for each of these series combinations and enter these in Table 2. Compare these calculated total resistance values to the DMM measured values.

**Question 2:** How well do the measured values of Rtotal compare to adding the individually measured (Equation) values to obtain Rtotal? Are they exactly the same, or are they off a little bit? They are nearly identical.

**Question 3:** What would cause the variation in the answers (if you had any) in Question 2? Human uncertainty.

You are using a DMM to measure both the individual values of each resistor and the series combination of resistors. Using a device introduces uncertainty in the measurement.

**Question 4:** How much uncertainty should you assign each measurement that you make with the DMM? ± 0.1 Ohm, 0.01 kOhm

**Resistors in Parallel Combination**

This combination causes the inverse of the total resistance of two, or more, resistors to combine as the inverses of the individual resistances.

R1

R3

R2

A

B

figure 3

Notice how the same sides of R1, R2, and R3 are connected together and these are connected to point A. The same goes for the other side of the three resistors which are connected to point B.

Use the same combinations of resistors as you did in Table 2 for these parallel combination of resistors. Record the measured values, and determine the calculated values and place them in Table 3 on the worksheet. Again, use the individually measured resistance values to determine the equation value.

**Question 5:** How do these measured values of the parallel combination compare to the total resistance as determined using the equation? They are almost identical.

**Series and Parallel Combination of Resistors in a Circuit using Kirchhoff’s Loop and Junction Rules**

In the following circuit diagram are various resistors connected in a series and parallel combination, along with a seat of EMF (the battery), and a DMM used as an Ammeter.

10 Ω (R1)

10 Ω (R2)

51 Ω (R3)

68 Ω (R5)

EMF (3V)

Ammeter

Jnc B

Jnc C

Jnc D

SW3

+

\_

Loop 1

Loop 2

figure 4

By traversing a particular Loop (from any starting point, around the loop, and stopping at the point you started from) the sum of the potential changes (voltage drops and voltage gains) about that Loop is equal to zero. To show that this statement is true, connect the circuit as indicated above (figure 4) together on the circuit board. The EMF will be two AA-cell batteries, but, don’t take for granted that the terminal voltage (the potential difference measured across the ‘+’ and ‘-‘ sign on the board) is equal to 3 volts. Measure the terminal voltage with a second DMM dialed to read voltage DC and record this value in Table 4 on the worksheet. Also, record the current that the Ammeter is reading. Then, use the second DMM to measure the potential difference across the Ammeter and each of the four resistors and enter their values in Table 4 on the worksheet.

Enter the current the Ammeter is reading for both the Ammeter and the Battery. For the resistors determine the current through each mathematically using the equation for Ohm’s Law (V = IR). Make sure that you use the measured values for the resistances and not the manufacturer’s values as printed on the circuit board in determining the currents through the resistors.

Disconnect the wires from the battery terminals, and while the batteries are still in the battery holder measure the voltage across the terminals and record this value on the worksheet.

Loop 1: Show that the sum of the voltage drops and gains of Loop 1 is equal to zero (or nearly so). Show work on the Excel worksheet.

Loop 2: Show that the sum of the voltage drops and gains of Loop 2 is equal to zero (or nearly so). Show work on the Excel worksheet.

**Question 6:** Are the sums about Loop 1 and Loop 2 equal to zero (or nearly so)? If the sums are close to zero, but not exactly zero, can this amount be accounted for by the uncertainty in the DMM? Yes. Yes.

Current flows from a position of high potential to one of lower potential. On the diagram in figure 4 there are 3 Junctions indicated. Two are real Junctions, while Junction C is merely a point between R3 and R2, but is still of interest**. Copy figure 4, include it in your report, and draw on figure 4 the directions of all the currents entering and leaving each Junction**. A current entering a Junction will be considered positive, while a current leaving a Junction will be considered negative when applying currents to Kirchhoff’s Junction Rule.

Junction B: Show that the sum of the currents into and out of Junction B is equal to zero (or nearly so). Show work on the worksheet.

Junction C: Show that the sum of the currents into and out of Junction C is equal to zero (or nearly so). Show work on the worksheet.

Junction D: Show that the sum of the currents into and out of Junction D is equal to zero (or nearly so). Show work on the worksheet.

**Question 7:** Are the sums of the currents into and out of each of the Junctions equal to zero? If they are not exactly zero can the discrepancy be explained by a certain amount of uncertainty that the DMM has? Yes.

There are 4 resistors in the circuit in figure 4. These resistances (and the small resistance of the Ammeter) can be replaced with a single, equivalent resistance that will draw the same amount of current that this resistor combination is drawing from the battery. Use the voltage measured across the Ammeter and the current that is going through the Ammeter to mathematically determine the resistance of the Ammeter. Show work on the worksheet.

Determine the equivalent resistance of the circuit by mathematically combining all the resistors. You will have to do this piece-by-piece as you combine two resistors in series first and then combine this equivalent resistance in parallel with another, and so on. Show work on the worksheet.

Another way of determining the equivalent resistance of a circuit is to divide the terminal voltage, while the circuit was connected, by the current being drawn out of the battery (Ammeter reading).

Equivalent Resistance = Voltage/Current

Calculate the Equivalent Resistance on the worksheet showing calculation.

**Question 8:** How well did the equivalent resistance found by combining resistors compare to the equivalent resistance by computing V/I?

You measured the voltage across the battery terminals both for the circuit connected to the battery and for no circuit connected to the battery. The difference between these two readings is due to internal resistance of the battery holder.

Determine the internal resistance of the battery holder treating this resistance as being in series with the equivalent resistance of the circuit when the circuit is connected. Calculate and show work on the worksheet.

**Further Discussion: (answer these questions in the Discussion Questions section of your report).**

1. What conservation law does the loop law depend on?

2. What conservation law does the junction law depend on?

3. What is the difference between the source of EMF of a circuit and a potential difference in the circuit?

4. Determine the current being drawn from the 5 volt

5V

4 Ω

8 Ω

4 Ω

battery before the switch is closed, and the current drawn from

the battery after it is closed. Why did it change in this way?