Chapter 5

DC Circuits

Name: ___________  Lab Partner: ___________  Section: ____

5.1 Purpose

The purpose of this lab is to explore the basics of DC circuits, to familiarize you with the different physical quantities associated with electricity and to verify Ohm’s Law.

5.2 Introduction

It is well known that all atoms are composed of a nucleus (containing protons and neutrons) with electrons orbiting the nucleus. Objects can become positively or negatively charged when electrons are added or removed from the atoms in the object. The lead-acid storage battery in an automobile moves electrons by a chemical reaction when a circuit is completed between the positive and negative battery terminals.

The electrons in metallic objects easily move within the object when influenced by an electric field. A wire that connects two regions of differing potential, such as two battery terminals, will allow electrons to flow from the excess electron terminal (−), to the deficient electron terminal (+). This current flow is measured in Amperes which is a Coulomb/second. This is also $6.25 \times 10^{18}$ electrons/second. The current flow is opposite to the electron flow. This is by convention when it was thought that the positive charges were the main

<table>
<thead>
<tr>
<th>Charge</th>
<th>Coulomb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron Charge</td>
<td>$1.6 \times 10^{-19}$ Coulomb</td>
</tr>
<tr>
<td>Current</td>
<td>Ampere (or Coulomb/sec)</td>
</tr>
<tr>
<td>Electric Field</td>
<td>Newtons/Coulomb (or Volt/m)</td>
</tr>
<tr>
<td>Electric Potential</td>
<td>Joules/Coulomb = 1 Volt</td>
</tr>
<tr>
<td>Resistance</td>
<td>1 Ohm = 1 Volt/ Ampere</td>
</tr>
</tbody>
</table>

Table 5.1: Electrical SI units.
charge carriers. It was not until the discovery of the electron in 1897 by J. J. Thomson that it was realized that electrons are the mobile charge carriers in circuits.

The current in a circuit generates heat in varying amounts due to the circuit’s resistance to current flow. This heat is the result of electron-atom collisions which occur in the course of the current flow. This impedance to the flow of current is termed “resistance”. The unit of resistance is the Ohm and its symbol is Ω, the Greek letter omega. Resistance is a derived quantity and is related to voltage and current by Resistance = Volts / Amperes or $R = V / I$ for short. This relationship is known as **Ohm’s Law** for DC Circuits.

Electrical devices which are designed to resist current flow are called resistors. Resistors and other electrical devices can be arranged geometrically in a circuit in different ways. Two common arrangements are **series and parallel** circuits as shown in Figure 5.1. For resistors in series, the current flow is the same through each resistor because of charge conservation. For resistors in parallel, the potential across each resistor is the same.

The first part of the experiment considers resistors in series. Figure 5.1a shows how resistors are electrically connected to form a series circuit. When resistors are in series, the individual resistor values are simply added together to get the total resistance of the circuit:

$$ R_{total} = R_1 + R_2 + \ldots + R_N $$

where N is the number of resistors that are in **series**. Also note that for resistors in series the current in the same through each resistor.

$$ I_{total} = I_1 = I_2 = \ldots = I_N $$

However the voltage is different across each resistor and can be found using Ohm’s Law ($V_1 = R_1 I$, etc).

$$ V = V_1 + V_2 + \ldots + V_N $$

The second part of the experiment considers resistors in **parallel** as seen in Figure 5.1b. When the resistors are in parallel, the total resistance is **not** simply the sum of the individual resistors. The total resistance of resistors in parallel is given by:
where \( N \) is the number of resistors in parallel. For resistors in parallel the current is different through each resistor. Ohm’s Law is used to calculate the current through each resistor. This is possible because the potential is the same across each resistor, i.e., the voltage across each resistor is the voltage supplied by the power supply.

\[
\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_N}
\]  

\( (5.2) \)

The final part of the experiment considers more complicated arrangements. Some combinations of resistors are not simple series or parallel circuits. Here Kirchhoff’s rules can be used. Kirchhoff’s rules are stated as:

1. The sum of the currents entering any junction must equal the sum of the currents leaving the junction. (A junction being the point in the circuit where the currents can split)

2. The algebraic sum of the changes in potential across each element around any closed loop must be zero. (You should review your textbook about the sign convention concerning Kirchhoff’s loop rule before coming to lab.)

## 5.3 Procedure

The various circuits used in this experiment are pre-configured in a circuit box. Figure 5.3 shows a schematic diagram of the circuit arrangement. Provided on the circuit box are test
points for measuring voltage and current. Voltage measurements are made using the banana plugs connected to the voltage probe. Current measurements are made using the phone jack connected to the current probe and phone jack test points. Figure 5.2 shows the phone jack connector for measuring current along with other components of the equipment.

**Special Cautions:** The current probe has very low resistance to the flow of electrical current. It must have low resistance to minimize its effect upon the circuit.

### 5.3.1 Series Circuit

- Open the lab 'DC circuits'. Two meters showing voltage and current will be displayed on the computer monitor. 'Click' on the signal generator icon on the tool panel and the signal generator window will appear. A signal generator box will appear in 'DC' mode. The signal generator output will supply the voltage for this experiment. The signal generator should be set to 4 volts.

- Connect the signal generator output across the two resistors in series. The positive output of the signal generator should be attached to V3 and the negative (ground) of the signal generator should be connected to V1. Refer to Figure 5.3.

- Connect the black (negative) voltage probe banana connector to V1 and the red (positive) voltage probe banana connector to V3. (The voltage probes can be connected on top of the banana cables connecting the signal generator to the circuit box.)

- Using the voltage probes, measure and record the voltage between V1 and V2. Measure the voltage between V2 and V3. Using the current probe, measure and record the current at C1.

  Measured voltage between V1 and V2 __________
  Measured voltage between V2 and V3 __________
  Measured current at C1 __________
• Using Ohm’s law, calculate the current through the two resistors and the voltage across each resistor. Compare your calculated values (percentage difference) to your measure values for the current and voltages.

Calculated current at C1
Calculated voltage between V1 and V2
Calculated voltage between V2 and V3

% difference between calculated and measured voltage between V1 - V2
% difference between calculated and measured voltage between V2 - V3
% difference between calculated and measured current at C1

• Is the total voltage across the circuit equal to the sum of the measured voltages across each resistor?

Sum of voltage across V1 and V2 and voltage across V2 and V3

5.3.2 Parallel Circuit

• Connect the signal generator output across the two resistors in parallel. The positive (signal) output of the signal generator should be connected to V4 and the negative (ground) terminal to V3. Refer to Figure 5.3.

• With the phone jack plug and the current probe, measure the current at point C2.

Current at C2

• Calculate the total resistance of the two resistors in parallel. Calculate the current in the 91Ω and 110Ω resistor and the total current through the circuit.

Calculated total resistance of 91Ω and 110Ω resistors
Calculated current through 91Ω resistor
Calculated current through 110Ω resistor
Calculated total current

- Compare (percentage difference) the measured and calculated values of the current through the 91Ω resistor.

% difference of calculated and measured current through 91Ω resistor

5.3.3 Series-Parallel Circuits

- Connect the 4 volts from the signal generator across the entire circuit by connecting to V1 and V4.

- With the voltage probe banana plugs measure the voltage across the 82Ω resistor (V1 to V2). Measure the voltage across the 51Ω series resistor (V2 to V3). Measure the voltage across the resistors in parallel (V3 to V4). Be sure to observe the correct sign convention when measuring these voltages.

  Measured voltage between V1 and V2
  Measured voltage between V2 and V3
  Measured voltage between V3 and V4

- With the phone jack connector and current probe, measure the currents at C1 and C2.

  Measured current at C1
  Measured current at C2

- Using the voltage measurements, show that Kirchhoff’s loop rule holds for the circuit.

- Using Kirchhoff’s junction rule and the measured values of the currents at C1 and C2, determine the current through the 110Ω parallel resistor.

5.3.4 Questions

1. $N$ resistors each have equal resistance $R$. What is the total resistance if all resistors are in series?
2. If \( N \) resistors each have equal resistance \( R \), what is the total resistance if all the resistors are connected in parallel?

3. Explain what determines the sign of the voltage in Kirchhoff’s loop law.

4. You have four identical resistors of resistance \( R \). Draw two arrangements using all four resistors where the total resistance is \( R \).

5.4 Conclusion

Write a detailed conclusion about what you have learned. Include all relevant numbers you have measured with errors. Sources of error should also be included.