PARALLEL AND SERIES CIRCUITS

Purpose:

To investigate the properties of parallel and series circuits.

Apparatus:

Two Multi-meters, three resistors, experimental breadboard, breadboard wires, power supply, 6 wires

Background:

A battery cannot tell if there are hundreds of resistors in a circuit or if there is just one resistor in the circuit. The battery feels the load or the total resistance of the entire circuit. This leads us to the question of how the current flows in the circuit and what the voltage difference is across each resistor. We can say, and we will verify, that for each resistor in a circuit Ohm's law is valid. This means that the voltage across each resistor is equal to the product of its resistance and the current moving through it. The total voltage and current that the power supply or battery produces is, in general, different from what each resistor has across it or moves through it.

Memorize:

The *Ammeter* measures *current* **through** a resistor by connecting in **series** with it.

The *Voltmeter* measures *voltage* **across** a resistor by connecting in **parallel** with it.

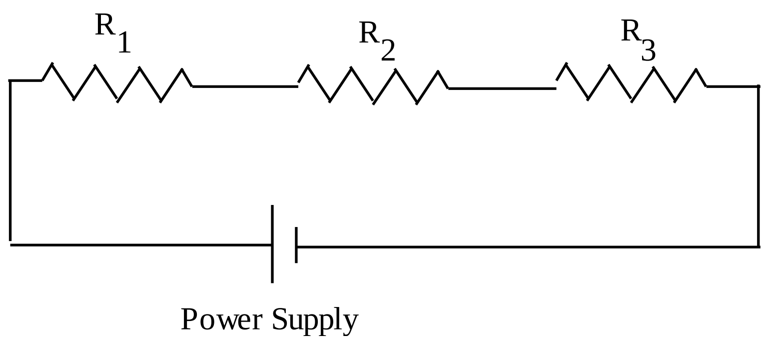

Figure 1. Three resistors of values R_1, R_2, and R_3 are connected in series with one another.

Let's first take a look at a series circuit. An illustration of this is seen in Figure 1. Here the resistors are lined up so that there is only one path that the current may take through the circuit. We will assume that the total current moving through the circuit is constant and, by conservation of charge, does not depend on which resistor it moves through. The sum total of the voltages across the resistors is equal to that of the power supply. This last sentence is another way of stating Kirchhoff's loop rule. We can use this to calculate the total resistance that the power supply sees as

$$R_T = R_1 + R_2 + R_3 \qquad \text{Eq.1)}$$

For a parallel circuit, shown in Figure 2, the current has several different paths to take. However, the voltage across each resistor is the same because each resistor is connected across the power supply. Using Ohm's law we can determine the current through each resistor. The sum total of the currents is that through the power supply. With this, the total resistance that the power supply sees is

$$^1/R_{tot} = {}^1/R_1 + {}^1/R_2 + {}^1/R_3 \qquad \text{Eq.2)}$$

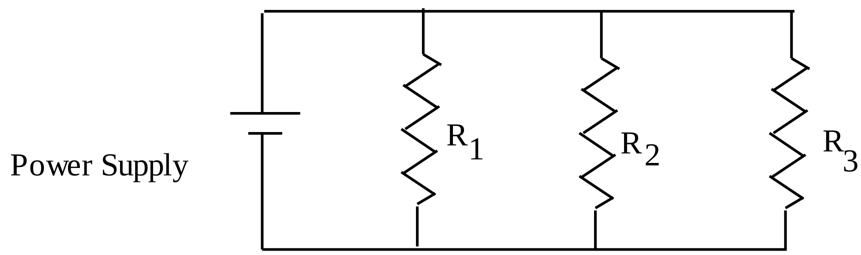

Figure 2. Three resistors of values R_1, R_2, and R_3 are connected in parallel with one another.

Kirchhoff's laws apply to any closed circuit. Kirchhoff's current law can be stated as, the sum of the currents entering a node must equal the sum of the currents leaving the node. The equation for this Kirchhoff law is

$$\sum_{\text{into node}} i_n = \sum_{\text{out from node}} i_n$$

The other Kirchhoff law is stated as : The sum of the voltage changes around a closed loop is zero. The equation for this law is

$$\sum_{\text{closed loop}} V_n = 0$$

In your background section prove equations 1 and 2 using Kirchoff's first and second rules (junction rule and loop rule), and ohm's law (V = IR) . Not all circuits are just parallel or series, some are a combination of both. In these cases we must use a combination of the rules from above to determine the voltage and current values in the circuit.

Set-up and Procedure:

Equipment Protection:

Before proceeding with this lab, the current limit on the power supply must be set in order to protect the ammeters. Do the following at the beginning of lab:

1) Turn current limit dials up a tiny bit (1/10 th of a turn max) so that the green light appears on the voltage side

2) Set the voltage limit to one volt.

3) Temporarily connect a wire between the 2 terminals of the power supply.

4) Set the current limit to .1 amps.

5) Disconnect the wire between the terminals

Now your power supply is ready for use on the circuit. The voltage is adjustable for the given requirements of the specific measurement, but the current supply settings should not be touched until part 5. **If you burn out the ammeter during this lab and the TA discovers that the power supply current limit is incorrect, it is an automatic 10 point subtraction.**

The circuit must be checked by the TA before turning on the power supply!

Part 1:

Measure the resistance of the three resistors at your workstation and record the values in your notebook. With the three measured resistors calculate the total resistance, R_{tot}, of a parallel and series circuit.

The resistors are marked with an error range band. It is the fourth band and gold means 5% and silver means 10% error. Use the propagation of errors equation from the first lab to calculate the error range expected for your own calculation of the parallel and series resistance. In your conclusion state if V/I for the entire circuits of parts I and II fall within the error ranges you calculated.

Part 2:

Build the series circuit as shown on Figure 3 below. Measure the current and voltage coming from the power supply (Position 1 in figure 3) with the power supply set to one volt. Use Ohm's law to determine the resistance of the entire circuit and compare this to the calculation made for a series circuit in part 1. Measure the current going into and out of each resistor along with the voltage drop across each resistor. This can be accomplished by placing the voltmeter and ammeter in positions 2, 3, and 4 as shown in Figure 3. Use Ohm’s law to determine the value of each resistor from the values just measured.

Repeat this experiment again but this time use to volts from the power supply.

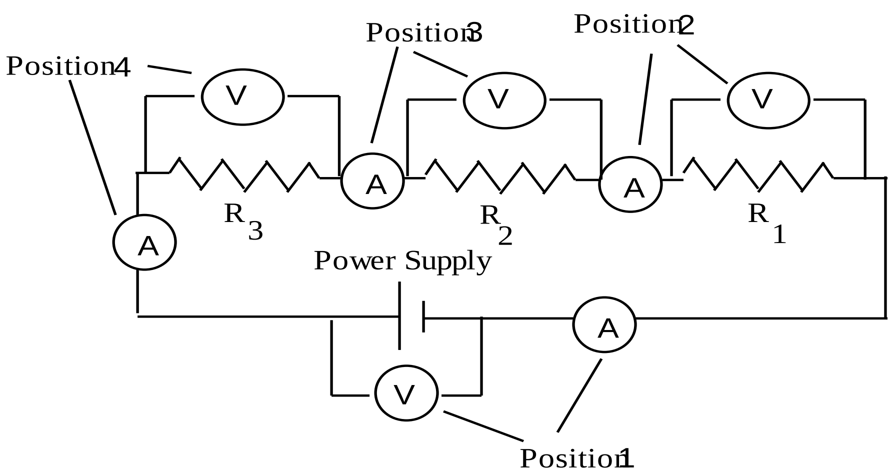

Figure 3. This illustration indicates the positions that the voltmeter, V, and ammeter, A, are to be placed to take data. Position 1 indicates the voltage and current the power supply is generating. Position 2 indicates the voltage difference across resistor 1 and the current running through resistor 1.

Part 3:

Set-up the circuit shown on Figure 4. Measure the current and voltage coming from the power supply and calculate the total resistance of the circuit. Calculate the total resistance of the circuit with the resistor values found in part one using equation 2. Measure the current and voltage for each resistor by placing the ammeter and the voltmeter in positions 2, 3, and 4 as shown on Figure 4. Use Ohm's law to determine the resistance of each resistor in the circuit with the voltage and current data obtained.

Repeat this part of the experiment this time using a different voltage setting.

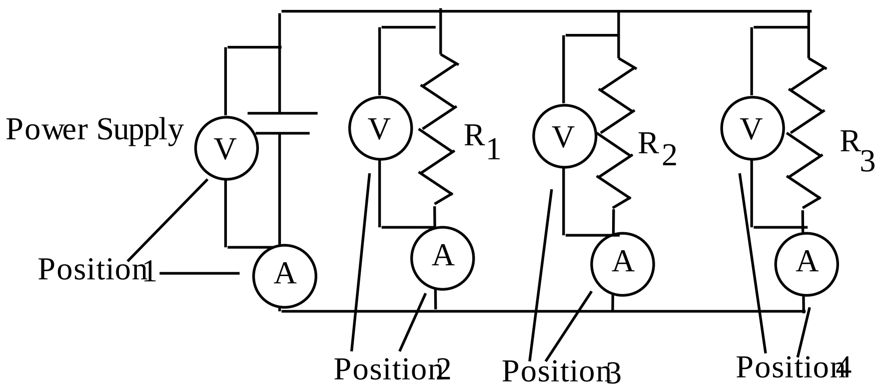

Figure 4. This illustration indicates the positions that the voltmeter, V, and ammeter, A, are supposed to be placed to take data. Position 1 measures the voltage and current that the power supply produces. Position 2 measures the current and voltage of resistor 1.

Part 4:

In this part we would like to investigate a more complicated situation. Set-up the circuit shown in Figure 5. Measure the current and voltage coming from the power supply and determine the total resistance seen by the battery. Measure the voltage across and the current moving through each resistor. Use Ohm's law to determine the value of each resistor in the circuit with the voltage and current data obtained. Using what you know about parallel and series circuits, calculate the total resistance seen by the battery with the values found in part one. Compare this value to the total resistance seen by the power supply.

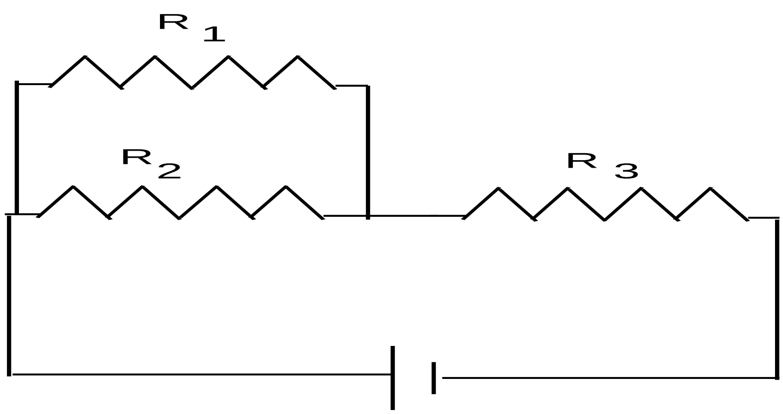

Figure 5. Construct the complicated circuit above and find the current through and voltage across each resistor and the power supply. Determine how to calculate the total resistance of the circuit.

Part 5)

Before beginning this part of the lab, put the wire from the ammeter in the 20 amp hole! Only after you have done this can you release the power supply from the current limit of .1 amps.

As an example of variable resistance you are provided with a lightbulb. Connect a circuit to provide power to the lightbulb and measure current and voltage for the lightbulb. Do not exceed the maximum voltage of 5 volts for the lightbulb when you control the voltage on the power supply. Make two graphs with the data of current and voltage you obtained for the lightbulb: resistance vs. voltage and resistance vs. power. What is happening to the resistance indicated in these graphs? Why is this happening?

Questions:

1.) In a series circuit, what can be said about the voltage across each resistor?

2.) In a series circuit, what can be said about the current going through each resistor?

3.) In a parallel circuit, what can be said about the voltage across each resistor?

4.) In a parallel circuit, what can be said about the current going through each resistor?

5.) For part 4, explain what happens with the voltage and current for the parallel and series part of the circuit.

Problems:

1.) a 9 Ω and a 6 Ω resistor are connected in series with a power supply. (a.) The voltage drop across the 6 Ω resistor is measured and found to be 12 V. Find the voltage output of the power supply. (b) The two resistors are connected in parallel across a power supply and the current through the 9 Ω resistor is found to be 1/4 A. Find the voltage setting of the power supply.

2.) If you have a 2 Ω, 4 Ω, and a 6 Ω resistor, how many different resistance values can you obtain from the set? Show how you would connect them to get each resistance value.

3.) Derive equations 1 and 2 from Kirchhoff's Laws. State the assumptions made.