Mark

High School Physics Laboratory

UNB Electrical & Computer Engineering Circuits Experiment

Name:________________

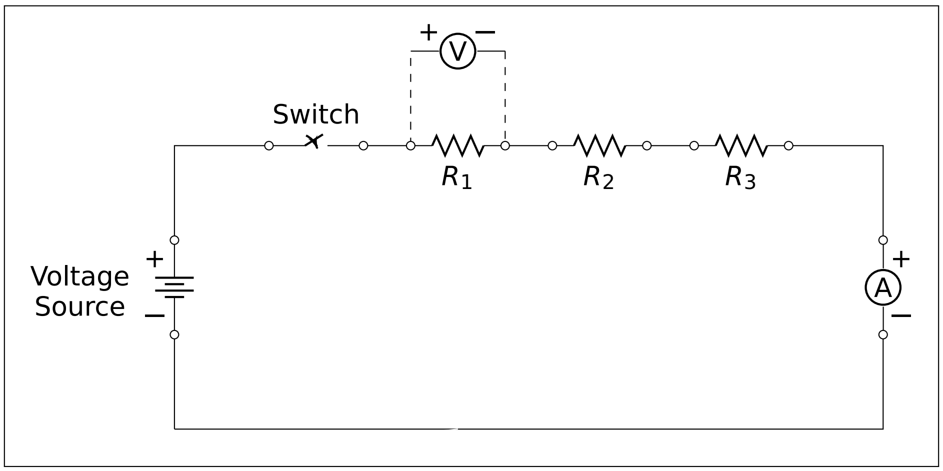
Purpose: To investigate circuits connected in series and parallel.

Apparatus: 12V Power Supply
5 x Digital MultiMeters (DMMs) used as Voltmeters, Ammeters and Ohmmeters
1 x Switch
3 x Resistors
Connecting leads

Series Circuit

Circuit Diagram:

Figure 1: Series Connected Circuit



Procedure: Series Connected Circuit

1. Verify that the power supply is unplugged and the switch in the resistance box is open. [If you are unsure about how to verify that the switch is open, ask the lab instructor.]

2. Conect the three different resistors in series, along with an ammeter and a switch, as shown in Figure 1 above. A good procedure to use is to begin at the + terminal of the power supply and connect each component in sequence as you go around the circuit. Where there are ammeters indicated in the circuit, they must be built into the circuit when you connect the components together, because the circuit current must pass *through* an ammeter. Where the voltmeter is indicated, you can leave it out of the initial set-up because it will be connected to make the readings on an "as needed" basis after you energize the circuit. Consider the voltmeter as a separate tool whose leads you will move around to several locations in the circuit.

3. Measure the voltage of the power source and record it below as V_{source} in the space provided in Table 1.

4. Have your circuit checked, then turn on the power supply, close the switch, and read and record the current indicated by the ammeter [note that the reading is in mA]. Open the switch. Try moving the ammeter to a new location, making sure it is still connected in series, and check the reading again. Record this reading as well.

5. Measure the potential difference across *each* of the resistors by connecting a voltmeter in parallel across each (see the circuit diagram in Figure 1, which shows the meter measuring V_1). Record these values as V_1, V_2 and V_3.

6. Measure the potential difference across all three resistors at once and record the value as V_{123}.

7. Calculate the resistance of each of the resistors and record them. Calculate the total resistance and record it.

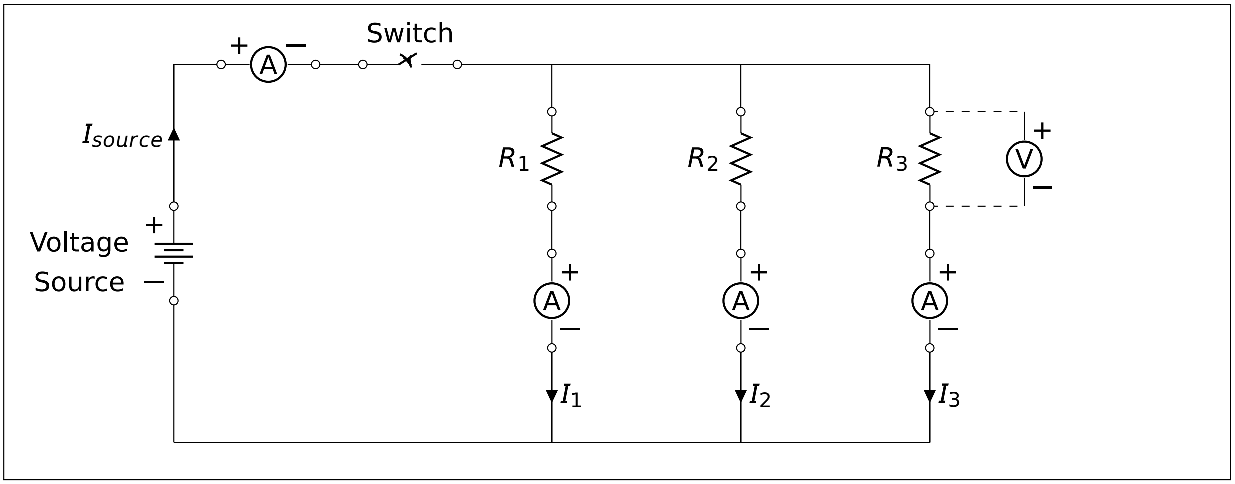
8. On the circuit diagram of Figure 1, write the calculated values of each resistor. Use an arrow and a label (I) to indicate the direction of current flow in the circuit.

9. Take the circuit apart. Measure the resistance of each resistor using the DMM as an ohmmeter and record them. Calculate the total resistance and record it as R_T. Measure the total resistance R_{123} and record this value. [Note that you have to disconnect the resistors from the circuit in order to measure their values with the ohmmeter.]

Table 1: Series Circuit Data

Current	Potential Difference	Resistance (Ω))	
(A) (measured)	(V) (measured)	(calculated)	(measured)
$1^{st}\ I =$	$V_1 =$	$R_1 = V_1/I =$	$R_1 =$
$2^{nd}\ I =$	$V_2 =$	$R_2 = V_2/I =$	$R_2 =$
	$V_3 =$	$R_3 = V_3/I =$	$R_3 =$
Totals	$V_T = V_1 + V_2 + V_3$ $V_T =$	$R_T = R_1 + R_2 + R_3$ $R_T =$	$R_T =$ $R_{123} =$
	$V_{123} =$	$R_{123} = V + 123/I =$ (calculated)	
$V_{source} = 12$V,nominal	$V_{source} =$	Note: V_{source} may be just above or below the nominal value	

Figure 2: Parallel Connected Circuit



Procedure: Parallel Connected Circuit

1. Verify that the power supply is unplugged and the switch to the resistance box is open.
2. Connect the parallel circuit shown in Figure 2 above. There is more than one strategy for performing the wiring, but beginning at the + terminal of the power supply (voltage source) is still a good one. Where there are ammeters indicated in the circuit, they must be included when you connect things together, because the circuit current passes through them. Where the voltmeter is indicated, you can leave it out of the initial set-up because it will be connected to make the readings on an "as needed" basis when you energize the circuit. The voltmeter in Figure 2 is shown measuring V_3, the voltage across R_3, but you will need to move the leads around to make all of the required measurements.
3. Have your circuit checked, then turn on the power supply and close the switch.
4. Measure the voltage of the power source and record it below as *Vsource* in the space provided in Table 2.
5. Read and record the currents indicated by the four ammeters (note that the readings are in mA).
6. Measure the potential difference across each of the resistors by connecting a voltmeter in parallel across each (see the circuit diagram in 2, which shows the meter measuring V_3). Record these values as V_1, V_2 and V_3.
7. Calculate the resistance of each resistor in the three branches of the circuit.
8. Calculate the reciprocal of each of the resistances and record the values in Table 2.
9. Use the reciprocal values, and the formula provided in Table 2 to calculate R_{eq}.

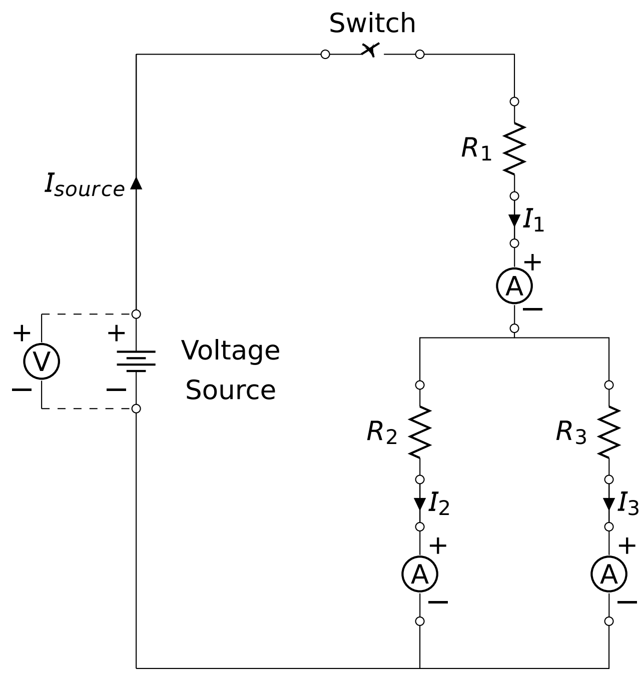
Table 2: Parallel Circuit Data

Current (A) (measured)	Potential Difference (V) (measured)	Resistance (Ω) (measured)	Reciprocal of R (Ω^{-1})(calculated)
$I_1 =$	$V_1 =$	$R_1 = V_1/I =$	$\frac{1}{R_1} =$
$I_2 =$	$V_2 =$	$R_2 = V_2/I =$	$\frac{1}{R_2} =$
$I_3 =$	$V_3 =$	$R_3 = V_3/I =$	$\frac{1}{R_3} =$
$I_T = I_1 + I_2 + I_3$			
Calculating $\mathbf{R_{eq}}$	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ or $R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$		$R_{eq} =$
$I_{Source} =$	$V_{Source} =$	$R_{eq} = V_{Source}/I_{Source} =$	
$V_{source} = 12\text{V}$,nominal			

Series-Parallel Circuit

Circuit Diagram:

Figure 3: Series-Parallel Connected Circuit



Procedure: Parallel Connected Circuit

1. Verify that the power supply is unplugged and the switch in the resistance box is open.
2. Connect the parallel circuit shown in Figure 3 above. Begin at the + terminal of the power supply (voltage source) and work your way around the circuit. Where there are ammeters indicated in the circuit, they must be included when you connect thing together, because the circuit current passes through them. Where the voltmeter is indicated, you can leave it out of the initial set-up because it will be connected to make the readings on an "as needed" basis when you energize the circuit.The voltmeter if Figure 3 is shown measuring V_{source}, but you will need to move the leads around to make all of the required measurements.
3. Have your circuit checked, then turn on the power supply and close the switch.
4. Measure the voltage of the power source and record it below as V_{source} in the space provided in Table 3.
5. Read and record the currents indicated by the three ammeters (note that the readings are in mA).
6. Measure the potential difference across *each* of the resistors by connecting a voltmeter in parallel across each. Record these values as V_1, V_2 and V_3.
7. Calculate the current and voltage sums indicated in Table 3.

8. Using the formula indicated in Table 3, calculate the value of R_{eq} using the directly measured resistance values (using the ohmmeter) that were recorded in Table 1 of the Series Circuit section of the lab.[1] Calculate it again using V_{source} and I_{source}, as indicated.

Table 3: Series-Parallel Circuit Data

Current (A)	Potential Difference (V)
$I_1 =$	$V_1 =$
$I_2 =$	$V_2 =$
$I_3 =$	$V_3 =$
Note that $I_{source} = I_1 =$	$V_{source} =$
Values above this row are measured; those below this row are calculated.	
$I_2 + I_3 =$	$V_1 + V_2 =$ $V_1 + V_3 =$
Calculating R_{eq}: $R_{eq} = R_1 + (R_2//R_3)$ or $R_{eq} = R_1 + \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = R_1 + \frac{R_2 R_3}{R_2 + R_3}$ Note that $R_2//R_3$ indicates that R_2 and R_3 are in parallel. It is not a division sign.	
$R_{eq} =$	
$R_{eq} = \frac{V_{source}}{I_{source}}$	

[1] For a more complete explanation of this calculation, see "Appendix A Background Material for Circuits Lab".

Questions

The following five questions refer to the series circuit

1. Is the measured potential difference across the source equal to the stated source voltage?

2. When the ammeter was moved to a different location in the series circuit, did the current reading remain the same or did it change? Why?

3. What is the sum of the voltages across the three resistors? How does this sume compare to the voltage measured across the three resistors, V_{123} and to the measured voltage of the source?

4. What is the sum of the three resistors? (Give the sum for both the calculated and measured values of resistance.) How do they compare?

5. Calculate the value of resistance using the measured voltage of the source voltage and the source current. How does the sum of the three resistors calculated in question 4 compare with the value of the resistance calculated using the measured source values?

The following three questions refer to the parallel circuit.

6. How do the values of V_1, V_2 and V_3 compare? How do these values compare with the measured potential difference of the source?

7. What is the sum of the currents in each of the three branches? How does this sum compare to the value of the current I_{source} as measured in the main section of the circuit?

8. You have calculated R_{eq} in Table 2 in two different ways. How does the value calculated from the individual voltages and currents compare to the value calculated from the source current and voltage?

The following three questions refer to the series-parallel circuit.

9. How does the current I_1 compare to the sum of I_2 and I_3?

10. You have calculated R_{eq} in Table 3 in two different ways. How does the value calculated from the directly measured resistances compare to the value calculated from the source current and voltage?

11. How does the calculated value of $V_1 + V_2$ compare to the calculated $V_1 + V_3$? How do these two values compare to the source voltage?

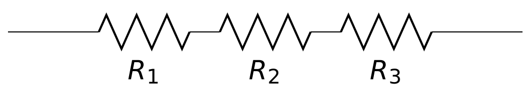
Appendix A
Background Material for Circuits Lab

The Meaning of R_{eq}, or "Equivalent Restance"

It is generally possible to replace a connected group of resistors with a single resistor, which we call the ***equivalent resistance***. By *equivalence*, we mean that when the *group* of resistors is replaced with a *single* equivalent resistance, the remaining portion of the circuit cannot "see" or detect any difference from the original configuration it replaced. The equivalent resistance will have the same voltage across it and the same current through it as was observed for the group of resistors that it replaced. These identical voltage and current characteristics define the notion of equivalence.

Calculating Equivalent Resistance for Series Connected Resistors

Resistors are said to be connected in series when two adjacent resistors share only one terminal in common, that is, they are only connected at one end (with no branching points between them). In the figure below, the three resistors, R_1, R_2 and R_3 are connected in series.

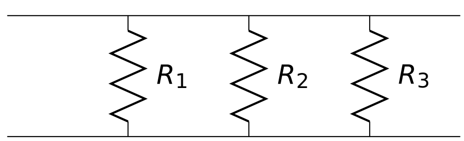


The equivalent resistance that replaces this series combination is determined by simply adding the values of the three resistances. $R_{eq} = R_1 + R_2 + R_3$

The example shows a calculation for three resistors, but the method is the same for any number of series connected resistors.

Calculating Equivalent Resistance for Parallel Connected Resistors

Resistors are said to be connected in parallel when or more resistors share two terminals in common, that is, they are only connected together at both ends. In the figure below, the three resistors, R_1, R_2 and R_3 are connected in parallel.



The equivalent resistance that replaces this parallel combination is determined by adding the values of the reciprocals of the three resistances, and taking the reciprocal of that.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

The example shows a calculation for three resistors, but the method is the same for any number of parallel connected resistors.

There is a special notation used to indicate that we must combine resistors in parallel. It is indicated by two sloped parallel lines. In an expression it would appear as $R_1//R_2$, indicating that R_1 and R_2 are connected in parallel and would require the appropriate calculation to determine an R_{eq}.

When dealing with two resistors in parallel, there is a more convenient form of the equivalence expression to use. We derive it using the basic formula for parallel resistors.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

First we bring the two terms on the right hand side to a common denominator, and then add them.

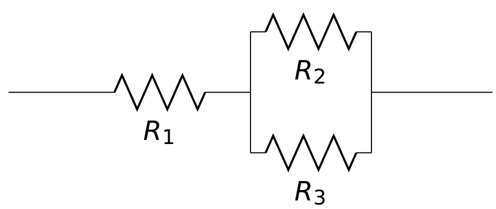
$$\begin{aligned}\frac{1}{R_{eq}} &= \frac{1}{R_1}\left(\frac{R_2}{R_2}\right) + \frac{1}{R_2}\left(\frac{R_1}{R_1}\right) \\ &= \frac{R_2}{R_1R_2} + \frac{R_1}{R_1R_2} \\ &= \frac{R_1 + R_2}{R_1R_2}\end{aligned}$$

and taking the reciptrocal of both sides, we get:

$$R_{eq} = \frac{R_1R_2}{R_1 + R_2}$$

Calculating Equivalent Resistance for Series-Parallel Connected Resistors

We can connect resistors in a way that involves both series and parallel connections in the same arrangement, as shown below. We can also reduce these arrangements of resistors to a single equivalent resistance.



To accomplish this calculation we use both the series and parallel methods of calculation, but they must be applied in the particular order necessary for the combination of resistors we have. For example, in the figure above we have to first calculate the equivalent resistance for the parallel connected pair, R_2 and R_3, and then treat that equivalent resistance as being connected in series with R_1. We then add R_1 to the parallel equivalent to get the value of R_{eq} for the three resistors.

This could be written as $R_{eq} = R_1 + (R_2 // R_3 R)$ where the parenthese indicate the operation on the parallel pair must be performed first, before adding that value to R_1.

After these two operations we have calculated the equivalent resistance that could replace the three resistors shown above.