PHYSICS

d.c. Circuit

Introduction

Modern electronic circuits are extremely complex. The tremendous number of different circuit elements all connected in ever more complicated manners makes the analysis of such circuits a nightmare. However, one need go so far in order to make things complex. Even with only simple resistors and power supplies, quite complex circuitry can be created. In order to help with the analysis of such circuits, laws are needed to limit the possible solutions to the problems.

Just as we found in our first semester physics class, there are conservation laws that can help in this regard. The first of these is the same as we had last semester: the conservation of energy. Just as any path you hike that leads back to the original starting point results in no net change in gravitational potential energy, no path in a circuit that leads back to the starting point can result in a change in energy.

We also have a new conservation law to guide us in our pursuits: the conservation of charge. In a circuit, electrons cannot be created nor destroyed. If a current comes to a juncture, the total amount of electrons going into the juncture must be equal to the total number leaving the juncture. If this is not true, then it would mean that electrons either appeared or disappeared in the juncture, which cannot happen.

Kirchhoff''s Rules

These two basic principles of circuitry were realized in 1845 by Gustav Kirchhoff. The actual laws, expressed mathematically, can be quite complex. However, for our purposes here, they are expressed easily by the following two statements about any multi-loop circuit:

1. The sum of the currents entering any circuit junction is equal to the sum of the currents leaving the junction.
2. The sum of the changes in potential across all elements around any closed circuit loop is equal to zero, with the conventions that traversing an emf from (-) to (+) results in a positive potential change, and resistors traversed in the direction of the current result in a negative potential change.

Theory and Model

In a series circuit (see Figure 1), the current going through each resistor is the same, and the total potential drop across the emf is just a sum of the individual potential drops across the resistors. From the emf's standpoint, this looks like it is attached to a resistor that has a value equal to the sum of the individual resistors, i.e.

$$
\begin{aligned}
V &= V_1 + V_2 + V_3 + \ldots \\
&= IR_1 + IR_2 + IR_3 + \ldots \\
&= I(R_1 + R_2 + R_3 + \ldots) = IR_{total}
\end{aligned}
$$

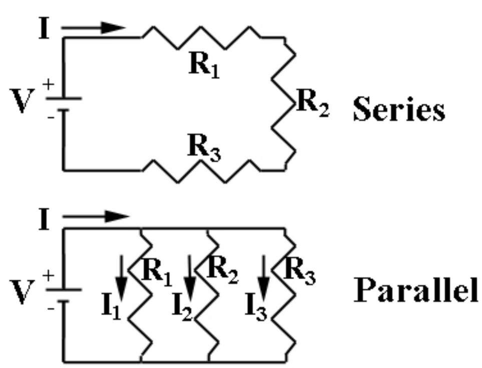

Fig. 1: Series and parallel circuits

In a parallel circuit, the potential drop across each resistor is the same and equal to that of the applied emf. Thus, the current running through each resistor depends only upon the value of its resistance, i.e.

$V = I_1R_1 = I_2R_2 = I_3R_3 = ...$

In order for this type of circuit to work, the emf must supply a current I that is the sum of all of the individual currents running through the resistors. Thus,

$$V = IR = (I_1 + I_2 + I_3 + ...)R = (\frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + ...)R = V(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...)R$$

Canceling the emf from both sides, we get the relationship that

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

In this week's experiment, we will test these rules and equations on three different circuits: one in which three resistors are in series, one in which three resistors are in parallel, and one in which two resistors in series are in parallel with the third.

Procedure

We will need a power supply, three resistors, wires for connecting all devices together, and a multimeter.

1. Secure the necessary lab equipment. Measure the actual resistance of all three resistors.
2. With the ammeter connected to the power supply, initially connect the three resistors in series.
3. Turn on the power supply, and adjust the output until the current from the power supply is .1 A.
4. Measure and record the potential drops across each resistor individually, and across all series of resistors.
5. Place the multimeter in series with the resistors and measure the current.
6. Disconnect the first resistor in the series and place it in parallel with the series combination of the other two resistors.
7. Measure the potential drop across each resistor.
8. Place the multimeter in series with each parallel subcircuit and measure the current.
9. Place the first resistor back in series with the other two. Remove the second resistor, and place it in parallel with the series combination of the other two.
10. Repeat steps 7-8.
11. Place the second resistor back in series with the other two. Remove the third resistor, and place it in parallel with the series combination of the other two.
12. Repeat steps 7-8.
13. Place all resistors in parallel. Measure the potential and current in each one.
14. Place all measurements on the activity sheet and answer the questions. Note that V_i and I_i on the activity sheet refer to the measured voltage and current going through the i^h resistor.
15. Shut off the power supply and replace all equipment where it was found.

Physics Activities	Activity Sheet d.c. Circuit

Name:

R_1 = ______ Ω
R_2 = ______ Ω
R_3 = ______ Ω

Configuration	V_{total}	I_{total}	V_1	I_1	V_2	I_2	V_3	I_3
1								
2								
3								
4								
5								

1. In configuration 1, does $I_1R_1 + I_2R_2 + I_3R_3 = V_{total}$? Does $V_1 = I_1R_1$, $V_2 = I_2R_2$, and $V_3 = I_3R_3$? What possible random or systematic errors could account for any differences?

2. In configuration 2, does $I_2R_2 + I_3R_3 = I_1R_1$? Does $V_1 = I_1R_1$, $V_2 = I_2R_2$, and $V_3 = I_3R_3$? What possible random or systematic errors could account for any differences?

3. In configuration 3, does $I_1R_1 + I_3R_3 = I_2R_2$? Does $V_1 = I_1R_1$, $V_2 = I_2R_2$, and $V_3 = I_3R_3$? What possible random or systematic errors could account for any differences?

4. In configuration 4, does $I_1R_1 + I_2R_2 = I_3R_3$? Does $V_1 = I_1R_1$, $V_2 = I_2R_2$, and $V_3 = I_3R_3$? What possible random or systematic errors could account for any differences?

5. In configuration 5, does $I_1R_1 = I_2R_2 = I_3R_3$? Does $V_1 = I_1R_1$, $V_2 = I_2R_2$, and $V_3 = I_3R_3$? What possible random or systematic errors could account for any differences?