KIRCHHOFF'S RULES

PURPOSE

In this experiment circuits containing several resistors and sources of emf will be built. The currents in different branches of the circuits will be measured and their values will be compared to those determined from the application of Kirchhoff's rules to the circuits.

EQUIPMENT AND SUPPLIES

- DC Power Supplies.
- Multimeter.
- Resistors.
- Wires and alligator clips.

DISCUSSION

Whenever a circuit is complicated (sometimes known as a *network*), analyzing it by application of the formulas for resistors in parallel or in series becomes impractical (or impossible). In such cases the analysis of the circuit can be done with the help of ***Kirchhoff's rules***. These rules are a direct consequence of two fundamental principles: The conservation of energy and the conservation of electric charge.

The loop rule**:** The net change in potential around any closed path in a circuit is zero.

The junction rule**:** The sum of all currents entering a junction in a circuit equals the sum of all currents leaving the junction.

The loop rule states that all the electric potential gains must be perfectly compensated by the electric potential drops if we move from a given point around any path and then return to the same point. Recalling that electric potential is just potential energy per unit charge, the loop rule is telling us that for a charge going through the loop the energy gained equals the energy lost. This is simply conservation of energy.

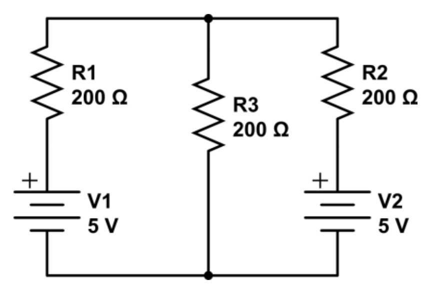

Figure 1: Example of branches

The current at a given point in a circuit is the charge per unit time flowing through that point. Therefore, according to the junction rule, at a given node the charge entering the junction per unit time must equal the charge leaving the junction per unit time. This is just conservation of charge. By the way, a ***branch*** is one or more circuit elements connected in series and carrying a unique current, and a ***junction*** (also known as a *node*) is a point where three or more branches meet.

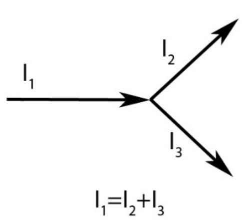

Figure 2: Example of junction

Let's see how Kirchhoff's rules are used in practice. We will analyze the circuit depicted in the Figure 3a and will determine the currents through all the branches. There are two junctions in this case (labeled *a* and *b*) and three branches (*b-e-a*, *b-f-a*, and *b-c-d-a*). First assign currents to the different branches (shown in Figure 3b). Don't worry about the directions, for if a current in the end is found to be negative that means its direction is the opposite of the original assignment. After choosing the currents, label with signs the potential rises and drops (also shown in Figure 3b). The rule for these signs is simple: Whenever a current traverses a resistor, there is a potential drop, so mark the entering point as + and the point of exit as $-$. For a source of emf, always label the negative terminal as $-$ and the positive terminal as +. When using the loop rule, the change in potential ($V = IR$) will be positive when going from $-$ to +, and negative when going from + to $-$.

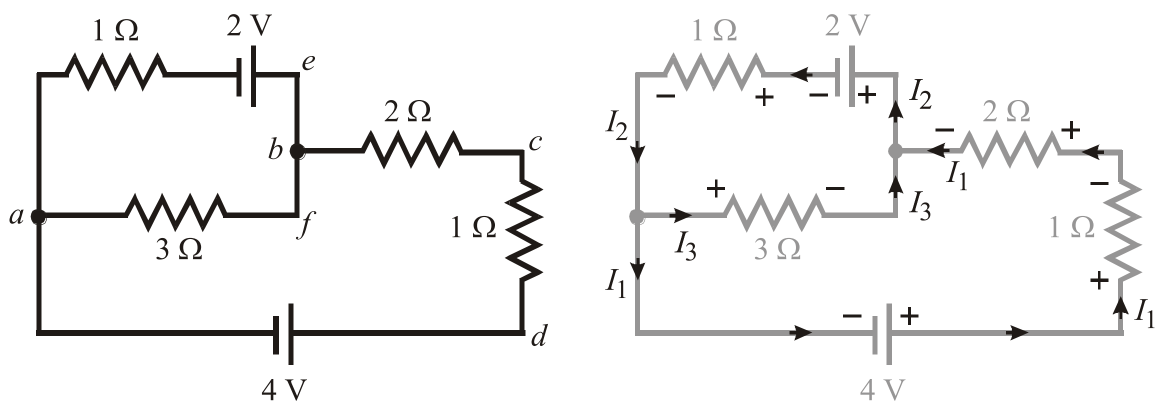

Figure 3

(a) (b)

There are three loops in this circuit (*a-f-b-e-a, a-f-b-c-d-a, a-d-c-b-e-a*), and so the loop rule will provide us with three equations. Considering that the junction rule gives two more equations (junctions *a* and *b*), Kirchhoff's rules provide a total of five equations in this example. On the other hand, there are only three unknown currents, so some equations will be redundant. This means that we need to be careful and choose only three *independent* equations. For example, the two junction equations are

For junction *a*: $I_2 = I_1 + I_3$, and for junction *b*: $I_3 + I_1 = I_2$

which are identical and therefore not independent.

Let's start by applying the loop rule to *a-f-b-e-a* (that is, in the counterclockwise direction). We find,

$$-3I_3 - 2 - I_2 = 0$$

For the loop *a-f-b-c-d-a* (that is, moving clockwise),

$$-3I_3 + 2I_1 + I_1 - 4 = 0$$

The third equation can be taken to be $I_2 = I_1 + I_3$ (from the junction rule).
The three equations can be written as

$$-3I_3 - I_2 = 2$$
$$-I_3 + 3I_1 = 4$$
$$-4I_3 - I_1 = 2$$

Multiplying the third equation by 3 and subtracting from the second equation, we find

$$-15I_3 = 10 \quad \Rightarrow \quad I_3 = -2/3 \text{ A}$$

The negative sign indicates that the direction of I_3 is the opposite of what we chose in the diagram. To find the other two currents, we plug this result into the first and third equations, yielding

$$I_2 = 0 \text{ and } I_1 = 2/3 \text{ A}$$

PROCEDURE

1. Using the multimeter, measure R_1 (100 Ω), R_2 (200 Ω), and R_3 (330 Ω). Record their values.
1. Build the circuit shown in Figure 4(a) below.

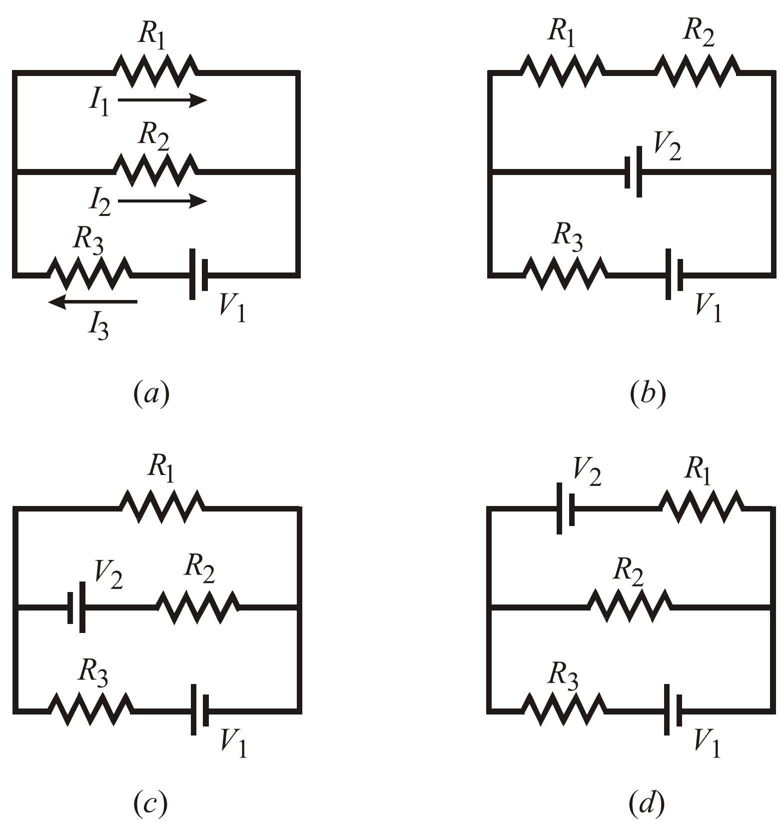

Figure 4

2. Measure the terminal voltages V_1 (5V) and V_2 (3V) across each power supply. (This is, in general, not equal to the emf when the power supply is connected to the circuit. Check your textbook for an explanation of why this is so.)
3. Measure currents I_1, I_2, and I_3 in the circuit and record their values. Determine the directions of the currents from your measurements and draw the directions (as arrows) in the Figure.
4. Repeat the steps for circuits (b) and (c) in Figure 4.

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6. Build the circuit shown in Figure 4(d). Repeat steps 3 and 4.

Name:______________________________ Date:__/__/__ Section:________________
Lab Partners Present:____

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LAB REPORT

DATA ANALYSIS

1. Use Kirchhoff's rules to calculate the expected values of the currents I_1 , I_2 , and I_3 along with V_1, V_2, and V_3 for each circuit. Fill out the corresponding table below and compute the % errors.

$R_1 =$_______ $R_2 =$_______ $R_3 =$_______

Circuit 4(*a*). $V_1 =$_______

	Measured	Calculated	% Error
I_1			
I_2			
I_3			
V_1			
V_2			
V_3			

Circuit 4(*b*). $V_1 =$_______ $V_2 =$ _______

	Measured	Calculated	% Error
I_1			
I_2			
I_3			
V_1			
V_2			
V_3			

Circuit 4(*c*). V_1 =________ V_2 = ________

	Measured	Calculated	% Error
I_1			
I_2			
I_3			
V_1			
V_2			
V_3			

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Circuit 4(*d*). V_1 =________ V_2 = ________

	Measured	Calculated	% Error
I_1			
I_2			
I_3			
V_1			
V_2			
V_3			

DISCUSSION AND CONCLUSIONS