

# Experiment 19

## Kirchhoff's Laws for Circuits

### Advanced Reading:

(Halliday, Resnick and Walker)  
Chapter 27, sections 27-4 through 27-7.

### Equipment:

- 1 Circuit board
- 2 D cell batteries with holders
- 1 Kelvin DMM with leads
- 1 10  $\Omega$  resistor
- 1 12  $\Omega$  resistor
- 1 15  $\Omega$  resistor
- 1 18  $\Omega$  resistor
- 1 22  $\Omega$  resistor

### Objective:

The object of this experiment is to apply Kirchhoff's rules for circuits to a two loop circuit in order to determine the currents and voltage drops in each loop.

### Theory:

The two basic laws of electricity that are most useful in analyzing circuits are Kirchhoff's laws for current and voltage. Kirchhoff's Current Law (KCL) states that at any junction of a circuit, the sum of all the currents entering the junction equals the sum of the currents leaving the junction. In other words, electrical charge is conserved. Kirchhoff's Voltage Law (KVL) states that around any closed loop or path in a circuit, the algebraic sum of all the voltage drops must equal zero. In other words, energy is conserved.

There are three generally accepted ways to solve multiple loop circuit problems, the branch method, the nodal method, and the loop method. You will use the loop method in this experiment.

In this method a current loop is drawn for each closed loop of the circuit. To avoid confusion, it is good to arbitrarily have all the currents going clockwise. The currents in a loop always flow through a junction, so the KCL is satisfied. We need only to worry about satisfying the voltage requirements. To do this the following rules need to be followed:

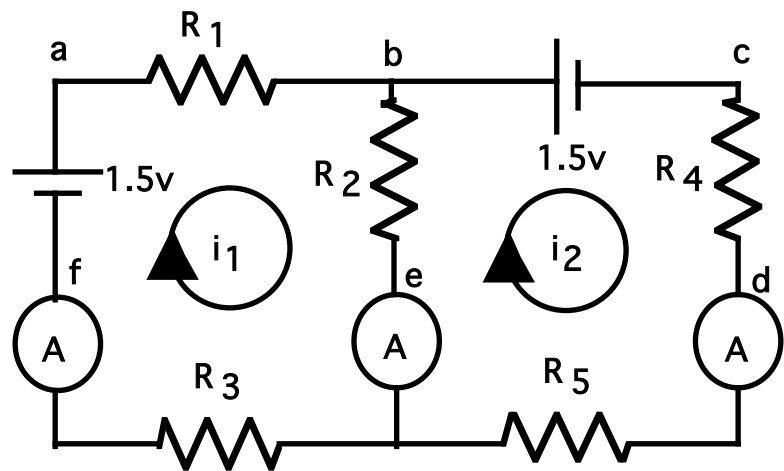


figure 19-1

(1) If a current that traverses a resistor in the direction of the current flow, the change in potential is  $-iR$ ; in the opposite direction it is  $+iR$ .

(2) If a seat of emf (voltage source) is traversed in the direction of the emf (from - to + on the terminals), the change in potential is  $+\epsilon$ ; if it is traversed in the opposite the emf (from + to -), the change in potential is  $-\epsilon$ .

For example, the equation for the loop one in figure 20-1 would be:

$$\epsilon - i_1 R_1 - i_1 R_2 + i_2 R_2 - i_1 R_3 = 0$$

or:

$$\epsilon - i_1 (R_1 + R_2 + R_3) + i_2 R_2 = 0$$

Similar equations can be written for the other loop and by solving the two equations simultaneously, the values for  $i_1$  and  $i_2$ .

### Procedure:

1. Measure and record the resistance of each of the five resistors on the lab table with the ohmmeter.
2. Construct a circuit with the five resistors and the two batteries on the circuit board as shown in figure 19-1. Make sure the battery polarity is correct.
3. Measure the potential across each of the batteries when the circuit is complete. **When this is done, disconnect the batteries.**

4. Calculate the currents  $i_1$  and  $i_2$  **using the measured resistor values**. To do this, write the equation for each of the loops as given in the theory section. Move the emf term ( $\epsilon$ ) to the right-hand side of the equation. (WATCH YOUR  $\pm$  SIGNS! This is one of the most common causes of incorrect answers.) The coefficients for the equations are the values of the resistances. Solve for  $i_1$  and  $i_2$ . (If either current has a negative value, do not be alarmed. This means that the real current flow is opposite to the arbitrary current direction chosen.)

5. Place the DMM between  $R_3$  and f on the circuit board. (See figure 19-1 for these locations.) Place the batteries back into the circuit and measure the current flow in the loop. Do this by removing the shunt and inserting the ammeter into this position. After measuring the current flow, return the shunt to its original position.

6. Repeat for the other ammeter positions. Try to do these measurements as quickly as possible. If the batteries are nearly dead, then the potential difference across the battery could change rather quickly, causing the currents to be different. **Be sure to check all of your connections. If one is loose, the probability of erroneous measurements is high.**

7. Compare the experimental values of  $i_1$  and  $i_2$  with the calculated values obtained in part 2. If they are not the same, check your calculations from part 2 and retest your circuit (or see warning above.)

8. Measure the voltage drops and emf's around each loop using the DMM. Do the loops obey Kirchhoff's voltage law?

## Part 2: Can you trust a measuring instrument all the time?

15. One a table at the front of the room, your lab instructor has two circuits. Both are series circuits; one with two 100 ohm resistors and the second has two 10 mega ohm resistors (i.e., two  $10 \times 10^6$  ohm resistors). Take your DMM to this table. Adjust the power supply to read 10 volts. Measure the potential differences across each of the resistors of both circuits.

Do the potential differences (of the resistors from each circuit) add to the potential difference across the power supply? (See question 4 below).

### Questions/Conclusions:

1. Explain what effect the DMM might have on the circuit when inserted to measure the current.

2. Would disconnecting the battery on the left-hand side of the circuit board effect the current  $i_2$ ? Calculate what  $i_2$  is for this case.

3. Solve the circuit used in the experiment above using Kirchhoff's current and voltage laws explicitly (i.e., use sum of voltage around loops and sum of current in and out of junctions to derive equations). You will have three equations and three unknowns. Show all work.

4. Discuss results of part 2 (**Can you trust a measuring instrument all the time?**) in the context Kirchhoff's voltage law and the effect of DMM on the circuit.