

Experiment 20

Kirchhoff's Laws for Circuits

Advanced Reading:
(Serway & Jewett 8th Edition)
Chapter 28, section 28-3.

Equipment:
1 Circuit board
2 D cell batteries with holders & leads
1 Kelvin DMM with leads
1 10 Ω resistor
1 12 Ω resistor
1 15 Ω resistor
1 18 Ω resistor
1 22 Ω 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, electric 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 potential has to return to the original value.

There are three generally accepted ways to solve multiple loop circuit problems, the branch method, the nodal method, and the loop method. The loop method will be used 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:

(1) If a current traverses a resistor in the direction of the current (loop) flow, the change

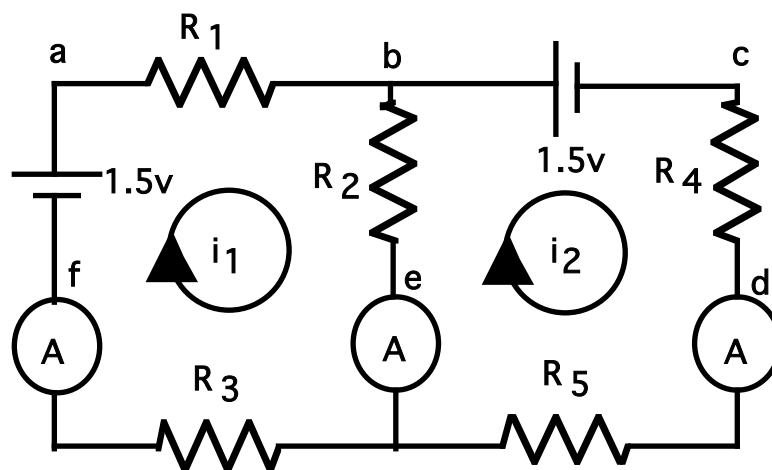


figure 20-1

in potential is $-iR$. If a 2nd current traverses the same resistor (e.g., R_2 in figure 20-1 above) in the opposite direction the change in potential 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:

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

A similar equation can be written for the other loop and by solving the two equations simultaneously, the values for i_1 and i_2 can be obtained.

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 20-1. Make sure the battery polarities are correct.

3. Measure the potential difference across each of the batteries while 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 (ϵ) 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 20-1 for these locations.) Place the batteries back into the circuit and measure the current flow in the loop. *You will have to remove one prong of the resistor plug and then complete circuit using the ammeter.* After measuring the current flow, return the resistor to its original configuration.

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?

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 10×10^6 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 (i.e., comment on whether the current **into** a junction is equal to the current **out** of a junction when uncertainty is considered.)

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

3. 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) derive the current equations to the circuit used in this experiment.

Do not solve. Simply set up equations and put in a form that is conducive to computer solution.

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.

You will need to calculate the equivalent resistance of both circuits assuming that the voltmeter (i.e., DMM) is a 10×10^6 Ohm resistor. Does the voltmeter affect the circuit?

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