KIRCHHOFF'S LAWS

Purpose

To study Kirchhoff's laws in the case of a two-loop circuit.

Theory

Consider the two-loop circuit shown in Figure 1.

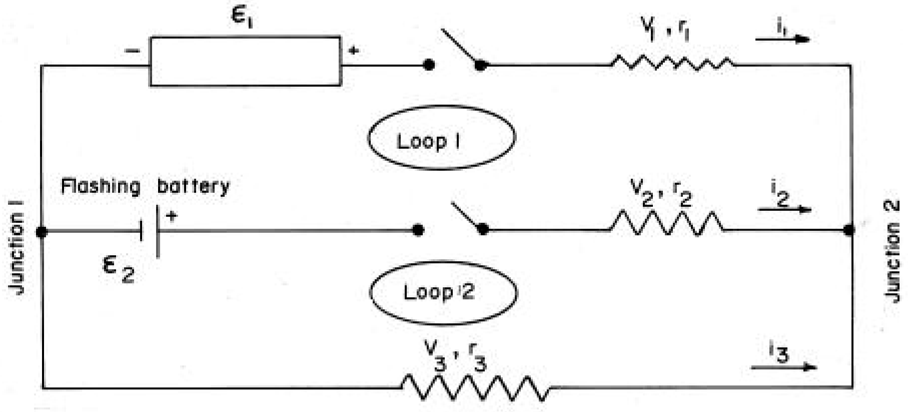

Figure I. Circuit used for the study of Kirchhoff's laws

There are two Kirchhoff's laws. The first says that at any junction the algebraic sum of the currents must be zero. (Note: We arbitrarily label positive a current approaching a junction and negative a current leaving it). For example, in the circuit of Figure 1, at junction 2 we have:

$$I_1 + I_2 + I_3 = 0 \quad (1)$$

The second Kirchhoff's law says the algebraic sum of the changes in potential around a loop equals zero.

For loop 1 above we have

$$E_1 - I_1 R_1 + I_2R_2 - E_2 = 0 \quad (2)$$

For loop 2

$$E_2 - I_2R_2 + I_3R_3 = 0 \quad (3)$$

Equations 1, 2 and 3 can be re-written as:

$$I_1 + I_2 + I_3 = 0$$
$$R_1 I_1 - R_2 I_2 = E_1 - E_2$$
$$R_2 I_2 - R_3 I_3 = E_2$$

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The solutions for I_1, I_2 and I_3 are:

$$I_1 = [R_2E_2 + (R_2 + R_3)(E_1 - E_2)] / D \quad (4)$$

$$I_2 = [R_1E_2 - R_3(E_1 - E_2)] / D \quad (5)$$

$$I_3 = -[(R_1 + R_2) E_2 + R_2 (E_1 - E_2)] / D \quad (6)$$

where

$$D = R_1R_2 + R_2R_3 + R_1R_3 \quad (7)$$

Procedure

The electrical circuit used in this experiment is shown in Figure 1. It includes two emfs (one power supply and a flashlight battery), and three resistors, connected in a two-loop circuit.

1. Set up the circuit shown in Figure 1, paying special attention to the polarity of the two emfs.

   Notes: (a) Your instructor will assign the values of R_1, R_2 and R_3 from the 2*3=6 combinations of three resistors (27 Ω, 47 Ω and 68 Ω) which are available.

   (b) You will measure voltages and currents using a **digital multimeter**.

2. Close the switches. Turn on the power supply. Turn the knob until E_1 = 10.0 V, as measured by the multimeter in the voltmeter function. Use the multimeter to measure E_2.

3. At junction 2 remove the wires from resistors R_1, R_2 and R_3, one at a time, and measure the currents I_1, I_2, and I_3, using the multimeter in the ammeter function.

4. Measure the voltage V_1, V_2, and V_3, across R_1, R_2 and R_3, respectively.

   Note: Use the switches to temporarily disconnect the emf's from the circuit while you are calculating, etc. Otherwise the battery will run down, making your measurements vary with time.

When measuring the currents note that the current is positive if the ammeter deflects upscale when the "COM" input is connected to junction 2 and the V-Ω-A input is connected to the resistor; otherwise switch leads, measure the current and label it negative (see Figure 2).

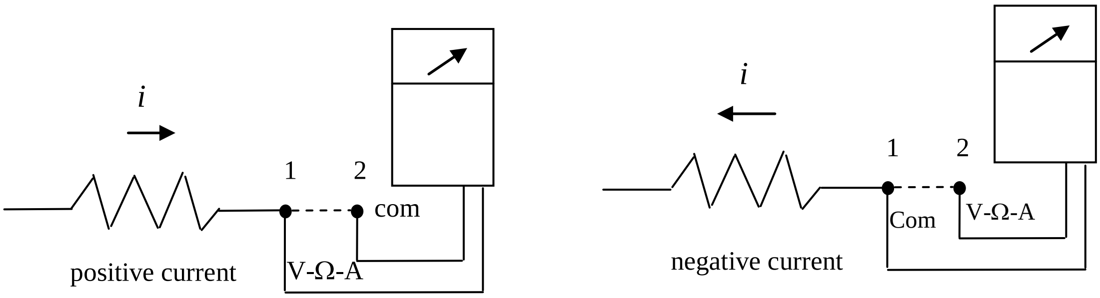

Figure 2. How to determine the direction of the current

The sign of the voltages is determined as shown in Figure 3.

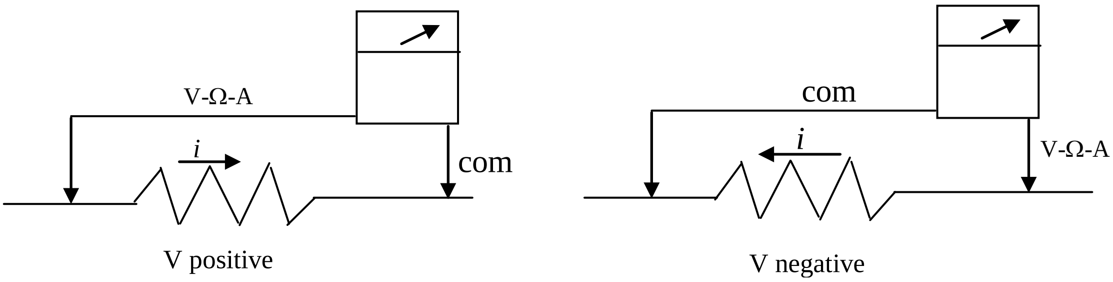

Figure 3. How to determine the sign of the

Analysis

1. Substitute the values of E_1, E_2, R_1, R_2 and R_3 into equations 4, 5, 6 and 7, and obtain the value of I_1, I_2 and I_3.

2. Using the calculated values of I_1, I_2 and I_3, calculate V_1, V_2 and V_3 using Ohm's law.

Questions

1. Does the sum of the measured currents at junction 2 equals zero in accord with the first Kirchhoff's law? If not, can you explain the difference?

2. Are the sums of the measured changes in potential around loop 1 and around loop 2 equal to zero in accord with the second Kirchhoff's law? Can you explain any differences?

3. How well do the measured values of I_1, I_2 and I_3 agree with the calculated values in magnitude and sign? Is the error reasonable considering the measurement accuracy and the resistor tolerance?

4. What is the first Kirchhoff's law equation for junction 1? Does it yield any new information about the current? Explain.