Experiment 17: Kirchhoff's Laws for Circuits

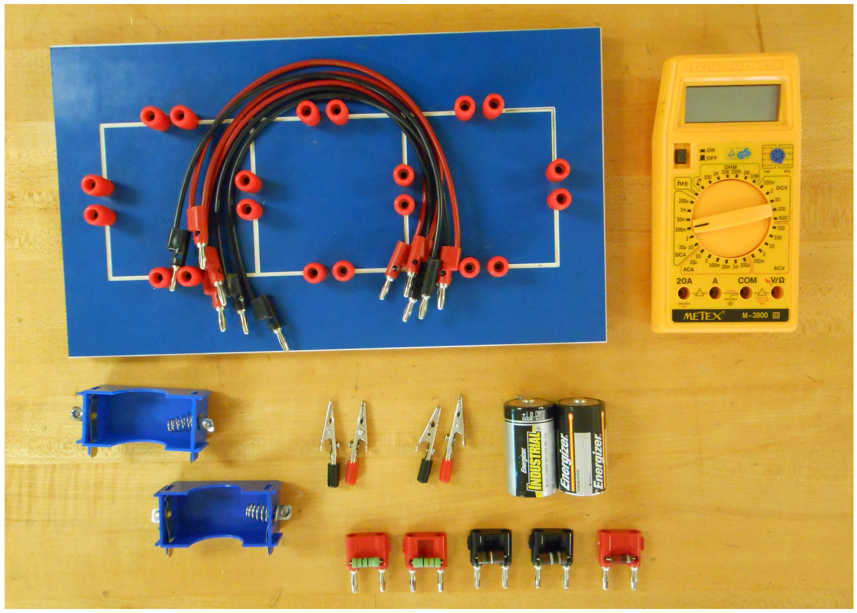

Figure 17.1: Kirchhoff's Law Circuit Board

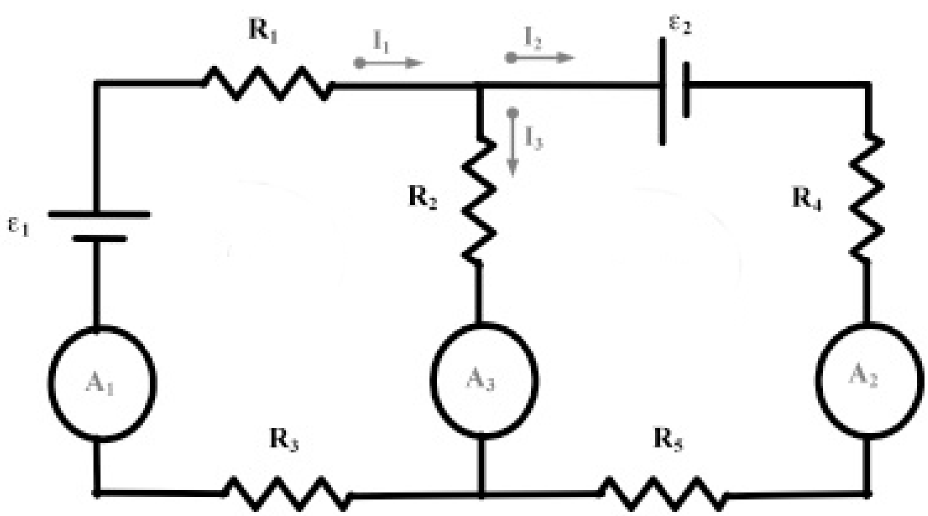

Figure 17.2: Schematic for Kirchhoff's Circuit

EQUIPMENT

(1) Universal Circuit Board
(2) D-Cell Batteries (1.5 V)
(2) Battery Holders
(4) Alligator Clips
(1) DMM

(5) Resistors:
$R_1 = 10\ \Omega$ Resistor
$R_2 = 12\ \Omega$ Resistor
$R_3 = 15\ \Omega$ Resistor
$R_4 = 18\ \Omega$ Resistor
$R_5 = 22\ \Omega$ Resistor

Advance Reading

Text: Kirchhoff's Voltage Law, Kirchhoff's Current Law

Lab Manual: Appendix A: Math Review (solving 3 equations with 3 unknowns)

Objective

The objective of this experiment is to apply Kirchhoff's rules for circuits to a two-loop circuit to determine the three currents in the circuit and the electric potential differences around 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 (The Junction Rule) states that at any junction (node) of a circuit, the algebraic sum of all the currents is zero (sum of the currents entering the junction equals the sum of the currents leaving the junction). In other words, electric charge is conserved.

$$\Sigma I_{in} = \Sigma I_{out} \tag{17.1}$$

Kirchhoff's Voltage Law (The Loop Rule) states that around any closed loop or path in a circuit, the algebraic sum of all electric potential differences is equal to zero.

$$\Sigma V_i = 0 \tag{17.2}$$

To calculate magnitudes of current and voltage in a circuit like Fig. 17.2, you will need to write three equations, making use of both the loop and junction rules. This results in three equations with three unknowns. For this experiment, you will measure ε_i and R_i, then solve for the three currents, I_i.

One might be able to guess the direction of current flow in a circuit, given a circuit such as the one in this experiment. However, as long as the current direction chosen at the beginning is used consistently throughout the calculation, the calculation will be correct. For the purposes of this experiment, all currents will be assumed to be in the direction shown in Fig 17.2. If any current is measured or calculated to be negative, that current actually flows in the opposite direction of what is indicated in Fig 17.2.

Apply the following rules when writing a KVL equation for a loop:

- If a source of *emf* is traversed from $-$ to $+$, the change in potential is $+\varepsilon$; if it is traversed from $+$ to $-$, the change in potential is $-\varepsilon$.
- Current flows from high potential to low potential. A loop crossing a resistor with the current constitutes a negative potential difference. A loop crossing a resistor against the current yields a positive potential difference.

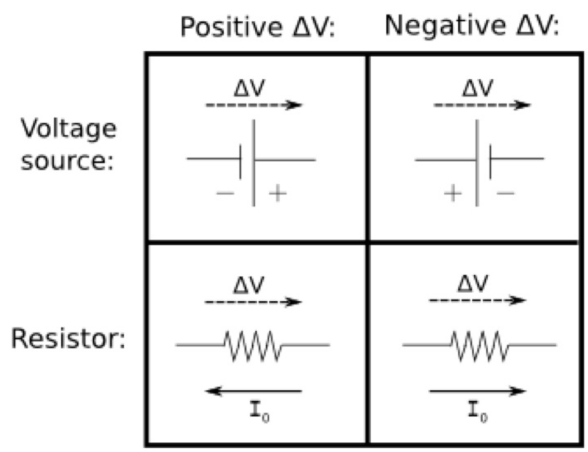

Figure 17.3: Potential Difference Sign Convention

Write and equation relating the currents to each other using the junction rule,. Then write equations for two different loops in terms of electric potential difference.

For example, the equation for the currents in the top center junction in Fig 17.2:

$$i_1 = i_2 + i_3 \tag{17.3}$$

And an equation for the loop consisting of $\varepsilon_1, R_1, R_2, and R_3$ in Fig 17.2 is:

$$\varepsilon_1 - R_1 i_1 - R_2 i_3 - R_3 i_1 = 0 \tag{17.4}$$

Write a similar equation for the loop consisting of $\varepsilon_2, R_4, R_5, and R_2$, then solve this system of three equations for the currents we predict through the three ammeters.