

Kirchhoff's Circuit Laws

Spring 2009

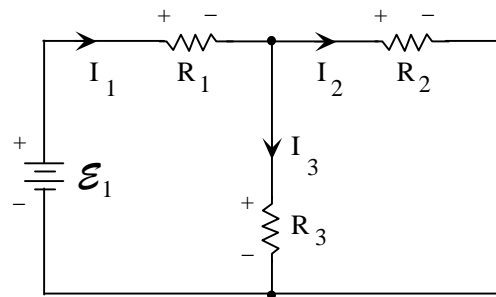
Introduction

This experiment will allow you to examine Kirchhoff's Current Law and Voltage Law. *Be sure to set your multimeter to get as much measurement precision as possible.*

Experiment

1. Kirchhoff's Current Law (the Node Rule)

- a. Make a large, neat sketch of the circuit shown above. Make sure you see the correlation between this diagram and the circuit board you are using.
- b. Create a table in your report as shown below:



Resistor	$R (\Omega)$	$I (A)$	$V_{\text{calculated}} = R \cdot I (v)$	$V_{\text{measured}} (v)$
R_1				
R_2				
R_3				

- c. **Before connecting any wires to the circuit**, set your multimeter to be used as an ohmmeter and measure each resistor on your board; write the value of each resistance on your circuit diagram, and in the data table.
- d. Two jumper wires will be used in this experiment to complete the circuit. Connect jumper wire J_2 on the right side of the circuit as shown below; this jumper will be in place for the first two experiments, and **removed** in step 3a for the third.
- e. Connect an ammeter and jumper wire J_1 as shown in figure 1 below:

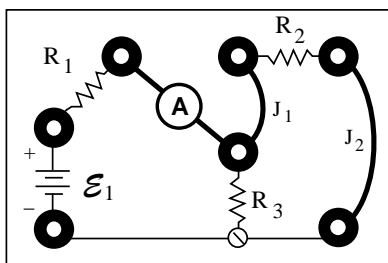


Figure 1

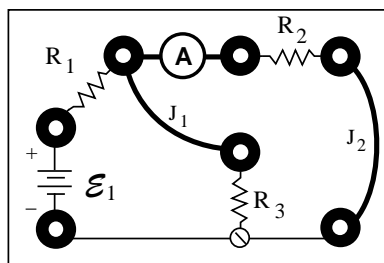


Figure 2

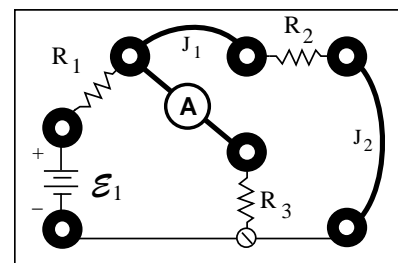


Figure 3

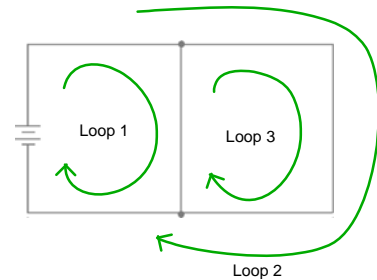
- f. Connect the DC power supply to your circuit board, set the voltage to 15.0 volts (as measured on the voltmeter), then measure and record I_1 , the current through R_1 . Move the ammeter and jumper wire J_1 to the positions shown in figures 2 and 3 to measure I_2 , and I_3 , respectively. The jumper wire ensures that the entire circuit is powered at all times.
- g. Kirchhoff's current law states that the total current flowing *into* a junction is equal to the total current flowing *out* of the junction ($I_{\text{in}} = I_{\text{out}}$). Check your measurements to see if $I_1 = I_2 + I_3$.

2. Kirchhoff's Voltage Law (the Loop Rule)

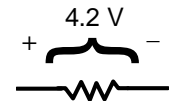
Kirchhoff's voltage law states that the sum of the voltages in *each loop* of the circuit will be zero:

$$\sum_{\text{around loop}} \Delta V = 0$$

- a. In your data table, calculate the voltage across each resistor from your measured resistance and current measurements.
- b. The figure at right shows the three loops you will follow for your circuit. Identify which resistors are contained in each loop. Is the voltage source included in each loop?
- c. Moving *clockwise* around the left loop ("Loop 1") of your circuit diagram, determine the sum of the calculated voltages and the voltage source.



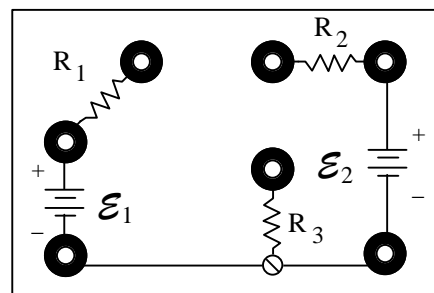
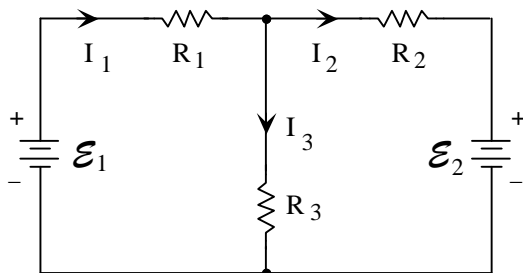
- d. Repeat your calculations for the outside loop ("Loop 2"), and then the right loop ("Loop 3"). Are the sums consistent with Kirchhoff's voltage law?
- e. Now you will measure the voltage across each resistor. Record the measured voltage in your data table, and on your circuit sketch; use a curly bracket on the circuit sketch to denote the magnitude and polarity of the voltage, as shown at right. Some things to consider:



- It is important that current flows through the *entire circuit* during your voltage measurements. Which configuration of \mathbf{J}_1 and the ammeter (Figure 1, 2, or 3) should you use? Does it matter?
 - You don't need to switch the position of \mathbf{J}_1 and the ammeter for each voltage measurement!
 - If additional wires are available, you can substitute another jumper wire for the ammeter during these voltage measurements.
- f. Record the measured voltages in your data table. Calculate the sum of these *measured* voltages around each loop. Are these sums consistent with Kirchhoff's voltage law?

3. The Current Law with **Two** Voltage Sources

- a. **Remove the second jumper wire (J_2) from your circuit!** If you fail to do this, you'll blow out a fuse!



Note: Remove second jumper before connecting \mathcal{E}_2

- b. Connect a *second* voltage source as shown above, and draw a second circuit diagram. Set the second voltage source to 10.0 volts (as measured on the voltmeter).

- c. The derivation of the equations for I_1 , I_2 , and I_3 is tedious, but the solutions for the currents with the two sources (defined in the sketch) are shown below. Use these equations to calculate the *expected* value of each current:

$$\left. \begin{aligned} I_1 &= \frac{(\mathcal{E}_1(R_2 + R_3)) - \mathcal{E}_2 R_3}{D} \\ I_2 &= \frac{(\mathcal{E}_1 R_3 - \mathcal{E}_2(R_1 + R_3))}{D} \\ I_3 &= \frac{(\mathcal{E}_1 R_2 + \mathcal{E}_2 R_1)}{D} \end{aligned} \right\} \text{ where } D = R_1 R_2 + R_2 R_3 + R_1 R_3$$

- d. Again measure the current through each resistor (using the same configurations of the ammeter and J_1 as shown in part 1 above). Compare your measured currents to their expected values. Be sure to observe the polarity of the resistors (from part 2) when connecting the ammeter.
- e. Once again, use your measured currents to see if $I_1 = I_2 + I_3$.

Discussion

- Summarize your numerical results (calculated and measured, and current and voltage sums) from the three parts of this experiment.
- Discuss whether or not your numerical results are consistent with Kirchhoff's Node and Loop rules.
- Look carefully at the circuit diagram from step (3a). Now look at your measured and calculated currents. What's wrong with this diagram as it is drawn?