# EXPERIMENT 2

## Kirchoff's Laws

### Objectives

1) Verify Kirchoff's Current Laws.
2) Verify Kirchoff's Voltage Law

### Introduction

Gustav Kirchoff formulated two useful general rules for analyzing circuits. The current law simply states the sum of the currents entering a point must exactly equal the sum of the currents leaving the point. To apply the law, assume a direction for each current. If your assumption is incorrect, the resulting current will be negative. However, the magnitude of the current will be correct. In equation form, the current law is:

$$\sum I_{in} = \sum I_{out}$$

Two wires are shown meeting at a junction in figure 1.

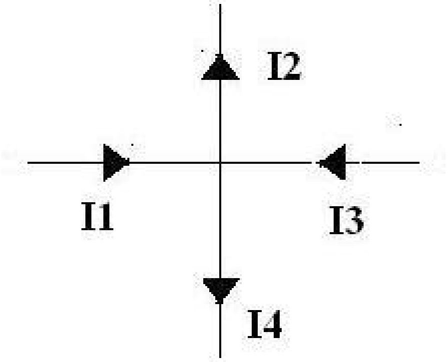


**Figure 1: Currents at a junction**

Currents I1 and I 3 are entering the junction, while currents I3 and I4 are leaving the junction. Applying the current law to this junction yields:

$$I1 + I3 = I2 + I4$$

The voltage law states the algebraic sum of the voltage changes around any closed loop in a circuit is zero. To apply the law, you need to define the voltage drops in a consistent direction going around the loop. If you sum the voltage changes around a loop in the same direction as a current, the voltage change across a resistor is negative. On the other hand, if you sum the voltage changes around a loop in the opposite direction to a current, the voltage change across a resistor is positive. For batteries the voltage change is positive if you move from the negative side of the battery to the positive side. When applied to a circuit with a single voltage supply, the law simply means that the voltage drops across the circuit element(s) is equal to the voltage supply. If the law is applied to a parallel arrangement of two circuit elements, the voltage law states that the voltage drop across the two elements is the same. Why? Since there is no voltage supply in the loop formed by the parallel elements, the voltage changes must be equal in magnitude.

Figure 2 shows a series circuit with two voltage supplies and two resistors. Because this is a series circuit, the current (I) is the same through all of the circuit elements.

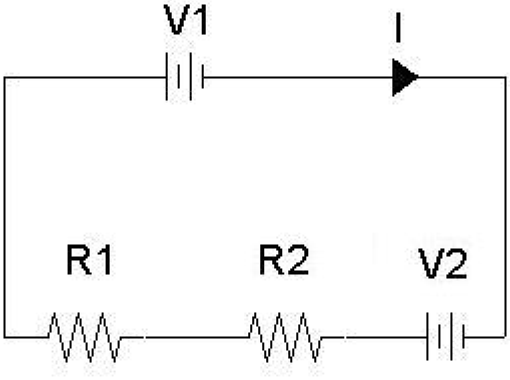


**Figure 2: Voltage around a closed loop**

To apply the voltage rule, you need to choose a direction around the loop in which you will sum the voltage changes. Choosing counterclockwise around the loop to sum the voltage changes yields:

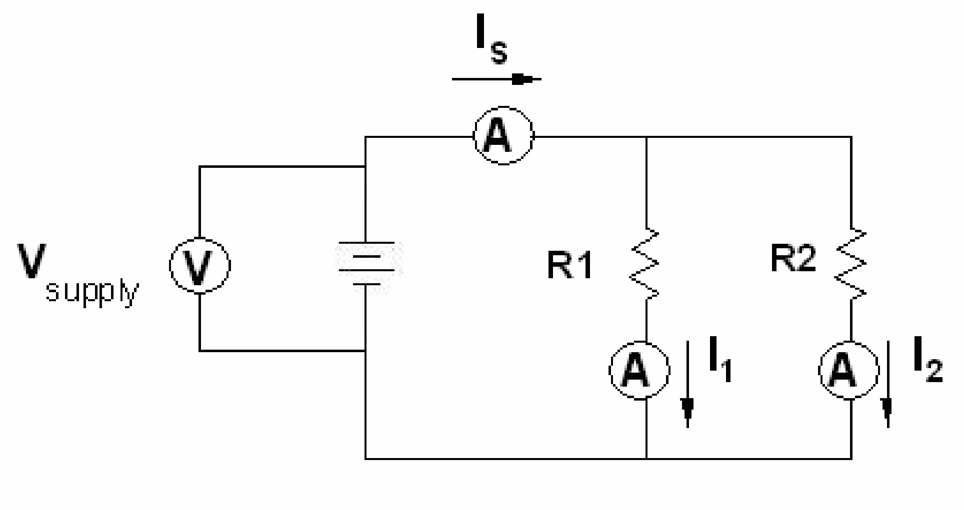
$$+V2 - I \times R2 - I \times R1 - V1 = 0$$

The sign on V1 is negative because when moving counterclockwise around this loop, you move from the positive side of V1 to its negative side. If you had chosen to sum the voltage changes around the loop in a clockwise direction, the sign of each of the voltages would change. This is equivalent to multiplying the counterclockwise equation by -1. So, you get the same result regardless of the direction you choose.

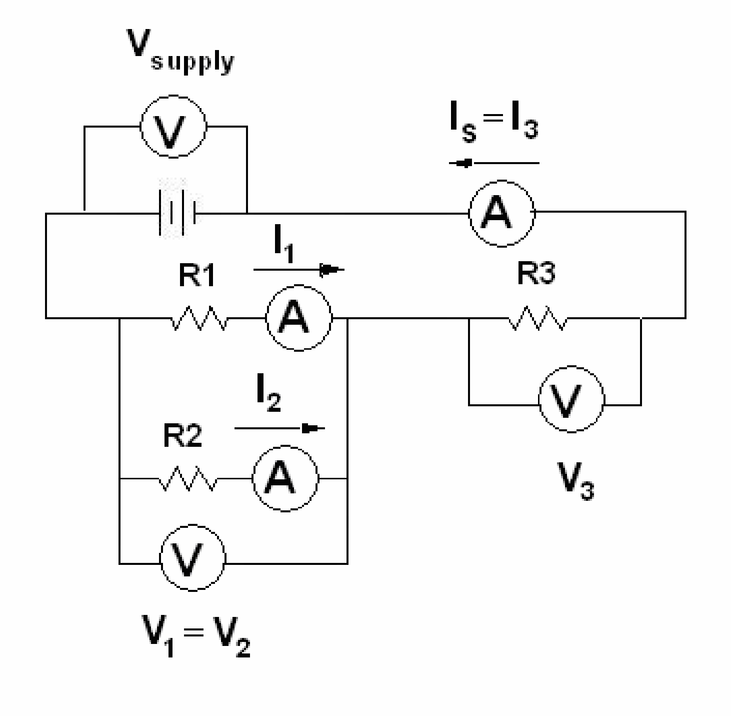
## Procedure

1. Verifying Kirchoff's Current Law: *Two resistors in parallel.*
   (Because the ammeter has an internal resistance of 6Ω, **you want to use resistors that each have a much greater resistance, at least 1000 Ω.**). Use two different resistors having resistances of approximately 1 kΩ and 2 kΩ..

   Connect the circuit as shown below and measure the currents $I_1$, $I_2$, $I_S$ and the voltage $V_{supply}$. Verify $I_S = I_1 + I_2$. Notice, this is the same circuit you constructed in the final part of the last experiment. Record your measurements and the results of your calculations in Data Table 1 in your Excel spreadsheet. Although the diagram below indicates three ammeters, you will only have one ammeter to use. You will measure one current at a time by inserting the meter into the desired location. You will almost certainly find it helpful to use the *Suggestions for Building Circuits* in the Ohm's Law experiment as a guide to measuring the currents and the supply voltage.



2. *Combining Kirchoff's Current and Voltage Laws*: Construct the circuit shown below. Notice, this is the same circuit as the previous circuit with one resistor added in series with the two parallel resistors. The additional resistor should have a resistance different resistance than either $R_1$ or $R_2$. Use resistor with a resistance of approximately 3 kΩ for $R_3$. Connect the circuit as shown below. Record your measurements and your results in Data Table 2.



## Questions

Part 1:

1. Compare $\{I_1 + I_2\}$ with $I_S$ and comment.
2. Calculate the theoretical values of $I_1$ and $I_2$, using $V_{supply}$ and the resistance from the color codes. (Give the theoretical expression for each current.) Compare them with the experimental values and comment. *Hint: $\delta I/I = \delta V/V + \delta R/R$, but the uncertainty in V is negligible compared to the uncertainty in R.*

Part2:

3. Compare $V_1$ and $V_2$, and comment.
4. Calculate $V_1$+$V_3$= ____________±____________ Compare this sum to $V_{supply}$ and comment.
5. Calculate $I_1$+$I_2$= ____________±____________ Compare this sum to $I_3$ and comment.
6. If resistors R1 and R2 are removed from the circuit and replaced by a single resistor, what size resistor should be used such that V3 and I3 remain unchanged? (show your calculation)
7. Calculate the theoretical values of $V_1$ and $V_3$, using $V_{supply}$, the supply current $I_S$ and the resistances of the three resistors obtained from their color codes. (Give the theoretical expression for each voltage.) Compare them with the experimental values and comment. *Hint: Use the answer to question 6. Also, $\delta I/I \approx \delta V/V + \delta R/R$, but the fractional uncertainty in v (i.e. $\delta V/V$) is negligible compared to the fractional uncertainty in R (i.e. $\delta R/R$).*