Kirchhoff's Laws

General Physics Laboratory (PHY119) Fall 2014

1 Introduction

In analyzing circuits, we usually use the rules of series and parallel combinations of resistors and the expression $\Delta V = IR$ to find the voltage a current passing through each element in the circuit. This method however, is not usually applicable for complicated circuits. Thus, a general method is needed. This general law or method was first described by Gustav Kirchhoff, and hence it is referred to as Kirchhoff's Laws.

2 Objective

1. To investigate Kirchhoff's law using resistors in DC circuits connected in series and parallel.

3 Theory

3.1 Kirchhoff's Laws:

Kirchhoff's Current Law (KCL):

Kirchhoff's Current Law is a form of conservation of electrical charge. At any node, the sum of currents must equal to zero,

$$\Sigma I = 0 \tag{1}$$

where we use a positive sign for currents entering the node and a negative sign for currents leaving the node.

Kirchhoff's Voltage Law (KVL)

Kirchhoff's voltage Law follows from the law of conservation of energy. The sum of potential differences across all elements around any closed circuit loop must be zero. When moving from higher potential to lower potential, we take V negative. Likewise, we take V positive when moving from lower potential to higher potential.

$$\Sigma V = 0 \tag{2}$$

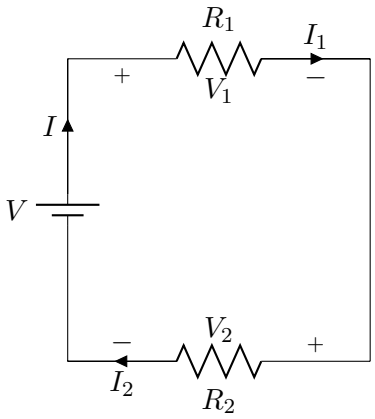


Figure 1: Resistors in series

3.2 Kirchhoff's Laws application:

Resistors in series

As seen in Figure 1, there is no points / nodes, where the current divide. This implies that the current flowing in each resistor is the same as the original current supplied by the battery.

$$I = I_1 = I_2 \tag{3}$$

If we apply Kirchhoff's Voltage Law on the only loop in this circuit, we get,

$$V - V_1 - V_2 = 0 \tag{4}$$

where we have used our sign convention (from high potential to low potential V is negative, and from low potential to high potential V is positive). We can write equation (4) as,

$$V = V_1 + V_2 \tag{5}$$

Implying that the voltage of the battery is divided between the resistors.

Resistors in parallel

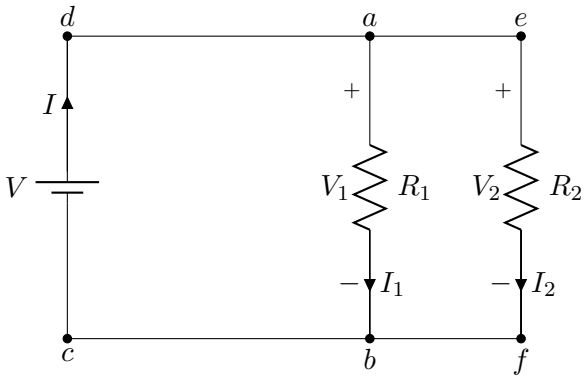


Figure 2: Resistors in parallel

We can apply Kirchhoff's current law by selecting a suitable node. In this case we have picked node a in Figure 2. The current entering a is only I, while I_1 and I_2 are both exiting the node. Hence,

$$I - I_1 - I_2 = 0 \tag{6}$$

We can write it as,

$$I = I_1 + I_2 \tag{7}$$

Therefore, for resistors connected in parallel, the total current is divided between the resistors.

As for the voltage, if we choose the loop (a,b,c,d), then from Kirchhoff's Voltage Law,

$$V - V_1 = 0 \;\Rightarrow\; V = V_1 \tag{8}$$

Applying Kirchhoff's Voltage Law on another loop (d,e,f,c), this time we find,

$$V - V_2 = 0 \;\Rightarrow\; V = V_2 \tag{9}$$

Thus, from equation 7 and 8 we deduce that the voltage is the same in all parallel elements.

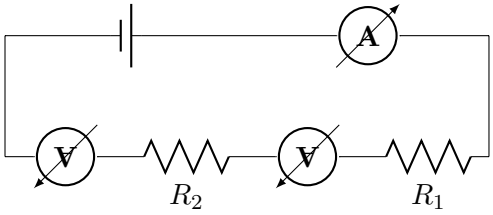
4 Equipment

DC power supply – 3 digital multimeters – breadboard - resistors – connecting leads.

5 Procedure

Part A:

1. Connect the circuit as in the following figure:



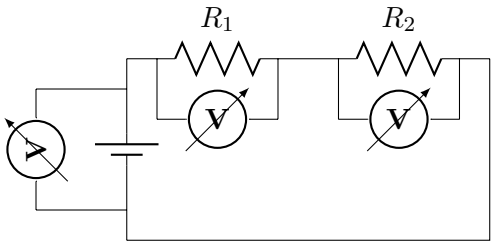
2. Calculate the maximum voltage the resistors can withstand.
3. Turn the power supply on, and then change the voltage V to any value less than V_{max}.
4. Read the corresponding currents from each ammeter.
5. Repeat steps 3-4 two times.These measurements should be recorded in the following table,

I_1 (.....)	I_2 (.....)	I (.....)	Relation between I, I_1, I_2

6. Compare between the relation between currents and equation (3).
7. State your conclusion.

Part B:

1. Connect the circuit as in the following figure:



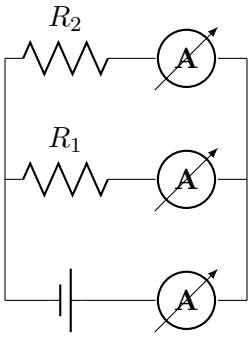
2. Calculate the maximum voltage the resistors can withstand.
3. Turn the power supply on, and then change the voltage V to any value less than V_{max}.
4. Read the voltages from each voltmeter.
5. Repeat steps 3-4 two times.These measurements should be recorded in the following table,

V_1 (.....)	V_2 (.....)	V (.....)	Relation between V, V_1, V_2

6. Compare between the relation between voltages and equation (5).
7. State your conclusion.

Part C:

1. Connect the circuit as in the following figure:



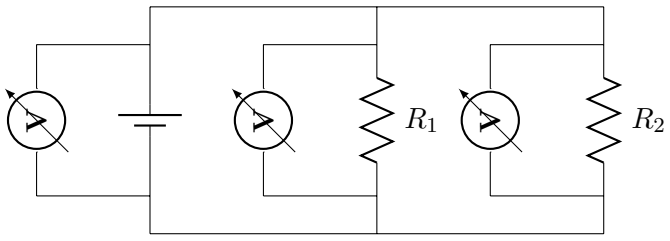
2. Calculate the maximum voltage the resistors can withstand.
3. Turn the power supply on, and then change the voltage V to any value less than V_{max}.
4. Read the corresponding currents from each ammeter.
5. Repeat steps 3-4 two times.These measurements should be recorded in the following table,

I_1 (.....)	I_2 (.....)	I (.....)	Relation between I, I_1, I_2

6. Compare between the relation between currents and equation (7).
7. State your conclusion.

Part D:

1. Connect the circuit as in the following figure:



2. Calculate the maximum voltage the resistors can withstand.
3. Turn the power supply on, and then change the voltage V to any value less than V_{max}.
4. Read the voltages from each voltmeter.
5. Repeat steps 3-4 two times.These measurements should be recorded in the following table,

V_1 (.....)	V_2 (.....)	V (.....)	Relation between V, V_1, V_2

6. State your conclusion.