A03-271E-Y01

# Kirchhoff's Law

## Purpose

1. Students can learn the connection of an electrical circuit and how to correctly operate a voltmeter and a galvanometer
2. Understand Kirchhoff's circuit laws and its application in real electrical circuit.

## Theory

In some complex circuits, it is difficult to measure their current and voltage in the circuits, especially when the circuit involves in EMF. With the help of Kirchhoff's law, we can easily measure the current and voltage in a circuit. Kirchhoff's law can be discussed from two aspects:

1. Kirchhoff's voltage law (KVL): The sum of the electrical potential difference $\Delta V$ in any closed network (circuit) is zero.

2. Kirchhoff's current law (KCL): At any node of a circuit, the current that flows into this node equals to the current that flows out of this node. $\Sigma I_{in} = \Sigma I_{out}$.

When applying Kirchhoff's law to circuits, we need to first assume the direction of unknown EMF and current. Use the law to list all equation and then calculate the actual direction of EMF and current. If value is negative, assumption is opposite to the actual direction.

As shown in **Figure 1**, suppose the current passing $R_2$、$R_3$、$R_4$ are $i_1$、$i_2$、$i_3$. Their directions are shown in the figure. The current at $R_1$ and $R_5$ are $i_1$ and $i_3$. At node e, e we can then get



$$i_1 + i_2 - i_3 = 0 \qquad (1)$$

From Kirchhoff's voltage law, we know that

$$\varepsilon_1 + i_1 ( R_1 + R_2 ) - i_2 R_3 = 0 \qquad (2)$$

$$\varepsilon_2 - i_2 R_3 - i_3 ( R_4 + R_5 ) = 0 \qquad (3)$$

By calculating equation (1) (2) (3), we can get values of $i_1$, $i_2$ and $i_3$.

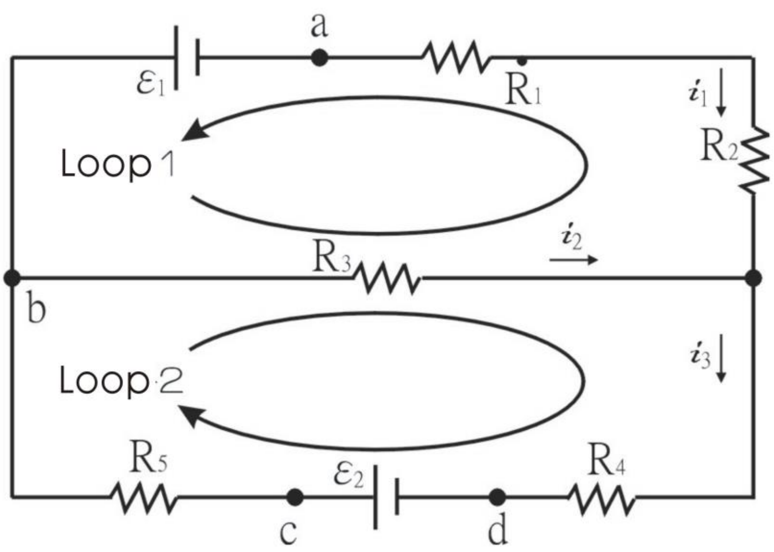


**Figure 1**

## Instruments

| Instrument list | | | | | |
|---|---|---|---|---|---|
| **No.** | **Accessory** | **Qty** | **No.** | **Accessory** | **Qty** |
| 1 | Kirchhoff's Laws | 1 | 2 | Digital DC voltmeters & ammeters | 2 |
| 3 | DC power supply | 2 | 4 | Plug wires | 10 |

## Procedure


**Figure 2**

(I) Single power supply

1. Connect the circuit as shown in **Figure 3**. Use a connecting wire to connect a-b to power supply. Connect c-d，e-f，g-h，i-j，k-l by connecting wires.

2. Use digital DC voltmeter to measure the voltage ε of power supply and three resistors $R_1$、$R_2$、$R_3$. Mark their potential difference as $V_1$、$V_2$、$V_3$ .

3. Use digital DC ammeter to measure current $i_1$、$i_2$、$i_3$. The value is measured values. (For example: when measuring current between c-d, take off the connecting wire and connect c-d and ammeter in series.)



4. Use Kirchhoff's Laws to calculate the theoretical current values of $R_1$、$R_2$、$R_3$.Compare theoretical values with measured values.

5. Change resistor values and repeat above procedures.

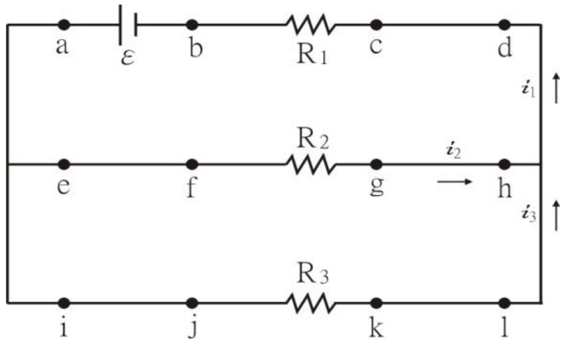


**Figure 3**

$$i'_1 = \frac{\varepsilon\,(R_2+R_3)}{R_1R_2+R_2R_3+R_3R_1}$$

$$i'_2 = \frac{\varepsilon R_3}{R_1R_2+R_2R_3+R_3R_1}$$

$$i'_3 = \frac{\varepsilon R_2}{R_1R_2+R_2R_3+R_3R_1}$$

(II) Dual power supply

1. As shown in **Figure 4,** connect the circuit to two DC power supplies. Select and record their resistor values $R_1$ 、$R_2$ 、$R_3$.

2. Use digital DC voltmeter to measure the voltage $\varepsilon_1$ and $\varepsilon_2$ of power supplies, and three resistors $R_1$ 、$R_2$ 、$R_3$. Mark their potential difference as $V_1$ 、$V_2$ 、$V_3$ .



3. Use digital DC ammeter to measure current $i_1$、$i_2$、$i_3$. The value is measured values. (For example: when measuring current between c-d, take off the connecting wire and connect c-d and ammeter in series.)

4. Use Kirchhoff's Laws to calculate the theoretical current values of $R_1$ 、$R_2$ 、$R_3$.Compare theoretical values with measured values.

5. Change resistor values and repeat above procedures.

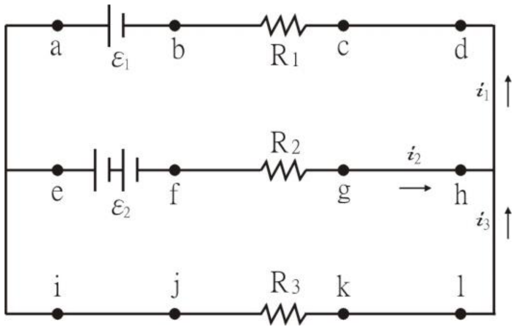


**Figure 4**

$$i'_1 = \frac{\varepsilon_1(R_2+R_3) - \varepsilon_2 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1}$$

$$i'_2 = \frac{-\varepsilon_2(R_1+R_3) + \varepsilon_1 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1}$$

$$i'_3 = \frac{\varepsilon_1 R_2 + \varepsilon_2 R_1}{R_1 R_2 + R_2 R_3 + R_3 R_1}$$

**Note: This is a DC experiment so pay attention to the positive and negative when connecting wires.**

# Experiment results

## 1. Single power supply

| | $R_1$ | $R_2$ | $R_3$ | $\varepsilon$ | $V_1$ | $V_2$ | $V_3$ | $i_1$ | $i_2$ | $i_3$ | $i'_1$ | $i'_2$ | $i'_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | |

$i_1$、$i_2$、$i_3$ are measured values and $i_1$'、$i_2$'、$i_3$'are theoretical values.

## 2. Dual power supply

| | $R_1$ | $R_2$ | $R_3$ | $\varepsilon_1$ | $\varepsilon_2$ | $V_1$ | $V_2$ | $V_3$ | $i_1$ | $i_2$ | $i_3$ | $i'_1$ | $i'_2$ | $i'_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | |

$i_1$、$i_2$、$i_3$ are measured values and $i_1$'、$i_2$'、$i_3$'are theoretical values.

# Questions and Discussions



1. Are measured values different from theoretical values? What are possible reasons of errors?

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