EXPERIMENT 4

Kirchhoff's Laws

Purpose:

The aim of this experiment is to examine the Kirchhoff's Laws and to make students aware of the analysis of complex circuits consisting of multiple loops. For this purpose, the accuracy of the Kirchhoff's Laws will be tested by means of measurements made via a given electric circuit. At the end of the experiment, students learn the concepts such as knot point, current arm and loop (ring). It is expected that they can resolve any given electric circuit using the Kirchhoff's Laws.

Instruments for the Experiment:

- Electricity laboratory set
- DC Power Supply
- Connection cable
- Resistors
- AVOmeter

Theoretical Information:

Some electric circuits with more than one loop can be reduced to a single loop using equivalents of series and parallel connected resistors and can be easily solved using Ohm's Law. That is, if the resistors in the circuit and the source of emf are known, then the current passing through each circuit element and the potential difference for the circuit element can be simply calculated. However, there are also circuits that cannot be reduced to a single closed loop. In this case, the Kirchhoff's Laws are used to analyze these circuits. In order to better understand these rules, we need to define the concepts of junction and loop:

- In an electric circuit, the point at which the current is divided into branches is called a junction circuit or node.
- Starting from any point of the circuit, passing through the circuit elements and connecting wires, we reach the starting point of the arbitrary closed path, which is called loop.

Kirchhoff's Laws:

1. Current Law: The sum of the currents entering into a circuit junction should be equal to the sum of the currents leaving the same junction. This is because it has no other place to go as no charge is lost. This idea by Kirchhoff is commonly known as the Conservation of Charge, as the current is conserved around the junction with no loss of current. If we apply this rule to the " a " node shown in **Figure 4.1**, we obtain Eq. 4.1.

$$\sum I_{IN} = \sum I_{OUT}$$

$$I_1 + I_2 = I_3 + I_4 \tag{4.1}$$

Dr. N. Yıldırım Giraz, Assoc. Prof. Y. Moğulkoç & Assoc. Prof. F. Bağcı

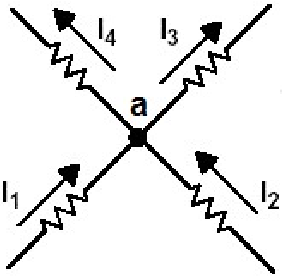

Figure 4.1 Circuit junction

2. Voltage Law: The algebraic sum of the potential differences between the ends of all circuit elements must be zero throughout any circuit loop. The Voltage Law refers to the conservation of energy. According to the conservation of energy, the sum of the energies that a charge gained when it came back to the point where any load moving along a closed loop in a circuit came to the point where it started to move is equal to the sum of its lost energies.

The following practical calculation rules shown in **Figure 4.2** should be observed during the application of this principle.

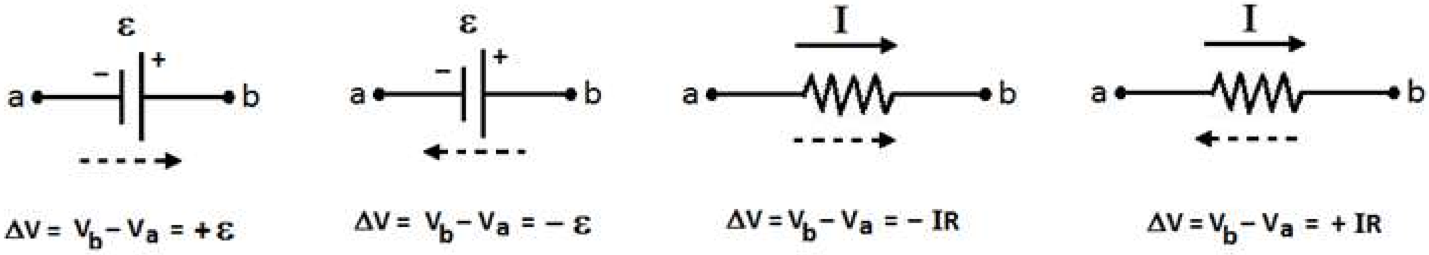

Figure 4.2 Practical Calculation Rules for the Kirchhoff's Voltage Law

In order to resolve a complex circuit using the Kirchoff Rules;

- First, draw the circuit diagram and mark the symbols and values of all known and unknown quantities on this diagram.
- Specify an arbitrary direction for currents in each branch of the circuit. When doing this, make sure that the current passing through the circuit elements connected to each other is the same.
- Apply the node rule (first Kirchhoff's rule) to the points where you can relate to the various currents in the circuit.
- Divide the electric circuit into the closed loops as you need and apply second Kirchhoff's rule to each loop. To apply this rule, you must start from any point of the loop and move around the loop to return to the starting point. You can select the direction of movement arbitrarily. Thus, the number of loops of the electric circuit will be obtained. In order for your equations to be valid, you must comply with "four practical rules" outlined above.
- Finally, you need to solve the system of equations to calculate unknown quantities.
- If the current you find as a result of the calculations is negative, the direction of the current passing through the circuit is in the opposite direction to the direction you selected.

EXPERIMENT 4

Kirchhoff's Laws

DATE :

GROUP ID :

Student ID	Name Surname	Signature

Experiment Expectation	

Dr. N. Yıldırım Giraz, Assoc. Prof. Y. Moğulkoç & Assoc. Prof. F. Bağcı

CALCULATIONS AND RESULTS:

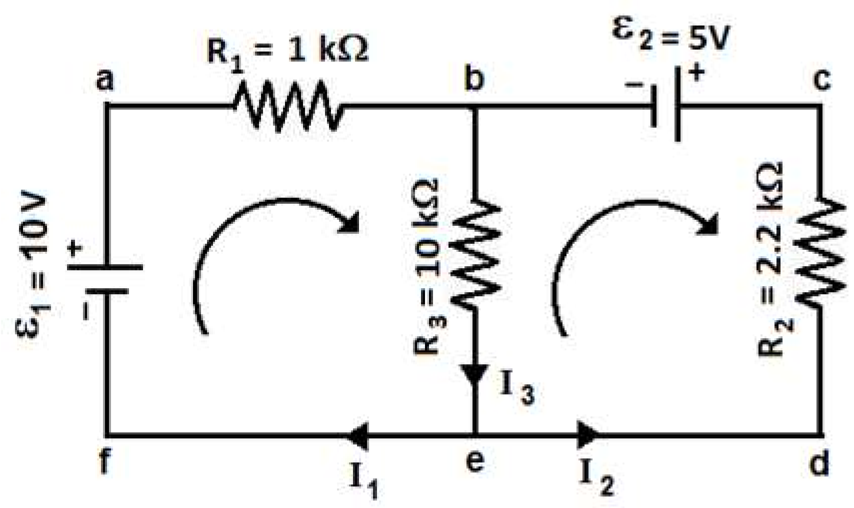

Figure 4.3 Circuit to be used to examine the Kirchhoff's Laws

1. Make a circuit as shown in Figure 4.3 and keep the power supplies off until the circuit is checked by the lecturer. Once the circuit has been checked, switch on the power supplies and measure the quantities and record them in the Table 4.1.

Table 4.1 Measured values of the circuit in Figure 4.3 by avometer.

Values of resistors	**R_1**	**R_2**	**R_3**
Voltages of power supplies (measured via voltmeter)	ε_1		ε_2
Voltages of resistors	V_1	V_2	V_3
Currents of resistors	**I_1**	**I_2**	**I_3**
Potential difference between two points	V_{ca}		V_{db}

2. Calculate the currents I_1, I_2 and I_3 theoretically using the following equations which have been found by using the current and direction of movement in Figure 4.3 and note to Table 4.2. Compare the results with the values you measured in the experiment.

$$I_1 = \frac{\varepsilon_1 R_2 + (\varepsilon_1 + \varepsilon_2) R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3} \quad (4.2)$$

$$I_2 = \frac{-\varepsilon_2 R_1 - (\varepsilon_1 + \varepsilon_2) R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3} \quad (4.3)$$

$$I_3 = \frac{\varepsilon_1 R_2 - \varepsilon_2 R_1}{R_1 R_2 + R_1 R_3 + R_2 R_3} \quad (4.4)$$

Table 4.2. Calculated current values

I_1	I_2	I_3

3. Using the circuit rules, calculate the potential difference between two points and record to the Table 4.3.

   For example, to find the potential difference between points “a” and “c”:

   - From “abc” way

     $$V_a - I_1 R_1 + \varepsilon_2 = V_c \quad (4.5)$$

     $$\Rightarrow V_{ca} = -I_1 R_1 + \varepsilon_2 \quad (4.6)$$

   - From “afedc” way

     $$V_{ca} = -\varepsilon_1 - I_2 R_2 \quad (4.7)$$

Table 4-3. Calculated voltage values

	V_{ca}	V_{db}	V_{da}	V_{ce}
1. way:				
2. way:				

DISCUSSION AND COMMENTS:

1) Write how you have proved the Kirchhoff’s laws in this experiment.

Dr. N. Yıldırım Giraz, Assoc. Prof. Y. Moğulkoç & Assoc. Prof. F. Bağcı