2.2. EXPERIMENTS

2.2.1. OHM's LAW and THERMISTOR

2.2.1.1. PART I: OHM's LAW

MAIN PRINCIPLE:

I. Ohm's law is used to find the values of unknown resistors using the current flowing through known resistors. Testing the concept of equivalent resistance in series-parallel circuits.

II. Determination of internal resistance and EMF.

EQUIPMENT

Ammeter, Voltage Source, Resistor, Connection Cables.

Figure 2.10: Experimental setup

THEORY

Electric Measuring Instruments: The most basic measuring instruments used in electrical circuits are an ammeter, voltmeter, and potentiometer.

Ammeter: An instrument that measures current is called an ammeter. The ammeter is connected in series with the circuit. In order to make the measurement precisely, the internal resistance R_A of the ammeter must be very small compared to the external circuit resistance.

$$R_A \ll r + R_1 + R_2 \tag{2.7}$$

The ideal ammeter has zero internal resistance. Only in such an ammeter is the power loss zero.

Voltmeter: An instrument that measures the potential difference is called a Voltmeter. The voltmeter is connected parallel to the circuit. For the measurement to be accurate, the internal resistance R_V of the voltmeter must be very large compared to the resistance of the circuit part whose potential difference is to be measured.

The internal resistance of an ideal voltmeter should be infinite so that the power loss in the voltmeter is zero.

$$R_V \gg R_1 \tag{2.8}$$

Galvanometers are the most sensitive instruments that can also act as voltmeters and ammeters.

Potentiometer: ε_x for a potentiometer that measures the electro-motor force of a standard ε_s of known value compared to the electro-motor force of an $\varepsilon_x$of unknown value,

$$\varepsilon_x = \varepsilon_s \left(\frac{R_x}{R_s}\right) \tag{2.9}$$

A. OHM's LAW

Ohm's Law: The ratio of the potential difference between the two terminals of a conductor to the current flowing through it is constant. This constant is called the resistance of the conductor and

$$R = \frac{V}{I} \tag{2.10}$$

is given with. Here, $[V] = Volt$, $[I] = Ampere$, $[R] = {}^{Volt}/_{Ampere} = Ohm(\Omega)$ units. Powers of the Ohm unit are often used, which are $1\ K\Omega = 10^3\ \Omega, 1\ M\Omega = 10^6\ \Omega$.

B. RESISTORS ARE GENERALLY USED IN ELECTRICAL CIRCUITS BY CONNECTING IN TWO WAYS

1. Serial Connection

R_s the equivalent resistance is obtained by connecting resistors R_1, R_2 as seen in Figure 2.11. R_s is given by,

$$R_s = R_1 + R_2 + R_3 \tag{2.11}$$

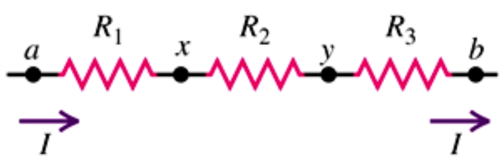

Figure 2.11: Series resistance connection

2. Parallel Connection

The equivalent resistance R_p obtained by connecting resistors R_1, R_2 as shown in Figure 2.12 is calculated by the following relation.

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \tag{2.12}$$

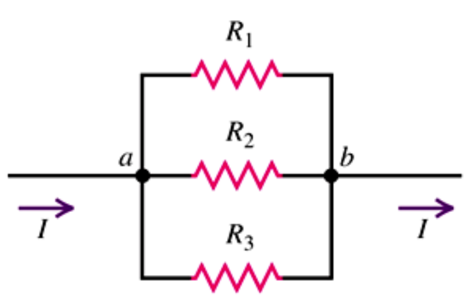

Figure 2.12: Parallel resistance connection

C. ELECTRO-MOTOR FORCE (EMF)

The potential difference is measured between the terminals of a voltage source from which no current is supplied.

D. KIRCHHOFF'S LAW

Two rules that are often used in analyzing electrical circuits and solving problems.

I. Kirchhoff's Law

In a multi-ring circuit, the algebraic sum of the currents at any intersection is zero. According to Figure-3, It is given by the following relation.

$$I_1 - I_2 + I_3 - I_4 = 0 \tag{2.13}$$

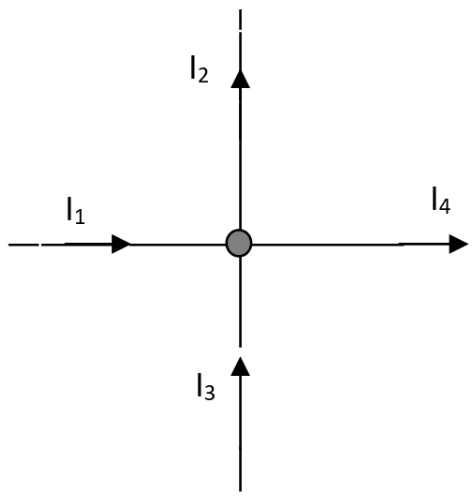

Figure 2.13: Schematic representation of currents passing through a knot point

II. Kirchhoff's Law

The electro-motor force ε in a closed electric circuit is equal to the sum of the potential drops across all resistances in the circuit. Let R_i represent the internal resistance of the voltage source and R the external equivalent resistance of the circuit,

$$\varepsilon = IR_i + IR \tag{2.14}$$

the relation can be written. If the potential drop across R is represented by V, the relation (2.14),

$$\varepsilon = IR_i + V \tag{2.15}$$

or

$$V = \varepsilon - IR_i \tag{2.16}$$

can also be written as.

SETUP AND PROCEDURE

1- The circuit in Figure 2.14 is built. R in the figure is replaced by 10 different resistors selected from the resistor box and *I* currents passing through the milli ammeter are read and recorded in Table 2.3.

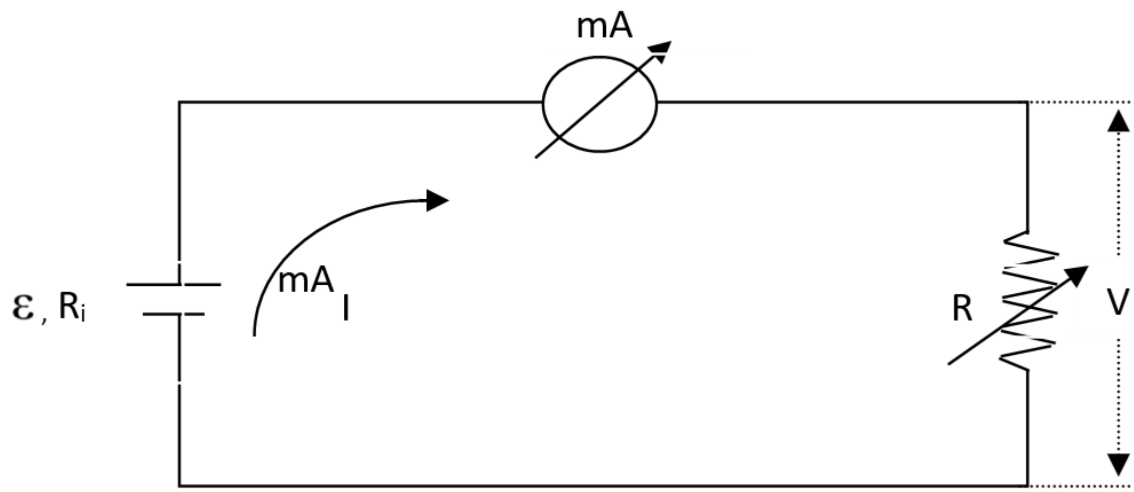

Figure 2.14: Circuit

Table 2.3

R (kΩ)	I (mA)	V (mV)
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

2- The graph of $I = f(R)$ showing the dependence of current intensity on resistance values is drawn (Figure 2.15).

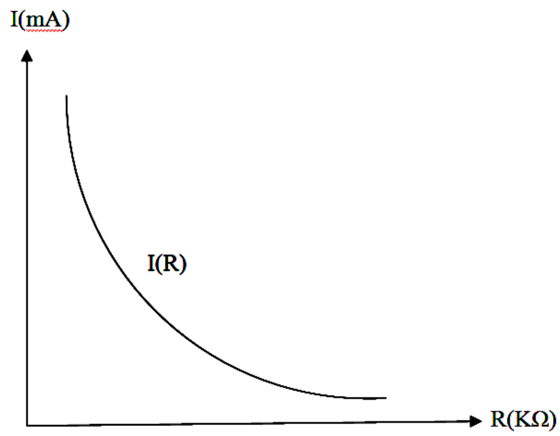

Figure 2.15: Relation of current intensity vs resistance

3- This time unknown resistors R_1 and R_2 are connected instead of resistance R in Figure 2.14.

4- R_1 and R_2 are connected once in series and once in parallel. The currents passing through the circuit are recorded in Table 2.4.

5- The resistance values found by plotting the currents corresponding to the unknown resistors on the graph $I = f(R)$ are recorded in Table 2.4.

Table 2.4

R	I (mA)	R (Ω) - Graph	R (Ω) - Formula
R_1			
R_2			
R_s			
R_p			

6- Using R_1 and R_2 values found by the graphical method, R_s series, and R_p parallel equivalent resistances are calculated from relations (2.11) and (2.12). They are entered in Table 2.4. R_s and R_p values found by graphical method and calculation are compared with each other.

$$R_s = R_1 + R_2 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \Omega$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \Omega$$

7- The potential drops on the resistors R in Table 2.3 selected from the resistor box are calculated by the relation (2.10) and recorded in Table 2.3.

8- $V = f(I)$ graph showing the dependence of potential drops on current intensities is drawn (Figure 2.16). This should be a line according to the relation (2.16). From this graph, the EMF of the voltage source is found from $V = \varepsilon$ for $I = 0$.

$\varepsilon = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ Volts

9- A selected I-V pair is found in the graph $V = f(I)$ and the internal resistance R_i of the voltage source is found in the relation (2.16).

$I = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ mA $= \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ A

$V = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ Volts

$$R_i = \frac{\varepsilon - V}{I} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\Omega$$

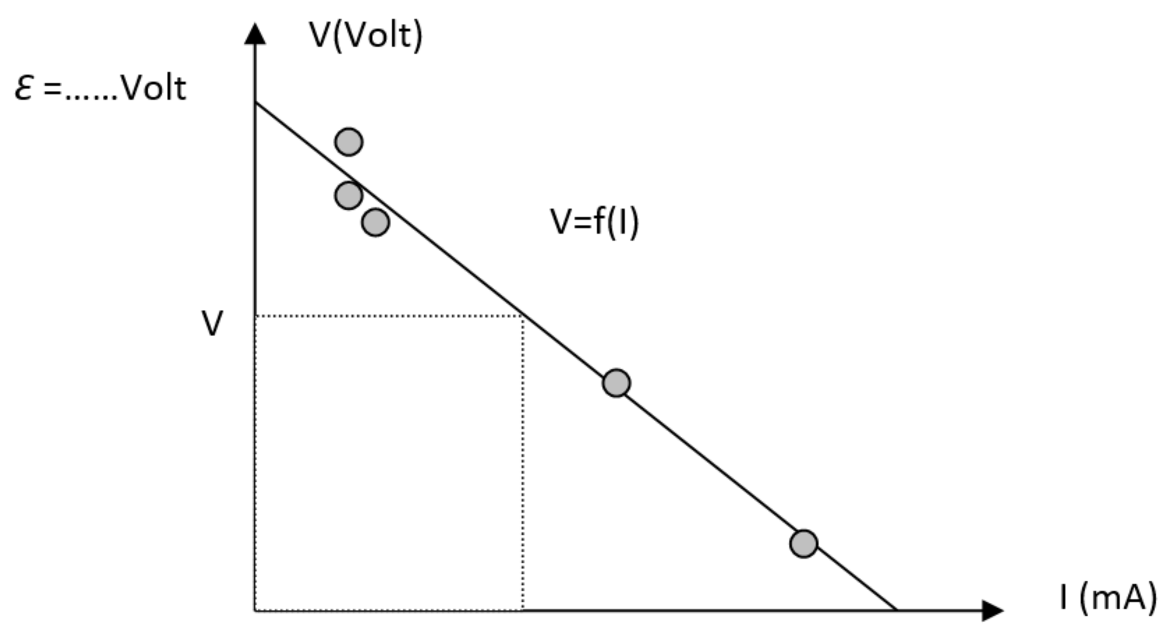

Figure 2.16

2.2.1.2. PART 2: TEMPERATURE MEASUREMENT WITH THERMISTOR

MAIN PRINCIBLE

The structure of a thermistor, observation of the relationship between temperature and resistance of the thermistor, and determination of a method to be used to determine the temperature of any substance by using this relationship.

EQUIPMENT

Heater, Beaker, Glass tube, Thermistor (470 Ω), Milli Ammeter (DC), Power supply, Thermometer, Connection cables.

THEORY

Today, thermal sensors of various structures and types are widely used in many fields of technology. One of the most widely used of these is the thermistor, due to its low cost, robust structure, and ease of manufacture.

After thermometers, which were the first detectors used to observe temperature changes, mankind made a real start in its search for detectors with the use of metal resistance elements with thin plate structures and small heat capacities, which we can call detectors in the real sense. The need to meet the needs accelerated the research on the elements on which the conductivity properties of matter depend.

The most basic properties that a good detector element should have are a heat capacity as small as possible, the ability to respond as quickly as possible to changes in temperature, and the ability to operate in a wide radiation region (frequency range). The need to obtain such a sensing element led to the idea of continuing the studies on semiconductors, which have a greater advantage in terms of the thermal properties of the above-mentioned material. As a result of studies on semiconductors, thermistors were first produced in Germany during World War II. Since they have 100 times smaller heat capacity compared to previously used thin-plate metal resistors, they have gradually replaced them and continue to be used in many fields to this day.

The thermistors used today are circuit elements made of oxides of transition elements Cr, Mn, Fe, Co, and Ni. Depending on the need, there are thermistor types used at very low temperatures such as 3 - 4 K in the context of the relationship between heat capacity and temperature, both at room temperature and in the case of more precise measurements. It is possible to obtain them in various geometric shapes according to the need and service brought by technology. The resistance of a thermistor is determined by its value at 20 °C. If we give an example; From the expression "a 400 Ω thermistor" we understand that the resistance of this thermistor is 400 Ω at 20 °C. The relationship between the temperature of a substance and its resistance is simply given as $R = R_0(1 + \alpha\Delta T)$. Here α is a constant that determines the change in resistance with temperature and is related to the structure of the material, R_0 is the initial value of resistance, R is the final value of resistance, and ΔT is the change in temperature of resistance. This relation given above appears as a result of the $\alpha = \frac{1}{R}\frac{\partial R}{\partial T}$ derivative equation. As can be seen, it shows the response of the α coefficient (resistance temperature coefficient) to the change in temperature.

a. If the coefficient takes a negative value, the thermistor is called an NTC (Negative Temperature Coefficient) type thermistor.

b. If the coefficient takes a positive value, then the thermistor is called a PTC (Positive Temperature Coefficient) type thermistor.

While the resistance of NTC-type thermistors shows an inversely proportional change with temperature, in PTC-type thermistors the resistance-temperature relationship is directly proportional.

Note: For more information about thermistors, you can use the resources related to Thermal Detectors.

SETUP AND PROCEDURE

1- The circuit in Figure 2.17 is established. Before the heater is switched on, the temperature of the water and therefore the temperature of the thermistor is measured with the help of a thermometer and recorded on the table.

2- The heater is switched on and the current flowing through the circuit at 5 °C intervals is measured with the help of an ammeter and recorded in Table 2.5. The measurement process continues until approximately 80 °C.

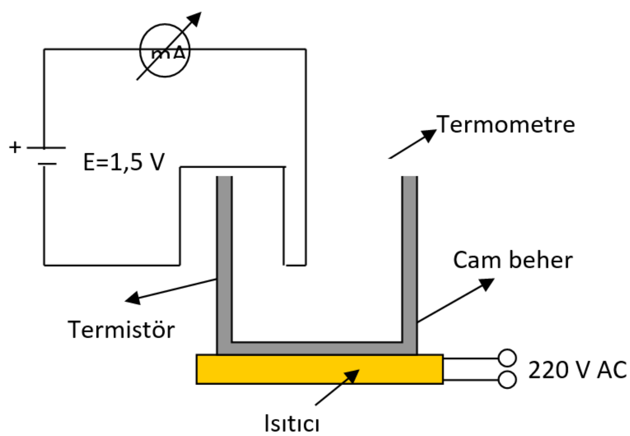

Figure 2.17: Experimental setup

Table 2.5

T (°C)	I (mA)	R (Ω)

3- Since the emf of the voltage source in the circuit is 1.5 $volts$ and the internal resistance is negligibly small, the voltage at the thermistor terminals is $V = 1.5\ volts$. Using this value of the voltage and the current magnitudes in the table and using Ohm's law ($V = I.R$), the resistance values corresponding to each temperature value of the thermistor are calculated and recorded in Table 2.5.

Note: It is possible to determine the temperature of any object using these two graphs. These graphs are a ruler of measurement for us.

4- $I = f(t)$ and $R = f(t)$ graphs are shown in Figure 2.18 and Figure 2.19 are drawn from the table.

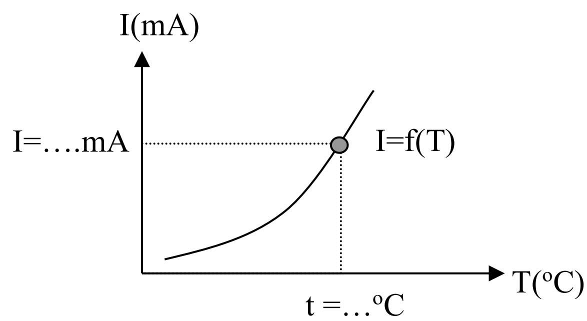

Figure 2.18

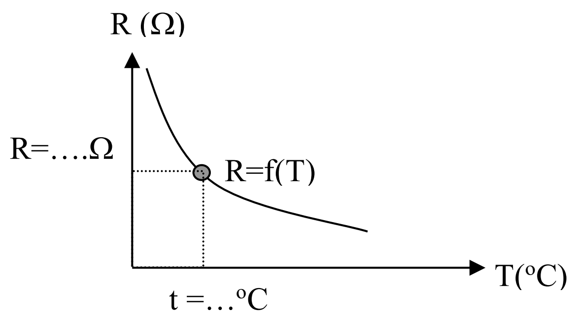

Figure 2.19

QUESTIONS

1. What is a thermistor?

2. What is the type of thermistor you used in the experiment?

3. What are the characteristics of a quality thermistor?

4. What are the possible uses of thermistors?

5. What is the resistance temperature coefficient (α), and what its function is in determining the type of thermistor?

6. What is the basic structure of a thermistor?

7. What do we need to know about the transition elements that play a role in the conductivity of a thermistor and why do we use transition elements?