PHYS143

Physics for Engineers

Lab Report - 4

2nd February, 2023

Instructor

Mr. Nejad AlAgha

Experiment 1

Purpose:

To experimentally determine equivalent resistance in a circuit and compare theoretical results with experimental results.

Hypothesis:

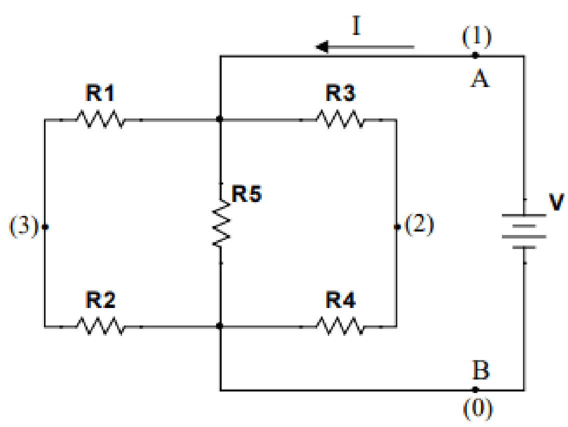
Equivalent resistance flowing through a conductor depends on the arrangement of resistors (series or parallel).

Materials:

- Power Supply
- 5 resistors
- Multimeter
- 4 crocodile-banana cables

Procedure:

1. Select the known resistances R1 to R5.
2. Construct the circuit given below and determine R_{eq} by applying a DC voltage source across points A and B.



Data and Observations:

Exp.	V_{AB} (V)	R_1 (Ω)	R_2 (Ω)	R_3 (Ω)	R_4 (Ω)	R_5 (Ω)	R_{Eq} [Calc] (Ω)	R_{Eq} [Exp] (Ω)	% Error
1	1.5	8.2	15	12	22	5.6	3.98	3.95	0.75
2	2.5	[redacted]					3.98	3.91	1.76
3	4.0						3.98	3.85	3.27

To get the calculated value of R_{eq}, the resistances are simplified and summed as follows:

R_{series} ⇒ $R_1 + R_2 = 8.2 + 15 = 23.2\ \Omega$

$R_3 + R_4 = 12 + 22 = 34\ \Omega$

$R_{parallel}$ ⇒ $\frac{1}{R_{eq}} = \frac{1}{23.2} + \frac{1}{34} + \frac{1}{5.6}$

$\frac{1}{R_{eq}} = 0.2510866416$

$R_{eq} = \frac{1}{0.2510866416} = 3.98\ \Omega$

To get the experimental value of R_{eq}, we use the formula $R_{eq} = \frac{V}{I}$ where the values measured for I in each experiment are: I_1 = 0.38 A, I_2 = 0.64 A and I_3 = 1.04 A

Experiment 2

Purpose:

To determine the current flowing through each part in a circuit using Kirchoff's current and junction rule.

Hypothesis:

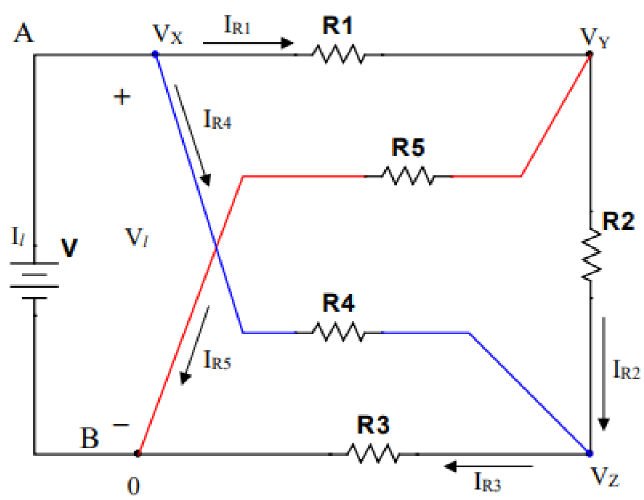
Current entering through each node in a circuit is equal to the current leaving the node

Materials:

- Power supply
- Multimeter
- 5 resistors
- 4 crocodile-banana cables

Procedure:

1. Construct the circuit given below.



2. Apply a voltage source across AB and measure the current I and the currents through each resistance I_{R1} to I_{R5}.
3. Write down 3 equations using Kirchhoff's junction rule.
4. Write down 3 equations using Kirchhoff's Loop rule given the source voltage.
5. Solve the linear system AX=B where X = $I, I_{R1}, I_{R2}, I_{R3}, I_{R4}, I_{R5}$ (Vertically).

Data and Observations:

Kirchoff's Junction Rule:

$$I = I_{R1} + I_{R4}$$

$$I_{R1} = I_{R2} + I_{R5}$$

$$I_{R3} = I_{R2} + I_{R4}$$

Kirchoff's Loop Rule:

$$3 + 1200 I_{R1} + 2200 I_{R2} + 3300 I_{R3} = 0$$

$$2200 I_{R2} + 3300 I_{R3} - 820 I_{R5} = 0$$

$$1200 I_{R1} + 2200 I_{R2} - 1500 I_{R4} = 0$$

We obtain the matrix:

$$Ax = b$$

$$\begin{bmatrix} 1 & -1 & 0 & 0 & -1 & 0 \\ 0 & 1 & -1 & 0 & 0 & -1 \\ 0 & 0 & -1 & 1 & -1 & 0 \\ 0 & 1200 & 2200 & 3300 & 0 & 0 \\ 0 & 0 & 2200 & 3300 & 0 & -820 \\ 0 & 1200 & 2200 & 0 & -1500 & 0 \end{bmatrix} \begin{bmatrix} I \\ I_{R1} \\ I_{R2} \\ I_{R3} \\ I_{R4} \\ I_{R5} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ -3 \\ 0 \\ 0 \end{bmatrix}$$

Solving the matrix, we get:

$$\begin{bmatrix} I \\ I_{R1} \\ I_{R2} \\ I_{R3} \\ I_{R4} \\ I_{R5} \end{bmatrix} = \begin{bmatrix} -0.0022 \\ -0.0014 \\ -0.0002 \\ -0.0006 \\ -0.0008 \\ -0.0016 \end{bmatrix}$$

Circuit Input Data		Measured Current (A)		Calculated Current (A)	Relative Error (%)
R_1	1200 Ω	I_{R1}	0.00160	0.00140	12.5
R_2	2200 Ω	I_{R2}	0.00022	0.00020	10
R_3	3300 Ω	I_{R3}	0.00055	0.00060	9.1
R_4	1500 Ω	I_{R4}	0.00090	0.00080	11.1
R_5	820 Ω	I_{R5}	0.00163	0.00160	1.84
V_A - V_B	3 V	I	0.00222	0.00220	0.9

The measured and calculated current values are very close to each other, therefore we can accurately calculate R_{eq} as follows:

$$R_{eq} = \frac{V}{I} = \frac{3}{0.00222} = 1351.4\,\Omega$$

Experiment 3

Purpose:

To estimate the time constant in an RC circuit

Hypothesis:

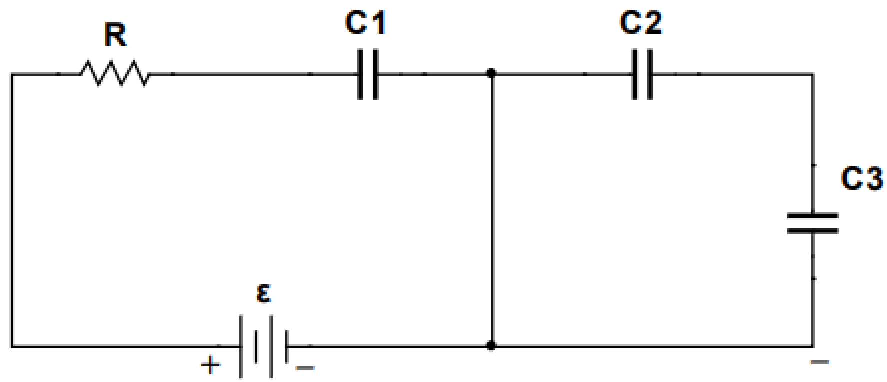
Voltage increases in a linear manner over a period of time

Materials:

- Power supply
- One large resistor value
- 3 capacitors
- 3 multimeters

Procedure:

1. Construct the circuit given below



Data and Observations:

$V = 5$ V $R = 22$ kΩ

$C = 1000$ μF $\tau = RC = 22$ s

Time	Measured V_{C1}	Calculated V_{C1}	Measured V_{C2}	Calculated V_{C2}	Measured V_{C3}	Calculated V_{C3}
0.2RC	0.81	0.906	0	0	0	0
0.4RC	1.40	1.648	0	0	0	0
0.6RC	2.13	2.25	0	0	0	0
0.8RC	2.62	2.75	0	0	0	0
1.0RC	3.05	3.16	0	0	0	0
1.2RC	3.40	3.49	0	0	0	0
1.4RC	3.53	3.72	0	0	0	0
1.6RC	3.72	3.99	0	0	0	0
1.8RC	4.13	4.27	0	0	0	0
2.0RC	4.27	4.32	0	0	0	0

To obtain the calculated values for V_{C1} we used the formula: $V_{C1} = V\,(1 - e^{-\frac{t}{RC}})$

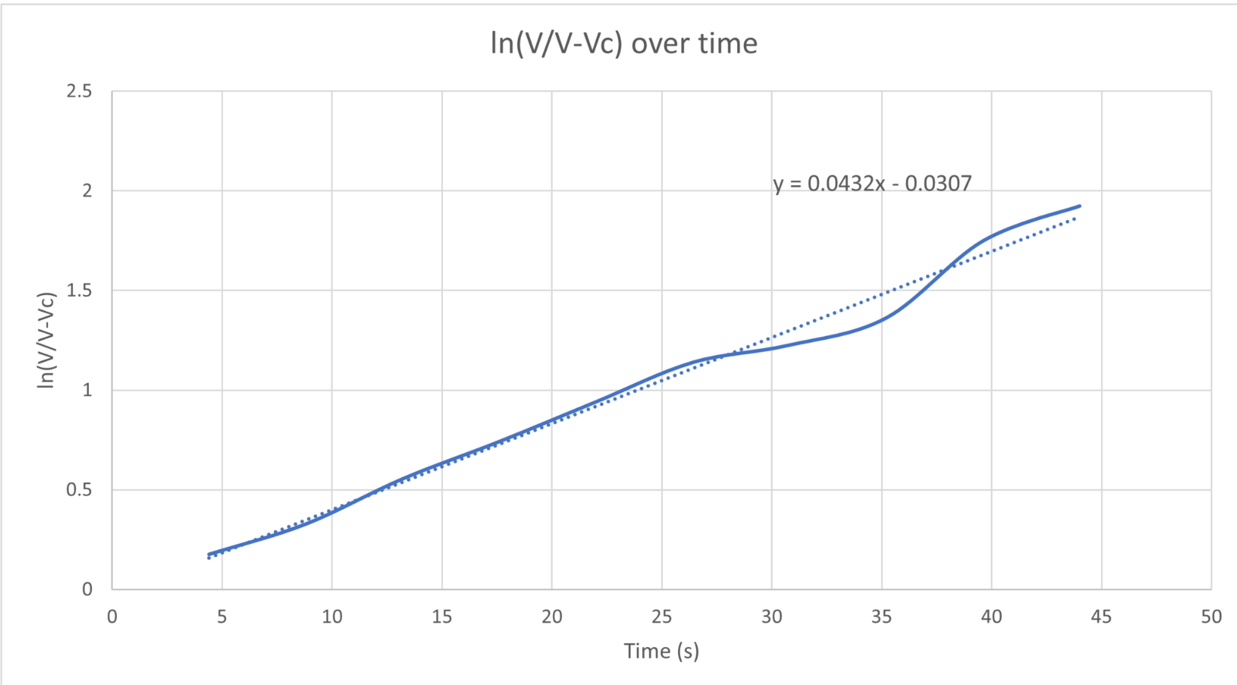
Which can be rearranged as:

$$\frac{V - V_{C1}}{V} = e^{-\frac{t}{\tau}}$$

$$ln(\frac{V - V_{C1}}{V}) = -\frac{t}{\tau}$$

$$ln(\frac{V}{V - V_{C1}}) = \frac{1}{\tau}t$$

This equation can be plotted on a graph with $ln(\frac{V}{V - V_{C1}})$ as y and t as x to give $\frac{1}{\tau}$ from the slope.



From the equation of graph $\frac{1}{\tau}$ = 0.0432, therefore to find τ we rearrange the equation to get:

$$\tau = \frac{1}{0.0432} = 23.15s$$

The value of τ obtained is close to the calculated value of 22s, therefore the result is valid

Experiment 4

Purpose:

To charge a capacitor by using the charge of another capacitor

Hypothesis:

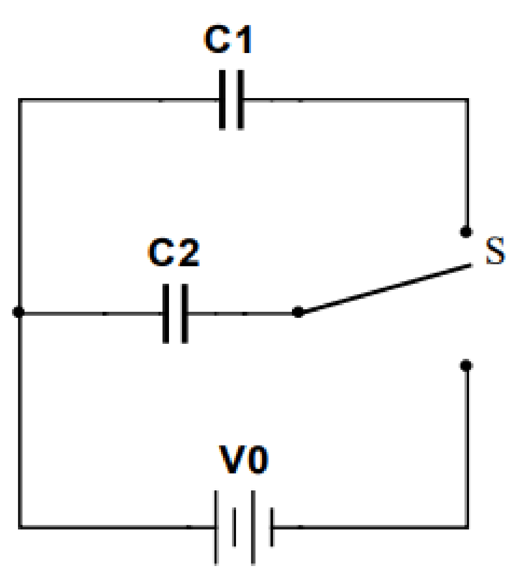
Since both capacitors have the same capacitance and are connected in series, the charge will split up evenly between them.

Materials:

- Power supply
- 2 capacitors
- Multimeter
- 4 crocodile-banana cables

Procedure:

1. Construct the circuit



2. Set the switch in order to charge C2.
3. After some time, set the switch such that C1 is charged only using C2.
4. After a long time, measure the voltage across the capacitance (C1) and deduce the charge on each capacitance. Compare the experimental results with the theoretical results.

Data and Observations:

$C_1 = C_2 = 1000\ \mu F$

$V = 3\ V$

Charge equally divides between the two capacitors, therefore:

$$V_1 = V_2 = \left(\frac{C_1}{C_1 + C_2}\right) V \ = \frac{1}{2} \times 3 = 1.5\,V$$

Since both capacitors have the same capacitance, the charge distribution will also be equal, hence:

$$Q_1 = Q_2 = CV = 1000 \times 10^{-3} \times 1.5 \ = 1.5 \times 10^{-3} A$$

Measured V_1	Calculated V_1	Measured V_2	Calculated V_2	Measured Q_1	Calculated Q_1	Measured Q_2	Calculated Q_2
1.8 V	1.5 V	1.8 V	1.5 V	1.8 mA	1.5 mA	1.8mA	1.5 mA

Conclusion:

The equivalent resistance lab determines the total resistance of a circuit made up of resistors connected in series or parallel, verifying the concept of equivalent resistance.

The lab focuses on resistance, not magnetic fields. But we have used kirchhoff junction law to find out the value of the resistors.

We experimented with resistance in electric circuits and connected the power supply, resistors, multimeter, and ammeter using banana cables. In the other parts we have also used in the following parts more banana cables and most importantly capacitors. In a lab, capacitors can reduce circuit resistance by storing electrical energy and acting as a short circuit for high frequency signals in a circuit with a resistor. This principle is used in the design of filters, coupling/decoupling circuits and power supplies. and larger resistor valuer .

Human and instrumental errors can occur and it is important to double-check and focus on professional connections if repeating the lab. The lab provides hands-on experience in electrical circuit design and understanding basic electrical engineering principles.