UNIVERSITY OF WOLLONGONG IN DUBAI

LAB REPORT 4

EQUIVALENT RESISTANCE

Subject: PHYS143 (DB123) Physics for Engineers.

Group Members:

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Experiment 1

Purpose

The goal was to determine the equivalent resistance of parallel-series arrangement of resistors experimentally and compare the values with the theoretical results.

Hypothesis

It is expected that the experimental values of the total resistance will be close to the calculated values of the total resistance.

Materials used

- Power supply
- 5 resistors
- Multimeter
- Probe wires
- Power supply wires
- Bread Board
- Wires

Procedures

1) Set up the circuit by putting the 8.2kΩ and 15kΩ resistors in series to each other but parallel to the 5.6kΩ resistor. Put the 12kΩ and 22kΩ resistors in series to each other but parallel to the 5.6kΩ resistor.
2) Connect the ammeter to the power supply which was set to 3 different values and read the corresponding values of current.

Data

Current (mA)	Voltage V_{AB} (V)	R_1 (kΩ)	R_2 (kΩ)	R_3 (kΩ)	R_4 (kΩ)	R_5 (kΩ)	R_{eq} calculated (kΩ)	R_{eq} experimental (kΩ)	Relative error (%)
0.4	1.5	8.2	15	12	22	5.6	3.9826	3.750	5.84
0.63	2.5	8.2	15	12	22	5.6	3.9826	3.9683	0.359
1.04	4	8.2	15	12	22	5.6	3.9826	3.8462	3.425

Calculations

$$\frac{1}{Req} = \left(\frac{1}{R1}\right) + \left(\frac{1}{R2}\right) + \left(\frac{1}{R3}\right) + \left(\frac{1}{R4}\right) + \left(\frac{1}{R5}\right)$$

R_{eq} (calculated) = 3.9826kΩ

R_{eq} (experimental) = V_{AB}/I

Example of R_{eq} (experimental): $\frac{1.5}{0.4}$ = 3.75 kΩ

Relative error = $\frac{[Req\ (calculated) - Req\ (experimental)]}{Req\ (calculated)} * 100$

Example of Relative error: $\left[\frac{3.9826 - 3.9683}{3.9826}\right] * 100$ = 0.359%

Conclusion

The objective was to compare the theoretical and experimental values of the total resistance. The experimental total resistance can be calculated after finding the corresponding value of current to the voltage. Set up a circuit with five known resistors. Place the 8.2kΩ and 15kΩ resistors in series to each other but parallel to the 5.6kΩ resistor. Put the 12kΩ and 22kΩ resistors in series to each other but parallel to the 5.6kΩ resistor. Read the corresponding values of the current to the voltage from the ammeter. The power supply was set to 1.5V, 2.5V, and 4V.

Some sources of error may include:

- Improper connections of materials used.
- Resistors may not be the exact value as written. (Ex: 8.2kΩ may not be the exact value of the resistance).
- Human error, such as, mistakes made when calculating or measuring data.

When attempting this experiment for a second time, repeat the experiment 2 or 3 more times or take multiple readings of the current to stay more accurate.

Experiment 2

Purpose

The experiment's purpose is to measure the current and currents flowing through each resistance in a circuit, then compare the experimental results to theoretical values obtained using Kirchhoff's laws and a reliable matrix solving software such as MATLAB.

Hypothesis

The experimental results for various values of current must be nearly similar to the theoretical values of the currents.

Materials used

- Bread board
- Probe wires
- Power supply
- 5 different resistors
- Multimeter
- Wires
- Power supply wires

Procedure

1) A circuit was set up on the bread board which consisted of wires, resistors and a multimeter as shown in the handout.
2) After ensuring that the connections on the breadboard were proper, the power supply was connected to the circuit.
3) A voltage of x volts was applied and the current I was measured.
4) Using both the Kirchhoff's junction rule and the loop rule, the linear equations for 6 different values of I were noted.
5) The linear system of equations was arranged in the matrix form Ax=B and then solved either manually or by using a matrix solving software such as MATLAB. The matrix x consisted of the values for different values of I.
6) After obtaining the values for various I, the experimental values and the theoretical values of I were calculated.

Data

The following table shows the data for the resistors used in the experiment, the experimental and theoretical values of the currents calculated and observed during the experiment and the relative error of the experiment.

Circuit input data		Measured currents (mA)		Calculated currents (mA)	Relative error (%)
R_1	1.2kΩ	I_{R1}	1.34	1.39	3.59%
R_2	2.2kΩ	I_{R2}	(−)0.22	(−)0.227	3.08%
R_3	3.3kΩ	I_{R3}	0.53	0.554	4.33%
R_4	1.5kΩ	I_{R4}	0.75	0.781	3.97%
R_5	0.82kΩ	I_{R5}	1.55	1.620	4.32%
Va−Vb (V)	3V	I_L	2.08	2.174	4.32%

Observation

We can see that there is an average of 3.94 percent of relative error between the measured value and calculated value of the current. This can be caused due to the limitation of the measuring device or due to the environmental factors like temperature or humidity of where the experiment was conducted.

Calculations

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

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

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

$-V + 1200\, I_{R1} + 2200\, I_{R2} + 3300\, I_{R3} = 0$

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

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

All current values are mentioned in the table above.

I_L is the total current, and I_{R1}, I_{R2}, I_{R3}, I_{R4}, I_{R5} are the currents for R_1, R_2, R_3, R_4, R_5 respectively.

Conclusion

The purpose of the experiment described in the paragraph was to measure the current and resistance in a circuit and compare the results to theoretical values obtained using Kirchhoff's laws and a matrix solving software such as MATLAB. The procedure included building the circuit, connecting it to a voltage source, and measuring the current I and currents flowing through each resistance. The Kirchhoff junction and loop rule equations were written, and the linear system was solved manually or using MATLAB. The experimental measurements were compared to the theoretical values, and the equivalent resistance of the circuit was calculated.

Some of the possible sources of error for the experiment includes:

- Current and resistance measurements may be inaccurate due to measurement instrument limitations or human error.
- The circuit may not be properly configurated.
- The equations written using Kirchhoff's laws may not accurately represent the behaviour of the circuit, resulting in theoretical value errors.
- There is a chance of making mathematical errors while solving the linear system of equations.

Finally, the experiment successfully demonstrated the use of Kirchhoff's laws and linear systems to analyze a circuit and determine its equivalent resistance. The results demonstrated that the theoretical values closely matched the experimental measurements, demonstrating the method's accuracy.

Experiment 3

Purpose

The goal of this experiment was to understand how voltage changes with time through a capacitor and determine the time constant of the RC circuit using a large resistor value.

Hypothesis

It is expected that the voltage across the capacitor would increase as time passes by and the voltage across the resistor would decrease.

Materials used

- Breadboard
- Wires
- Power supply
- Power supply wires
- Resistor
- Multimeter
- Capacitor
- Banana cables

Procedure

1) Assemble the circuit according to the diagram given in the handout.
2) Choose RC values to maximize the circuit's time constant.
3) Using the voltage across a capacitor in an RC circuit formula, measure the voltage across each capacitor (VC_1, VC_2, VC_3) both experimentally and theoretically.
4) Make a table with the measured and theoretical voltage values.
5) Using Excel, estimate the time constant from the obtained data by plotting the natural logarithm of the difference between the maximum voltage and the voltage at each time point against the time.
6) Repeat the measurements multiple times to obtain a better estimate of the time constant and to verify the results.

Data

TABLE 1

Time (s)		Measured Voltage Across C_1	Theoretical Voltage Across C_1
0.2RC	4.4	0.75	0.906
0.4RC	8.8	1.462	1.648
0.6RC	13.2	2.07	2.256
0.8RC	17.6	2.46	2.753
1.0RC	22	2.839	3.16
1.2RC	26.4	3.261	3.494
1.4RC	30.8	3.483	3.767
1.6RC	35.2	3.791	3.991
1.8RC	39.6	3.974	4.174
2.0RC	44	4.123	4.323

TABLE 2

$\ln(V/(V-V_c))$ [$V = V_{max}$]	Time, t (s)
0.162519	3.575416
0.345876	7.609279
0.534435	11.75758
0.677274	14.90002
0.838867	18.45507
1.056128	23.23481
1.192703	26.23947
1.419644	31.23218
1.58377	34.84294
1.740686	38.2951

Observation

As we can see from table 1, our hypothesis is confirmed which says that as time passes by, voltage across the capacitor increases.

Graph and calculations

$V_{C1} = V_{max\_C1}\,(1 - e^{-t/\tau})$ to calculate the theoretical voltage

$$Y = \ln\left(\frac{V_{max\_C1}}{V_{max\_C1} - V_{C1}}\right)$$

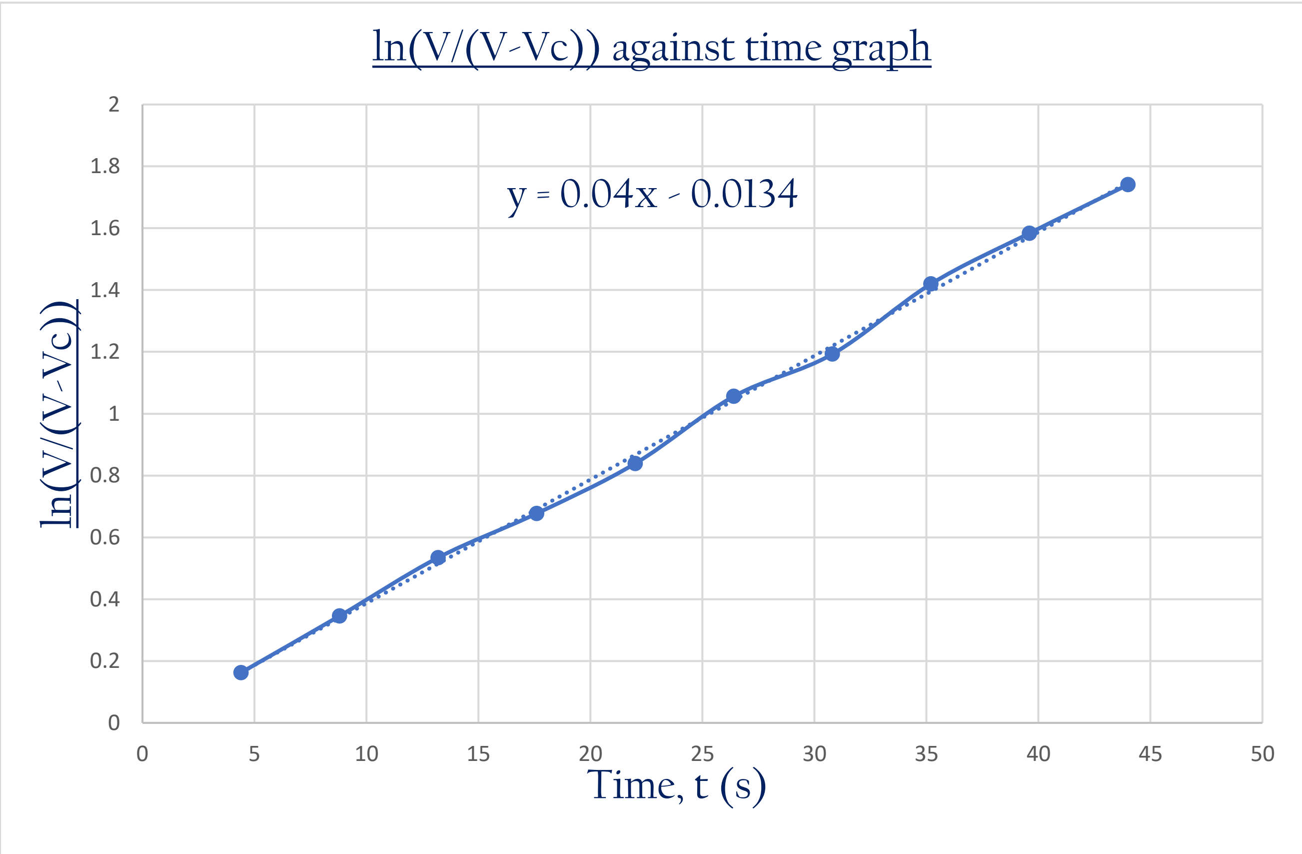
$$\ln\left(\frac{V_{max\_C1}}{V_{max\_C1} - V_{C1}}\right) = \frac{1}{\tau}t$$

So, $t = Y^*\tau$

$\tau_{calculated} = RC = 22000*1000*10^{-6}$

$\tau_{calculated} = 22$

Graph for TABLE 2



$\tau_{experimental} = 1/\text{gradient}$

$\tau_{experimental} = 1/0.04$

$\tau_{experimental} = 25$

Conclusion

The experiment was carried out to determine the time constant of an RC circuit. The circuit was set up using a power supply, a resistor, three capacitors, multimeter, and probe wires. The values of RC were chosen to maximize the time constant of the circuit. Voltage across each capacitor was measured at different time points and recorded. The data was then plotted in Excel, and points were fit to a straight line to obtain the time constant from the slope of the line of best fit. The experiment was repeated to verify the results.

Some of the possible sources of error include

- The circuit may not be properly configurated.
- Measurements may be inaccurate due to measurement instrument limitations.
- Human reaction time may ruin the accuracy of the results. Turning the power supply on and starting the stopwatch simultaneously is very difficult to achieve.
- The theoretical value for time constant assumes ideal conditions, hence it can cause a significant difference in the experimental and theoretical results.

In conclusion, the experiment aimed to find the time constant of an RC circuit using a large resistor value, as well as to comprehend the behavior of voltage across a capacitor in an RC circuit. The time constant of the circuit was successfully calculated by measuring the voltage across each capacitor at different time points and plotting the data in a graph. The observations demonstrated the relationship between voltage across the capacitor and time in an RC circuit, as well as the concept of exponential decay. This experiment teaches us the fundamentals of RC circuits and the underlying principles of electrical circuits.

Experiment 4

Purpose

This experiment aims to determine the voltage across the capacitance (C_1) and the charge on each capacitance. The experimental results are then compared to theoretical calculations.

Hypothesis

It is expected that the voltage found on each capacitor will be equal in magnitude and similar to their theoretical values if the charging and discharging of capacitors is observed.

Materials used

- Power supply
- 2 capacitors
- Multimeter
- 4 banana cables
- Breadboard
- Power supply wires
- Probe wires

Procedures

1) Connect a DC voltage source with voltage of 3 V to a circuit containing two capacitors (C_1 and C_2) in parallel.
2) Connect a switch between the capacitors to control the direction of charge flow.
3) Connect a voltmeter to measure the voltage across C_1.
4) Calculate the theoretical voltage of the capacitors and record them.
5) Set the switch to charge C_2.
6) Wait a long time to allow C2 to reach its maximum charge.
7) Set the switch to charge C_1 from C_2.
8) Wait a long time to allow C_1 to reach its maximum charge from C_2.

Data and Calculations

Using the formula Q = CV, calculate the charge on each capacitor, where C is capacitance and V is the voltage across each capacitor.

C = 1 μF

$V_0 = 3$ V

$Q = 3*1000*10^{-6} = 3$ mC

$V_{C1} = C_1*V_0/\ (C_1+C_2) = 1.5$ V

Since they have the same capacitance, they will also have the same voltage so, $V_{C1} = V_{C2} = 1.5$ V.

Theoretical charge

$Q_0 = Q_1 + Q_2$

$Q_0 = V_1C_1 + V_2C_2$

$Q_0 = 1.5*0.001 + 1.5*0.001$

$Q_0 = 3$ mC

Experimental charge

$Q_0 = Q_1 + Q_2$

$Q_0 = V_1C_1 + V_2C_2$

$Q_0 = 1.69*0.001 + 1.72*0.001$

$Q_0 = 0.00169 + 0.00172$

$Q_0 = 3.41$ mC

Observations

The experimental values for the voltage must have been similar to the calculated values but in our case, it was $V_1 = 1.69$ V and $V_2 = 1.72$ V. Due to some errors, the values are different. And hence the values of the charge would differ as well (calculations shown above). A reason for the weird results could be that the capacitors may not be fully discharged and hence have an original value of charge.

Conclusion

The objective of this experiment was to measure the voltage across capacitor C_1 and deduce the charge on each capacitor, then compare it with theoretical calculations. The hypothesis was that the experimental measures would match the theoretical calculations. The steps taken in the experiment were to set the switch in order to charge C_2, set the switch to charge C_1 from only C_2, and measure the voltage across the capacitance (C_1) and deduce the charge on each capacitance.

Some possible sources of error in this experiment could include:

- Inaccurate readings from the multimeter or voltmeter,
- Variations in the power supply voltage,
- Imperfections in the capacitors affecting their capacitance value,

When attempting this experiment, a second time, minimize these sources of error and obtain accurate results by following proper experimental procedures and calibrating the equipment perfectly. This experiment provides insight into the principles of capacitance and helps to demonstrate the relationship between voltage and charge on a capacitor. The results obtained from this experiment can be used to validate theoretical predictions and contribute to a better understanding of capacitance in electrical circuits.