UNIVERSIDAD DE OVIEDO

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Fundamentals of Circuit Analysis: Understanding Multimeters, Circuit Design, Ohm's Law Validation and Capacitor Charging Analysis

Waves and Electromagnetism

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Introduction:

Electrical circuits serve as the spine of different designing disciplines, including software engineering, controlling various electronic gadgets essential to present day life. Understanding the standards of circuit examination is fundamental for engineers to plan and overpass complex frameworks successfully.

This laboratory session was planned to supply students with a hands-on presentation to crucial circuit examination concepts, with a specific center on the verification of Ohm's Law and the use of the multimeter. Useful skills that every engineer should control.

By making practical experiments, students had the opportunity to create significant abilities in circuit plan, multimeter operation, and information interpretation, setting a strong establishment for their assist thinks about in electrical designing as well as understanding better the use of excel formulas.

Objectives:

1. Introduction to Circuit Components:

Students were presented to the basic components of an electrical circuit. Resistors, capacitors and batteries among others where utilized. Understanding the work of these components was essential for verifying ohm’s law as well as the combination of resistors equations.

2. Multimeter Utilization:

Through commonsense works out, students learned how to operate a multimeter, an adaptable instrument used for measuring distinctive electrical amounts such as voltage, current, between others. Capability in utilizing a multimeter was vital for conducting exact circuit examinations.

3. Circuit Design:

Students picked up hands-on involvement in planning simple electrical circuits based on hypothetical standards. By applying Ohm's Law and circuit investigation methods, they learned how to build circuits to attain objectives.

4. Verification of Ohm's Law:

The practice session included excel tables to verify Ohm's Law, which built up a basic relationship between voltage (V), current (I), and resistance (R) in a closed electrical circuit. By conducting tests and analysing the gotten data, students confirmed the legitimacy of this basic law.

5. Verification of Resistor Combinations:

Students investigated the equations of the equivalence of resistor combination in series and parallel arrangements. Through viable demonstrations, they understood how to calculate the equivalent resistance of such combinations and analysed their results.

6. Loading process of a Capacitor:

The students will understand the relationship of the time and the charge stored in a capacitor as well as the maximum charge that can be stored in each capacitor. They will try to represent the formulas and finally check their results with theoretical ones.

Theoretical Basis:

The experimental examination conducted in this laboratory session pointed to approve crucial principles of circuit analysis, especially centering on the verification of Ohm's Law and charging capacitors equations.

Ohm's Law sets up a direct relationship between the voltage (V) over a conductor, the current (I) passing through it, and the resistance (R) of the conductor, as communicated by the equation:

$$V = IR$$

"Ohm's law by Georg Simon Ohm in 1827."

This relationship was tried through practical tests including the estimation of voltage (Vexp) over a resistor at different time intervals. The theoretical voltage (Vteo) was calculated based on the known resistance of the resistor and the current passing through it.

The results gotten from the tests were compared with the hypothetical forecasts to approve Ohm's Law. The experimental information, counting the time intervals and comparing measured and hypothetical voltages, were collected and analysed through a table in excel to survey the correlation between the watched and anticipated values.

The investigation of the test information pointed to illustrate the consistency of Ohm's Law in depicting the behaviour of electrical circuits and to highlight the significance of understanding and applying this fundamental law in circuit examination and design.

$$Vteo = \frac{Q}{C} = \varepsilon * (1 - e\hat{\ }(-\frac{t}{RC}))$$

"Charging capacitor equation by Cristina Echevarría Bonet in UNIOVI in 2024."

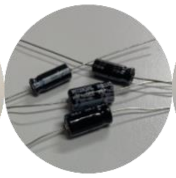
The second part of the experiment was made to check the formula of the charge of the capacitors during a given time interval. After calculating, measuring and plotting the results in an excel table they will see the least squares approximation. Students will see by their eyes a good way to check the veracity of the equations.

Experimental Procedure: Meter interruptor

1. Required Material:

- Circuit board: The setup includes a circuit board equipped with light bulbs and a rheostat (or potentiometer) to regulate resistance.

- Electronic Materials: Additional components include resistors, capacitors, multimeters, batteries, chronometers, a switch and connecting cords.

"Image of the switch: https://elcom-in.com/electrical-switches-history-types-uses/ in 2024".

"Photos of the circuit board, resistors, battery and capacitors taken from the ohm's sheet by Cristina Echevarría Bonet in UNIOVI in 2024.".

"Photo of the multimeter taken by Álvaro Puebla Ruisánchez in 2024.".

"Image of the chronometer: Flaticon.com".

1.1 Notes on the Board:

- The springs on the board serve as association focuses, with a few welded to circuit components just like the potentiometer, bulb attachments, or battery cells.

- Treat all components and consumables with care to encourage classmates' hone.

- Pay consideration to component polarity, especially with batteries, guaranteeing alignment with the board's markings.

2 Learning to Use a Multimeter:

A multimeter could be a versatile gadget for measuring electrical quantities such as current, voltage, resistance, and capacitance.

In this experiment, focus is on direct current (DC) estimations.

Set the multimeter to the DC image for all estimations.

Select the suitable cable outputs, regularly "COM" and the assigned attachment for each estimation.

Utilize diverse scales on the multimeter depending on the anticipated value for precise readings.

When measuring current, put the ammeter (multimeter in ammeter mode) in series with the circuit. For voltage estimations, put the voltmeter (multimeter in voltmeter mode) in parallel.

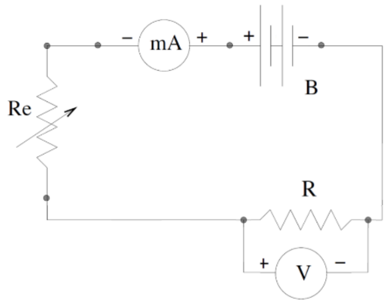
Hone measuring potential contrast over a single battery and over two batteries associated in arrangement.

3 Resistors:

Determine the resistance esteem of resistors utilizing color codes with the resistors table.

Record the resistance values gotten utilizing this strategy and calculate the mistake for each resistor.

4 Ohm's Law:



Set up the circuit as portrayed in the image of the circuit, counting batteries, a rheostat, an ammeter, a voltmeter, and resistors.

Alter the rheostat to establish least and most extreme potential contrasts.

Conduct numerous estimations of potential contrast and current over resistors, covering the complete potential contrast extend.

Record estimations and their exactnesses, and plot potential contrast vs. current for each resistor.

Perform straight least-squares fitting to get the resistance values and their instabilities.

"Circuit from the ohm's sheet by Cristina Echevarría Bonet in UNIOVI in 2024.".

5 Combination of Resistors in Series and Parallel:

Utilize gotten resistance values to calculate comparable resistances for resistor combinations in series and parallel utilizing suitable conditions.

Supplant resistors within the circuit with series and parallel combinations and degree potential contrast and current.

Calculate proportionate resistances and compare with hypothetical values, considering instabilities.

6 Loading Process of a Capacitor:

Students proceeded by constructing the designated circuit, ensuring the capacitor was discharged initially. Upon closing the switch and starting the timer simultaneously, they halted the timer every five seconds to record the potential difference across the capacitor and the corresponding time.

This iterative process continued until the potential difference stabilized, indicating full charge. Subsequently, they measured the electromotive force (ε) and the resistance (R) of the resistor. Finally, they plotted the theoretical function (The formula shown in the theoretical basis) alongside the experimental values to compare theoretical and experimental graphs with the use of excel.

Obtained Results:

1 Measuring the difference of potential between the ends of a battery and a series combination of two:

Batteries	1	2
$\Delta V = V_{ab}$ (V)	1,50 ± 0.01	3,00 ± 0.01

2 Check the value of the resistances:

R1 = 22.0 ± 1.1 ohms

R2 = 220 ± 11 kohms

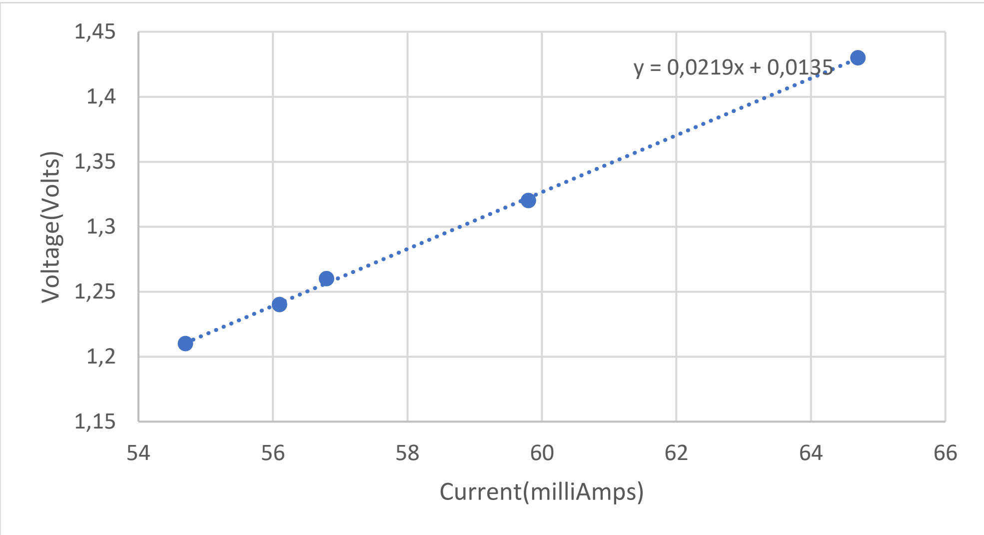
3 Perform 5 measurements varying the resistance of the potentiometer:

For resistance 1:

I(mA)	V(V)
54,7	1,21
56,1	1,24
56,8	1,26
59,8	1,32
64,7	1,43

The error of I is ± 0.1 and the one for the V is ± 0.01

4 Plot the results:



If you increase 1mA the current value of the voltage should increase in 0,0219 V

5 Perform the least squares approximation of the form y=ax+b:

	a (V/mA == kohm)	b (V)
Parameter	0,021883902	0,01354244
Error	0,000316093	0,01850034
Correlation	0,999374495	0,00251265

A correlation of 0,999 means a strong relationship of the variables.

6 Practical Result:

R1 ± ΔR1 = 21.88 ± 0.32 ohms

Confirming the ohm's law, because the experimental value obtained in the laboratory is in good agreement with the value given by the supplier, also confirming the ohm's law.

7 Time and potential difference:

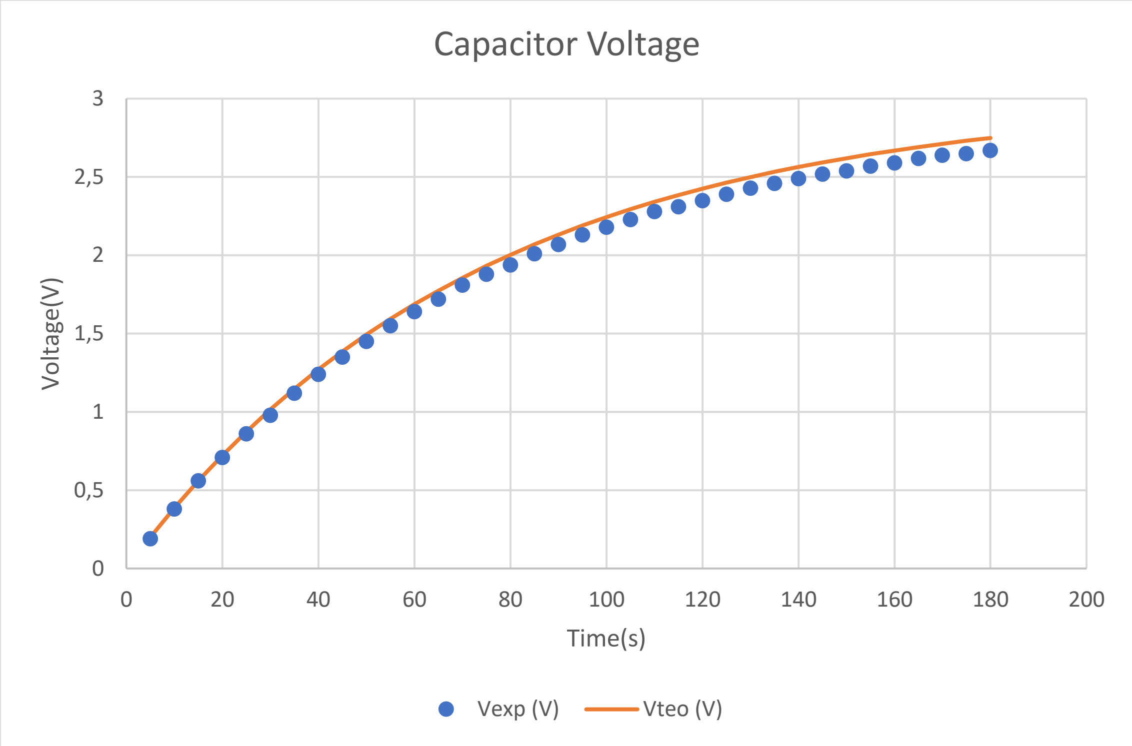
Constants for the experiment measured with the multimeter and the table of resistances:

Ɛ (V)	R (kΩ)	C (mF)
3	220	0,330

Results by activating the switch and the chronometer at the same time:

Time (s)	Vexp (V)	Vteo (V)	Time (s)	Vexp (V)	Vteo (V)
5	0,19	0,1997	95	2,13	2,1894
10	0,38	0,3860	100	2,18	2,2433
15	0,56	0,5600	105	2,23	2,2937
20	0,71	0,7224	110	2,28	2,3407
25	0,86	0,8740	115	2,31	2,3846
30	0,98	1,0155	120	2,35	2,4255
35	1,12	1,1475	125	2,39	2,4637
40	1,24	1,2708	130	2,43	2,4994
45	1,35	1,3859	135	2,46	2,5328
50	1,45	1,4933	140	2,49	2,5638
55	1,55	1,5936	145	2,52	2,5929
60	1,64	1,6872	150	2,54	2,6200
65	1,72	1,7746	155	2,57	2,6453
70	1,81	1,8561	160	2,59	2,6689
75	1,88	1,9322	165	2,62	2,6909
80	1,94	2,0033	170	2,64	2,7115
85	2,01	2,0696	175	2,65	2,7307
90	2,07	2,1316	180	2,67	2,7486

8 Plot the graph:



Conclusions:

The laboratory experiment has demonstrated acceptance of Ohm's law in comparison with experimental measurements and theoretical predictions.

By collecting and analysing real information and calculating time intervals and measured voltages, we attempted to assess the agreement between observed values and expected values.

Exploring the information provides an understanding of Ohm's role in describing electrical behaviour. The difference and the flow of the measured values were directly related, confirming the basic principle of Ohm's law.

This proof emphasizes the importance of understanding and applying Ohm's law in circuit testing and planning, because it is a fundamental system for predicting and controlling electrical behaviour. The test also calculates the relationship between the measured resistance value and the theoretical value provided by the manufacturer. The comparison of the measured resistance values with the theoretical one searched in the table of resistors confirms the accuracy of our exploratory setup.

In conclusion, this research work has given profitable bits of knowledge into the behaviour of electrical circuits. By affirming the legitimacy of Ohm's Law, we have upgraded our understanding of essential electrical concepts and strengthened their commonsense applications in circuit investigation and design.

Bibliography:

- Photos of the circuit board, resistors, battery and capacitors taken from the ohm's sheet and the capacitors sheet as well as the laboratory theoretical information and the practice by Cristina Echevarría Bonet in UNIOVI in 2024.
- Photo of the multimeter taken by Álvaro Puebla Ruisánchez in 2024.
- Image of the chronometer: Flaticon.com.
- Image of the switch: https://elcom-in.com/electrical-switches-history-types-uses/ in 2024.
- Ohm's law by Georg Simon Ohm in 1827.