PHY224: Ohm's Law Lab

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Abstract

The focus of this lab was studying the resistance of a resistor in a simple electrical circuit. The resistance of a resistor and of a potentiometer were considered in this lab. Their resistance was calculated using current and voltage measured using an ammeter and voltmeter respectively. The resistor was found to have a resistance of $476\Omega \pm 4\Omega$ ohms and the potentiometer was found to have a resistance of $1280\Omega \pm 10\Omega$ ohms.

1 Introduction

The purpose of this experiment was to measure the resistance of a resistor and potentiometer using measured current and voltage. Applying Ohm's law to the measured current and voltage the resistance of the the resistor and potentiometer were found.

2 Methods and Materials

- Two (2) Tegam 130A Digital Multimeters
- Breakout Box (Electrical Components Board)
- DC Power Supply with Varying Voltage Control
- Six (6) Electrical Wires

3 Experimental Procedure

1. It was ensured that one multimeter is set to be an ammeter and one is set to be a voltmeter. This was done by turning the bottom knob to the "DCA" mode for the ammeter and "DCV" mode for the voltmeter. Additionally, the top knob was set to 20 mA/V setting for both multimeters. For further clarification on this set up refer to instrument manual[2].
2. The materials listed above were arranged as shown in the circuit diagram of figure 1, ensuring the ammeter was connected in series and the voltmeter was connected in parallel.
3. The DC power supply was the switched on and the current and voltage were recorded into the lab notebook. The voltage was varied 4 more times, for a total of 5 trials, using the knob on the power supply and the voltages and currents were recorded in the lab notebook.
4. The ammeter was then changed into an ohm meter by turning its top knob into the "Ohm (Ω)" mode. The resistance of the resistor was measured and recorded in the lab notebook.
5. The coloured bands on the resistor were recorded in the lab notebook.

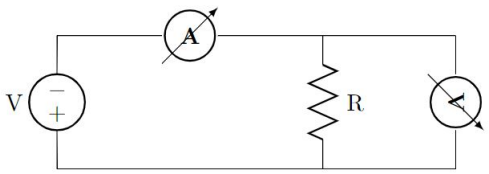

Figure 1: Circuit Diagram of Experimental Set Up [1]

6. The resistor was then disconnected from the circuit and replaced by a potentiometer maintained at a constant resistance using its resistance varying knob. Steps 3 and 4 were then repeated using this set up and the all measured values (voltages, currents, and resistance) were recorded in the lab notebook.

4 Results

4.1 Resistor

The current and voltage that were obtained using the ammeter and voltmeter, respectively, during the 5 trials are shown in the tables bellow:

Table 1: Measured Observations of Current for Resistor

Beginning of Data			
Trial Number	Current(mA)	Error of Accuracy (mA)	Error of Precision (mA)
1	2.79	0.02*	0.01
2	7.44	0.06*	0.01
3	8.99	0.07*	0.01
4	10.52	0.08*	0.01
5	14.96	0.1*	0.01
End of Data			

Error of Accuracy is 0.75% as given by the multimeter manual [2]
Error of Precision is given by considering last decimal given by the multimeter
* indicates the largest error

Table 2: Measured Observations of Voltage for Resistor

Beginning of Data			
Trial Number	Voltage (V)	Error of Accuracy (V)	Error of Precision (V)
1	1.31	0.003	0.01*
2	3.50	0.009	0.01*
3	4.26	0.01	0.01*
4	5.00	0.01	0.01*
5	7.08	0.02*	0.01
End of Data			

Error of Accuracy is 0.25% as given by the multimeter manual [2]
Error of Precision is given by considering last decimal given by the multimeter
* indicates the largest error

Using the data above the resistance was calculated for each trial using Ohm's law which is given by:

$$R = \frac{V}{I} \tag{1}$$

Where R is the resistance in ohms, V is the voltage in volts, and I is the current in amps.

A sample calculation using the data from trial 1 is shown bellow:

$$R = \frac{V}{I} = \frac{1.31V \pm 0.01V}{2.79mA \pm 0.02mA} = \frac{1.31V \pm 0.76\%}{2.79 \times 10^{-3}A \pm 0.75\%} = 469.53\Omega \pm \sqrt{(0.75)^2 + (0.76)^2} = 470\Omega \pm 5\Omega \tag{2}$$

The same process as seen in eqn 2 was applied to trial 2 through 5 to find the resistance for each trial. These mean of these resistances was then found using the following equation:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{3}$$

Where $\bar{x}$ is the mean, N is the number of trials and the x_i's are the five calculated resistances.

This was calculated as follows:

$$\bar{R} = \frac{1}{5}(470 + 470 + 473 + 493 + 473) = 475.80\Omega \approx 476\Omega \tag{4}$$

The standard distribution of the resistance was used to calculate the uncertainty in the mean, known as the standard error, using the following equations:

$$\sigma = \sqrt{\frac{\sum_i^N (x_i - \bar{x})^2}{N-1}} \tag{5}$$

Where σ is the standard deviation, N is the number of trials, $\bar{x}$ is the mean resistance, and the x_i's are the measured resistances

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{N}} \tag{6}$$

Where $\sigma_{\bar{x}}$ is the standard error

The calculation for the standard error is as follows:

$$\sigma = \sqrt{\frac{1}{4}(470-476)^2 + (470-476)^2 + (473-476)^2 + (493-476)^2 + (473-476)^2} \approx 10 \tag{7}$$

$$\sigma_{\bar{x}} = \frac{10}{\sqrt{5}} \approx 4 \tag{8}$$

Hence from eqns 4 and 8 the mean resistance was found to be $476\Omega \pm 4\Omega$ when rounded to the right amount of significant digits.

The ammeter was turned into a ohm meter to measure the resistance of the resistor to serve as a comparison to the calculated value. The measured value was $473\Omega \pm 0.01\Omega$. Additionally, the bands on the resistor were found to be yellow, blue, brown and gold. Using the guide found in the lab handout [1] this was found to represent a resistance of $460\Omega \pm 23\Omega$

4.2 Potentiometer

The current and voltage that were obtained using the ammeter and voltmeter, respectively, during the 5 trials are shown in the tables bellow:

Table 3: Measured Observations of Current for Potentiometer

Beginning of Data			
Trial Number	Current(mA)	Error of Accuracy (mA)	Error of Precision (mA)
1	2.26	0.02*	0.01
2	3.87	0.03*	0.01
3	4.84	0.04*	0.01
4	6.37	0.05*	0.01
5	9.69	0.07*	0.01
End of Data			

Error of Accuracy is 0.75% as given by the multimeter manual [2]
Error of Precision is given by considering last degit given by the multimeter
* indicates the largest error

Table 4: Measured Observations of Voltage for Potentiometer

Beginning of Data			
Trial Number	Voltage (V)	Error of Accuracy (V)	Error of Precision (V)
1	2.91	0.007	0.01*
2	4.98	0.01	0.01*
3	6.20	0.02*	0.01
4	8.16	0.02*	0.01
5	12.39	0.03*	0.01
End of Data			

Error of Accuracy is 0.25% as given by the multimeter manual [2]
Error of Precision is given by considering last digit given by the multimeter
* indicates the largest error

The data collected on the potentiometer was analyzed in a very similar fashion as the resistor data. The resistance of each trial was calculated exactly as shown in eqns 1 and 2. Eqn 3 was then applied to this data set, in a similar fashion to what is seen in eqn 4, to determine the mean resistance of the potentiometer. Additionally, the standard error was calculated using eqns 5 and 6, in a similar fashion as is seen in eqns 7 and 8. **The result was that the potentiometer was found to have a resistance of** $1280\Omega \pm 10\Omega$. The resistance of the potentiometer was also measured using an ohm meter and was found to be $1290\Omega \pm 0.01\Omega$

5 Discussion

For both the resistor and the potentiometer the calculated values of resistance were close to the expected values. For the resistor the obtained value of $476\Omega \pm 4\Omega$ using Ohm's law was close to the value measured using the ohm meter ($473\Omega \pm 0.01\Omega$) and the value obtained using the band colours ($460\Omega \pm 23\Omega$). We see then that the calculated value when taking into account the associated uncertainty lies in the range of the two expected values and their uncertainties. A similar pattern is see when we compared the measured value of the potentiometer ($1280\Omega \pm 10\Omega$) which lies within the range of the expected value from the ohm meter ($1290\Omega \pm 0.01\Omega$). We see then that for all trials Ohm's law holds and does a very good job at predicting the experimental result. Any discrepancy between Ohm's law and the experimental values (which are accounted for in the uncertainties), are likely due to imperfect equipment. These are things such as: the wires having a small resistance, errors of accuracy and precision arising from limitations in the actual multimeters, and slight imperfections in the DC power source.

6 Conclusion

The resistance of a resistor and a potentiometer were calculated using measured current and voltage using a ammeter and voltmeter respectively. Using measured current and voltage Ohm's law was used to calculate the resistance. The resistor was found to have a resistance of $476\Omega \pm 4\Omega$ and the potentiometer was found to have a resistance of $1280\Omega \pm 10\Omega$. Both results agreed with predicted resistance values obtained using an ohm meter.

References

[1] Christopher Lee Ohm's Law Lab Handout https://q.utoronto.ca/courses/138270/assignments/256753.

[2] Keithley Model 130A/131 Digital Multimeter Instruction Manual https://www.physics.utoronto.ca/vutha/405_instrument_manuals/Keithley_130A_multimeter.pdf.

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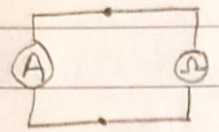
Lab 0: Ohms Law: Using a multimeter to perform voltage and current measurments on a resistor to find resistance via ohms law

Practice Circuts:

Measure resistance of the voltmeter

Measured Value: 0.1 KΩ

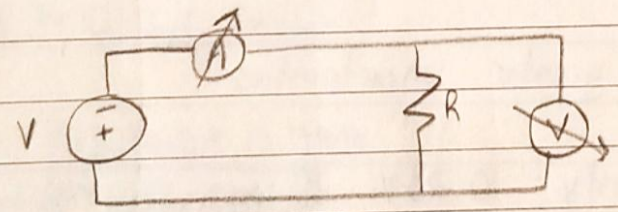


Measure resistance of the ammeter

Measured Value: 0.1KΩ

Start of Lab: Resistor Value on BreakBox: 470 ohms

	Voltage (V)	Accuracy (V) Uncertainty *	Persicion (V) Uncertainty	Current (mA)	Accuracy (mA) Uncertainty *	Persicion (mA) Uncertainty
1)	1.31	0.003	(0.01)	2.79	(0.02)	0.01
2)	3.50	0.009	(0.01)	7.44	(0.06)	0.01
3)	4.26	0.01	(0.01)	8.99	(0.07)	0.01
4)	5.00	0.01	(0.01)	10.52	(0.08)	0.01
5)	7.08	(0.02)	0.01	14.96	(0.1)	0.01



The following circut was wired

Circled values are greater Uncertainties

Reference Resistance Reading: 473Ω

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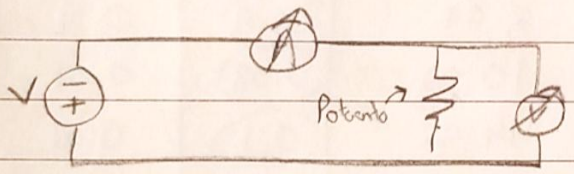
Manufactors Resistance Tolerance and Value (Bands)

Yellow	Blue	Brown	Gold
4	6	x10	± 5%

↳ 46 x10 = 460 Ohms ± 5%

Potentiometer Data: Referance Resistance Reading: 1290Ω

	Voltage (V)	* Accuracy uncertainty (V)	Percision uncertainty (V)	Current (mA)	* Accuracy uncertainty (mA)	Percision uncertainty (mA)
1)	2.91	0.007	(0.01)	2.26	(0.02)	0.01
2)	4.98	0.01	(0.01)	3.87	(0.03)	0.01
3)	6.20	(0.02)	0.01	4.84	(0.04)	0.01
4)	8.16	(0.02)	0.01	6.37	(0.05)	0.01
5)	12.39	(0.03)	0.01	9.69	(0.07)	0.01



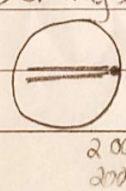
The following circuit was wired

Circled Values are greater uncertainties

* Accuracy Uncertainty: 0.25% of measured values (V)
* Accuracy Uncertainty: 0.75% of measured values (mA)

Multimeter Settings for both sets of measurments:

Top Dial:



Bottom Dial: DCV (For Voltmeter)
DCA (For Ammeter)

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Analysis

Resistor : Find R by using $R = \frac{V}{I}$

1) $R = \frac{1.31V \pm 0.01V}{2.79mA \pm 0.02mA}$

$R = \frac{1.31V \pm 0.01V}{2.79 \times 10^{-3}A \pm 0.01 \times 10^{-3}A}$

$R = \frac{1.31V \pm 0.76\%}{2.79 \times 10^{-3}A \pm 0.75\%}$

$R = 469.53\Omega \pm \sqrt{(0.75)^2 + (0.76)^2}$

$R = 469.53\Omega \pm 1.07\%$

$R = 469.53\Omega \pm 5.01\Omega$

$\boxed{R = 470\Omega \pm 5\Omega}$

For the remaining trials, we use the exact same method to determine R with uncertainties

2) $R = 470.43\Omega \pm 0.85\%$

$\boxed{R = 470\Omega \pm 4\Omega}$

3) $R = 473.86\Omega \pm 0.79\%$

$\boxed{R = 473\Omega \pm 4\Omega}$

4) $R = 492.60\Omega \pm 0.78\%$

$\boxed{R = 493\Omega \pm 4\Omega}$

5) $R = 473.26\Omega \pm 0.80\%$

$\boxed{R = 473\Omega \pm 4\Omega}$

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Potentiometer : Find R by using $R = \frac{V}{I}$

We use the exact same method as the resistor to determine R with uncertainties

1) $R = 1287.61\ \Omega \pm 0.82\%$

$\boxed{R = 1290\ \Omega \pm 10\ \Omega}$

2) $R = 1286.82\ \Omega \pm 0.78\%$

$\boxed{R = 1290\ \Omega \pm 10\ \Omega}$

3) $R = 1280.94\ \Omega \pm 0.67\%$

$\boxed{R = 1281\ \Omega \pm 9\ \Omega}$

4) $R = 1281.00\ \Omega \pm 0.79\%$

$\boxed{R = 1280\ \Omega \pm 10\ \Omega}$

5) $R = 1278.64\ \Omega \pm 0.79\%$

$\boxed{R = 1280\ \Omega \pm 10\ \Omega}$

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Average and Standard Deviation

$\bar{X}_{resistor} = (470 + 470 + 473 + 493 + 473)\ \frac{1}{5} = 475.80\,\Omega = 476\,\Omega$

$\bar{X}_{potentiometer} = (1290 + 1290 + 1281 + 1280 + 1280)\ \frac{1}{5} = 1284.20\,\Omega = 1280\,\Omega$

$S_{resistor} = ([(470 - 476)^2 + (470 - 476)^2 + (473 - 476)^2 + (493 - 476)^2 + (473 - 476)^2]/4)^{\frac{1}{2}}$

$= ([36 + 36 + 9 + 9 + 289]/4)^{1/2} \simeq 10.$

$S_{potentiometer} = ([(1290 - 1280)^2 + (1290 - 1280)^2 + (1281 - 1280)^2 + (1280 - 1280)^2 + (1280 - 1280)^2]/4)^{1/2}$

$= ([100 + 100 + 1 + 0 + 0]/4)^{1/2} \simeq 22$

$\sigma_{\bar{X}_{resistor}} = 10/\sqrt{5} \simeq 4$

$\sigma_{\bar{X}_{potentiometer}} = 22/\sqrt{5} \simeq 10$