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Verifying Ohm's first and second laws

Aims:

The aims of this experiment is to verify Ohm's 1st and 2nd laws via repeated measurements, and to calculate the resistivity of the material used.

Background information:

Ohm's first law states[1] that the potential difference between two points, also referred to as voltage, is directly proportional to the current passing through the resistance, and the resistance of the circuit itself. The formula for Ohm's first law is hence $V = I\,R$.
Instead, for what regards Ohm's second law, the focus is on how the resistance is affected by several factors. These elements are the length of the wire, the cross-sectional area of the wire, and the nature of the wire, therefore the material. Combined into a formula, the resulting equation for the resistance is $R = \rho\frac{L}{A}$, where *p* represents the resistivity of the material used. In addition, attention must be paid to Joule heating, a type of resistance which causes the dissipation of power, and is usually present with high currents.

Instruments and material:

Instruments:
- Voltmeter —> sensitivity ± 0,001 V ; range 2 V
- Ammeter —> sensitivity ± 0,01 A ; range 10 A
- Micrometer —> sensitivity ± 25 mm ; range 0,01 mm
- Meter —> sensitivity ± 0,1 cm ; range 3 m

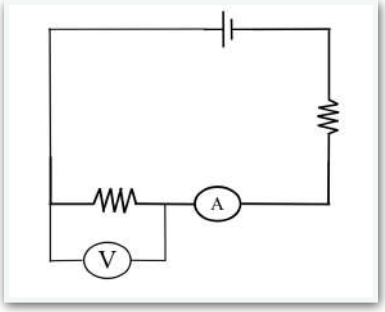
Materials:
- Nickelcromo wire
- Power unit
- Resistance

Safety issues:

- The first, and most important, safety concern is to not touch the circuit when current is passing through the components, in order to not have an electroshock
- Secondly, low currents must be used throughout all the experiment because in this way the wires don't heat up excessively, hence avoiding Joule heating, and to have minimal effects in the case someone touches the wires while operational.

Procedure for Ohm's 1st law:

- In first place, the circuit must be set up before any measurement can be taken. This must be done while the power unit is off, and preferably not even plugged to the current port.
- As mentioned earlier, an additional resistance must be placed, specifically at the starting point, just after the power unit, to reduce the current passing through the wires.



Graph 1 —> circuit diagram

[1] *Ohm's Law and Resistance - TOPPR-Guides*.

- Next, an Ammeter should be positioned in series just before the second resistance, which in this case will be a 1 meter Nickelcromo wire. In this way, the current passing through the resistance can be measured, and it will serve in the formula $V = I\,R$ by representing *I*.
- As the voltage must be also known to calculate the value for *R*, it will be measured by using a Voltmeter positioned in parallel with the second resistance. It is preferable to set it at 2 Volts, so that the sensitivity of the instrument is of a higher degree.
- Lastly, the power unit can be turned on. At this point, the values for the Voltage and the Current should be reported for 15 different voltages. The voltage can be changed by increasing the power supply from the power unit.

Procedure for Ohm's 2nd law:

- The first operations of the procedure to verify Ohm's 2nd law are identical to the procedure to verify Ohm's 1st law without the last step. Indeed the circuit is the same in both cases, with the only difference that now the length of the Nickelcromo wire is variable.
- After having completed the first four actions in the previous procedure, the diameter of the wire should be measured using a micrometer. It is suggested to take several measurements along the length of the wire to see if the value is consistent.
- From the diameter of the wire, the cross-sectional Area of it can be calculated using the formula for the area of a circle $A = \pi r^2$.
- In last place, the values for the Voltage and the Current should be reported for 10 different lengths of the wire.

Results:

Ohm's 1st law:

Voltage (V ; ± 0.001)	Current (*I*) (A; ± 0.01)
0,248	0,04
0,356	0,06
0,449	0,08
0,552	0,10
0,656	0,11
0,762	0,13
0,852	0,15
0,955	0,17
1,000	0,19
1,155	0,20
1,260	0,22
1,888	0,34
1,692	0,3
1,584	0,28
1,373	0,24

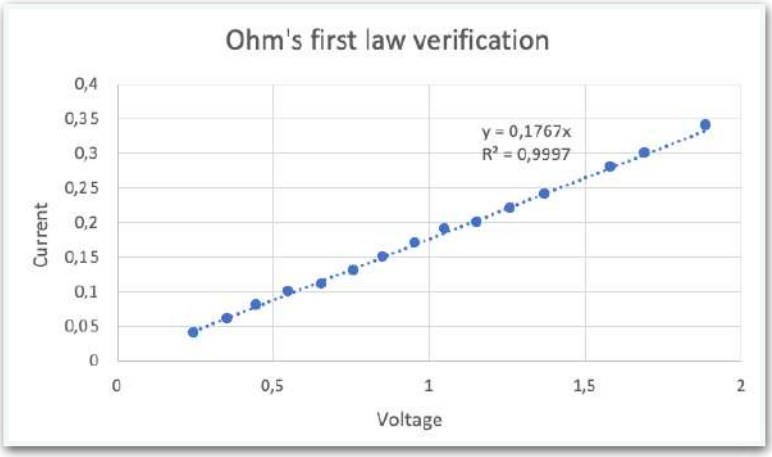
Ohm's 2nd law:

Voltage (V ; ± 0.001)	Current (*I*) (A; ± 0.01)	Length (cm; ± 0.1)
0,405	0,32	9,40
0,517	0,31	17,6
0,677	0,30	29,4
0,827	0,28	40,1
0,923	0,27	50,1
1,040	0,26	60,1
1,137	0,25	69,8
1,241	0,24	81,3
1,305	0,23	87,9
1,402	0,22	99,6

And the value measured by the micrometer for the diameter is: (0,049 mm ± 0,001)

Analysis:

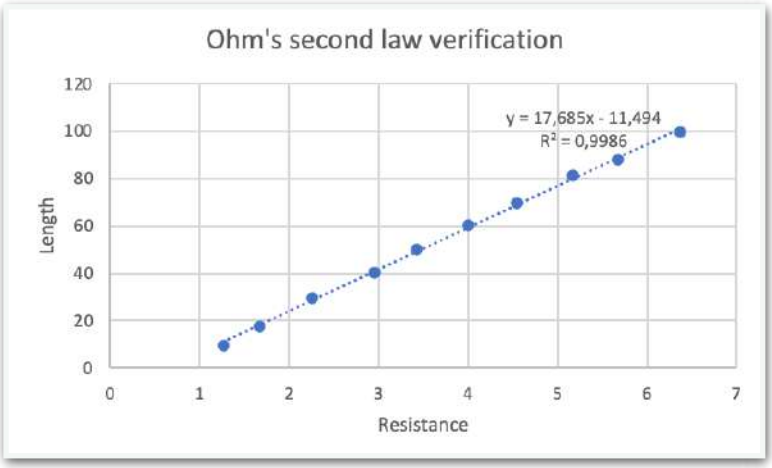
Ohm's 1st law analysis:



- The R^2 value obtained by the linear regression between the values for the voltage and the current is of 0.9997, hence the regression predictions perfectly fit the data.
- The equation derived is $y = 0{,}1767x$.

Graph 2 —> linear regression for Ohm's first law

Ohm's 2nd law analysis:



Graph 3 —> linear regression for Ohm's second law

Calculation of R (Ohms ; Ω)	Results (Ohms ; Ω)
0,405 * 0,32	1,266
0,517 * 0,31	1,668
0,677 * 0,30	2,257
0,827 * 0,28	2,954
0,923 * 0,27	3,419
1,040 * 0,26	4,000
1,137 * 0,25	4,548
1,241 * 0,24	5,171
1,305 * 0,23	5,674
1,402 * 0,22	6,373

- The cross-sectional area can be calculated by doing: $A = \pi(\frac{0{,}48}{2})^2 = 0{,}18095\, mm^2 \pm 0{,}0072$
- The R^2 value obtained by the linear regression between the values for the length and the resistance is of 0.9986, hence it means again that the regression predictions perfectly fit the data.
- The equation derived is instead in this case $y = 17{,}685x - 11{,}494$.
- The value for the resistivity p is instead calculated by multiplying the gradient of the equation with the cross-sectional area: $\rho = 17{,}685 * 0{,}049 = 0{,}867\, \Omega m$

Conclusion:

In conclusion, both Ohm's laws were verified with R^2 values of 0,9997 and 0,9986 respectively. This means that the formula provided for the first law relates correctly Voltage, Resistance and Current, and similarly the formula provided for the second law relates correctly Resistance, the cross-sectional area, and resistivity. The value discovered for the resistivity of the Nickelcromo wire is instead of 0,867 Ωm.

The reasons for which the value for R^2 isn't exactly 1 are several. For instance, one of them is that the instruments used such as the meter, do not have a high degree of accuracy, leading to less precise results, and hence lower values for R^2. In addition, another motive for this is that the cross-sectional area of the wire was measured few times, and no average was taken of the diameters found, but instead a value was reported based on the most recurring one.

Bibliography:

Ohm's Law and Resistance - TOPPR-Guides. www.toppr.com/guides/physics/electricity/ohms-law-and-resistance/.