

Measuring the Internal Resistance of a generator

Aims:

The aim of this experiment is to measure the internal resistance of a generator and estimate the uncertainty present on the parameters of the line of best fit.

Background:

An electrical cell is made from materials (metal or chemicals, for example), and these materials have a resistance. Therefore, a cell must have resistance, and it is called the internal resistance of the cell. In a circuit, a cell can be thought of as a source of electromotive force (EMF) with a resistor connected in series. Current flows through this resistor when the cell is set in a circuit, and as a consequence, a certain amount of potential difference will be lost. Ohm's first law states¹ 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 $V = I R$, and can be used to calculate the amount of Voltage used by the internal resistance.

Hence, the electromotive force of a cell can be calculated with the formula $\varepsilon = I(R + r)$, and the Potential difference produced by the generator without the internal resistance is $V = \varepsilon - rI$.

Instruments and material:

Instruments:

- Voltmeter → sensitivity $\pm 0,01$ V ; range 20 V
- Ammeter → sensitivity $\pm 0,01$ A ; range 10 A

Materials:

- Potential divider → between 0 - 15 Ω
- Power unit

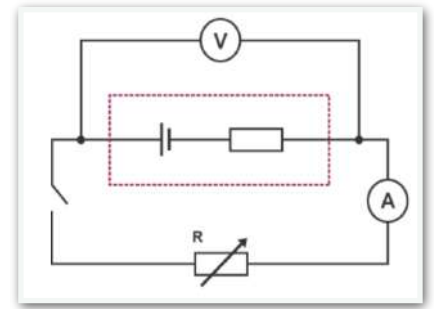
Safety issues:

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

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

Procedure:

- 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.
- We will build up the circuit by starting from the generator. The positive end of the cell should be connected to the external potential divider, so that a value for R in the electromotive force formula is present.
- Secondly, a cable connected to the external variable resistance, should be connected with an ammeter in series. This will allow to know the current flowing through the circuit at the different timings. Although, theoretically the current should remain constant throughout the whole experiment.
- Thirdly, the voltmeter should be added to the circuit. Precisely, it should be positioned on the two end of the generator. The reason is that the ammeter is not ideal, therefore a slight resistance is present across it, and connecting the voltmeter directly to the cell would avoid this problem. It is preferable to set it at 20 Volts, so that the sensitivity of the instrument is of a higher degree.
- Lastly, the resulting circuit should be looking similar to the one pictured in Picture N.1.² At this point, the generator can be plugged in and turned on. Measurements of the Voltage and the current should be recorded for at least 10 different resistances.



Picture N. 1 —> circuit exemplar

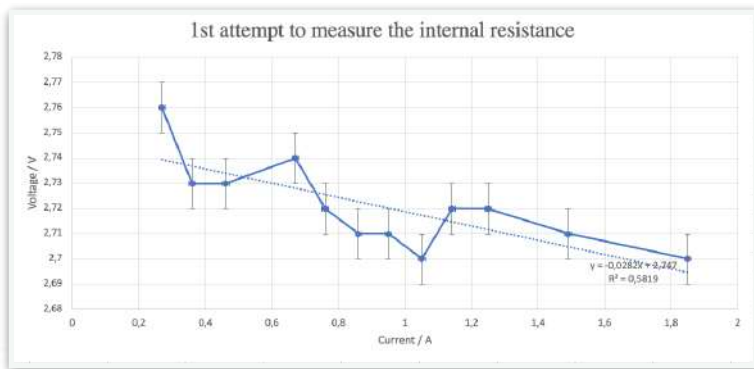
Results:

Voltage — 1st attempt	Current (I) — 1st attempt	Voltage — 2nd attempt	Current (I) — 2nd attempt
(V ; ± 0.001)	(A; ± 0.01)	(V ; ± 0.001)	(A; ± 0.01)
2,7	1,85	1,45	1,29
2,71	1,49	1,47	1,12
2,72	1,25	1,48	0,98
2,72	1,14	1,48	0,87
2,7	1,05	1,49	0,74
2,71	0,95	1,49	0,65

² BBC. (n.d.). Finding the EMF and internal resistance of a cell - electrical sources and internal resistance - higher physics revision - BBC Bitesize. BBC News. Retrieved November 25, 2021.

Voltage — 1st attempt	Current (I) — 1st attempt	Voltage — 2nd attempt	Current (I) — 2nd attempt
(V ; ± 0.001)	(A; ± 0.01)	(V ; ± 0.001)	(A; ± 0.01)
2,71	0,86	1,50	0,54
2,72	0,76	1,51	0,46
2,74	0,67	1,53	0,36
2,73	0,46	1,53	0,26
2,73	0,36	1,54	0,22
2,76	0,27	1,54	0,19
		1,55	0,15

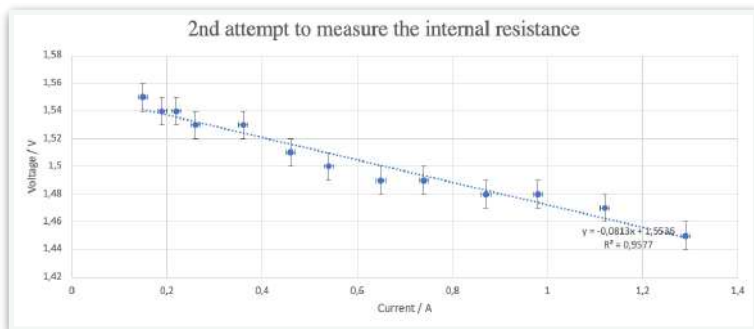
Analysis:



Graph N. 1 \rightarrow 1st attempt between V and I

- The R^2 value obtained in the first attempt is of $R^2 = 0,5819$, which does not represent a strong relationship between the two quantities.

- Even though, the expected R^2 value should be representative of a stronger linearity. Therefore, there was an issue with the instruments, leading to misleading data, and hence invalidating any further statistical analysis conducted on this set of data.



Graph N. 2 \rightarrow 2nd attempt between V and I

-The R^2 value obtained in the second attempt is of $R^2 = 0,9577$, which does instead mean that the regression predictions fit the data almost perfectly. This value for the coefficient of determination is suitable for the research, thus a deeper statistical analysis can be made.

- The value calculated for the internal resistance is $r = 0,081 \Omega \pm 0,054$, or $\pm 65\%$ of uncertainty.
- The negative gradient of the graph does in addition follow the formula previously stated formula $V = \varepsilon - rI$ for which as the current increases, the greater will be the potential difference used up by the internal resistance.

Conclusion:

In conclusion, the internal resistance of the generator was discovered and it is $r = 0,081 \Omega \pm 0,054$, which is very low compared to external resistors present in circuits. Even though, the uncertainty with which this value comes along is very high, meaning that the accuracy of the measurements must be improved in order to obtain more reliable data and information about this specific internal resistance. The R^2 value is instead considerably high ($R^2 = 0,9577$) for the relationship between voltage and current, so proving the formulas provided for the electromotive force of cells.

Several improvements could be made to this investigation, and the majority of them regard the sensitivity of the instruments used. For instance, the Voltmeter used had a sensitivity of only 0,01 V, which is not enough to find an accurate value for the internal resistance. Moreover, the experiment was attempted twice due to an issue with a Voltmeter which displayed wrong values as it was broken.

Bibliography:

- *Ohm's Law and Resistance - TOPPR-Guides*. www.toppr.com/guides/physics/electricity/ohms-law-and-resistance/.
- BBC. (n.d.). *Finding the EMF and internal resistance of a cell - electrical sources and internal resistance - higher physics revision* - BBC Bitesize. BBC News. Retrieved November 25, 2021, from <https://www.bbc.co.uk/bitesize/guides/zxx66sg/revision/2>.