Introduction

Aim

This experiment aims to determine the electromotive force (EMF) and the internal resistance of a cell.

Background Theory

In electrical circuits, the EMF of a cell is defined as the electrical action produced by non-electrical sources. It can also be described as the voltage a source develops when no current is flowing. Internal resistance, meanwhile, is the resistance within the cell that causes a voltage drop when a current flows through it. Understanding these is essential for predicting the performance of cells in practical applications.

Hypothesis

The hypothesis for this experiment is that the EMF of the cell is equal to the terminal voltage when no current flows, and that the internal resistance can be deduced by measuring voltage drops at various currents. This relationship can be modeled through the equation $E = IR + Ir$, where E is the EMF, I is the current, R is the external resistance, and r is the internal resistance.

Method

Apparatus and Diagram

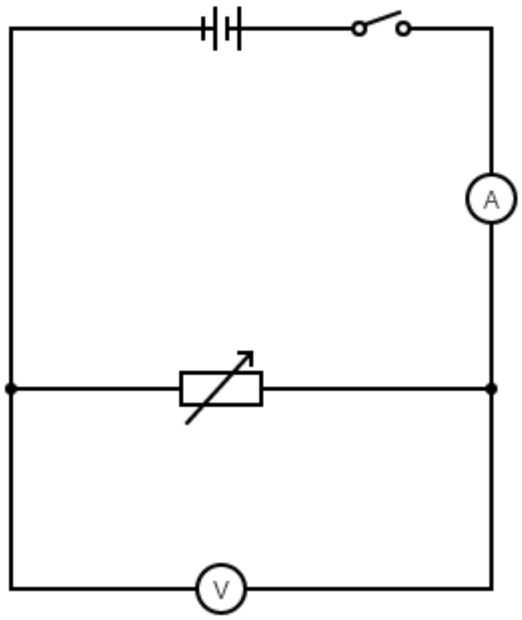
The experiment used the following apparatus:

- Two identical cells (3V D type batteries)
- Two cell holders
- One ammeter (multimeter set to measure current)
- One voltmeter (multimeter set to measure voltage)
- One variable resistor
- Connecting wires

Procedure

1. **Circuit Assembly:**
    - We place each cell in a cell holder to ensure stability and safety in the setup.
    - Connect the two cells in series to increase the overall voltage for the experiment, ensuring one cell's positive terminal connects to the other's negative terminal.
    - Insert the ammeter in series with the cells to measure the current flowing through the circuit, ensuring it flows from the positive terminal through the ammeter.

- Add the variable resistor in series with the ammeter and cells. The variable resistor helps change resistance values, which alters the current flow and voltage across the circuit.
- Attach the voltmeter parallel to the variable resistor to measure the voltage drop across the resistor without affecting the current flow in the main circuit.



2. **Safety Checks:**

- Before making the circuit live, ensure all connections for correctness and security to prevent any short circuits or loose connections.
- Ensure the circuit is not live while making adjustments or setting up connections to avoid any risk of electric shock.

3. **Conducting the Experiment:**

- Once the setup is confirmed safe and accurate, power the circuit by connecting the free ends of the circuit setup to the remaining terminals of the cells.
- Begin with the variable resistor set to its lowest resistance value. This starting point helps gradually observe the changes in voltage and current as resistance increases.
- Record the initial voltage across the variable resistor and the current flowing through the circuit using the voltmeter and ammeter, respectively.
- Gradually increase the resistance on the variable resistor, taking and recording voltage and current readings at each new setting. This step is repeated until the resistor is at its highest resistance setting.
- It is important disconnect the circuit between each adjustment to prevent overheating of the cells, which can affect the accuracy of the results.

4. **Data Recording:**
   - Note each reading in a table format for easy analysis later. Each entry should include the corresponding voltage, and the current.
   - Maintain consistency with the intervals of resistance change to ensure uniform data for analysis.
   - Take multiple readings, by disconnecting and reconnecting the EMFs, wait a few moments before taking another reading to ensure accuracy for each setting of resistivity.
5. **Post-Experiment Procedures:**

- Once all readings were taken, the circuit was disconnecting and switched off completely.

6. **Analysis:**

- Using the recorded data to analyse the relationship between voltage, current, and resistance in the circuit. Then by applying formulas, calculate expected outcomes and compare them with the measured results.
- Using the recorded data, a graph was formulated and the trends were analysed, which helped understand the principles more clearly.

Variables

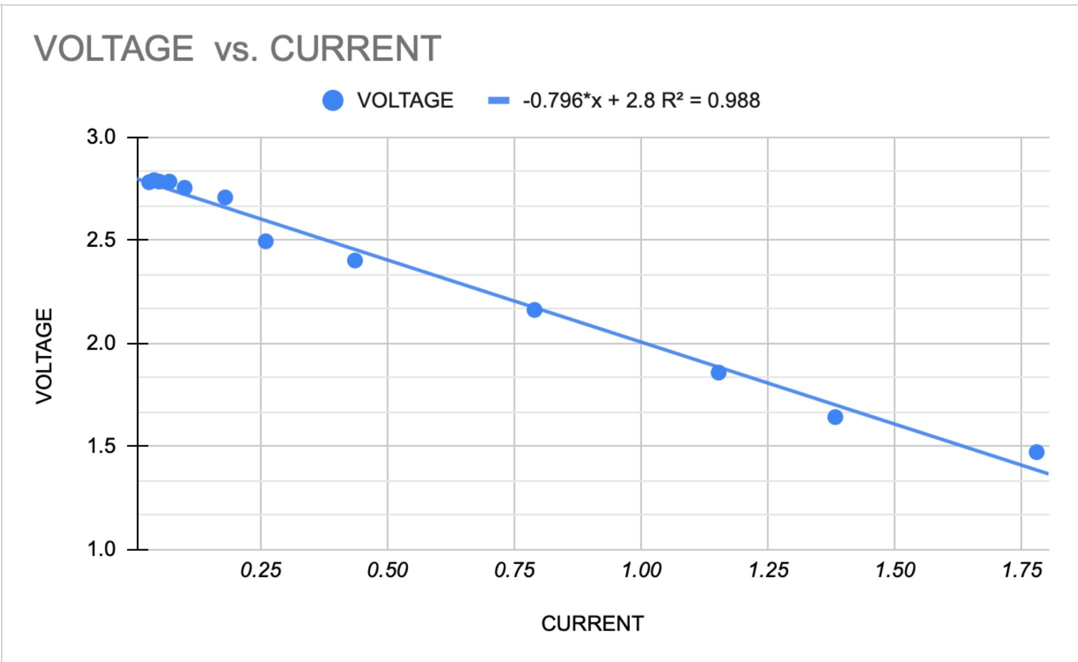
- Independent variable: Resistance of the variable resistor
- Dependent variable: Voltage across the resistor and current in the circuit
- Controlled variables included ambient temperature and connection integrity, which were maintained by conducting the experiment in a controlled environment and checking connections before each reading.

Safety Precautions

In the experiment, basic safety rules were always followed to ensure everyone stayed safe. This included wearing safety glasses to protect the eyes from harm while working with electrical apparatus. It was also essential to make sure that the circuit was turned off, or not 'live,' when changes were being made to it. This step is crucial because it prevents any chance of damaging the equipment, such as overheating the resistors. Ensuring the circuit is off

	Voltage				Current			
Reading	1	2	3	Average	1	2	3	Average
1	2.78	2.78	2.78	2.78	0.03	0.03	0.03	0.03
2	2.79	2.79	2.79	2.79	0.04	0.04	0.04	0.04
3	2.79	2.78	2.78	2.783	0.05	0.05	0.05	0.05
4	2.79	2.78	2.78	2.783	0.07	0.07	0.07	0.07
5	2.76	2.75	2.75	2.753	0.1	0.1	0.11	0.1
6	2.7	2.71	2.71	2.706	0.18	0.18	0.18	0.18
7	2.47	2.5	2.51	2.493	0.26	0.26	0.26	0.26
8	2.41	2.39	2.4	2.4	0.44	0.43	0.44	0.436
9	2.18	2.15	2.15	2.16	0.8	0.79	0.78	0.79
10	1.9	1.84	1.83	1.856	1.16	1.15	1.15	1.153
11	1.64	1.64	1.64	1.64	1.38	1.39	1.38	1.383
12	1.5	1.47	1.47	1.47	1.8	1.78	1.76	1.78

before touching helps avoid draining the cells. Further more, to avoid shorting the circuit the



edges of the variable resistor were avoided.

Results

GRADIENT= - 0.796 Ohms Internal resistance

Y-intercept = 2.8

Percentage Difference (3 - 2.8 / 3) x 100 = 6.67%

The gradient was taken from the line of best-fit equation, which is -0.796*x + 2.8

Results Graph and Gradient

A graph of Voltage vs. Current was plotted. The line of best fit was determined to be $V = -0.796 \times I + 2.8$ with a correlation coefficient of $R^2 = 0.988$. The negative gradient, -0.796 Ohms, indicates the cell's internal resistance and the y-intercept of 2.8 V suggests the EMF. The percentage difference between the experimental EMF and a presumed theoretical EMF of 3 V is approximately 6.67%.

Discussion

Analysis of Results

The experiment aimed to measure a cell's electromotive force (EMF) and internal resistance. The data showed a linear relationship between the cell's voltage and the current flowing through it. From the gradient of the line on the Voltage vs. Current graph, the cell's internal resistance was calculated at 0.796 Ohms. This resistance value reflects the natural opposition to electric current within the cell, which arises from its chemical composition. The linear relationship helps verify the electrical components' predictable behaviour, making understanding how they perform in different settings easier.

The y-intercept of the Voltage vs. Current graph indicates the electromotive force (EMF) of the cell, which is found to be 2.8 volts. EMF represents the voltage a cell provides when no current flows through it, ensuring there is no internal voltage loss due to its resistance. These results are crucial as they confirm the basic principles of Ohm's Law, which predicts how voltage, current, and resistance behave in an electrical circuit. This law is important in basic electrical engineering, providing a crucial understanding of the behaviour of circuits that include resistive components. The experiment's results match what is expected from theory, demonstrating the accuracy and predictability the basic electrical principles are.

The high correlation coefficient ($R^2 = 0.988$) from the experiment indicates a strong and straightforward relationship between voltage and current, which confirms the accuracy of the measurements. A correlation coefficient this close to 1 confirms that the data collected closely matches the predicted line. Specifically, the R^2 value means that 98.8% of the changes in voltage can be predicted just by looking at changes in current. This high level of predictability is great way of determining wether or not the experiment has successfully established an accurate and true correlation between two variables. This correlation is important because it confirms that the relationship between voltage and current follows the expected pattern, helping to prove the principles.

The results of this experiment match well with what other studies have found about how cells work inside. The internal resistance of small cells is usually less than one ohm, similar to the 0.796 ohms found in this experiment. Also, the electromotive force (EMF) measured at 2.8 volts fits within the expected range given by the manufacturers of the cells. This consistency shows that the results are reliable and in line with what is expected for such cells, according to both past research and manufacturers' details.

When the experimental EMF, which measured 2.8 volts, is compared to the expected theoretical value of 3 volts for these cell types, there's a 6.67% difference. This difference is generally acceptable in experimental settings. There are several reasons why such differences can occur. First, the accuracy of the equipment used to measure the voltage might not be perfect, which can slightly alter the results. Secondly, the way measurements are taken can also contribute to this variation; even small mistakes or inconsistencies in recording data can affect the outcome. Additionally, the cells themselves might vary slightly in how they are made, which affects their performance. Lastly, another factor which can needs to be taken into account is the age of the batteries and how often they were used prior to the experiment, as this can greatly impact the overall voltage output as well as the power remaining in the batteries. These types of variations are common and are expected when conducting laboratory experiments with electrical components.

The method used to analyse the data in this experiment included using linear regression techniques. Linear regression is a simple method to understand how different factors are related or if there is an established correlation. In this case, it helps explain the relationship between voltage and current in an electrical circuit. This method is particularly useful because it shows how changing one factor, like current, can affect another, such as voltage. Understanding this relationship is important in fields like electrical engineering, where knowing how changes in current impact voltage can help in designing circuits and solving problems. Using linear regression in the experiment made it possible to clearly see how voltage changes with current, providing valuable insights into how the cells behave electrically.

Anomalies

Anomalies in experimental data can often indicate errors or unexpected variables affecting the results. However, in this experiment, the data points collected closely followed the predicted linear relationship with no significant deviations or outliers. The absence of such anomalies suggests that the setup was free from external disturbances and that the measurement process was robust. However, the experiment was not completely immune to errors as the data is processed by hand, there can be misreading when handling a lot of data, which must be thoroughly checked in order to make sure it does not deviate the final results that are concluded from the experiment.

Conclusion

The laboratory experiment was successful in determining the electromotive force (EMF) and internal resistance of a cell with high accuracy. The results closely matched the expected theoretical values, proving the effectiveness of the chosen methodology. Particularly, the EMF and internal resistance measurements were consistent with the predictions, with only a minor deviation. This deviation, about 6.67% from the expected EMF, demonstrates the experiment's precision and the methods' reliability.

This slight deviation is typical in scientific experiments and is a normal part of testing theories such as Ohm's Law, which explains the relationship between voltage, current, and resistance in a circuit. The alignment of the experimental results with theoretical predictions confirms that Ohm's Law can be effectively applied in practical scenarios involving cell technology. This finding is significant because it means that this law can be used to design and understand electronic devices better. The experiment's success validates the measurements' accuracy and reinforces the practical applicability of fundamental scientific principles to everyday technologies.

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