A Guide to Internal Resistance in Electric Circuits

Teaching Approach

In this series we investigate electric circuits including internal resistance of the cells. We will look at the resistance of a conductor which is the extent to which a conductor impedes the flow of charge. From there we will investigate the concept of internal cell resistance since cells, just like other components in an electric circuit, have a resistance.

It is necessary to discuss that resistors do not occur in isolation. They are almost always part of a larger circuit, and frequently that larger circuit contains many resistors. It is often the case that resistors occur in both series and parallel combinations.

Educators can challenge the learner’s concept of electric circuits further with practical examples which will assist with understanding various concepts such as emf, lost volts and the load of a circuit.

The videos can either be used independently for the learners to revise after learning the content at school, or as part of the lessons. If it is possible, the use of practical circuits to explain and reinforce concepts helps the learners understand and grasp new concepts.

The task video has been prepared in such a way as it could be used as either an exercise tool, or it can be used as a complete test for the learners, or as a way for the learners to test their knowledge independently.
Video Summaries

Some videos have a ‘PAUSE’ moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given.

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day’s lesson; if desired, learners can be given specific questions to answer in preparation for the next day’s lesson

1. **Internal Resistance in Series Circuits**
   In this lesson we will look at the concept of resistance and internal cell resistance, and then do calculations with a circuit that contains resistors in series.

2. **Parallel Circuits**
   In this lesson resistors in parallel are investigated, and problems in which a circuit that contains parallel resistors as well as internal cell resistance are worked through.

3. **Internal Resistance in Combination Circuits**
   In this lesson we start with combinations of resistors in parallel and series, and then complete problems of circuits in which this type of combination appears with internal cell resistance.
## Resource Material

<table>
<thead>
<tr>
<th>Resource Material</th>
<th>Link</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="http://www.youtube.com/watch?v=ZkCqJ0GOoBU">http://www.youtube.com/watch?v=ZkCqJ0GOoBU</a></td>
<td>A video on electric circuits resistors.</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.youtube.com/watch?v=P_TGVc-0o_s">http://www.youtube.com/watch?v=P_TGVc-0o_s</a></td>
<td>A video on adding resistors to electric circuits.</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.youtube.com/watch?v=zhwr-UO_XPM">www.youtube.com/watch?v=zhwr-UO_XPM</a></td>
<td>A resource on resistors in parallel</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.s-cool.co.uk/a-level/physics/resistance/revise-it/combinations-of-resistors">http://www.s-cool.co.uk/a-level/physics/resistance/revise-it/combinations-of-resistors</a></td>
<td>Combination of resistors</td>
</tr>
</tbody>
</table>
Task

Question 1
A battery tester measures the current supplied when the battery is connected to a resistor of 100 Ω. If the current is less than 50 mA, the battery is “flat” (it needs to be replaced). Calculate the maximum internal resistance of a 6 V battery that will pass the test.

Question 2
The circuit diagram shows a battery, with an internal resistance $r$, connected to three resistors, M, N, and Y. The resistance of N is 2 Ω and the reading on voltmeter V is 14 V. The reading on ammeter A₁ is 2 A and the reading on ammeter A₂ is 1 A. (Ignore the resistance of the ammeters and the connecting wires.)

2.1 State Ohm's law in words.
2.2 How does the resistance of M compare with that of N? Explain how you arrived at the answer.
2.3 If the emf of the battery is 17 V, calculate the internal resistance of the battery.
2.4 Calculate the potential difference across resistor N.
2.5 Calculate the resistance of Y.

Question 3
Ignore the resistance of the connecting wires, ammeter and switch. The voltmeters have a very high resistance and the battery has significant internal resistance. When the switch S is open the voltmeter V₁ reads 9 V. When the switch is closed the ammeter reads 600 mA. The switch, S, is now closed.
3.1 Calculate the total resistance in the external circuit.
3.2 Calculate the internal resistance of the battery.
3.3 Calculate the reading on the voltmeter $V_1$.
3.4 Explain why the voltmeter reading changes when the switch is closed.

**Question 4**

A battery of emf $\varepsilon$ and internal resistance $r = 25 \, \Omega$ is connected to this arrangement of resistors.

![Circuit Diagram]

The resistances of voltmeters $V_1$ and $V_2$ are so high that they do not affect the current in the circuit.

4.1 Explain what is meant by “the emf of a battery”.
4.2 If the current in the 100 resistor is 9A, calculate the reading on voltmeter $V_1$.
4.3 Calculate the reading on voltmeter $V_2$.
4.4 Calculate the emf of the battery.
Task Answers

Question 1

\[ \text{Emf} = I_r + IR_{\text{TOTAL}} \]

\[ 6 = 0.05r + 0.05 \cdot 100 \]

\[ 6 - 5 = 0.05r \]

\[ R = 20 \Omega \]

Question 2

2.1 The current through a conductor is directly proportional to the potential difference across its ends at constant temperature

2.2 Equal

2 A divides equally at T (and since \( I_m = 1 \) A it follows that \( I_n = 1 \) A)

2.3 \[ \text{emf} = IR + Ir \]

\[ 17 = 14 + Ir \]

\[ Ir = 3 \text{ V} \]

\[ 2r = 3 \]

\[ R = 1.5 \Omega \]

2.4 \[ VN = IRN = (1)(2) = 2 \text{ V} \]

2.5 \[ V_Y = 14 - 2 = 12 \text{ V} \]

\[ V_Y = IR_Y \]

\[ 12 = (2)R_Y \]

\[ R_Y = 6 \Omega \]

Question 3

3.1 \[ R_{\parallel} = \frac{R_{\text{prod}}}{R_{\text{sum}}} = \frac{6 \times 6}{6 + 6} \]

\[ = 3 \Omega \]

\[ R_{\parallel} = 3 \Omega + 4 \Omega = 7 \Omega \]

3.2 \[ E = I(R + r) \]

\[ 9 = 1.2 \left(7 + r\right) \]

\[ r = 0.5 \Omega \]

3.3 \[ V_1 = IR \]

\[ = 1.2 \times 7 \]

\[ = 8.4 \text{ V} \]

3.4 Energy is used moving charge through the internal resistance of the battery. There is a drop in potential across the battery i.e. volts are lost to the external circuit.

Question 4

4.1 The Emf of a cell is the maximum amount of energy which the cell can supply.

4.2 \[ \frac{1}{R_p} = \frac{1}{50} + \frac{1}{50} \]

\[ = 2/50 \]

\[ R_p = 25 \Omega \]

\[ R_{\text{TOTAL}} = 25 + 100 + 25 \]

\[ = 150 \Omega \]

\[ V_1 = I.R \]

\[ = 9 \times 150 \]
4.3 I = 4.5A resistor same size so current divided equal

\[ V_2 = IR \]

\[ = 4.5 \times 50 \]

\[ = 225 \text{ V} \]

4.4 \( \text{Emf} = Ir + IR_{\text{TOTAL}} \)

\[ = 9 \times 25 + 9 \times 125 \]

\[ = 1350 \text{ V} \]
Acknowledgements
Mindset Learn Executive Head
Dylan Busa
Content Manager Classroom Resources
Jenny Lamont
Content Coordinator Classroom Resources
Helen Robertson
Content Administrator
Agness Munthali
Content Developer
Tina Botha
Content Reviewers
Xolani Sithenjwa
Liz Harris

Produced for Mindset Learn by Traffic
Facilities Coordinator
Cezanne Scheepers
Production Manager
Belinda Renney
Director
Alriette Gibbs
Editor
Belinda Renney
Presenter
Banji Longwe
Studio Crew
Abram Tjale
James Tselapedi
Wilson Mthembu
Graphics
Wayne Sanderson

Credits

This resource is licensed under a Attribution-Share Alike 2.5 South Africa licence. When using this resource please attribute Mindset as indicated at http://www.mindset.co.za/creativecommons