A Guide to Electromagnetism

Teaching Approach

Learners should know about magnetism from grade 10. Electromagnetism describes the interaction between current and electric and magnetic fields. An electric current creates a magnetic field and a changing magnetic field creates a flow of charge.

This has resulted in the invention of many devices which are useful to humans, for example cellular telephones, microwave ovens, radios, televisions and many more.

In the series we explore how electricity and magnetism work together. We will discover that when a current passes through a coil of wire, the coil acts like a magnet. We describe how to make an electromagnet and investigate the factors that affect the strength of an electromagnet.

The following list summarises the topics covered in this chapter.

- **Magnetic fields**: are associated with current carrying wires. The idea that magnetism and electricity are linked is introduced. The concept of a magnetic field around a current carrying wire is explored and a simple method to determine the direction of the magnetic field for a current carrying conductor, a looped coil and a solenoid is explained.
- **Faraday’s law**: relates the emf produced to the magnetic flux around a loop of conductor. The concept of electromagnetic induction is introduced. The direction of this induced current is explained. The formula for Faraday’s law is derived and some simple calculations using
- **Faraday’s law are shown**: it is important to notice that the direction of the induced current is a very difficult concept to grasp. Teachers need to pay special attention to this section.
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. Is there a Magnetic Field Around a Current Carrying Conductor?
   In order to understand the field that forms around a current carrying conductor, we need to understand the magnetic field around a bar magnet as well as the electric field around a point charge.

2. The Right Hand Rule
   In this video we look at the shape, direction and strength of the magnetic field around a straight line conductor, a loop and a solenoid. We need to learn and apply the right hand rule to be able to draw these fields.

3. Electromagnets and the Environment
   In this lesson we look at an application of the magnetic field that forms around a current carrying conductor. We learn how to make our own electromagnet and the factors that influence the strength of the magnet.

4. Electromagnetic Induction
   In this lesson we investigate electromagnetic induction and we investigate the factors that affect the strength of the induced emf through a variety of practical activities.

5. The Direction of the Induced Current
   In this lesson we investigate a law that is known as Lenz’s law, and we learn how to determine the direction of the induced current by making use of the right hand solenoid rule.
6. The Magnetic Field
We define magnetic flux and derive a formula to calculate the magnetic flux. We will also apply this formula to calculate the magnetic flux if the magnetic field is perpendicular to a surface, and when the magnetic field is at an angle to a surface.

7. Faraday's Law
Faraday changed our world when he discovered that electricity can be produced with a magnet. We will look at his discovery and then we derive an equation to calculate the induced emf. We will also revise the direction of the induced current.

8. Induced Emf
This video summarise the series into a logical sequence of events. We revisit some of the key concepts of the magnetic field and Faraday's Law. The equation that was derived in lesson seven is used to solve problems.
## Resource Material

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<td><a href="http://www.youtube.com/watch?v=jCcUocTbV0">www.youtube.com/watch?v=jCcUocTbV0</a></td>
<td>This You tube video explains the magnetic field around a current-carrying wire using the right hand curl rule.</td>
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<td>[<a href="http://www.magnet.fsu.edu/educatio">http://www.magnet.fsu.edu/educatio</a> n/tutorials/java/magwire/](<a href="http://www.magnet.fsu.edu/educatio">http://www.magnet.fsu.edu/educatio</a> n/tutorials/java/magwire/)</td>
<td>A tutorial on the magnetic field around a wire.</td>
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<td>3. Electromagnets and the Environment</td>
<td><a href="http://seplessons.ucsf.edu/node/21">http://seplessons.ucsf.edu/node/21</a></td>
<td>A lesson on making an electromagnetism</td>
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<td><a href="http://www.youtube.com/watch?v=nPlAueJGdzA">www.youtube.com/watch?v=nPlAueJGdzA</a></td>
<td>This demonstration from the National High Magnetic Field Laboratory shows how to make a simple electromagnet using a battery, wire and iron nail or other iron core.</td>
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<td><a href="https://www.youtube.com/channel/HCyZ5FAOi-x2k">https://www.youtube.com/channel/HCyZ5FAOi-x2k</a></td>
<td>Videos on the concept of electromagnetic induction and its features.</td>
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<td><strong>Induced Current</strong></td>
<td><img src="https://www.youtube.com/watch?v=HNmgE0rJ_xk" alt="Image" /></td>
<td>This video explains Lenz's Law. It is intended to be viewed after playing with the PhET simulation called Faraday's Law.</td>
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<td><strong>6. The Magnetic Field</strong></td>
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<td>This page defines Magnetic Flux</td>
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<td>A teaching resource on Faraday's Electromagnetic Lab</td>
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<tr>
<td><img src="http://www.sparknotes.com/testprep/books/sat2/physics/chapter16section2.rhtml" alt="Image" /></td>
<td>A clear and concise resource that helps learners understand Faraday's Law.</td>
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<td><img src="https://sites.google.com/site/physicsacehci/page" alt="Image" /></td>
<td>A summary of electromagnetism.</td>
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Task

Question 1
This diagram shows two compasses and a bar magnet. Show the direction that each compass will point.

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Question 2
A current flows in a conductor from positive to negative. Use the correct rule to show the direction of the magnetic field formed around the compass that is underneath the conductor.

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Question 3
Show the direction of the magnetic field around the following conductor

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Question 4
Label the north pole and south pole of this current carrying solenoid.
Question 5
A magnetic field is produced when current flows through this open coil of wire. Give three ways in which the magnetic field can be increased.

Question 6
The magnet moves past the wire in this diagram. Which motion will produce the greatest voltmeter reading: perpendicular, parallel, or no motion at all?

Question 7
Explain the term emf

Question 8
A coil of wire is connected to a sensitive galvanometer as shown in the diagram.
8.1 What is observed when the magnet is moved towards the coil?
8.2 Explain why this occurs.
8.3 Describe what happens when the speed of the magnet is increased.

Question 9
Wire 1 (length $L$) forms a single loop, and a bar magnet is dropped through. Wire 2 (length $2L$) forms a two-turn loop, and the same magnet is dropped through. Compare the magnitude of the induced voltages in these two cases. Choose the correct answer.
A light aluminium ring is suspended from a long thread as shown in the diagram.

10.1 When a strong magnet is moved away from it, the ring follows the magnet. Explain why.

10.2 What would happen if the magnet was moved towards the ring?

**Question 11**

Define magnetic flux.

**Question 12**

In order to change the magnetic flux through the loop, what would you have to do?

A. Drop the magnet  
B. Move the magnet upwards  
C. Move the magnet sideways  
D. Only (A) and (B)  
E. All of the above

**Question 13**

Find the magnetic flux. One circular turn of wire of radius \( r = 0,25 \text{ m} \); constant perpendicular magnetic field of magnitude \( B = 4,9 \text{ T} \).

**Question 14**

Find the magnetic flux A triangular coil, base \( b = 7 \text{ cm} \), height \( h = 9,5 \text{ cm} \); magnetic field of magnitude \( B = 4,6 \text{ T} \) at an angle \( \Theta = 22^\circ \) from normal.
Question 15
A coil has 5000 turns. What is the emf induced in the coil when the magnetic flux cutting the coil changes by $8 \times 10^{-4}$ Wb in 0.1 s?

Question 16
A square loop, 15 cm per side sits in a magnetic field of 0.75 T into the page. The field changes to 0.75 T out of the page in 0.01 s.

16.1 Calculate the induced emf in the loop
16.2 Calculate the direction of the induced current in the loop.
Task Answers

Question 1

1. Add an iron core to the coil
2. Add more windings
3. Increase the strength of the current

Question 2

Question 3

Question 4

Question 5
1. Add an iron core to the coil
2. Add more windings
3. Increase the strength of the current

Question 6
The perpendicular motion will produce the greatest voltmeter reading. The other two motions will result in no readings.
Question 7
Emf stands for electromotive force. It is a potential difference applied to a full circuit.

Question 8
8.1 The needle in the galvanometer deflects.
8.2 An emf is induced in the coil of wire, which in turn produces a current which moves the needle.
8.3 There is a greater deflection of the needle.

Question 9
A. \( V_1 < V_2 \)
   Faraday’s law: depends on \( N \) (number of loops) so the induced emf is twice as large in the wire with 2 loops.

Question 10
10.1 Current flows in the ring in such a direction as to oppose the change which caused it.
    Therefore the ring follows the magnet.
10.2 The ring would be repelled.

Question 11
Magnetic flux is defined as the product of magnetic flux density multiplied by area.

Question 12
B. All of the above
   Moving the magnet in any direction would change the magnetic field through the loop and thus the magnetic flux.

Question 13
The area of the loop is equal to
\[ A = \pi r^2 = 0,196 \text{ m}^2 \] .
The magnetic flux through the loop is therefore given by
\[ \phi_B = B \perp A \]
\[ \phi_B = 4,9(0,196) \]
\[ \phi_B = 0,96 \text{ Wb} \]

Question 14
The area of a triangle
\[ A = \frac{1}{2} \text{b} \times \text{h} \]
\[ A = \frac{1}{2} \left( \frac{7}{100} \right) \left( \frac{9,5}{100} \right) \]
\[ A = 0,003325 \text{ m}^2 \]
and
\[ \phi_B = BA \cos \theta \]
\[ \phi_B = (4,6)(0,003325) \cos 22 \]
\[ \phi_B = 0,014 \text{ Wb} \]
Question 15

\[ \varepsilon = -N \frac{\Delta \phi_B}{\Delta t} \]

\[ \varepsilon = 5000 \frac{8 \times 10^{-4}}{0.1} \]

\[ \varepsilon = 40V \]

Question 16

\[ \varepsilon = -N \frac{\Delta \phi_B}{\Delta t} \]

16.1 \[ \varepsilon = -(1) \frac{(-0.75 - 0.75)(0.15)}{0.01} \]

\[ \varepsilon = 3.4V \]

16.2 Current is clockwise
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Facilities Coordinator Cezanne Scheepers
Production Manager Belinda Renney
Director Ariette Gibbs
Editor Talent Maphisa
Presenter Banji Longwe
Director Abram Tjale
Director James Tselapedi
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