Module 6: Electromagnetism

NSW HSC Physics Year 12

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Module Overview

This module explores electromagnetic interactions between charged particles, currents, and magnetic fields. Understanding these interactions led to significant technological developments including electric motors, generators, and transformers.

Indicative Hours: 60 hours (combined with Depth Study)

Related Outcomes:

- **PH12-6** explains and analyses the electric and magnetic interactions due to charged particles and currents and evaluates their effect both qualitatively and quantitatively
- **PH12-13** explains and analyses the electric and magnetic interactions due to charged particles and currents

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Inquiry Questions

1. **What happens to stationary and moving charged particles when they interact with an electric or magnetic field?**
2. **Under what circumstances is a force produced on a current-carrying conductor in a magnetic field?**
3. **How are electric and magnetic fields related?**
4. **How has knowledge about the Motor Effect been applied to technological advances?**

Key Concepts

6.1 Charged Particles in Electric and Magnetic Fields

> **Learning Focus**
>
> Analyse the motion of charged particles in uniform electric and magnetic fields.

Content:

- Derive and analyse interactions between charged particles and uniform electric fields
- Calculate electric field strength between parallel plates
- Analyse acceleration of charged particles in electric fields
- Compare trajectories in electric fields with projectile motion in gravitational fields
- Analyse force on charges moving in magnetic fields

Key Formulas:

Quantity	Formula
Electric field (parallel plates)	$E = \frac{V}{d}$
Force on charge	$F = qE$
Work done on charge	$W = qV = qEd$
Kinetic energy gained	$K = \frac{1}{2}mv^2 = qV$
Magnetic force	$F = qv_\perp B = qvB\sin\theta$

6.2 The Motor Effect

> **Learning Focus**
>
> Investigate and quantify the force on current-carrying conductors in magnetic fields.

Content:

- Investigate the interaction between current-carrying conductors and magnetic fields
- Determine conditions for maximum and zero force
- Analyse force between parallel current-carrying wires
- Relate the SI definition of the ampere to Newton's Third Law

Key Formulas:

Quantity	Formula
Force on conductor	$F = lI_{\perp}B = lIB\sin\theta$
Force between parallel wires	$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$

Right-Hand Rules:

- **Force direction**: Thumb = current, fingers = field, palm pushes in force direction
- **Field around wire**: Thumb = current, curled fingers = field direction

6.3 Electromagnetic Induction

> **Learning Focus**
>
> Apply Faraday's Law and Lenz's Law to analyse electromagnetic induction phenomena.

Content:

- Describe how magnetic flux changes
- Apply Faraday's Law to calculate induced EMF
- Apply Lenz's Law to determine direction of induced current
- Analyse transformers: ideal operation and efficiency limitations

Key Formulas:

Quantity	Formula
Magnetic flux	$\Phi = B_{\parallel}A = BA\cos\theta$

Quantity	Formula
Faraday's Law	$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$
Transformer voltage ratio	$\frac{V_p}{V_s} = \frac{N_p}{N_s}$
Transformer power (ideal)	$V_p I_p = V_s I_s$

Lenz's Law: The induced EMF opposes the change in flux that produces it (conservation of energy).

6.4 Applications of the Motor Effect

> **Learning Focus**
>
> Analyse the operation of motors, generators, and other electromagnetic devices.

Content:

- Investigate DC motor operation, components, and torque production
- Analyse effects of back EMF in motors
- Compare DC and AC generators
- Analyse AC induction motors
- Apply conservation of energy to motors and magnetic braking

Key Formulas:

Quantity	Formula
Torque on coil	$\tau = nIA_\perp B = nIAB\sin\theta$

Working Scientifically

Practical Investigations

1. **Motor Effect Investigation**
    - Measure force on current-carrying conductor in magnetic field
    - Verify $F = BIl$ relationship
    - Investigate conditions for maximum force
2. **Parallel Wires Experiment**

- Demonstrate force between parallel current-carrying wires
- Observe attraction (same direction) and repulsion (opposite)

3. **Electromagnetic Induction**
   - Investigate factors affecting induced EMF
   - Demonstrate Lenz's Law with moving magnets and coils
   - Measure transformer efficiency

4. **DC Motor Construction**
   - Build and analyse a simple DC motor
   - Identify components and their functions
   - Observe effect of load on motor speed (back EMF)

HSC Exam Coverage

This module is heavily assessed in Section II extended response questions, often combined with Module 5 concepts. Common question types:

- Calculate force on charged particles in fields (4-6 marks)
- Compare electric and magnetic field effects (5-7 marks)
- Explain transformer operation and efficiency (4-6 marks)
- Analyse motor/generator operation (6-9 marks)

Practice Resources

- Module 6 Quiz
- Electromagnetism Worksheet
- Past HSC Questions - Module 6

Key Definitions

Motor Effect The force experienced by a current-carrying conductor in a magnetic field.

Electromagnetic Induction The production of an EMF due to a change in magnetic flux through a circuit.

Magnetic Flux A measure of the total magnetic field passing through a surface; measured in webers (Wb).

Faraday's Law The induced EMF equals the negative rate of change of magnetic flux.

Lenz's Law The direction of induced current opposes the change in flux that produces it.

Transformer A device that transfers electrical energy between circuits through electromagnetic induction.

Back EMF The EMF induced in a motor that opposes the applied voltage.

Torque The rotational effect of a force; measured in newton-metres ($N \cdot m$).