



SKJ Education

LC HL PHYSICS

CORE PHYSICS

PROGRAM: WEEK 3

MAGNETIC

FIELDS

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LC HL PHYSICS – CORE PROGRAM

Week 3: Magnetic Fields & Electromagnetism

Learning Objectives

- To explain and apply concepts related to magnetic forces and fields.
- To calculate the force on a moving charge and on a current-carrying conductor within a magnetic field.
- To analyse the magnetic field produced by a current.
- To describe induced electromotive force (EMF) and magnetic flux, and apply Faraday's Law of Electromagnetic Induction.
- To explain the principles of mutual and self-inductance and analyse transformers.

Key Terms - Week 3

- **Magnetic Field (B):** A vector field that represents the magnetic force per unit charge and velocity at a given point.
- **Force on a Moving Charge:** $F = qvB \sin \theta$, where q is the charge, v is the velocity, B is the magnetic field strength, and θ is the angle between the velocity and magnetic field.
- **Force on a Current-Carrying Conductor:** $F = BIL \sin \theta$, where B is the magnetic field strength, I is the current, L is the length of the conductor, and θ is the angle between the current and magnetic field.
- **Magnetic Field Produced by a Current:** The magnetic field around a current-carrying wire is given by $B = \frac{\mu_0 I}{2\pi r}$, where μ_0 is the magnetic constant and r is the distance from the wire.
- **Magnetic Flux (Φ):** The product of the magnetic field strength and the area perpendicular to the field, given by $\Phi = BA \cos \theta$.
- **Induced EMF (ϵ):** The electromotive force induced in a conductor due to a changing magnetic flux, given by $\epsilon = -\frac{d\Phi}{dt}$ (Faraday's Law).
- **Mutual Inductance (M):** The ratio of the induced EMF in one coil to the rate of change of current in another coil.
- **Self-Inductance (L):** The ratio of the induced EMF in a coil to the rate of change of current in the same coil.
- **Transformers:** Devices that transfer energy between two circuits through electromagnetic induction, used to step up or step down voltages.

Weekly Challenge: Investigate a real-world application of electromagnetic induction, such as a generator or a transformer. Analyse the principles involved and describe how they are used to achieve a specific purpose. Share your findings on Google Classroom.



WEEK 3 STUDY PLAN

Day	Activities & Time Commitment	✓	Rating (1-10)
Monday	- Review Learning Objectives (5 min) - Rank your current ability (5 min) - Review Key Terms (10 min) - Complete Exercise A1 (15 min) - Watch Video (Exercise A2) (20 min) <i>Focus: PREPARATION</i>		
Tuesday	- Complete Exercise B (60 min) <i>Focus: QUESTIONING</i>		
Wednesday	- Reflect on content so far (what has been challenging?) (10 min) - Plan remaining study sessions (10 min) <i>Focus: PROCESSING</i>		
Thursday	- Complete Exercise C (30 min) - 1-hour online lesson (60 min) <i>Focus: ERROR ANALYSIS</i>		
Friday	- Complete Exercise D (45 min) <i>Focus: REVISION</i>		
Saturday	- Complete Exam Question Assessment (D) (60 min) <i>Focus: EXECUTION</i>		
Sunday	- Correct assessment (30 min) - Complete self-reflection (15 min) - Plan next week (15 min) <i>Focus: REFLECTION & RECHARGING</i>		

Study Tips for Success

- **Active Recall:** After studying, close your notes and write down **everything you remember**. Force your brain to grow.
- **Spaced Repetition:** Review concepts **multiple times** over several days.
- **Physics in Action:** Look for **real-world examples** of the concepts you're learning.
- **Ask Questions:** Don't hesitate to ask for help when concepts are unclear. Reach out via *Google Classroom* or email; steven@skjeducation.com.



C. Calculation Error Analysis: Forensic Physics - Magnetic Forces and Fields

Learning Focus: Developing **critical analysis skills** by identifying and correcting common physics **misconceptions** and **calculation errors** related to **magnetic forces, fields, and electromagnetic induction**.

Analysis Tips

1. **Locate the Error:** Is there anything wrong with this statement/calculation?
2. **Diagnose the Error:** Is this a **Procedural Error** (miscalculation), a **Conceptual Error** (misunderstanding), or an **Omission Error** (incomplete answer)?
3. **Explain the Misconception:** What does the answer reveal about their understanding of how to *communicate* this idea?
4. **Correct the Solution:** Provide the complete, textbook-quality answer.
5. **Metacognitive Reflection:** "This error is subtle because the number is right. What is one personal strategy I can adopt to ensure I never overlook a crucial detail like this under exam pressure? (e.g., always drawing a diagram with the right-hand rule)."

Forensic Physics Task

Your job isn't to find the right answer, but to find the **flaw in the thinking**. Explain **why** each statement/calculation is wrong and **correct them**.

Essential Magnetic Field Formulas

- Force on moving charge: $F = qvB \sin \theta$
- Force on current-carrying wire: $F = BIL \sin \theta$
- Field from long straight wire: $B = \frac{\mu_0 I}{2\pi r}$
- Field inside solenoid: $B = \mu_0 n I$
- Magnetic flux: $\Phi = BA \cos \theta$
- Faraday's Law: $\varepsilon = -N \frac{\Delta \Phi}{\Delta t}$
- Self-inductance EMF: $\varepsilon = -L \frac{\Delta I}{\Delta t}$
- Transformer equation: $\frac{V_p}{V_s} = \frac{N_p}{N_s}$
- Permeability of free space: $\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$
- $1 \text{ Wb} = 1 \text{ T} \cdot \text{m}^2$

Error Analysis Exercises

Statement: "If you cut a bar magnet in half, you get one piece with only a north pole and one piece with only a south pole."

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Statement: "A charged particle moving through a magnetic field gains kinetic energy from the magnetic force acting on it."

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Statement: "Electric field lines begin on positive charges and end on negative charges. Similarly, magnetic field lines begin at north poles and end at south poles."

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Statement: "A stationary electron placed in a magnetic field will experience a magnetic force and begin to accelerate."

Flawed Thinking

Error Analysis:

Correct Approach

Correction:



Force on Moving Charge - Angle Error: A proton ($q = 1.60 \times 10^{-19}$ C) moves at 3.0×10^6 m/s through a magnetic field of 0.50 T. The velocity makes an angle of 30° with the field. Calculate the magnetic force.

Incorrect Calculation: $F = qvB \cos \theta = (1.60 \times 10^{-19})(3.0 \times 10^6)(0.50) \cos(30^\circ)$
 $F = (2.40 \times 10^{-13})(0.866) = 2.08 \times 10^{-13}$ N

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Force on Moving Charge - Direction Error: An electron moves eastward through a magnetic field that points northward. Using the right-hand rule, the magnetic force on the electron is upward.

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Force on Current-Carrying Wire - Unit Error: A wire 25 cm long carries a current of 4.0 A perpendicular to a magnetic field of 0.80 T. Calculate the force on the wire.

Incorrect Calculation: $F = BIL = (0.80)(4.0)(25) = 80$ N

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Force on Current-Carrying Wire - Missing Angle: A 0.50 m wire carrying 3.0 A is placed in a 0.40 T magnetic field at an angle of 60° to the field. Calculate the force.

Incorrect Calculation: $F = BIL = (0.40)(3.0)(0.50) = 0.60$ N



Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Magnetic Field from Wire: Calculate the magnetic field 5.0 cm from a long straight wire carrying 10 A.

Incorrect Calculation: $B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(10)}{2\pi(5.0)} = \frac{4 \times 10^{-6}}{10\pi} = 1.27 \times 10^{-7} \text{ T}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Solenoid Field - Turns Error: A solenoid has 500 turns and is 25 cm long. It carries a current of 2.0 A. Calculate the magnetic field inside the solenoid.

Incorrect Calculation: $B = \mu_0 NI = (4\pi \times 10^{-7})(500)(2.0) = 1.26 \times 10^{-3} \text{ T}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Magnetic Flux - Angle Definition: A rectangular coil of area 0.20 m² is placed in a uniform magnetic field of 0.50 T. The plane of the coil makes an angle of 30° with the magnetic field. Calculate the magnetic flux through the coil.

Incorrect Calculation: $\Phi = BA \cos \theta = (0.50)(0.20) \cos(30^\circ) = (0.10)(0.866) = 0.087 \text{ Wb}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:



Faraday's Law - Missing Turns: A coil with 100 turns has a magnetic flux that changes from 0.05 Wb to 0.02 Wb in 0.10 s. Calculate the induced EMF.

Incorrect Calculation: $\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{(0.02 - 0.05)}{0.10} = -\frac{-0.03}{0.10} = 0.30 \text{ V}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Lenz's Law - Direction Error: A magnet with its north pole facing down is dropped through a horizontal conducting loop. A student states: "As the north pole approaches the loop, the induced current flows clockwise when viewed from above, to attract the falling magnet."

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Faraday's Law - Area Calculation: A circular coil of radius 10 cm with 50 turns is placed perpendicular to a magnetic field that increases uniformly from 0 T to 0.60 T in 0.30 s. Calculate the induced EMF.

Incorrect Calculation:

$$\text{Area} = \pi r^2 = \pi(10)^2 = 314 \text{ cm}^2$$

$$\Delta\Phi = B \times A = 0.60 \times 314 = 188.4 \text{ Wb}$$

$$\varepsilon = N \frac{\Delta\Phi}{\Delta t} = 50 \times \frac{188.4}{0.30} = 31,400 \text{ V}$$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:



Self-Inductance: A coil with inductance 0.40 H carries a current that changes from 5.0 A to 2.0 A in 0.20 s. Calculate the induced EMF.

Incorrect Calculation: $\varepsilon = L \frac{\Delta I}{\Delta t} = (0.40) \frac{(5.0 - 2.0)}{0.20} = (0.40)(15) = 6.0 \text{ V}$

”The EMF is 6.0 V in the same direction as the original current.”

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Transformer - Voltage/Current Confusion: An ideal step-up transformer has 200 turns in the primary coil and 1000 turns in the secondary coil. If the primary voltage is 24 V and primary current is 5.0 A, find the secondary voltage and current.

Incorrect Calculation:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \text{ so } V_s = 24 \times \frac{1000}{200} = 120 \text{ V}$$

$$\frac{I_s}{I_p} = \frac{N_s}{N_p} \text{ so } I_s = 5.0 \times \frac{1000}{200} = 25 \text{ A}$$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:



Transformer - Power Conservation: A step-down transformer reduces voltage from 240 V to 12 V. A student claims: "This transformer amplifies electrical power by a factor of 20 since it converts high voltage to low voltage more efficiently."

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Circular Motion in Magnetic Field: A proton ($m = 1.67 \times 10^{-27}$ kg, $q = 1.60 \times 10^{-19}$ C) enters a uniform magnetic field of 0.20 T perpendicular to its velocity of 2.0×10^6 m/s. Calculate the radius of its circular path.

Incorrect Calculation: "The magnetic force provides centripetal force:"

$$qvB = \frac{mv^2}{r}$$

$$r = \frac{mv^2}{qvB} = \frac{mv}{qB} = \frac{(1.67 \times 10^{-27})(2.0 \times 10^6)}{(1.60 \times 10^{-19})(0.20)}$$

$$r = \frac{3.34 \times 10^{-21}}{3.20 \times 10^{-20}} = 0.10 \text{ m}$$

"The proton moves in a clockwise circle of radius 0.10 m."

Flawed Thinking

Error Analysis:

Correct Approach

Correction:



Motional EMF: A 0.50 m long conducting rod moves at 4.0 m/s perpendicular to a magnetic field of 0.30 T. The rod makes an angle of 90° with the field. Calculate the induced EMF.

Incorrect Calculation: $\varepsilon = BLv \cos \theta = (0.30)(0.50)(4.0) \cos(90^\circ) = 0.60 \times 0 = 0 \text{ V}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Two Parallel Wires: Two long parallel wires are 20 cm apart and carry currents of 5.0 A in opposite directions. Calculate the magnetic field at a point midway between them.

Incorrect Calculation:

At the midpoint, $r = 0.10 \text{ m}$ from each wire.

$$B_1 = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(5.0)}{2\pi(0.10)} = 1.0 \times 10^{-5} \text{ T}$$

$$B_2 = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(5.0)}{2\pi(0.10)} = 1.0 \times 10^{-5} \text{ T}$$

”Since the currents are in opposite directions, the fields cancel:”

$$B_{\text{net}} = B_1 - B_2 = 0 \text{ T}$$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:

Energy Stored in Inductor: Calculate the energy stored in a 2.0 H inductor when it carries a current of 3.0 A.

Incorrect Calculation: $E = \frac{1}{2}LI = \frac{1}{2}(2.0)(3.0) = 3.0 \text{ J}$

Flawed Thinking

Error Analysis:

Correct Approach

Correction:



Self-Assessment

After completing the assessment:

- Grade your work honestly
- Identify areas needing improvement
- Scan and submit via Google Classroom
- Reflect on your performance in your weekly reflection

Another excellent week of work completed - ***well done!*** You are another step closer to *smashing your exams*, and another week closer to your summer holidays!

Weekly Reflection Zone

What worked well this week?

What challenges did I face?

What surprised me the most this week?

Key physics concepts I want to review:

Goals for next week: