Induced potential

4.7.3.1 · Magnetism and electromagnetism · revision notes

If a wire moves relative to a magnetic field, or the magnetic field around a wire changes, a potential difference is induced across it: the generator effect. You need to recall what affects the size and direction of the induced potential difference and current, explain why the induced current opposes the change, and apply these ideas to new situations. GCSE Physics only, Higher tier only.

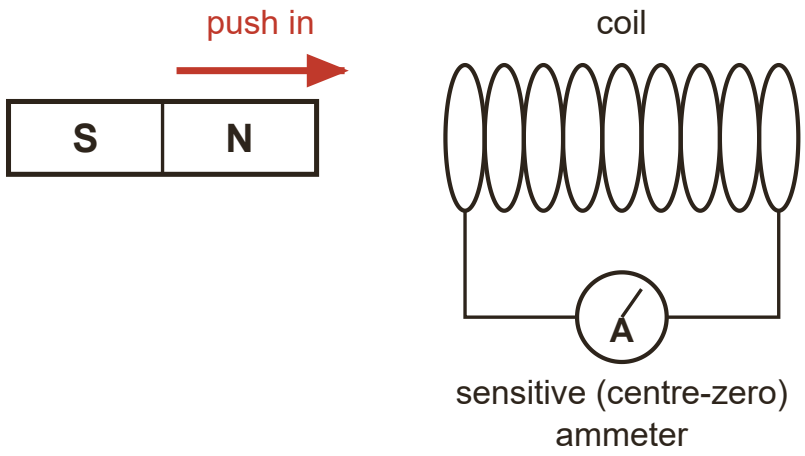
Key facts

- Generator effect: a pd is induced when a conductor moves relative to a magnetic field, or the field around it changes
- Bigger induced pd: faster movement, stronger field, more turns
- No relative movement and no change in field → no induced pd
- Motor effect: current + field → movement. Generator effect: movement + field → pd (and current)
- Complete circuit → induced current
- Direction reverses: reverse the movement or reverse the field
- Grade 8+ only The induced current's magnetic field opposes the change that caused it

Notes

The generator effect

- A **potential difference (pd) is induced** across the ends of a conductor if the conductor **moves relative to** a magnetic field (cutting through the field lines), or if the magnetic field around the conductor **changes**.
- If the conductor is part of a **complete circuit**, a current is induced too.
- This is the **generator effect**: movement and a magnetic field give a pd. (The motor effect is the other way round: current and a magnetic field give movement.)
- It is **relative** movement that counts: moving a magnet into a coil or moving the coil onto the magnet both work. If nothing moves and the field does not change, nothing is induced.



Moving the magnet (or the coil) induces a pd. No movement, no pd.

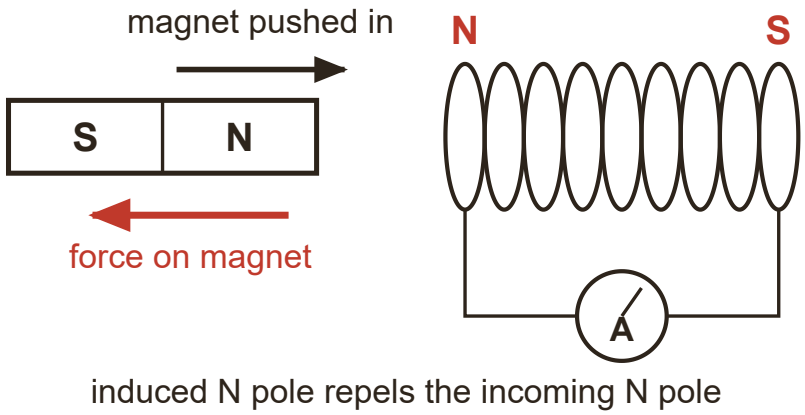
- A changing current in a nearby coil makes a changing field, so it can induce a pd without anything moving. This is how transformers work.

Size and direction

- The induced pd (and current) is **bigger** if the movement is faster (the field changes faster), the magnetic field is stronger, or the coil has more turns.
- The **direction** of the induced pd (and current) reverses if the movement reverses (e.g. pulling a magnet out instead of pushing it in), or if the field is reversed (e.g. using the other pole).
- Reversing both the movement and the field leaves the direction unchanged.
- Moving a magnet in and out of a coil again and again induces an **alternating** current.

The induced current opposes the change Grade 8+ only

- An induced current produces its own magnetic field. This field always **opposes the change** that caused it: either the movement or the change in field.
- Push a north pole into a coil: the near end of the coil becomes a north pole, which repels the magnet.



The induced field opposes the change: here, the near end of the coil repels the magnet.

- Pull the north pole out: the near end becomes a south pole, which attracts the magnet back.
- So you have to do work to move the magnet, and this work is the energy transferred to the circuit.

How to answer each type of question

State the factors that affect the induced pd or current 1 to 4 marks **Grade 6**

1. Size: speed of movement, strength of the field, number of turns.
2. Direction: direction of movement, direction of the field (which pole).
3. No movement and no change in field means zero pd.

Example. A student pushes a bar magnet into a coil connected to a sensitive ammeter. The needle moves to the right and then returns to zero.
(a) Give two ways the student could get a bigger reading. [2 marks]
(b) State one way the student could make the needle move to the left. [1 mark]
(c) The student holds the magnet still inside the coil. State the reading on the ammeter. [1 mark]

Model answer.

(a) Any two, 1 mark each: move the magnet faster; use a stronger magnet; use a coil with more turns.
(b) Pull the magnet out of the coil, or turn the magnet round and push the other pole in (1).
(c) Zero (1)

Explain why a pd is (or is not) induced

2 to 3 marks | **Grade 6**

1. Say what is moving relative to the field, or how the field is changing.
2. Say that this induces a pd (the generator effect), and a current if there is a complete circuit.
3. If nothing is moving or changing, say there is no relative movement, so no pd.

Example. A wire is connected to a voltmeter. The wire is moved quickly downwards between the poles of a horseshoe magnet.
Explain why the voltmeter shows a reading while the wire is moving, but not when it stops. [3 marks]

Model answer. When the wire moves, it cuts through the magnetic field lines / moves relative to the magnetic field (1), so a potential difference is induced across the ends of the wire (the generator effect) (1). When the wire stops there is no relative movement, so no pd is induced (1).

Explain how the induced current opposes the change

2 to 3 marks | **Grade 8**

1. Say a current is induced in the coil.
2. Say the induced current makes a magnetic field that opposes the change (the movement of the magnet).
3. Name the pole made at the near end of the coil and whether it attracts or repels the magnet.

Example. The north pole of a bar magnet is pushed towards one end of a coil. The coil is part of a complete circuit.
Explain why there is a force pushing back against the magnet. [3 marks]

Model answer. A current is induced in the coil (1). The induced current produces a magnetic field that opposes the change / the movement of the magnet (1). The end of the coil nearest the magnet becomes a north pole, which repels the north pole of the magnet (1).

Apply the generator effect to a new situation

3 to 4 marks | **Grade 9**

1. Work out what is moving or changing, and when.
2. Direction: moving into the coil and moving out of it give opposite pds.
3. Size: faster movement gives a bigger pd, over a shorter time.

Example. A bar magnet is dropped, north pole first, through the middle of a vertical coil connected to a data logger. As the magnet falls into the top of the coil, the data logger records a positive pd.
Describe and explain the pd recorded as the magnet leaves the bottom of the coil. [4 marks]

Model answer. The pd is negative / in the opposite direction (1) because the magnet is now moving out of the coil, so the field through the coil changes the opposite way (1). The peak pd is bigger (and lasts for a shorter time) (1) because the magnet is moving faster, as it has been accelerating as it falls (1).

Don’t lose marks

- Saying a pd is induced when the magnet is held still inside the coil.
- Saying a current is always induced: a current needs a complete circuit. Otherwise there is only a pd.
- Writing 'a bigger magnet' instead of 'a stronger magnet'.
- Mixing up the generator effect with the motor effect.
- Saying the induced field helps the movement: it always opposes the change.

More tips

Memory tricks

- Bigger induced pd: 'Faster, Stronger, More': faster movement, stronger magnet, more turns.
- Direction: flip one thing (the movement or the field) and the pd flips. Flip both and it does not.
- No change, no pd: if nothing is moving and the field is not changing, the reading is zero.
- The coil always fights back: it repels a magnet coming in and attracts a magnet going out.

Exam technique

- Use the word 'induced' for the pd or current, and say the movement is 'relative to' the field.
- In 'apply' questions, first say what is moving or changing, then use the rules for size and direction.
- On a graph of induced pd, the sign (+ or −) shows the direction and the height of the peak shows the size.
- If a generator is disconnected it is easier to turn: there is no complete circuit, so no induced current and no magnetic field to oppose the movement.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 5 — **State when a potential difference is induced**
When a conductor moves relative to a magnetic field, or the magnetic field around it changes.

Grade 5 — **State when an induced current flows**
A current is only induced if the conductor is part of a complete circuit.

Grade 6 — **Recall what affects the size of induced pd**
Faster movement (faster change of field), a stronger magnetic field and more turns on the coil all increase it.

Grade 6 — **Recall what affects the direction of induced pd**
Reversing the direction of movement, or reversing the magnetic field, reverses it.

Grade 7 — **Explain why a still magnet induces nothing**
With no relative movement the field through the coil does not change, so no pd is induced.

Grade 8 — **Explain how the induced current opposes the change**
The induced current makes a magnetic field that opposes the movement, e.g. the coil repels a magnet being pushed in.

Grade 9 — **Apply the generator effect to new situations**
e.g. describe and explain the pd recorded as a magnet falls right through a coil.

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