Electromagnetism

4.7.2.1 · Magnetism and electromagnetism · revision notes

A current in a wire produces a magnetic field around it. You need to describe how to show this, draw the fields around a straight wire and a solenoid with their directions, and explain how a solenoid and an iron core make the field stronger. In GCSE Physics (not Combined Science) you also use diagrams to explain how electromagnetic devices such as relays and electric bells work.

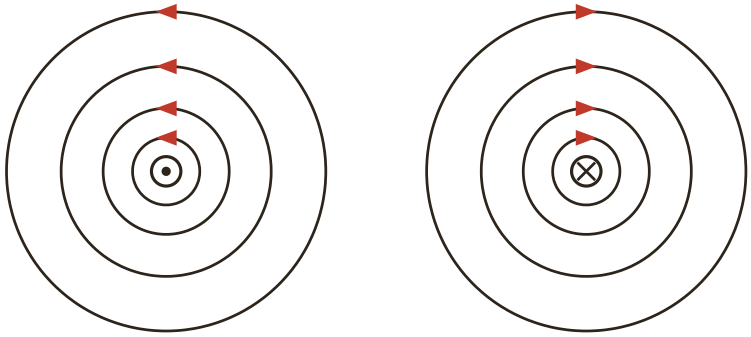
Key facts

- Current in a wire → magnetic field around the wire
- Right-hand grip rule: thumb = current, curled fingers = field
- Electromagnet = solenoid with an iron core
- Iron core: easily magnetised, and loses its magnetism quickly when the current is switched off
- Straight wire: circles centred on the wire; stronger for more current, weaker further away
- Solenoid: field inside is strong and uniform; outside it is like a bar magnet's field
- Stronger electromagnet: bigger current, more turns, iron core
- Device chain: current on → electromagnet attracts iron armature → contacts or hammer move → spring returns armature when current off

Notes

Field around a straight wire

- When a current flows through a wire, a **magnetic field** is produced around the wire.
- The field lines are **circles centred on the wire**.
- The field is **stronger** for a bigger current, and **weaker** further from the wire (draw the circles further apart as you go out).
- Reversing the current reverses the direction of the field.
- **Right-hand grip rule:** point your right thumb in the direction of the current (+ to −). Your curled fingers show the direction of the field lines.

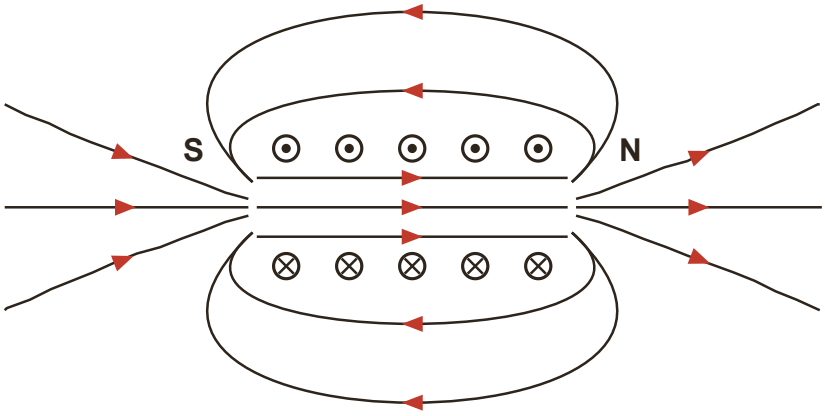


Right-hand grip rule: thumb along the current, fingers curl the way the field goes.

- To show it: put plotting compasses on a card around a vertical wire. With the current on, they line up in a circle; reversing the current reverses them.

Solenoids and electromagnets

- A **solenoid** is a wire wound into a long coil. Shaping the wire into a solenoid makes the magnetic field much stronger.
- This is because the fields of all the turns add together (reinforce each other) inside the coil.
- Inside a solenoid the field is **strong and uniform**: straight, parallel, equally spaced lines.
- Outside, the field has the **same shape as a bar magnet's field**. One end acts as a north pole and the other as a south pole.

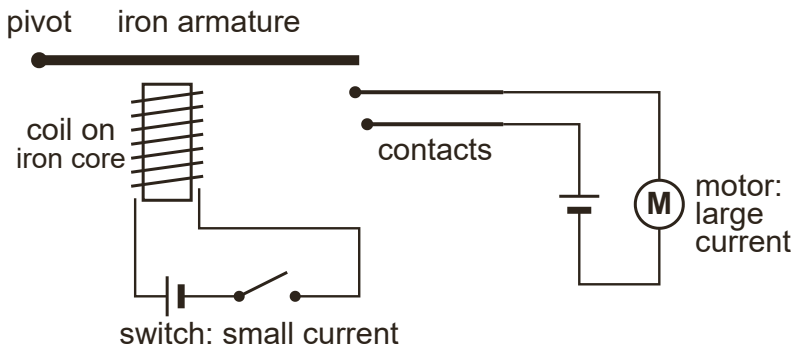


Solenoid (cut through lengthways; dots: current out of page, crosses: into page). Strong, uniform field inside; bar-magnet shape outside.

- To find the north end: curl the fingers of your right hand the way the current goes round the turns. Your thumb points to the north pole.
- An **electromagnet** is a solenoid with an **iron core**. The iron becomes magnetised, which makes the field much stronger.
- To make an electromagnet stronger: increase the current, add more turns, or add an iron core.
- Iron is used because it is easily magnetised and loses its magnetism quickly when the current is switched off.

Electromagnetic devices

- For a device you have not met, follow the chain: current on → electromagnet magnetised → iron part attracted → what that movement does. Current off → iron part released (often by a spring).
- **Relay:** a small current in one circuit magnetises an electromagnet. It attracts an iron armature, which pushes contacts together and switches on a second circuit, e.g. one carrying a large current to a car's starter motor.



Relay: current in the coil → core magnetised → armature attracted → contacts pushed together → motor circuit switched on.

- **Electric bell:** the electromagnet attracts the armature, so the hammer hits the gong. This breaks the circuit, so the electromagnet switches off and a spring pulls the armature back. The circuit is remade and the cycle repeats.

How to answer each type of question

Describe how to show the magnetic effect of a current 2 to 3 marks **Grade 4**

1. Describe the set-up: a wire through a card, connected to a power supply.
2. Say where the plotting compasses go (around the wire, on the card).
3. Say what you see when the current is switched on (and reversed).

Example. Describe how you could show that there is a magnetic field around a wire carrying a current. [3 marks]

Model answer. Pass the wire vertically through a horizontal piece of card and connect it to a power supply (1). Place several plotting compasses on the card around the wire (1). When the current is switched on, the compasses turn to point in a circle around the wire (and they reverse when the current is reversed) (1).

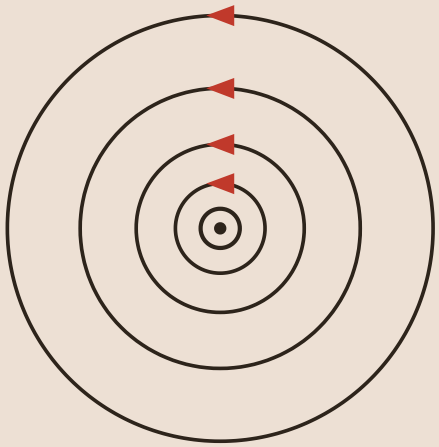
Describe or draw the field around a wire or solenoid

2 to 3 marks | **Grade 5**

1. Straight wire: circles centred on the wire, getting further apart further out.
2. Solenoid: straight, parallel, equally spaced lines inside; bar-magnet shape outside.
3. Find the direction with the right-hand grip rule and show it with arrows or words (clockwise or anticlockwise, and from which viewpoint).

Example. A long straight wire passes vertically through a horizontal piece of card. The current in the wire is upwards.
Describe the magnetic field pattern on the card, and give its direction as seen from above. [3 marks]

Model answer.



seen from above: current up, out of the card

Concentric circles, further apart further out, anticlockwise from above.

Circles centred on the wire (1). The circles get further apart further from the wire (1). The field is anticlockwise as seen from above (1).

Explain how to make an electromagnet stronger 2 to 3 marks **Grade 4**

1. Name the changes: bigger current, more turns, iron core.
2. If asked to explain the core, say the iron becomes magnetised and adds to the field of the coil.

Example. A student makes an electromagnet by winding insulated wire around an iron nail and connecting it to a battery.
(a) Give two changes the student could make so the electromagnet picks up more paper clips. [2 marks]
(b) Explain why the magnetic field is stronger with the iron nail than without it. [1 mark]

Model answer.

(a) Increase the current, e.g. use a higher potential difference (1). Wind more turns of wire around the nail (1).
(b) The iron becomes magnetised (an induced magnet), so its field adds to the field of the coil (1).

Explain how an electromagnetic device works 3 to 6 marks **Grade 5**

1. Start with the current: what switches it on, and where it flows.
2. Say the core becomes magnetised (an electromagnet).
3. Say what the electromagnet attracts, and what that movement does.
4. Finish with what happens when the current stops.

Example. A car's starter motor needs a very large current. The key switch is in a separate circuit with a small current. This circuit contains a coil wound round an iron core. Next to the core is a pivoted iron armature. When the armature moves, it pushes two contacts together, which completes the starter motor circuit.
Explain how turning the key makes the starter motor turn. [4 marks]

Model answer. Turning the key completes the circuit, so there is a current in the coil (1). The iron core becomes magnetised / the coil becomes an electromagnet (1). The electromagnet attracts the iron armature (1). The armature pushes the contacts together, completing the motor circuit, so a large current flows through the starter motor (1).

Don’t lose marks

- Drawing the circles round a wire evenly spaced: they get further apart further from the wire.
- Drawing the lines inside a solenoid curved or spreading out: inside they are straight, parallel and equally spaced.
- Using the left hand to find the direction of the field round a wire.
- Suggesting a steel core: steel would stay magnetised after the current is switched off.
- Forgetting the arrows on field lines.

More tips

Memory tricks

- Right hand for fields round a current (thumb = current, fingers = field). The left hand is only for the motor-effect force.
- Solenoid ends: look at one end. If the current goes anticlockwise, that end is a north pole; if clockwise, it is a south pole.
- Stronger electromagnet: more Current, more Turns, an Iron core.
- Outside a solenoid, draw the field as if the coil were a bar magnet.

Exam technique

- When asked how a solenoid 'increases the magnetic effect', say that the fields from all the turns add together inside the coil.
- Give directions clearly: 'clockwise' or 'anticlockwise' plus the viewpoint, e.g. 'as seen from above'.
- For 'explain how it works' questions, write a chain of steps, joining each to the next with 'so'.

What each grade needs

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

Grade 3 — **State that a current produces a magnetic field**
When a current flows through a wire, a magnetic field is produced around the wire.

Grade 4 — **Describe how to show a wire's magnetic field**
Put plotting compasses around a vertical wire: they line up in a circle when the current is switched on.

Grade 5 — **Draw the field around a straight wire**
Circles centred on the wire, further apart further out, with arrows showing the direction.

Grade 5 — **State what affects the strength of the field**
The field is stronger for a bigger current, and weaker further from the wire.

Grade 5 — **Explain how solenoids and iron cores strengthen fields**
The fields of all the turns add together inside the coil, and an iron core becomes magnetised, making the field much stronger.

Grade 5 — **Explain how an electromagnetic device works**
e.g. in a relay, a small current magnetises an electromagnet, which attracts an iron armature and closes the contacts of a second circuit.

Grade 6 — **Use the right-hand grip rule for field direction**
Point your right thumb along the current (+ to −); your curled fingers show the direction of the field.

Grade 6 — **Draw the magnetic field of a solenoid**
Outside, like a bar magnet's field; inside, strong and uniform (straight, parallel, equally spaced lines).

Free notes, Full packs, practice papers and mock exams at chhetriacademy.com. Written for this site; not taken from past papers. Stuck? 1-to-1 tutoring with a free 30-minute trial lesson.