

Magnetism and electromagnetism

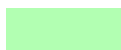
Specification 8464 · AQA

Free edition

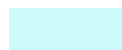
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

This booklet is a study aid written from the published specification.
It is not affiliated with, endorsed by or approved by AQA.

Free to download and share for personal study.
Please do not sell or republish it as your own.
For enquiries, please email pcfgyrdi@gmail.com

Define Magnetic pole

- the place on a magnet where the magnetic forces are strongest.

Define Magnetic material

- a material a magnet attracts: iron, steel, cobalt and nickel.

Define Magnetic field

- the region around a magnet where a force acts on another magnet or on a magnetic material.

Define Non-contact force

- a force between objects that are not touching, e.g. magnetic attraction.

Define Solenoid

- a wire shaped into a coil, giving a strong, uniform field inside it.

Define Magnetic flux density (B)

- a measure of the strength of a magnetic field, in tesla (T).

Define Fleming's left-hand rule

- the rule giving the relative orientation of force, current and field in the motor effect.

Define Permanent magnet

- a magnet that produces its own magnetic field.

Define Induced magnet

- a material that becomes a magnet in a magnetic field and loses most/all of its magnetism quickly when removed.

Define Magnetic field line

- a line showing field direction, drawn from the north (seeking) pole to the south (seeking) pole.

Define Magnetic compass

- a small bar magnet whose needle points along the field it is in.

Define Electromagnet

- a solenoid with an iron core.

Define Motor effect

- the force a magnet and a current-carrying conductor in its field exert on each other.

24.1 Permanent and induced magnetism, magnetic forces and fields

24.1.1 Poles of a magnet

- The **poles** of a magnet are the places where the magnetic forces are strongest. Every magnet has a **north (seeking)** and a **south (seeking)** pole.
- Two **like** poles **repel**; two **unlike** poles **attract**. These are examples of a **non-contact force**.
- A **permanent magnet** produces its own magnetic field.
- An **induced magnet** is a material that becomes a magnet when placed in a magnetic field. Induced magnetism **always causes a force of attraction**, and an induced magnet loses most/all of its magnetism quickly when removed from the field.

	Permanent magnet	Induced magnet
Field	Produces its own, always	Magnetic only while in another magnet's field
Poles	Fixed N and S poles	Poles induced so the nearer pole is always opposite to the one causing it
Force	Can attract or repel	Always attraction
Removed from the field	Unchanged	Loses most/all magnetism quickly
Example	Bar magnet, compass needle	Iron paperclip hanging from a magnet

WATCH OUT

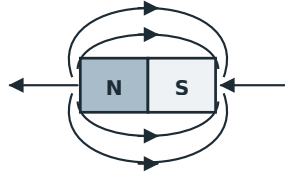
"A magnet picks up a paperclip, so the paperclip is a magnet." It is an **induced** magnet — poles are induced in it the right way round to attract. That is why a magnet can never repel a plain iron paperclip, and why a hanging chain of clips collapses the moment the magnet is removed.

24.1.2 Magnetic fields

- The **magnetic field** is the region around a magnet where a force acts on another magnet or on a **magnetic material** (iron, steel, cobalt, nickel).
- The force between a magnet and a magnetic material is **always one of attraction**.
- The **strength** of the field depends on the **distance from the magnet**, and is **greatest at the poles**.
- The **direction** of the field at a point is the direction of the force that would act on **another north pole** placed there. Field lines run **from north to south**.
- Drawing a bar magnet's field: lines are **closest together at the poles** (strongest field) and **spread out** further away (weaker field); each line has an **arrow** from N to S; lines never cross.

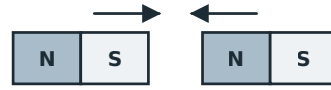
Magnetic field patterns

Field around a bar magnet



Field lines run from the north pole to the south pole, and are closest together at the poles where the field is strongest.

Two magnets: attract and repel



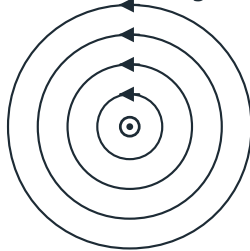
unlike poles attract — they pull together



like poles repel — they push apart

The arrows show the forces on the magnets. These are non-contact forces.

Field around a straight wire carrying a current

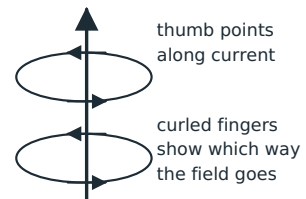


The field lines are circles around the wire.

They are closer together near the wire, where the field is strongest.

The dot means the current comes out of the page.

Right-hand grip rule

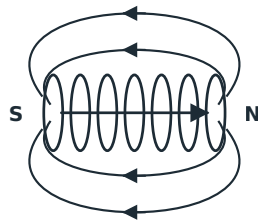


thumb points along current

curled fingers show which way the field goes

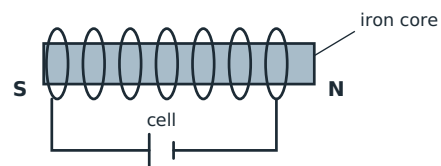
Solenoid and electromagnet

Solenoid



Outside, the field has the same shape as a bar magnet's. Inside the coil the field is strong and uniform (evenly spaced parallel lines).

Electromagnet



An electromagnet is a solenoid with an iron core. Iron is easily magnetised, so the core makes the magnetic field much stronger.

ANALOGY

Field lines work like **contour lines on a map**: the lines are not real objects, but where they bunch tightly the ground is steep — and where field lines bunch tightly the field is strong.

Plotting the field pattern with a compass:

1. Place the bar magnet on paper and draw round it.
2. Put a **plotting compass** near one pole; mark a dot at each end of the needle.
3. Move the compass so the needle's tail sits on the dot just marked; mark the new head position. Repeat to the other pole.
4. Join the dots into a smooth line, arrowed in the direction the compass north pointed, then start again elsewhere to build up the pattern.

The Earth's magnetic field. A magnetic compass contains a **small bar magnet**, and its needle points in the direction of the **Earth's magnetic field**. Since only a magnetic field can turn a compass, and it turns with no other magnet nearby, the field must come from the Earth itself — evidence that the Earth's core must be magnetic.

24.2 The motor effect

24.2.1 Electromagnetism

- When a current flows through a conducting wire, a magnetic field is produced around the wire. Its strength depends on the **current** and the **distance from the wire**.
- **Straight wire:** the field is a set of **concentric circles** centred on the wire, spaced further apart further out. Direction comes from the **right-hand grip rule** — point the thumb of your right hand along the current and your curled fingers give the field direction.
- Demonstrating the magnetic effect of a current: pass a vertical wire through a horizontal card, put plotting compasses on the card, switch on the current — the compasses swing into circles, and all reverse if the current reverses.
- Shaping a wire to form a solenoid increases the strength of the magnetic field. The field inside a solenoid is strong and uniform (straight, parallel, evenly spaced lines).
- The field **around** a solenoid is similar in shape to that of a bar magnet, with a north pole at one end. The right-hand grip rule works here too: curl your fingers the way the current flows round the coils and your thumb points to the **north** end.
- Adding an iron core increases the strength of a solenoid's field. An electromagnet is a solenoid with an iron core.
- To increase the magnetic effect: more current, more turns, add an iron core. An electromagnet can be **switched on and off** — used in scrapyard cranes, electric bells, relays and circuit breakers.

HIGHER TIER

24.2.2 Fleming's left-hand rule **HT ONLY**

- **HT ONLY** When a conductor carrying a current is placed in a magnetic field, the magnet producing the field and the conductor exert a force on each other. This is the **motor effect**, caused by the magnet's field interacting with the field made by the current.
- **HT ONLY** The force is greatest when the conductor is at right angles to the field and **zero when it is parallel** to it.
- **HT ONLY** Factors affecting the **size** of the force: **magnetic flux density B** , **current I** , and **length** of conductor in the field l .
- **HT ONLY** Reversing **either** the current **or** the field reverses the force; reversing **both** leaves it unchanged. **HT ONLY** **Fleming's left-hand rule** gives the relative orientation of force, current and field. Hold the **left hand** with thumb and first two fingers at right angles: **First finger = Field** (N to S), **seCond finger = Current** (conventional, + to -), **thuMb = Motion** (the force).

Fleming's left-hand rule

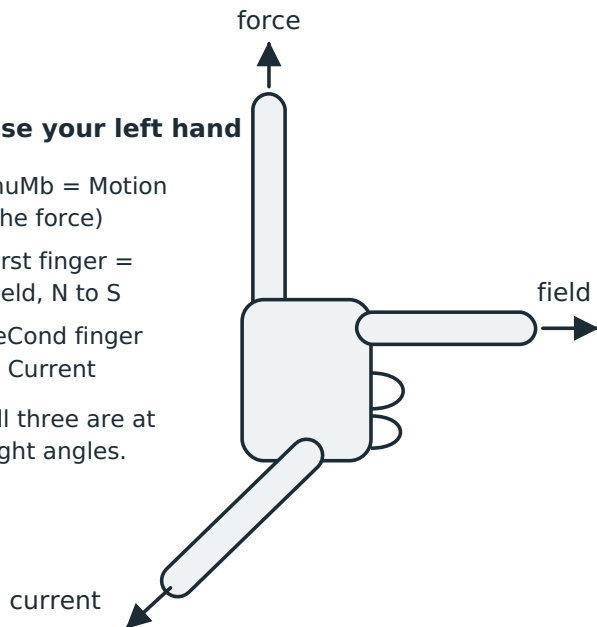
Use your left hand

thuMb = Motion
(the force)

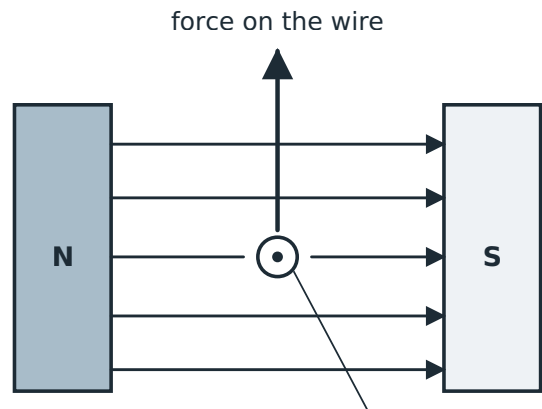
First finger =
Field, N to S

seCond finger
= Current

All three are at
right angles.



The motor effect



The dot shows current coming out of the page.
The field runs from the north pole to the south.

First finger along the field, seCond finger along
the current: the thuMb then gives the force.

Size of the force

force = magnetic flux density × current × length

$$F = B I l$$

force, F , in newtons, N

magnetic flux density, B , in tesla, T

current, I , in amperes, A

length, l , in metres, m

The conductor must be at right angles to
the magnetic field for this equation to apply.

ANALOGY

The memory device is hidden in the finger names: **F**irst finger = **F**ield, se**C**ond finger = **C**urrent, thu**M**b = **M**otion. Use the **left** hand for the motor effect — "L for Left, L for the Load being pushed". The **right** hand belongs to the grip rule for the field around a wire.

WATCH OUT

Which hand? Use the **left** hand for the **motor effect** (force on a current-carrying conductor in a field). The **right**-hand grip rule is for the **direction of the field** around a current-carrying wire or solenoid — it says nothing about force.

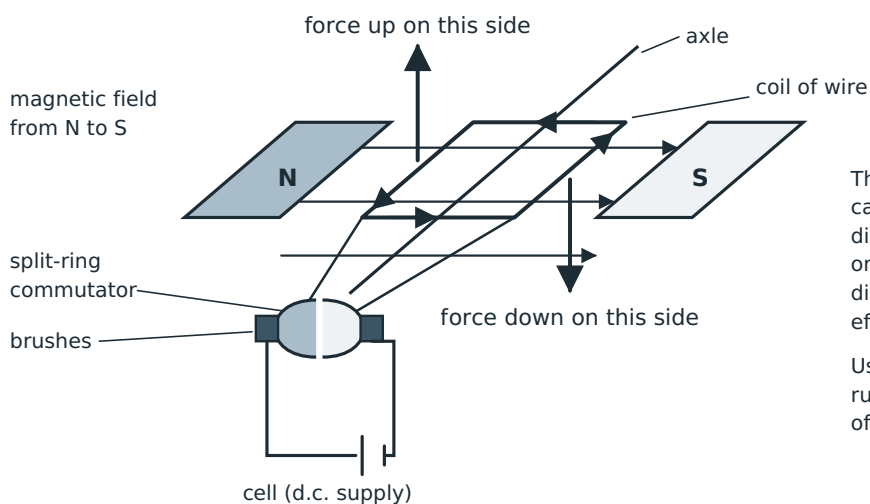
24.2.3 Electric motors **HT ONLY**

- **HT ONLY** A coil of wire carrying a current in a magnetic field tends to rotate. This is the basis of an **electric motor**.
- **HT ONLY** Explaining the rotation: 1. The coil sits between the poles of a permanent magnet and carries a current. 2. Its two sides carry current in **opposite** directions, so by Fleming's left-hand rule one side is pushed **up** and the other **down**. 3. This pair of forces gives a **turning effect**, so the coil rotates. 4. A **split-ring commutator** reverses the current in each side every half turn, so the coil keeps turning the same way.
- **HT ONLY** Larger current, stronger field or more turns makes it turn faster. Reversing the current **or** the field reverses the rotation.

The electric motor

Higher tier only

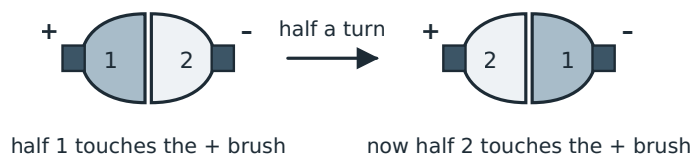
A simple d.c. electric motor



The two sides of the coil carry current in opposite directions, so the forces on them are in opposite directions. This turning effect rotates the coil.

Use Fleming's left-hand rule to find the direction of each force.

Why the split-ring commutator is needed



Every half turn the halves swap brushes, so the current in the coil reverses.

Each side of the coil moves from the north side of the magnet to the south side every half turn.

Reversing the current at the same moment keeps the force on each side turning the coil the same way.

Without the commutator the coil would stop after half a turn.

24.3 Key ideas in physics

The complex and diverse phenomena of the natural and man-made world can be described in terms of a small number of **key ideas** in physics. They run through every topic and are **assessed across all papers**, so expect questions that ask you to apply them to unfamiliar situations.

- **The use of models** — for example the **particle model of matter**, and the **wave models** of light and of sound.
- **Cause and effect** — explaining links such as that between **force and acceleration**, or between changes in atomic nuclei and radioactive emissions.
- 'Action at a distance' and the field — the field is the key to analysing **electrical, magnetic and gravitational** effects, as in this topic.
- **Differences are the drivers of change** — differences in **pressure, temperature** or **electrical potential** are what make things happen.
- **Proportionality** — for example between the **weight and mass** of an object, or between the **force and extension** of a spring; it is an important aspect of many models in science.
- Physical laws and models are expressed in mathematical form — which is why the equations, their units and their rearrangements matter.