

7 · Magnetism and electromagnetism

AQA · GCSE · Physics

Magnetism and electromagnetism: movement from current

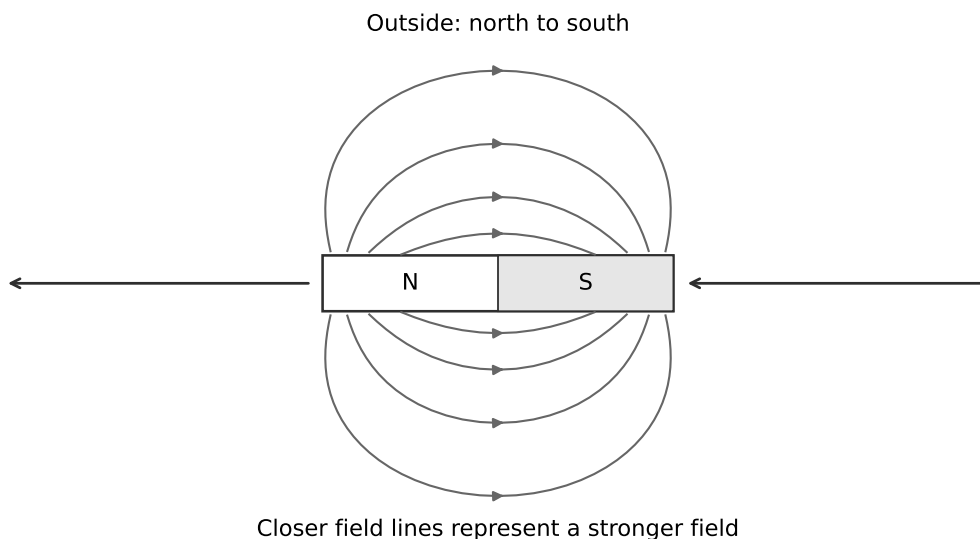
A changing magnetic field can induce a potential difference; a complete circuit can then carry current. Current in a magnetic field can cause movement. Every motor, generator, power station and loudspeaker lives in this topic. This reference covers **AQA GCSE Physics 8463, topic 4.7 Magnetism and electromagnetism**.

How the exam treats this topic:

- Paper 2 carries this topic. $F = BIl$ and the two transformer equations may be supplied on the equation sheet; check the examination series.
- Fleming's left-hand rule, motors, loudspeakers, the generator effect, alternators/dynamos, microphones and transformers are **HT only**; everything from 4.7.3 onwards is also **physics only**.
- You must **draw field patterns**: bar magnet, straight wire, solenoid.

Permanent and induced magnets, magnetic fields

- **Poles** : where the magnetic force is strongest.



Like poles repel; unlike poles attract – a non-contact force.

- A **permanent magnet** produces its own field. An **induced magnet** becomes magnetised in an external field; induced magnetism causes **attraction** to the magnet producing that field. It loses most or all of this magnetism quickly

when the field is removed. Soft iron loses it readily; steel can retain more.

- The **magnetic field** is the region where a force acts on another magnet or magnetic material (iron, steel, cobalt, nickel). A magnet attracts initially unmagnetised magnetic material. Another permanent magnet can attract or repel, depending on its poles.
- Field is **strongest at the poles**; direction = the force on a **north pole** at that point. Field lines run **north → south outside the magnet**; they form closed loops, returning through the magnet.
- A **compass** is a small bar magnet; it points along the Earth's field – evidence the Earth has a magnetic field. The field is associated with processes in the core; a bar magnet is a model, not a literal magnet inside the Earth.

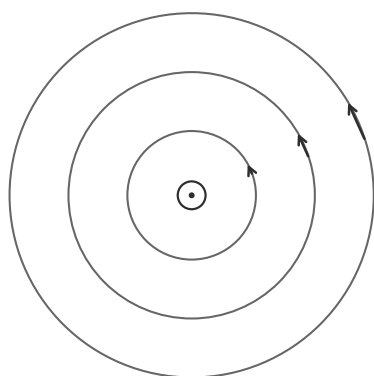
Plotting a field: put a small plotting compass near the magnet, mark both needle ends, identify the north-seeking end, then move the other end to the previous north-tip mark. Repeat, join smoothly and add arrows in the north-tip direction; start again elsewhere for several lines. Iron filings show a pattern but not its direction.

Electromagnetism

A **current-carrying wire** has a magnetic field around it (concentric circles; right hand grip – thumb with the current, fingers curl with the field). The field is **stronger with more current** and **weaker further from the wire**.

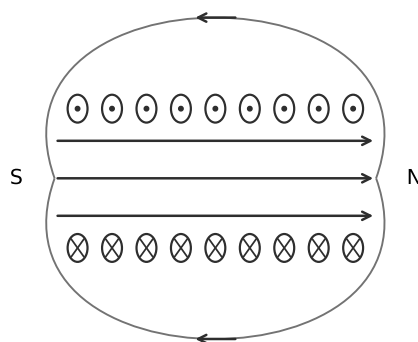
Bending the wire into a **solenoid** :

Wire: anticlockwise field



Dot: current out of page

Solenoid: uniform field inside



Dots out; crosses into page

- the fields of the loops add – the field inside is **strong and uniform**;
- outside, the shape matches a **bar magnet**'s;
- adding an **iron core** increases the strength further – this is an **electromagnet**

An electromagnet can be switched on and off and its strength changed with the current – that is why it beats a permanent magnet in scrapyards and relays.

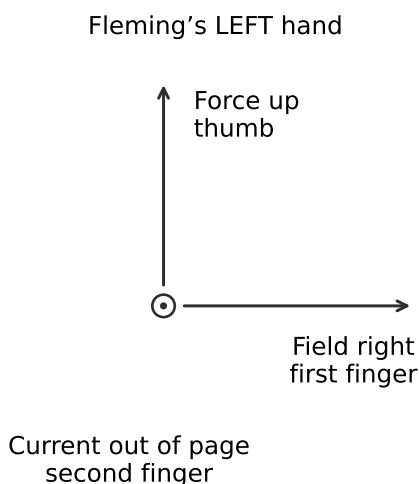
Demonstrating the field: place a compass near a straight wire, switch the current on, observe deflection, then reverse the current and observe the reversed field direction. Compare equal positions at different currents; switch off before moving apparatus.

Relay model (physics only): a small control current magnetises an iron-cored coil. It attracts an iron armature, closing a separate load-circuit contact. On switching off, a spring returns the armature. Identify the control coil and load circuit separately; the magnetic action operates the contact without joining the two circuits.

The motor effect (HT)

A conductor carrying a current across a magnetic field feels a force (the **motor effect** – the field, the magnet and the conductor push on each other).

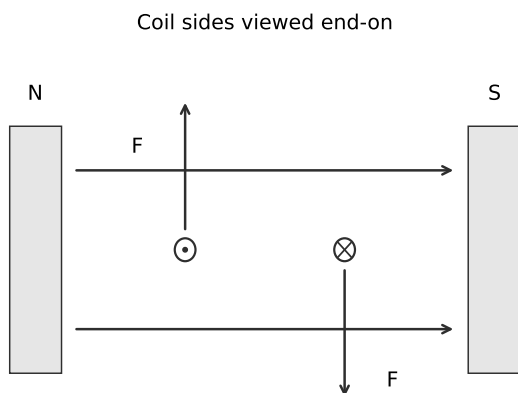
Fleming's left-hand rule: thumb = **force**, first finger = **field** (N→S), second finger = **current** – all three at right angles.



$$F = BIl$$

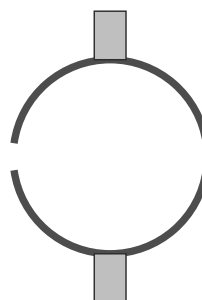
- F force in N; B **magnetic flux density** in tesla, T; I current in A; l length of conductor **in the field**, in m.
- Bigger force with: stronger field (larger B), larger current, longer conductor in the field. Use $F = BIl$ when the current is at **right angles** to the field; a current parallel to a uniform field has zero motor force.

Electric motor: a current-carrying **coil** in a field rotates because the two sides feel forces in opposite directions.



Opposite forces create a turning effect

Split-ring commutator



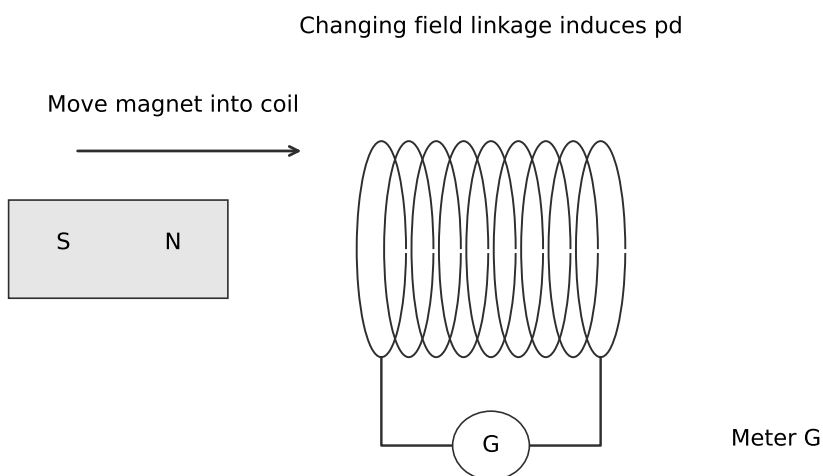
Fixed brushes

Fixed brushes contact a **split-ring commutator**, which swaps the coil connections each half-turn. Current reverses in each physical coil side, keeping the turning effect in the same sense. When the brushes meet insulating gaps, current and magnetic force briefly fall to zero. Inertia can carry an already rotating coil through this position; an ideal single coil at a dead spot does not start itself.

Loudspeaker (physics only): an alternating current through a coil in a field makes the coil vibrate in and out; the cone pushes the air into **pressure variations** – **sound waves** whose frequency matches the signal's.

The generator effect (physics only, HT)

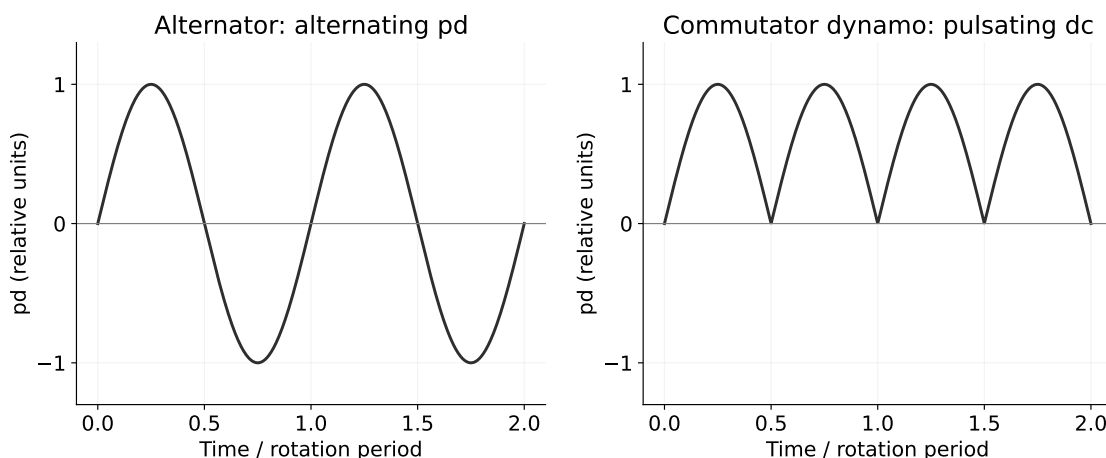
If a conductor **cuts magnetic field lines**, or the magnetic field linking it changes, a **potential difference is induced**; if the circuit is complete, a current flows – the **generator effect**.



- The **induced current's own field opposes the change** that made it.
- Bigger induced pd with: **faster** movement, **stronger** field, more turns of wire.
Reversed direction with: reversed movement or reversed field polarity.

When no pd is sustained: a stationary magnet and coil have no changing field linkage. Motion parallel to uniform field lines does not cut them. In a transformer, steady dc gives a steady field after switching; brief switching transients are different from sustained ac operation.

Alternator (ac generator): a coil rotates in a field – the induced pd **reverses direction** every half-turn, so the pd–time graph is a repeating wave crossing zero.

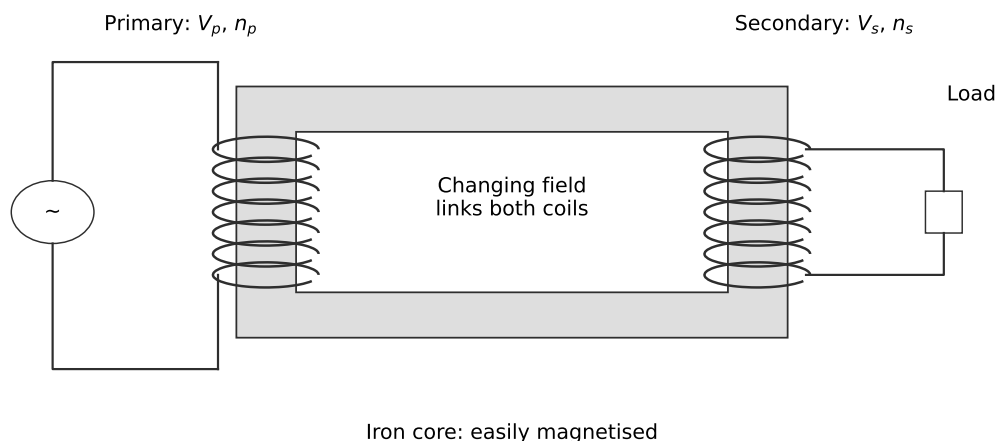


Dynamo (dc): a split-ring commutator flips the connections each half-turn, so the output stays on one side of zero (pulsating dc). Reversing the terminal labels reverses the sign; dc is one-directional, not necessarily positive. A real bicycle device called a “dynamo” can be an alternator; use its stated construction.

Microphone: the reverse of a loudspeaker – sound pressure variations move a coil in a field, **inducing a varying potential difference**. In a complete circuit this drives a varying current corresponding to the sound.

Transformers (physics only, HT)

A **transformer** : primary and secondary coils wound on an **iron core** (easily magnetised; laminations not required).



An **alternating current** in the primary makes a changing magnetic field in the core; that changing field **induces an alternating pd** in the secondary.

$$\frac{V_p}{V_s} = \frac{n_p}{n_s} \quad V_s I_s = V_p I_p \text{ (100\% efficient)}$$

- **Step-up:** $V_s > V_p$ (more secondary turns). **Step-down:** $V_s < V_p$.
- The second equation is power in = power out **only for the ideal, 100% efficient model**; use it to find the current drawn from the input supply.

Worked example. A transformer has 345 primary turns and 6000 secondary; the input is 230 V.

$$\frac{230}{V_s} = \frac{345}{6000} \Rightarrow V_s = 230 \times \frac{6000}{345} = 4000 \text{ V (a step-up)}$$

Worked example (power). Assume that transformer is 100% efficient and supplies 50 mA at 4000 V.

- Power out: $P = V_s I_s = 4000 \times 0.050 = 200 \text{ W}$.
- Input current: $I_p = P/V_p = 200/230 = 0.87 \text{ A}$.

The National Grid story closes the loop: **step-up before transmission** (at the same transferred power, larger pd means smaller current; for the same cable resistance, $P_{\text{loss}} = I^2 R$ falls), **step-down** for homes (see topic 2.7).

Checklist before you call this topic done

- State the pole rules; distinguish permanent from induced magnets.
- Draw bar-magnet, straight-wire and solenoid field patterns with directions; explain the compass/Earth link.
- (HT) Use Fleming's left-hand rule and $F = BIl$; explain the motor and the commutator.

- (physics only, HT) State the generator-effect conditions and the opposing induced field; distinguish alternator and dynamo graphs; explain the microphone.
- (physics only, HT) Use both transformer equations; explain induction between coils and the Grid advantage.