IGCSE PHYSICS 0625 · CHAPTER 10 NOTES · ~11 MIN READ

Magnetism & electromagnetism

Magnets and their fields, electromagnets, the motor effect, the d.c. motor, the a.c. generator and transformers — and how the grid delivers power.

Magnetic poles & materials | Fields | Electromagnets | Relays & loudspeakers | Force on a current | d.c. motor | Induction | a.c. generator

RS by Riyaz Sir
mentorriyaz.in

No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

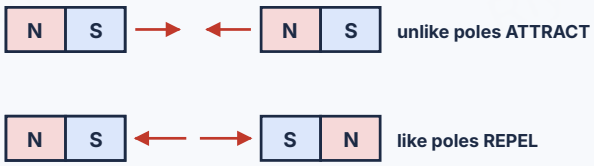
- Like poles repel, unlike poles attract. Magnets attract **iron, steel, nickel and cobalt**.
- A **current makes a magnetic field**. A coil with a current is an electromagnet.
- A wire carrying a current in a field feels a **force** — this is how the **motor** works.
- A conductor moving in a field (or a changing field) **induces an e.m.f.** — this is how **generators** and **transformers** work.
- **Transformers:** $V_p \div V_s = N_p \div N_s$. High-voltage transmission wastes less energy.

BY THE END YOU CAN

- Test materials for magnetism and describe permanent and temporary magnets.
- Draw field patterns for a bar magnet, a wire and a solenoid.
- Describe the motor effect, the d.c. motor and Fleming's left-hand rule. EXT
- Explain electromagnetic induction and the a.c. generator.
- Use the transformer equation and explain why the grid uses high voltage.

1 Magnets and magnetic fields

Poles, materials and induced magnetism



a magnet attracts iron, steel, nickel and cobalt only

Unlike poles attract. Like poles repel.

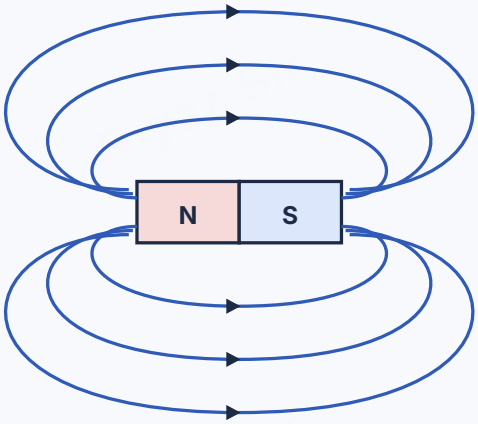
- **Repulsion is the only true test of a magnet.** A magnet will attract an unmagnetised piece of iron too, so attraction alone proves nothing.
- Magnetic materials: **iron, steel, nickel, cobalt**. Non-magnetic: copper, aluminium, plastic, wood.
- **Induced magnetism:** a piece of iron close to a magnet becomes a magnet itself, with the end nearest the magnet becoming the opposite pole. That is why a magnet picks up a chain of paper clips.

	Soft iron	Steel
magnetises	easily	with difficulty
keeps magnetism?	no — temporary	yes — permanent
used for	electromagnets, relays, transformer cores	compass needles, permanent magnets

- Permanent magnets are used in loudspeakers, motors, fridge doors and compasses. Electromagnets are used in scrapyard cranes, relays and doorbells.

Magnetic fields

Magnetic field — a region where a magnetic pole feels a force.



Field lines leave the N pole and enter the S pole. Lines never cross. Closer lines mean a stronger field.

- The direction of the field is the direction of the force on a free **north pole**.
- Plot the pattern with a small **plotting compass**, or sprinkle iron filings on paper over the magnet.
- EXT The spacing of the lines shows the relative strength: strongest at the poles. Magnetic forces arise when the fields of two magnets interact.

2 Currents and magnetic fields

The field around a wire



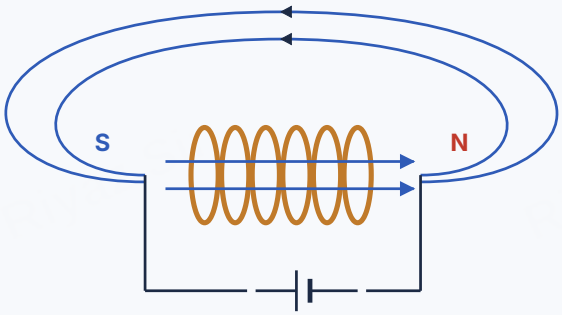
current out of page
field anticlockwise

current into page
field clockwise

Straight wire: circles around the wire. Use the right-hand grip rule — thumb along the current, fingers show the direction of the field.

- The field gets weaker with distance from the wire. A bigger current means a stronger field. **Reversing the current reverses the field.**

Solenoids and electromagnets



current in coil → field like a bar magnet
grip rule: curl fingers with the current, thumb points to N

A solenoid (coil) has a field like a bar magnet. Curl your fingers with the current and your thumb points to the N end.

- To make an electromagnet **stronger**: more turns, more current, or a soft iron core.
- Switch off the current and a soft iron electromagnet **loses its magnetism**, which makes it useful for lifting scrap.
- EXT Inside the solenoid the field is strong and uniform. Changing the current changes the field strength, and reversing the current reverses the field direction.

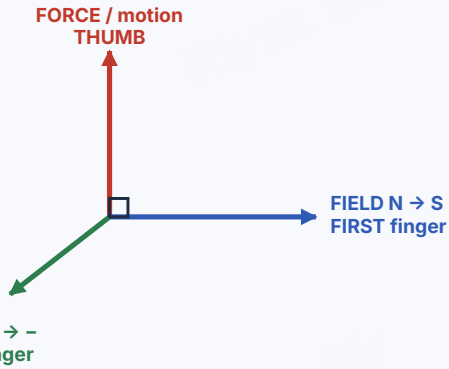
Relay and loudspeaker

- **Relay:** a small current in a coil magnetises a soft iron core. This pulls a lever (the armature) which closes the contacts of a second circuit carrying a large current. It lets a thin, safe switch control a powerful device.
- **Loudspeaker:** a coil attached to a paper cone sits in the field of a permanent magnet. The alternating current in the coil makes a changing force, so the cone vibrates and makes sound waves.

3 Force on a current

The motor effect

- A wire carrying a current in a magnetic field feels a **force**, because the field of the wire interacts with the field of the magnet.
- **Experiment:** a wire rests on rails between the poles of a magnet. When the current is switched on the wire rolls along the rails. **Reversing the current or the field reverses the force.**
- The force is bigger with a bigger current and a stronger magnet.

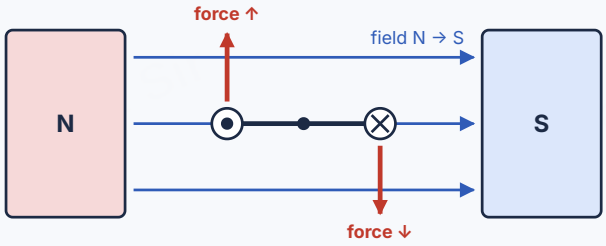


use your LEFT hand · thumb, first and second fingers at right angles

EXT Fleming's left-hand rule: thumb = force (motion), first finger = field (N to S), second finger = current (+ to –).

- EXT A beam of charged particles is also a current. Electrons are negative, so the conventional current points **opposite** to their motion.

The d.c. motor



the coil turns clockwise
current out of page on the left · into page on the right

The coil has current out of the page on one side and into the page on the other, so the forces are opposite and the coil turns.

- The turning effect is bigger with **more turns on the coil, a bigger current and a stronger magnetic field**.

- EXT **Split-ring commutator:** every half turn the two halves of the ring swap brushes, so the current in the coil reverses. The force on each side then keeps turning the coil the same way.

split-ring commutator + carbon brushes
every half turn the two halves swap brushes, so the current in the coil reverses

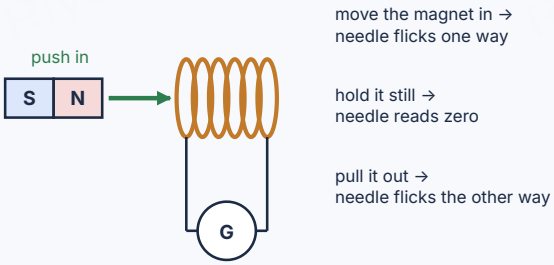


→ the force always pushes the coil the same way round
(the brushes stay still; the ring turns with the coil)

EXT The brushes stay still. The ring turns with the coil.

4 Electromagnetic induction

Making electricity from movement

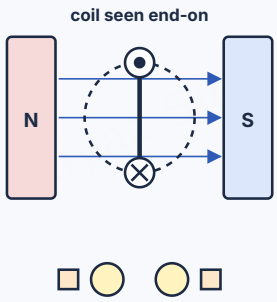


faster · stronger magnet · more turns → bigger induced e.m.f.

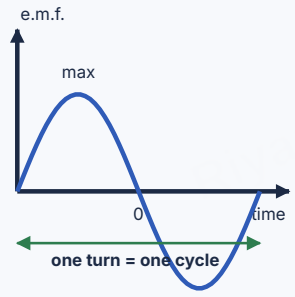
Move a magnet into a coil connected to a meter and the needle flicks. Hold it still and the reading is zero. Pull it out and the needle flicks the other way.

- An **e.m.f. is induced** when a conductor cuts magnetic field lines, or when the field through a coil changes. If the circuit is complete, a current flows.
- A bigger induced e.m.f. needs: **faster movement, a stronger magnet, more turns** on the coil.
- Reversing the direction of the movement (or the magnet) reverses the induced e.m.f.
- EXT **The induced e.m.f. opposes the change that causes it.** Pushing a N pole into a coil makes that end of the coil a N pole, which repels the magnet — so you must do work, and energy is conserved.

The a.c. generator



slip rings + brushes



max (reversed)

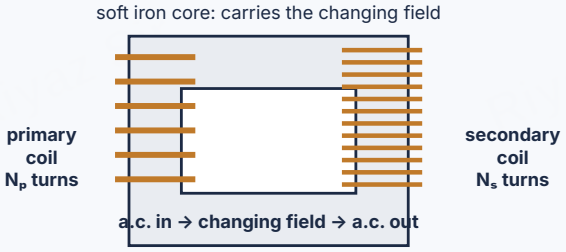
max when the sides cut the field fastest
zero when they move along it

A coil spins in a magnetic field. The e.m.f. is largest when the sides cut across the field lines fastest, and zero when they move along them.

- A coil (or a magnet) rotates, so the field through the coil keeps changing and an e.m.f. is induced. **Slip rings and brushes** connect the spinning coil to the outside circuit.
- The output is an **alternating** e.m.f. (a sine wave). It is **zero** when the coil is perpendicular to the field and at a **peak** (positive or negative) when the coil is parallel to the field.
- Spinning **faster** gives a bigger peak and a higher frequency. More turns or a stronger magnet also give a bigger e.m.f.

5 Transformers

How a transformer works



$$V_p \div V_s = N_p \div N_s$$

more turns on the secondary → step-UP (higher voltage)
fewer turns on the secondary → step-DOWN

Two coils wound on a soft iron core. An a.c. in the primary makes a changing magnetic field in the core, which induces an a.c. in the secondary.

- **Step-up:** more turns on the secondary, higher voltage out. **Step-down:** fewer turns on the secondary, lower voltage out.
- It only works with **a.c.**, because the magnetic field must keep changing to induce an e.m.f.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

p = primary, s = secondary, V = voltage, N = number of turns

EXT $I_p V_p = I_s V_s$

power in = power out for a 100% efficient transformer

WORKED EXAMPLE

A transformer has 1150 turns on the primary, connected to 230 V. How many turns does the secondary need to give 10 V?

1. $V_p \div V_s = N_p \div N_s$
2. $230 \div 10 = 1150 \div N_s$
3. **$N_s = 1150 \times 10 \div 230 = 50$ turns (a step-down transformer)**

WORKED EXAMPLE

EXT **A 100% efficient transformer has 240 V across its primary. The secondary gives 12 V to a lamp, with a current of 2.0 A. Find the primary current.**

1. Power out = $I_s V_s = 2.0 \times 12 = 24$ W
2. Power in = 24 W, so $I_p = P \div V_p = 24 \div 240$
3. **= 0.10 A**

The power grid



high voltage → low current → little energy lost as heat ($P = I^2R$)

transformers only work with a.c. (a changing field is needed)

power stations make a.c. at ~25 kV; the grid carries 400 kV; homes receive 230 V

Power stations generate a.c. Step-up transformers raise the voltage for the cables, and step-down transformers lower it again for homes.

- Transmitting at **high voltage** means a **low current** for the same power ($P = IV$), so much less energy is lost as heat in the cables.
- EXT The power lost in a cable is $\mathbf{P = I^2R}$. If the voltage is ten times higher, the current is ten times smaller and the power lost is **one hundred times** smaller.

WORKED EXAMPLE

EXT **100 kW is sent through a cable of resistance 2.0 Ω. Compare the power lost at 1000 V and at 10 000 V.**

1. At 1000 V: $I = P \div V = 100\,000 \div 1000 = 100$ A
2. loss $= I^2R = 100^2 \times 2.0 =$ **20 000 W**
3. At 10 000 V: $I = 10$ A
4. loss $= 10^2 \times 2.0 =$ **200 W**
5. **100 times smaller**

- High-voltage transmission also lets you use thinner, cheaper cables.

Riyaz Sir

6 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. What is the only sure test for a magnet?
2. Name two ways of making an electromagnet stronger.
3. Which wires of a motor are swapped every half turn, and by what?
4. Why can a transformer not work with d.c.?
5. Name three ways of increasing the e.m.f. induced in a coil.
6. Where does the fuse go in a plug?

EXAM-STYLE

7. A transformer has 500 turns on the primary and 100 turns on the secondary, and 240 V on the primary. Find the secondary voltage.
8. Describe how a relay lets a small current switch a large current. [3]
9. EXT An electron beam moves to the right through a magnetic field pointing into the page. State the direction of the force on the beam and explain. [2]
10. Explain why power is transmitted at high voltage. [3]

Show answers

1. Repulsion with another magnet.
2. more turns, a bigger current, or a soft iron core
3. The coil connections are swapped between the brushes by the split-ring commutator.
4. The field in the core must keep changing to induce an e.m.f.; a steady d.c. gives a steady field.
5. move the magnet faster, use a stronger magnet, use more turns
6. the live wire
7. $V_s = V_p \times N_s \div N_p = 240 \times 100 \div 500 = 48$ V
8. The small current magnetises the soft iron core of a coil
   which pulls the iron armature
   closing the contacts of a second circuit that carries the large current
9. Electrons moving right are a conventional current to the left
   using Fleming's left-hand rule, with the field into the page and the current to the left, the force is downwards
10. High voltage means a low current for the same power
    the heating loss in the cables is I^2R
    so much less energy is wasted

Stuck on a question?

Send it to me on WhatsApp. I read every message.

Want regular help? Send this to your parent →

Share with a friend

Ask Riyaz Sir