

AQA GCSE Physics (Separate Science) Unit 7: Magnetism and Electromagnetism

Poles of a Magnet

A magnet has two ends called **poles**: the **north pole** and the **south pole**. The magnetic forces of the magnet are strongest at the poles.



When two magnets are brought close together, they will **attract** or **repel**, depending on which poles are brought together:

- **Like poles** will **repel** one another e.g. N-N or S-S.
- **Opposite poles** will **attract** e.g. N-S.

The forces exerted between the poles of two magnets are a type of **non-contact force**: the magnets do not have to be touching for the effect to be observed.

Remember that only **iron**, **cobalt** and **nickel** (or alloys containing these metals) are magnetic.

A **permanent magnet** is one with its own magnetic field. The magnetism cannot be turned on or off e.g. a bar magnet or a horseshoe magnet.

An **induced magnet** is a material which becomes magnetic only when placed within a magnetic field. Induced magnets only attract other materials and lose most (if not all) of their magnetism when removed from the magnetic field e.g. iron filings.

Magnetic Fields

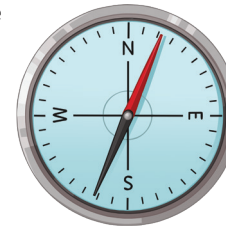
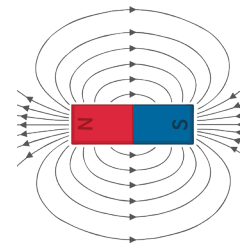
The **magnetic field** is the area surrounding a magnet where the force is acting on another magnet or magnetic material. It can be observed using a compass placed at different points around a bar magnet. The field lines can be drawn by using the compass to mark the direction at a range of points.

A magnet always causes a magnetic material to be **attracted**. The strength of the magnetic field is determined by the proximity to the magnet.

When looking at a diagram of magnetic field lines, the force is strongest where the lines are closest together. The magnetic field of the magnet is strongest at the poles. The direction of the magnetic field shows the direction the force would act on another north pole.

As a result, magnetic field lines always come away from the north pole (like poles repel) and towards the south pole (unlike poles attract).

The earth produces a magnetic field and a magnetic compass uses this to help aid navigation. The core of the earth is made of iron (a magnetic material). A compass contains a small bar magnet shaped as a needle, which points in the direction of the earth's magnetic field.

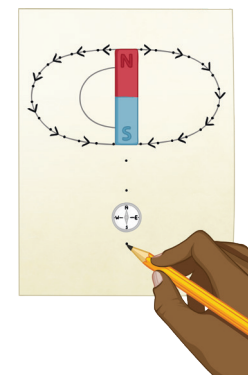


Plotting Magnetic Field Lines

A magnetic compass can be used to plot and draw the magnetic field lines around a magnet.

You should be able to describe this method for a bar magnet.

1. Place the bar magnet in the centre of a sheet of plain paper.
2. Using a magnetic compass, position it on the paper somewhere around the magnet.
3. Observe the direction of the needle and carefully draw a dot at the circumference of the magnet, in line with each end of the needle. Make sure you include an arrow to indicate the direction of north.
4. Repeat steps 2 and 3 for several positions around the magnet.
5. Join the arrows to complete the magnetic field lines and whole pattern.



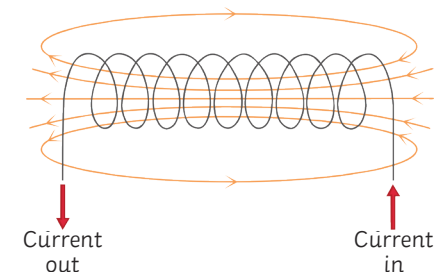
Electromagnetism

A circular **magnetic field** is produced when a current is passed through a conducting wire. This produces an **induced magnet**.

Switching off the current causes the magnetism to be lost.

The strength of the magnetic field can be increased by increasing the current flowing through the wire. The strength of the magnetic field is stronger closer to the wire.

Coiling the wire to form a **solenoid** will also increase the strength of the magnetic field. The strength of the magnetic field created by a solenoid is strong and uniform throughout.

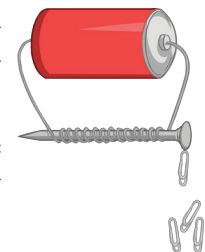


To increase the strength of the magnetic field around a solenoid you can...

- add an iron core;
- increase the number of coils in the wire;
- increase the current passing through the wire.

An **electromagnet** is a solenoid with an iron core. Electromagnets are **induced magnets** and can be turned on and off.

Electric motors, loudspeakers, electric bells and remotely controlled door locks all use **electromagnets**.



The Motor Effect and Fleming's Left-Hand Rule

When a wire carrying a current is exposed to the magnetic field of another magnet, then a **force** is produced on the wire at a **right angle** to the direction of the magnetic field produced.

This is called the **motor effect**.

The force produced by the motor effect can be calculated using this equation:

$$\text{force (N)} = \text{magnetic flux density (T)} \times \text{current (A)} \times \text{length (m)}$$

For example:

A current of 8A is flowing through a wire that is 75cm long. The magnetic field acting at a right angle on the wire is 0.5T. Calculate the force.

$$F = B \times I \times l$$

Remember: the equation uses length measured in m. The question gives you the length in cm so you need to convert it before you calculate your answer.

$$F = 0.5 \times 8 \times 0.75$$

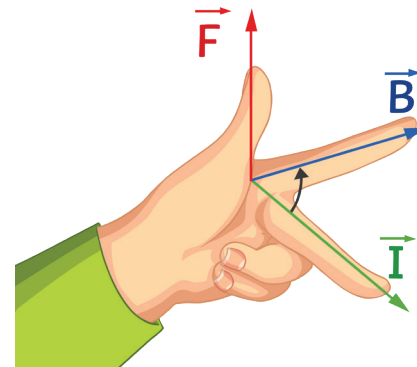
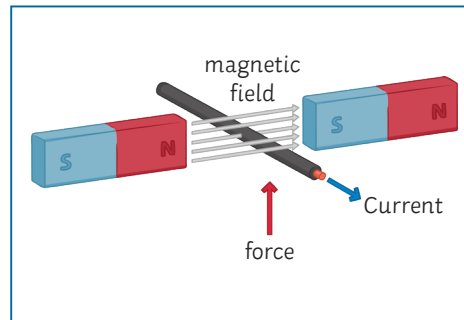
$$F = 3\text{N}$$

From the equation we can see that the force acting on a given length of wire (e.g. 1m) will be increased if the current increases or the magnetic flux density increases. If the current flowing through a wire is **parallel** to the magnetic field, then **no force** is produced – there is no motor effect.

You might be shown a diagram and asked to indicate the direction of the force produced. **Fleming's left-hand rule** can help you do this because it represents the **relative orientation** of the force produced by the motor effect.

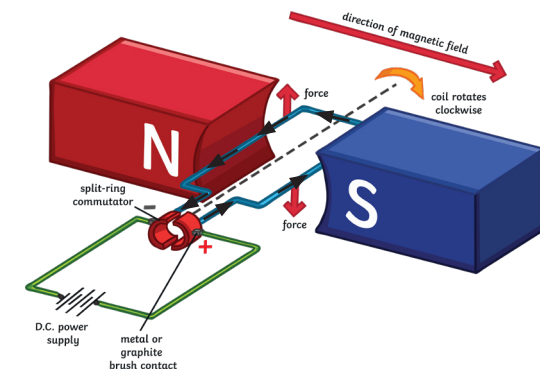
Remember:

- Use your **left hand!**
- The angle between your index finger and middle finger should be a **right angle** on the horizontal plane.
- The angle between your index finger and thumb should be a **right angle** on the vertical plane.
- Your **thumb** represents the direction of the **force**.
- Your **index finger** represents the direction of the **magnetic field**.
- Your **middle finger** represents the direction of the **current** flowing through the wire.



Electric Motors

When the wire carrying the current is **coiled**, the motor effect acting on it causes the wire to **rotate**. This is how an **electric motor** works.



As the **current** flows (from negative to positive), the force produced in each side of the coil acts in **opposite directions**, causing the coil to **rotate** overall.

When the coil reaches a **vertical position**, the force produced is now **parallel** to the magnetic field line and so would be **zero**. This would cause the motor to stop rotating.

To maintain the rotation of the coiled wire, a **split ring commutator** is used to supply the current to the wire. The DC supply reaches the split ring via graphite or metal **brushes** which maintain the connection while allowing it to rotate freely on the **axle**.

The two halves of the split ring commutator ensure that the **current supplied** to the wire **changes direction** each half-turn (or that the current supplied is the same direction on each side of the motor) and as a result, the force produced maintains a **constant rotation** in one direction overall.

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Headphones and Loudspeakers

Headphones work because they contain small loudspeakers inside them. A loudspeaker makes use of the motor effect to produce sound. Variations in the AC electric current supplied to the device causes variations in the magnetic field produced. These variations cause the cone in the loudspeaker to move and the vibrations are transferred to the air particles and generate a sound wave.

- An alternating current is supplied through a coil of wire in the loudspeaker.
- This produces an electromagnetic field around the wire.
- The electromagnetic field interacts with the magnetic field of the surrounding permanent magnetic and a force is produced (the motor effect).
- The force produced pushes the cone in the loudspeakers outwards.
- The current is reversed and the force changes direction, pulling the cone back inwards.
- The vibrations of the cone moving in and out creates vibrations in the air particles, which are transferred as sound waves.
- The sound waves produced match the electrical signals supplied.

Induced Potential and the Generator Effect

Induced potential or **electromagnetic induction** is when a **potential difference** (voltage) is created across a **conductor** (e.g. a wire) due to a change in the **magnetic field**.

If the conductor is connected in a **closed circuit**, then it will cause a **current** to flow.

Induced potential can be produced by either...

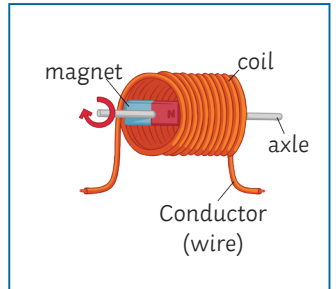
- moving a **magnet** in a **coil** of wire;
- moving an **electrical conductor** (wire) through **magnetic field lines**;
- moving a **coil** of wire in and out of a **magnetic field**.

Moving the conductor in the **opposite direction** or reversing the **polarity** of the magnet will cause the potential difference to reverse and the current will flow in the opposite direction.

Continuously moving the magnet or conductor to repeatedly change the direction of the potential difference is how an **alternating current** is produced.

A **generator** uses an induced potential to produce an alternating current.

A magnet on an axle is positioned in a coil of wire. The poles of the magnet are on the outer edges as the magnet is spun on the axle. Every half-turn on the axle rotation, the poles are reversed (swap sides in the coil) and this causes the induced potential to change direction. This produces an alternating current in the conducting wire.



To increase the voltage of a induced potential you can...

1. increase the **strength of the magnet** used;
2. increase the **number of turns** in the conducting coil of wire;
3. increase the **area** of the coil;
4. increase the **speed of the movement** (of the magnet or conductor).

Turning the magnet more quickly will not only increase the **voltage**, but also increase the **frequency**.

Transformers

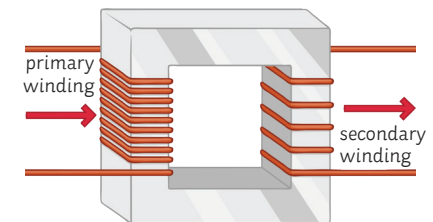
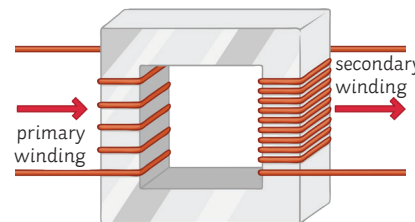
A **transformer** changes the **voltage** using an **induced potential** (electromagnetic induction).

Transformers only work for an **alternating current potential difference**. A transformer is simply **two coils of wire** (primary coil and secondary coil) connected by an **iron core**.

There are two main types:

Step-up transformers: increase (step-up) the **voltage**. There are fewer primary coils than there are secondary coils.

Step-down transformers: decrease (step-down) the **voltage**. There are more primary coils than there are secondary coils.



Transformers (continued)

A current doesn't flow through the **iron core**. The role of the iron core is to **transfer the changing magnetic field** between the two coils only.

When an **alternating current** is supplied to the primary coil, it produces a magnetic field with the iron core. The magnetic field in the iron core constantly changes direction due to the alternating current.

The voltage of the induced potential in the secondary coil depends on the ratio of turns between the primary and secondary coils:

- If there are **more turns** in the **secondary coil**, the **potential difference** will be **greater** (a step-up transformer).
- If there are **fewer turns** in the **secondary coil**, the **potential difference** will be **less** (a step-down transformer).

Remember: an **induced potential** can only be produced by a **changing magnetic field** so it only works with an **alternating current (AC)** and **not a direct current (DC)**.

The power supplied by a transformer can be calculated using the equations:

$$\text{power (W)} = \text{potential difference (V)} \times \text{current (A)}$$

Transformers are almost 100% efficient:

$$\text{electrical power in} = \text{electrical power out}$$

So...

$$\text{potential difference across primary coil} \times \text{current in the primary coil} = \text{potential difference across secondary coil} \times \text{current in the secondary coil}$$

This can also be written simply as:

$$V_p I_p = V_s I_s$$

Worked example:

Shannon is using her hair straighteners on holiday in Europe. A travel adaptor transforms the 110V AC mains supply to 230V. The current in the hair straighteners is 6A. Assuming the transformer is 100% efficient, calculate the current draw by the adaptor from the mains supply (in the primary coil). Give your answer to two decimal places.

$$V_p I_p = V_s I_s$$

$$110 \times I_p = 230 \times 6$$

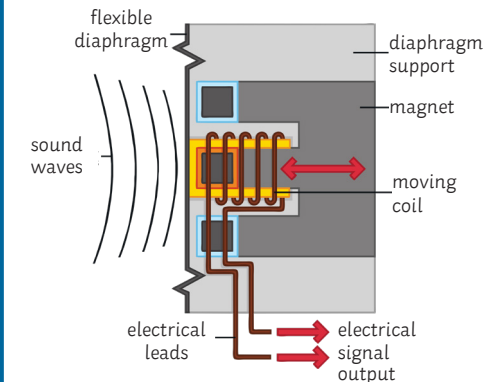
$$110 \times I_p = 1380$$

$$I_p = \frac{1380}{110}$$

$$I_p = 12.55\text{A}$$

Microphones

Essentially, a **microphone** works like a loudspeaker but uses the generator effect in reverse. Instead of using the alternating current to produce a changing magnetic field and cause movement in the cone, a microphone uses movement in a diaphragm to produce a changing magnetic field and create an alternating current.



- The **sound wave** vibrations in the air particles are transferred to the **flexible diaphragm**.
- This causes the diaphragm to move, **vibrating the coil**.
- The coil moves through the **magnetic field** of the **permanent magnet** and an **induced potential** is created.
- The induced potential causes a **current** to flow in the **closed circuit** which the coil is attached to.
- The induced potential changes to match the vibrations of the sound waves, which results in the current changing to match the induced potential, transferring the sound wave.