WJEC (Wales) Physics GCSE

1.9: Electromagnetism
Detailed Notes

(Content in **bold** is for higher tier **only**)

Magnetic Fields

Magnetic fields form around **magnets** but cannot be seen with the eye. **Magnets** exert **forces** upon magnetic objects that reside within their field (which flows from from their North pole to their South pole). These can be **attractive** or **repulsive** forces. **Iron filings** can be used to visually display the pattern of the magnetic field as the filings orient with the field lines.

Small **plotting compasses**, which show the direction of the magnetic field at a certain point, can be used to draw the shape of a magnetic field around a small magnetised object.
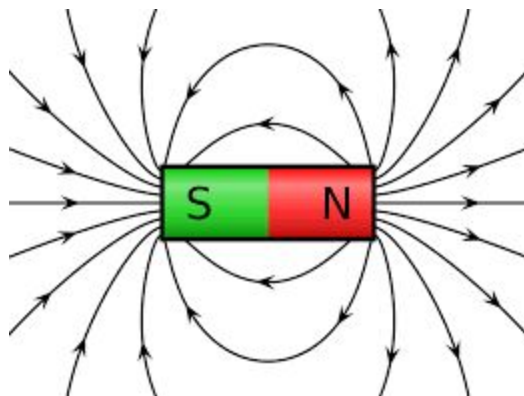
*Field lines around a single bar magnet (clipartart.com).*

Field lines must **always** have **arrows** showing their direction. The **greater the concentration** of field lines in an area, the **stronger** the magnetic field in that area.

The fields of two bar magnets will **interact** when brought into close proximity to one another. Two **like poles** will **repel** whereas two **opposite** poles will **attract**. When attracting, the field lines from the North pole will join up with the South pole on the other magnet.
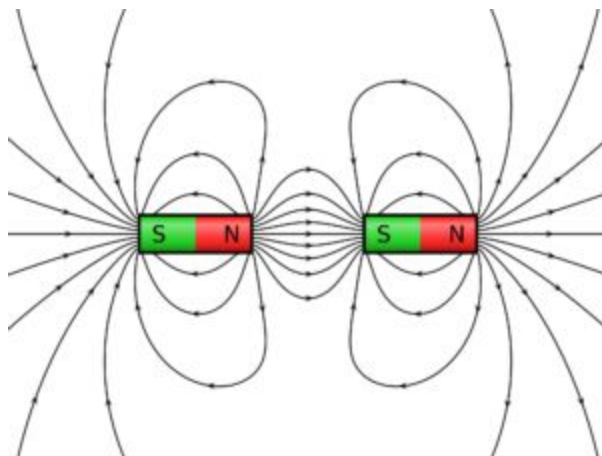
*Attraction between two like magnetic poles (toppr.com).*
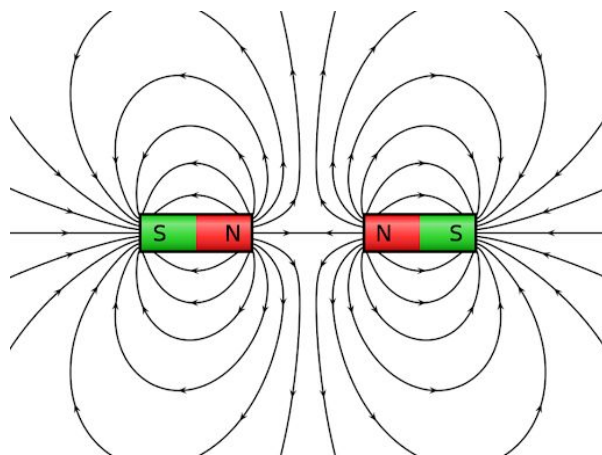
Repulsion between two like magnetic poles (physbot.co.uk).

Where the field lines are **equally spaced**, the magnetic field is said to be **uniform** as the **same force** is experienced everywhere.

Current

Current flowing in a wire produces a **magnetic field** around the wire. The direction of this field is dictated by the **'Right-hand Grip Rule'.** Plotting compasses on a piece of paper with a wire running through it will demonstrate this rule.
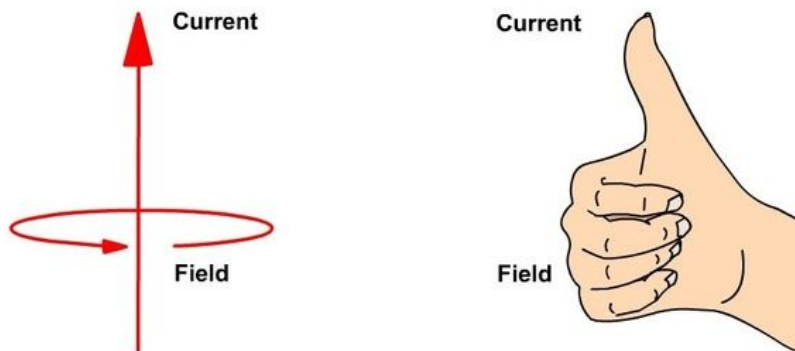
Right-hand Grip Rule for the magnetic field around a wire (Quora.com).

The strength of the force experienced in the magnetic field around a wire depends on the size of current flowing, the length of the wire (conductor) and magnetic flux density. Magnetic flux density is similar to the magnetic field strength and is measured in Tesla.

$$F = BIl$$

*F is force in Newtons (N), B is magnetic flux density in Tesla (T),
I is current in Amperes (A) and l is length of the conductor in meters (m).*

Solenoids

A solenoid is a **coil of wire** with a current flowing through it . The shape of the magnetic field around it is similar to that of a bar magnet. When the wire is wrapped into a coil a strong field is produced as many field lines are squeezed through a small area. This is not the case in a single wire, where field lines are more evenly dispersed.

Inserting an **iron core** in the centre of a solenoid increases its strength of the magnetic field induced.
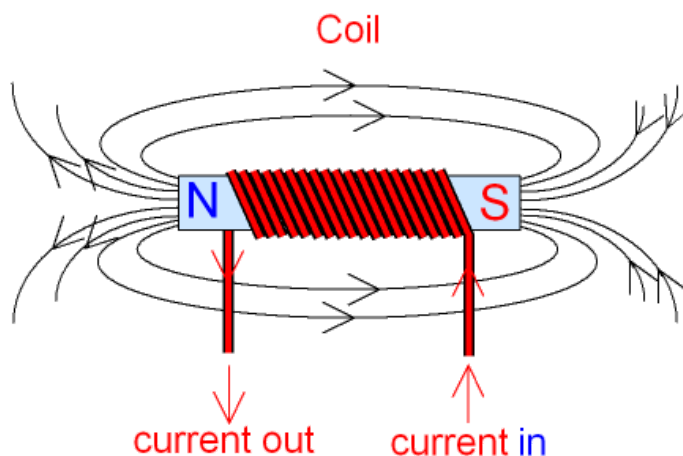
Magnetic field around a current-carrying coil of wire (gcsescience.com).

The Motor Effect

If a current carrying wire is placed in an external magnetic field **a magnetic force** may be exerted on the wire. This is the **motor effect**. When the wire is placed into a magnetic field so that the two fields sit at **right angles**, it will experience a **force at right angles** to the direction of current flow and to the magnetic field lines.
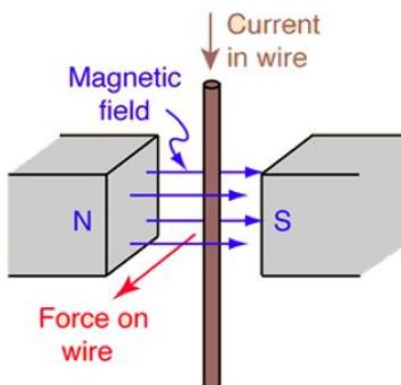
*The motor effect on a current-carrying wire (studyricket.co.uk).*

The direction of current, the magnetic field and force experienced all act at 90º to one another. **'Fleming's Left-hand Rule'** is an effective analogy, allowing us to figure out the directionality of any of these, provided the orientation of the other two is known.
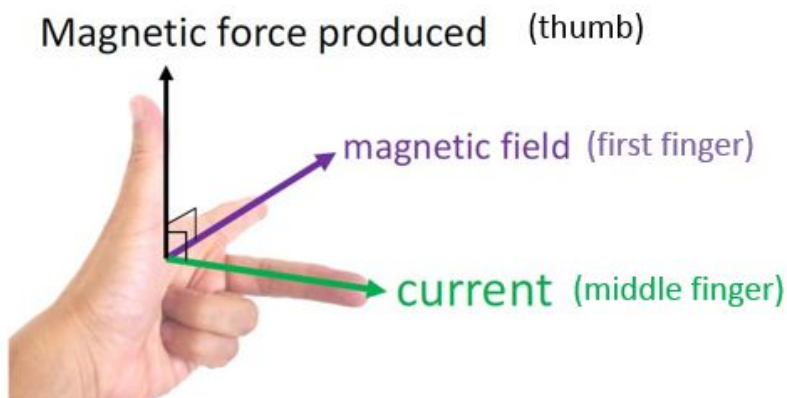
Fleming's Left-hand Rule (studyrocket.co.uk).

Electric Motors

Using this concept, simple electric motors can be built from a **loop of wire** that is free to **rotate** between two opposite, permanent magnetic poles. As the electric current flows through the coil, it **experiences a force** and moves.
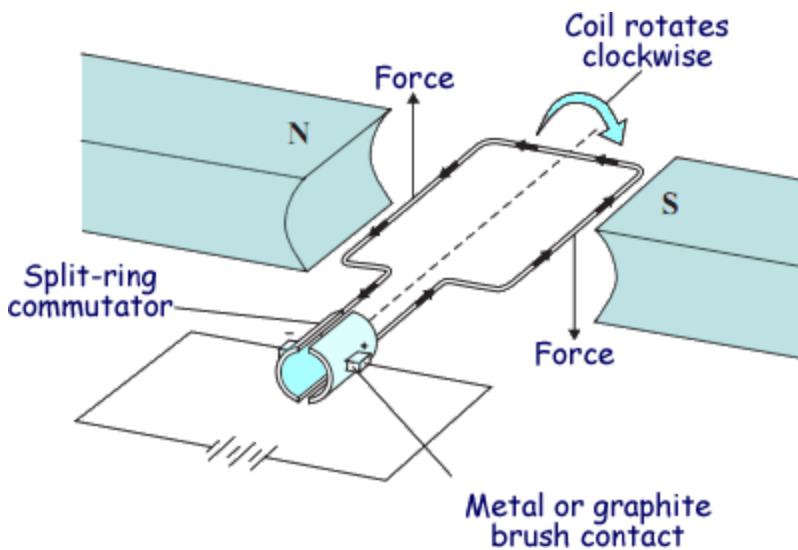
Simple electric motor using the motor effect (cyberphysics.co.uk).

The direction of the current has to be **reversed** for every **half turn** of the loop, otherwise its movement will stop. A conducting split ring called a **commutator** is used to do this. If a **coil** of wire is used instead of a single loop, the effect of the magnetic field **increases** as there are

more turns with current flowing through the magnetic field that may experience the magnetic force.

Electric Loudspeakers

A loudspeaker contains a **coil of wire** and **permanent magnets**. The coil of wire moves towards the permanent magnet when the speaker is switched on, as current flows through the coil creating an electromagnetic field.

This movement also **draws in the cone** of the speaker, creating **vibrations** which are then transmitted through the air as **sound waves**.
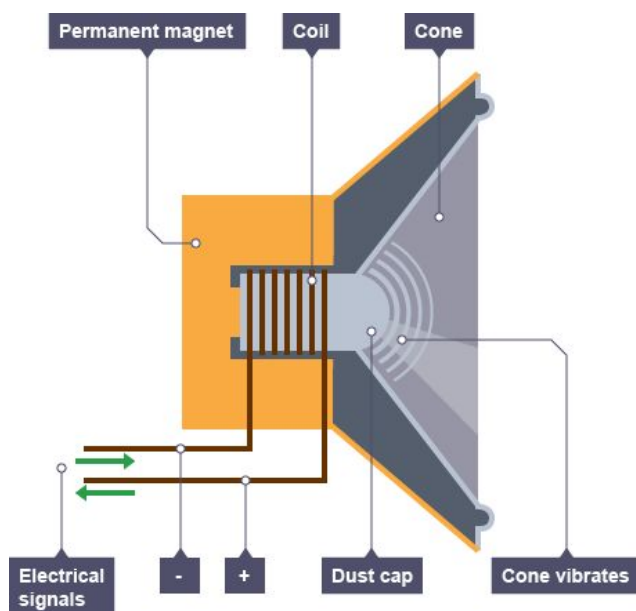
Electric loudspeaker components (bbc.co.uk).
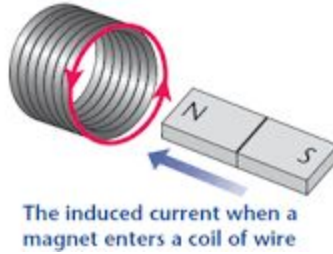
Electromagnetic Induction

Magnetic fields can be used to **generate** (induce) a current in a coil of wire. When a magnet is moved into the centre of the coil of wire, a **voltage is produced**. When the magnet is removed and moved out of the wire coil, a **reverse** voltage is produced. It can also be reversed when the **magnet direction** is reversed so that the other pole is moved into the coil.

Connecting the coil as part of a circuit means a **current** is able to be induced and flow in the circuit.

It is important to understand that there is **no voltage induced when the magnet is not moving**, even when inside the coil.
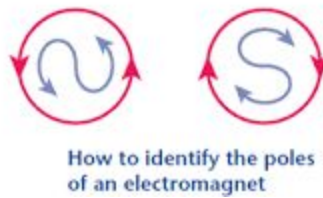
The size of the induced voltage can be **increased** by moving the magnet **faster**, increasing the **number of turns** on the wire coil or by increasing the **strength** of the magnet.

Electromagnetic induction (revisionworld.com).

The **direction of the current flow** and magnetic field relative to the direction of rotation of the wire coil can be found using the following method:

Using arrows to indicate the rotation of the coil can identify the pole (N or S)
and indicate the flow of current (revisionworld.com).

Generators

A generator uses a **magnetic field** and a **moving wire** to generate a current in a circuit. The movement of the wire, magnetic field and induced current all occur at **right angles** to one another. Therefore if the direction of the wire movement is **reversed**, the current induced will be in the **opposite direction**.
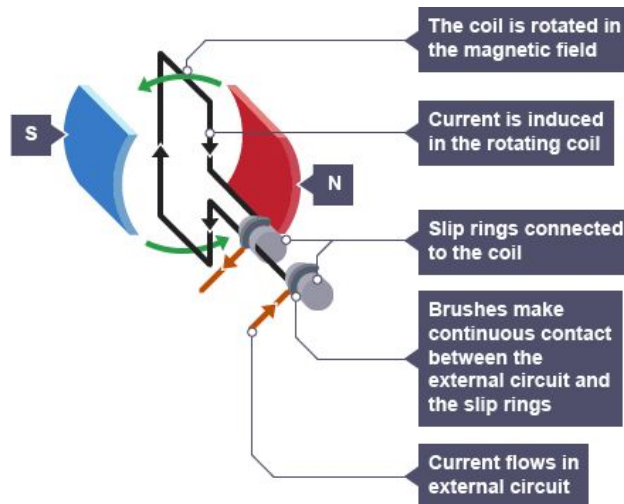
Electromagnetic AC generator (bbc.co.uk).

The use of a coil of wire means that for each half turn, one side of the coil moves **upwards** and the other side of the coil moves **downwards**. Therefore as the coil is rotated in the magnetic field, the **current induced changes direction** for every half turn of the wire. This is an **alternating current (AC)** where current and voltage are continually changing direction around a circuit.

The induced voltage can be increased by rotating the coil **faster**, including **more turns** of wire on the coil or by using **stronger magnets**. An **iron core** can also be added inside the coil to help increase the size of voltage induced.

Transformers

A transformer is a device used to **increase or decrease the voltage** in a circuit. **Two coils** of wire around a **soft iron core** use the concepts of electromagnetic induction to do this.

An alternating voltage is supplied to the first coil creating a **changing magnetic field**. This field is **transferred** through the soft iron core to the secondary coil. An **alternating voltage** is then **induced** in the secondary coil by this alternating magnetic field.

If there are **more turns** on the secondary coil, a **greater voltage** will be induced in that coil, creating a **step-up** transformer. If there are **fewer coils** on the secondary coil, a **step-down** transformer is produced, as a **smaller voltage** is induced on the secondary coil. This shows how the induced voltage depends on the **number of turns** on the coil and the **input voltage**.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

V_1 is the voltage in the primary coil (V), V_2 voltage in the secondary coil (V),
N_1 the turns on the primary coil and N_2 the turns on the secondary coils.

This equation is only accurate when the transformer has near **100% efficiency**.