EXAM PAPERS PRACTICE

Edexcel Physics IGCSE

Topic 6: Magnetism and Electromagnetism

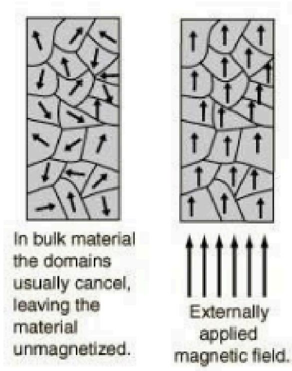
Summary Notes

(Content in **bold** is for physics only)

Magnetism

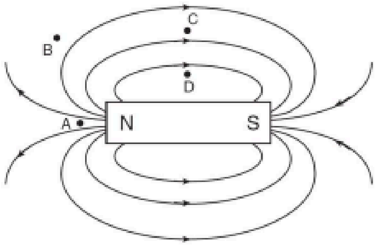
Magnets **repel and attract other magnets** and **attract magnetic materials.** Like poles of magnets repel and opposite poles attract.

- Non-magnetic materials are materials that are not attracted to magnets and cannot be magnetised (e.g. glass, plastic)
- Magnetic materials are materials that are attracted to magnets and can be magnetised (e.g. iron, steel, cobalt, nickel)
  - Magnetism can be **induced** in magnetic materials by **placing** them in a **magnetic field.**
  - Magnetic materials that can be **permanently** magnetised are described as **magnetically hard** (e.g. **steel**). Magnetic materials that are only **temporarily** magnetised are described as **magnetically soft** (e.g. **soft iron**).

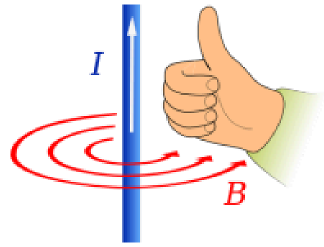


Magnetic field lines:

- **Magnetic field lines** represent the **magnetic force** on a **north pole** at a given point.
  - The **direction** of a magnetic field line shows the **direction** of the force.
  - How **close together** the magnetic field lines are shows the **magnitude** of the force.
- **Field lines** from magnets point **from north to south.**
  - The field lines of a bar magnet are shown in the diagram.
  - There is a **uniform** magnetic field between the opposite poles of two magnets placed close together, as the field lines move from the north pole of one straight towards the south pole of the other. The field lines are **parallel** and **evenly spaced**.



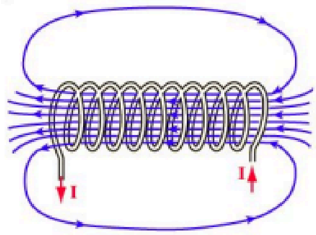
Electromagnetism

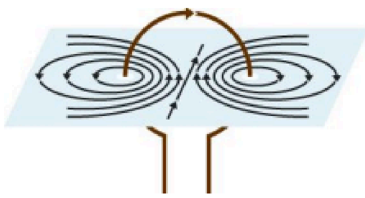


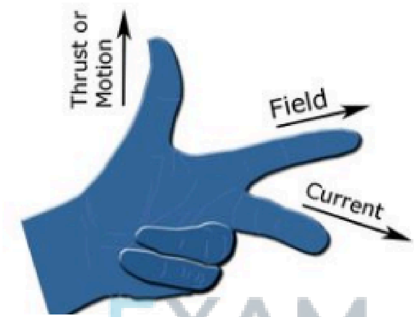
An **electric current** passing through a **conductor** produces a **magnetic field** around it.

Electromagnets consist of a coil of wire wrapped around a magnetically soft core and can be turned on and off.

- **The right-hand grip rule determines the direction of the magnetic field produced by a current carrying wire, shown in the first diagram.**
- **The magnetic field created by a current carrying solenoid is like the field produced by a bar magnet, shown in the second diagram.**
- **The magnetic field created by a current carrying flat circular coil is shown in the third diagram.**







A **force** acts on a **current-carrying conductor** in a magnetic field. **Fleming's left-hand rule** shows the relative directions of the force, field, and current…

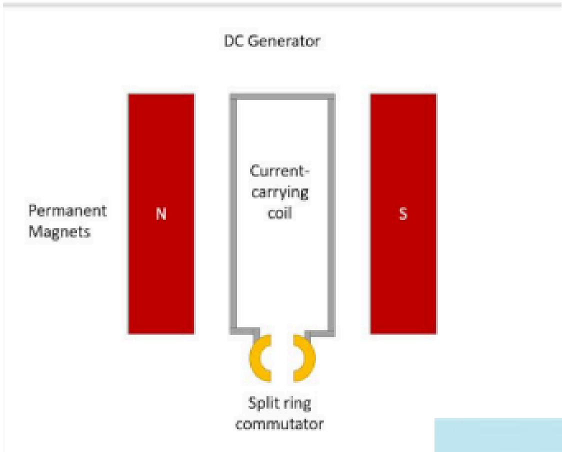
This is called the **motor effect**.

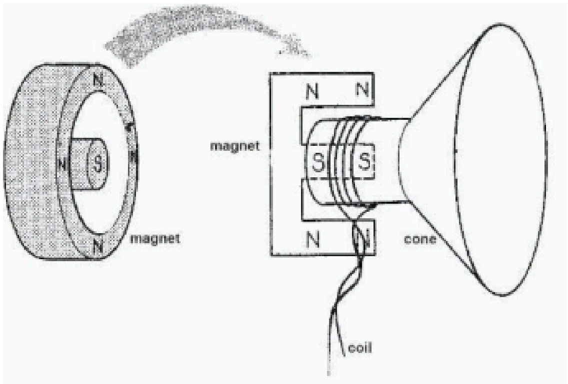
- If the **current** is **reversed** or the **magnetic field** is **reversed,** the **force** will be **reversed.**
- If the **magnitude** of the **current** or of the **magnetic field** is **increased,** the **magnitude** of the **force** will **increase.**

DC motors consist of a coil of wire in between two permanent magnets. **Direct current** flows through the wire and it experiences a **turning effect** due to the forces exerted on it in the magnetic field. As the current flows in opposite directions on each side of the coil, the forces on each side are in opposite directions - making it turn. The turning effect can be increased by:

- increasing the current
- using a stronger magnetic field
- increasing the number of turns on the coil.

A **split ring commutator** is used to ensure that the **direction** that the **current** flows in the coil reverses every half turn.





Loud speakers consist of a coil attached to a cone in a magnetic field. When **alternating current** flows through the coil, the cone is continuously pushed away and pulled back, making a **sound.** The **frequency** (and therefore pitch) of the sound can be altered by changing the frequency of the alternating current used.

A force is also exerted on charged particles moving in a magnetic field (because moving charged particles are current) as long as they are not moving parallel to the field.

Electromagnetic induction

- When there is relative movement between a conducting wire & a magnetic field, a voltage will be induced. For example, if conducting wire **moves across a magnetic field,** a voltage is induced in it. If it is part of a complete circuit, this causes a current to flow.

This is called the **generator effect**.

- The induced voltage can be increased by:
  - moving the wire **more quickly,**
  - using a **stronger magnetic** field,
  - or **increasing the length** of the wire inside the magnetic field (eg. by making it more coiled).
- A voltage is also induced in a coil with a **changing magnetic field** through it. For example, when a magnet is moved into a coil, a voltage is induced in it.
  - The **more quickly** the magnetic **field changes,** the **greater** the **voltage.**

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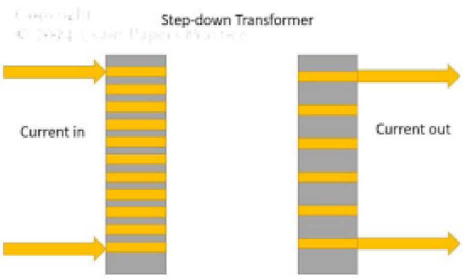
Electricity can be generated by **rotating a magnet** within a **coil** or by **rotating a coil** in a **magnetic field.** As they rotate, the magnetic field through the coil **changes,** which induces a **voltage** and therefore a **current** in the coil. The voltage can be increased by:

- **increasing the length of wire inside the magnetic field** (eg. by using a larger area, more turns or a longer wire)
- using a **stronger magnet**
- **increasing the speed** of rotation.

A transformer consists of two coils wrapped around a soft iron core and is used to change the size of a voltage.
They are used to:

- **step up the voltage (to a greater value) for transmission in power lines which reduces power loss (because lower current causes less power loss due to the resistance of the cables)**
- **then step down the voltage for usage in homes (to keep us safe)**

- **An alternating voltage produces an alternating current in the primary coil. This creates a changing magnetic field which links with the secondary coil and induces an alternating voltage in it.**
- **A step-up transformer has more turns on the secondary than the primary which means the voltage of the secondary is greater than that of the primary. A step-down transformer has fewer turns on the secondary than the primary which means the voltage of the secondary is less than that of the primary.**
- $\frac{primary\ voltage}{secondary\ voltage} = \frac{primary\ turns}{secondary\ turns}$
- **For a 100% efficient transformer, because the power used is constant,** $V_p I_p = V_s I_s$



Magnetic Fields and Their Properties

Definition: A magnetic field is a region around a magnet where magnetic forces can be observed.

Magnetic Field Lines:

- Magnetic fields can be represented by lines of force, known as magnetic field lines. The direction of these lines indicates the direction of the magnetic force, while the density of the lines indicates the strength of the field.
- Inside a magnet, magnetic field lines run from the south pole to the north pole, and outside the magnet, they loop back from the north to the south.

Key Properties:

- **Direction:** The magnetic field direction can be determined using the right-hand rule; if you curl the fingers of your right hand in the direction of the current, your thumb points in the direction of the magnetic field.
- **Strength:** The strength of the magnetic field decreases with distance from the magnet. The strength can also vary with the material surrounding the magnet, with ferromagnetic materials enhancing the magnetic field.

SI Unit: The unit of magnetic field strength is the Tesla (T), which is defined as one weber per square meter.

Electromagnets

Definition: An electromagnet is a type of magnet in which the magnetic field is produced by an electric current.

Construction:

- Electromagnets consist of a coil of wire (solenoid) wound around a core made of ferromagnetic material (like iron).
- When an electric current flows through the wire, a magnetic field is created around the coil.

Factors Affecting Strength:

- **Number of Coils:** Increasing the number of turns in the coil increases the strength of the magnetic field.
- **Current:** The strength of the magnetic field is directly proportional to the amount of electric current passing through the wire.
- **Core Material:** Using a ferromagnetic core enhances the magnetic field strength compared to using an air core.

Applications: Electromagnets are widely used in devices such as electric motors, magnetic locks, and relays.

The Motor Effect

Definition: The motor effect refers to the phenomenon where a current-carrying conductor placed in a magnetic field experiences a force.

Formula for Force: The force (F) experienced by the conductor can be calculated using the formula:

$$F = BIL\sin(\theta)$$

Where:

- B = magnetic field strength (in tesla, T)
- I = current (in amperes, A)
- L = length of the conductor in the magnetic field (in meters, m)
- θ = angle between the direction of the magnetic field and the current.

Key Points:

- The direction of the force can be determined using the right-hand rule: point your thumb in the direction of the current and your fingers in the direction of the magnetic field; your palm will point in the direction of the force.
- The motor effect is the principle behind electric motors, where electrical energy is converted into mechanical energy.

Applications: Electric fans, hard disk drives, and various types of machinery use the motor effect to operate.

Induction and Electromagnetic Induction

Definition: Electromagnetic induction is the process of generating an electromotive force (emf) in a conductor when it is exposed to a changing magnetic field.

Faraday's Law:

- Faraday's law states that the induced emf ($\mathcal{E}$) in a circuit is directly proportional to the rate of change of magnetic flux (Φ) through the circuit:

$$\mathcal{E} = -\frac{d\Phi}{dt}$$

Where:

- $d\Phi$ = change in magnetic flux (in webers, Wb)
- dt = change in time (in seconds, s).

Key Concepts:

- A change in the magnetic field strength, movement of the conductor, or the orientation of the conductor in the magnetic field can induce an emf.
- The negative sign indicates the direction of the induced emf is such that it opposes the change in magnetic flux (Lenz's Law).

Applications: Induction is used in transformers, electric generators, and inductive charging systems.

Applications of Magnetism in Technology

Definition: Magnetism plays a crucial role in various technologies that are essential in everyday life.

Key Applications:

- **Magnetic Resonance Imaging (MRI):** Utilizes strong magnetic fields and radio waves to create detailed images of organs and tissues inside the body.
- **Data Storage Devices:** Hard drives and tapes use magnetic fields to store data, with tiny magnetic domains representing binary information.
- **Maglev Trains:** Use magnetic levitation to lift and propel the train along the track, reducing friction and allowing for higher speeds.

Advantages:

- Technologies utilizing magnetism can offer improved efficiency, accuracy, and safety in various fields, such as medicine, computing, and transportation.

Challenges:

- Limitations include the need for strong magnets and the challenges in developing materials that can maintain magnetic properties at high temperatures.