Edexcel GCSE Physics

Your notes

Electromagnetism & The Motor Effect

Contents

Magnetic Fields in Wires

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The Field around a Wire

- When a **current** flows through a conducting wire a **magnetic field** is produced around the wire
  - A conducting wire is any wire that has **current** flowing through it
- The shape and direction of the magnetic field can be investigated using plotting compasses
  - The compasses would produce a magnetic field lines pattern that would like look the following

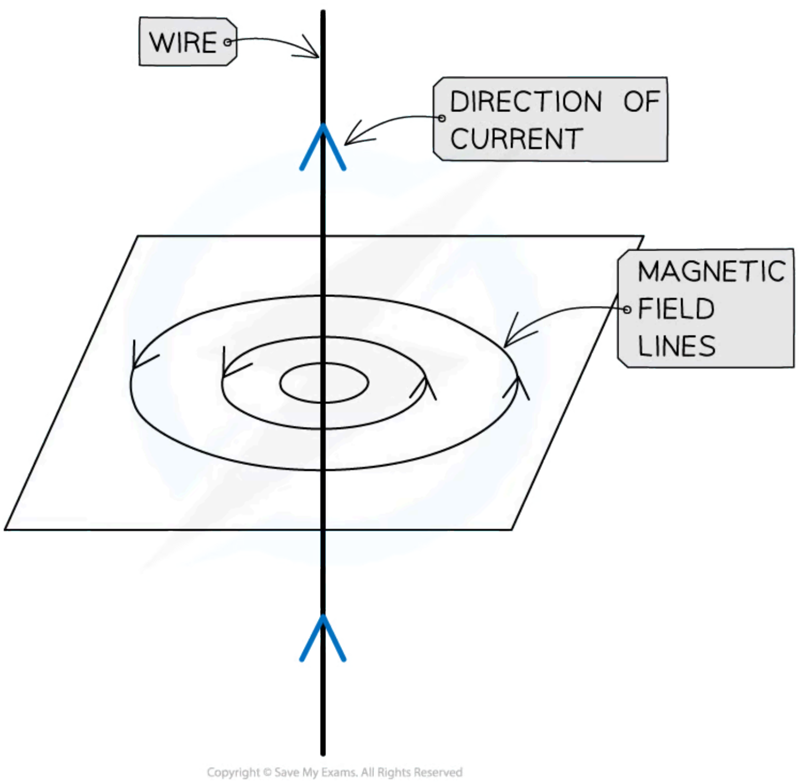
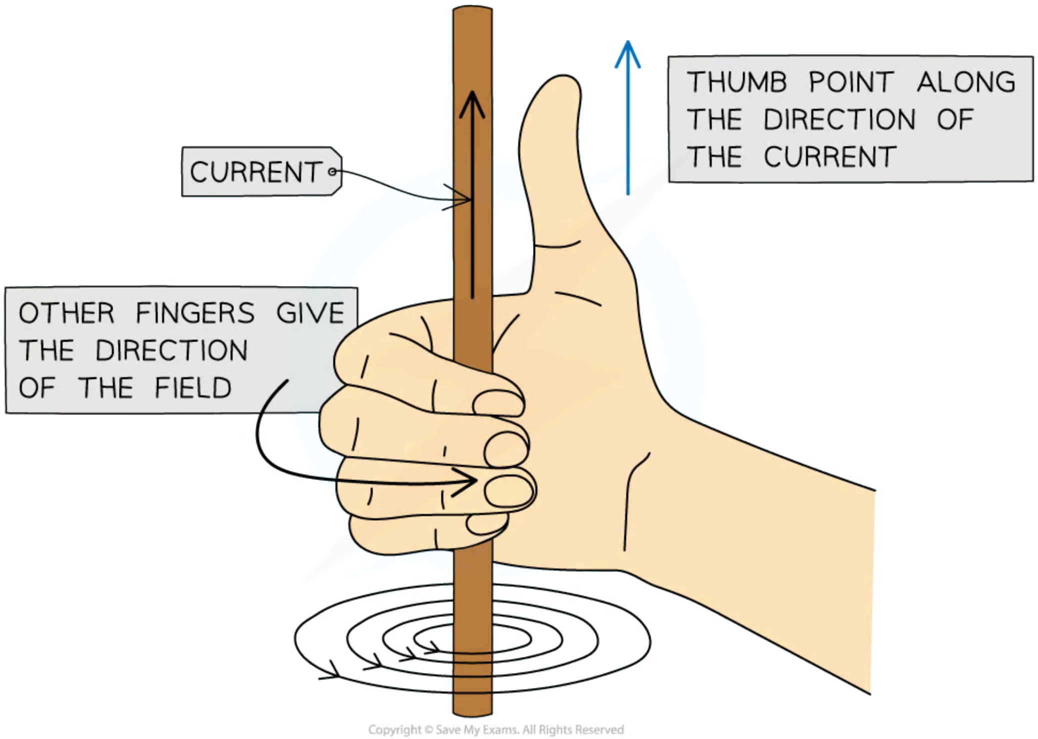


Diagram showing the magnetic field around a current-carrying wire

- The magnetic field is made up of **concentric circles**
  - A circular field pattern indicates that the magnetic field around a current-carrying wire has **no poles**
- As the distance from the wire increases the circles get further apart

- This shows that the magnetic field is strongest closest to the wire and gets weaker as the distance from the wire increases
- The **right-hand thumb rule** can be used to work out the **direction** of the magnetic field



The right-hand thumb rule shows the direction of current flow through a wire and the direction of the magnetic field around the wire

- Reversing the direction in which the current flows through the wire will **reverse the direction** of the magnetic field

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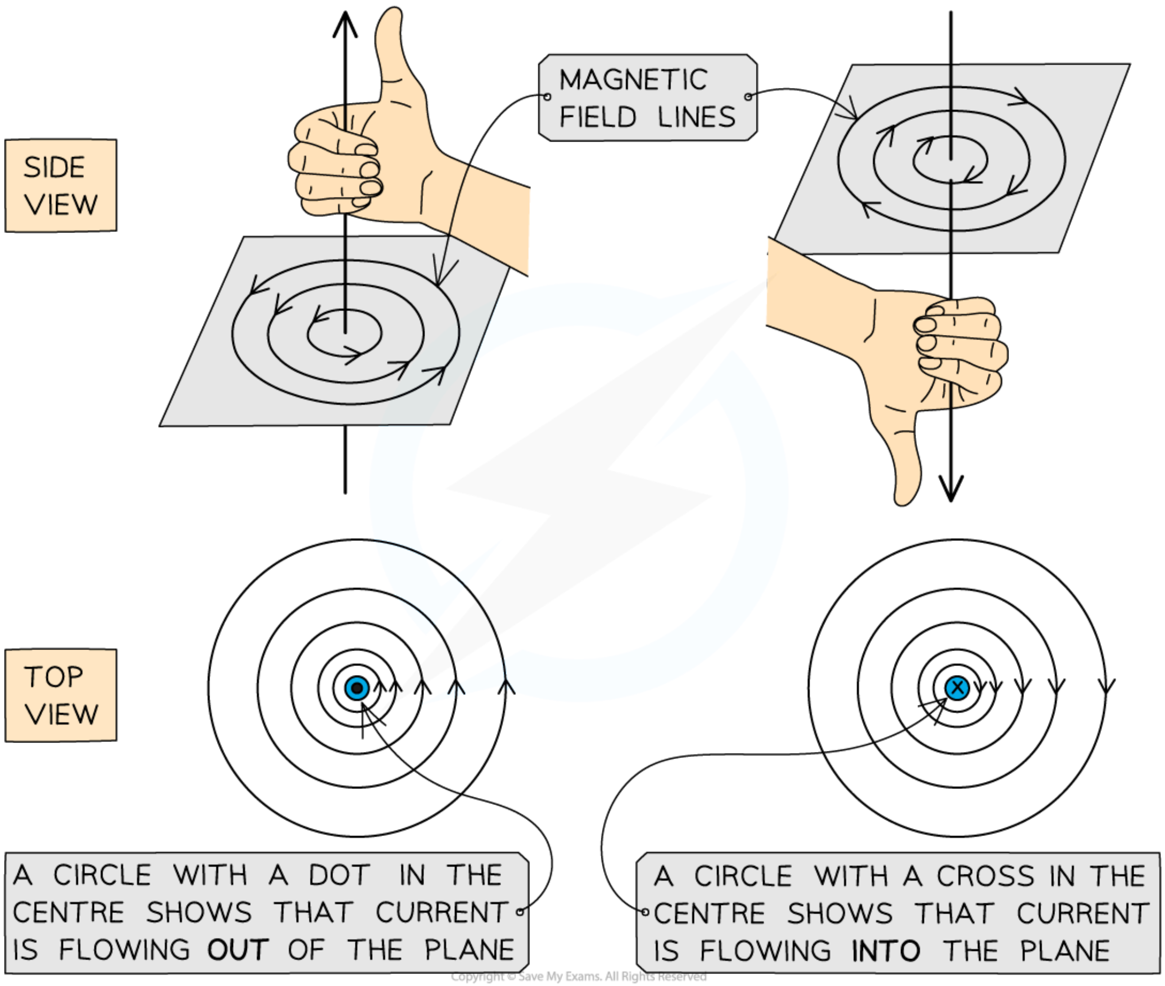

Side and top view of the current flowing through a wire and the magnetic field produced

- If there is **no current** flowing through the conductor there will be **no magnetic field**
- Increasing the amount of current flowing through the wire will increase the strength of the magnetic field
  - This means the field lines will become **closer together**

Factors Affecting Field Strength

- The strength of the magnetic field depends on:
  - The size of the current
  - The distance from the long straight conductor (such as a wire)

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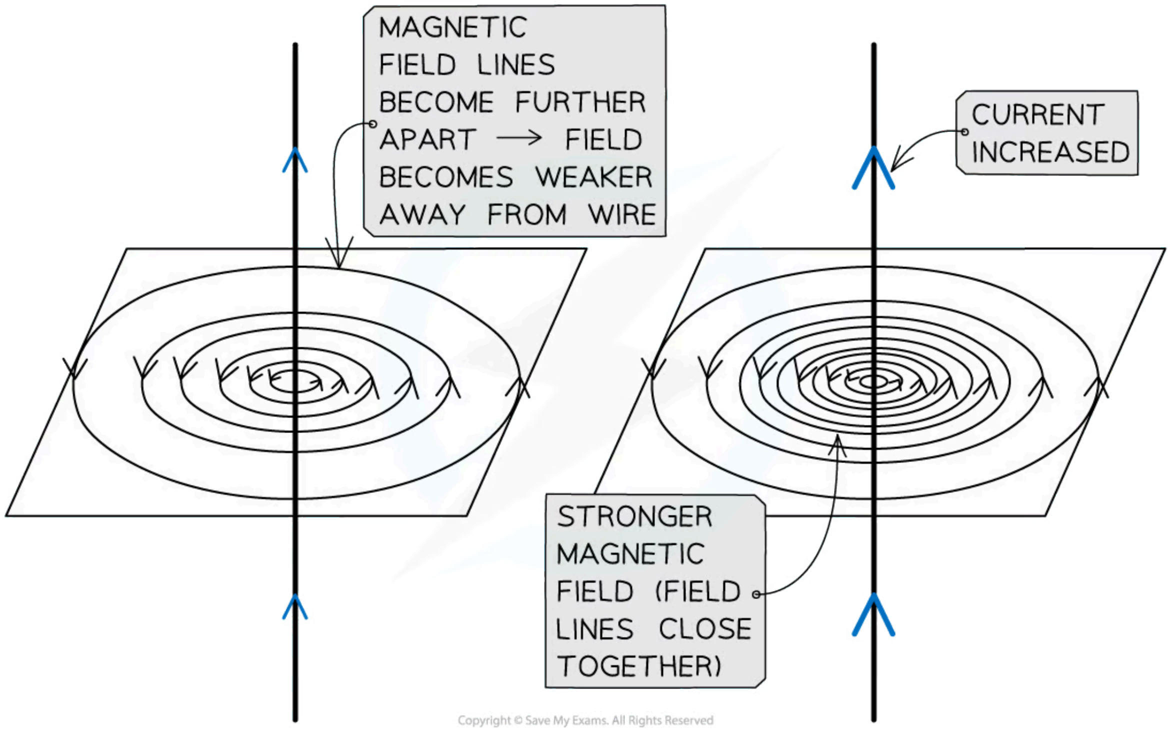
- A **larger** current will produce a **larger** magnetic field and vice versa
- The **greater** the distance from the conductor, the **weaker** the magnetic field and vice versa



The greater the current, the stronger the magnetic field. This is shown by more concentrated field lines

Examiner Tips and Tricks

When drawing these field lines around a wire, make sure it is clear the lines become further apart with increasing distance from the wire, it is better to exaggerate this for the examiner.

Magnetic Fields in Solenoids

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The Field around a Solenoid

- When a wire is looped into a **coil**, the magnetic field lines circle around each part of the coil, passing through the centre of it

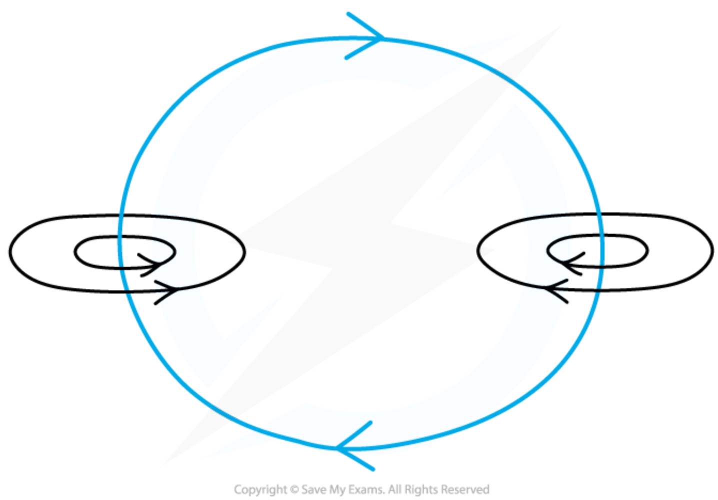
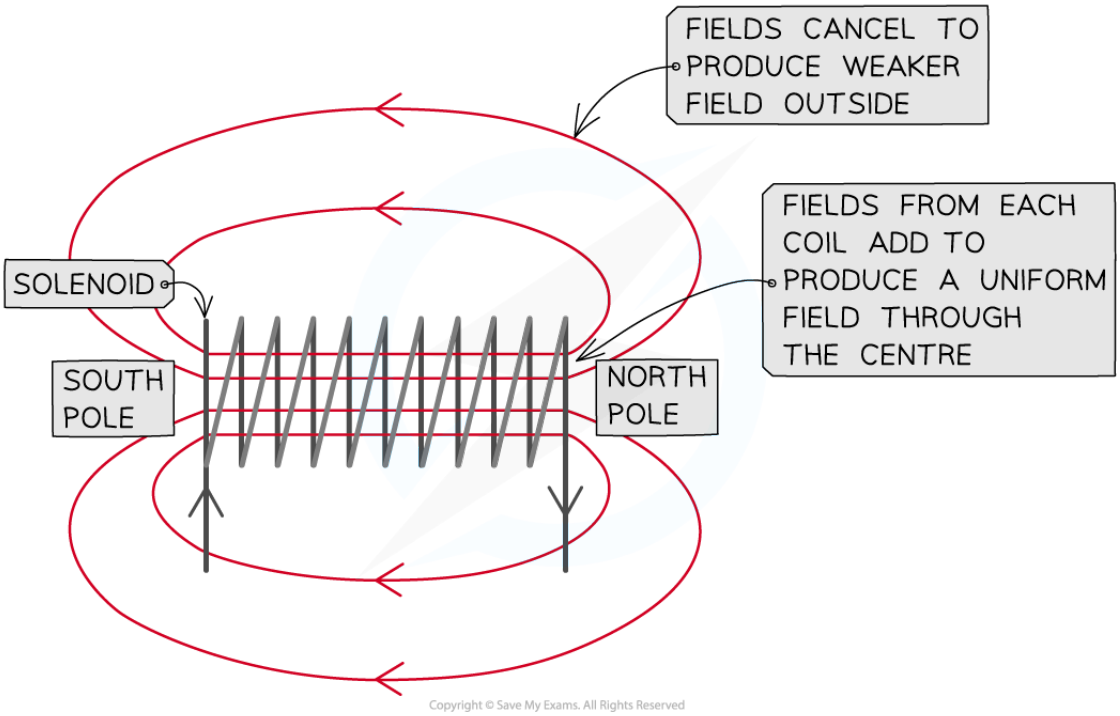


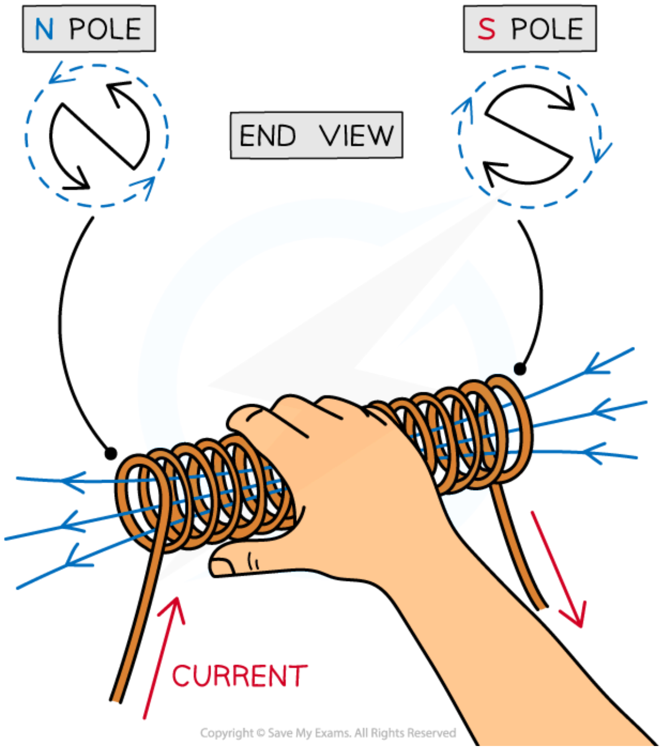
Diagram showing the magnetic field around a flat circular coil

- To increase the strength of the magnetic field around the wire it should be coiled to form a **solenoid**
- The magnetic field around the solenoid is similar to that of a **bar magnet**



Magnetic field around and through a solenoid

- The magnetic field inside the solenoid is strong and uniform
- Inside a solenoid (an example of an electromagnet) the fields from individual coils
    - **Add together** to form a very **strong** almost uniform field along the **centre** of the solenoid
    - **Cancel** to give a **weaker** field **outside** the solenoid
- One end of the solenoid behaves like the **north pole** of a magnet; the other side behaves like the **south pole**
    - To work out the polarity of each end of the solenoid it needs to be viewed from the end
    - If the current is travelling around in a **clockwise** direction then it is the **south pole**
    - If the current is travelling around in an **anticlockwise** direction then it is the north pole
- If the **current changes direction** then the north and south **poles will be reversed**
- If there is **no current** flowing through the wire then there will be **no magnetic field** produced around or through the solenoid



Poles of a Solenoid

- The strength of the magnetic field produced around a solenoid can be increased by:
  - Increasing the **size of the current** which is flowing through the wire
  - Increasing the **number of turns in the coil** in a given length
  - **Reducing the length** of the wire and **maintaining the number of turns**
  - Adding an **iron core** through the centre of the coils
- The iron core will become an induced magnet when current is flowing through the coils
- The magnetic field produced from the solenoid and the iron core will create a much **stronger** magnet overall

Examiner Tips and Tricks

Remember the term 'uniform field' means a field which has the same strength and direction at all points. This is represented by parallel field lines. When discussing the strength of an electromagnet,

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avoid saying "add more coils":

The coil describes the overall object – the individual loops of wire should be referred to as **turns**.

The correct phrase to use is "add more **turns** to the coil".

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The Motor Effect

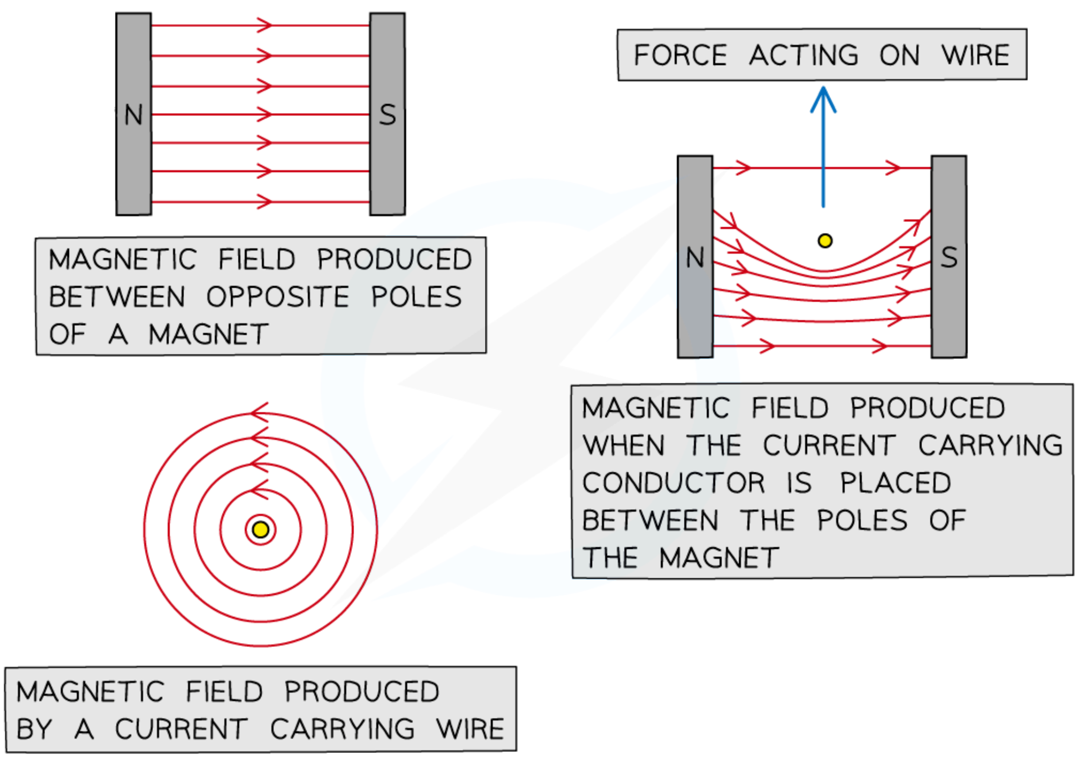
The Force on a Wire

Higher Tier Only

- The **motor effect** occurs:

  When a wire with current flowing through it is placed in a magnetic field and experiences a force

- This effect is a result of **two** interacting **magnetic fields**
  - One is produced around the wire due to the current flowing through it
  - The second is the magnetic field into which the wire is placed, for example, between two magnets
- As a result of the interactions of the two magnetic fields, the wire will experience a **force**



The magnetic field between opposite poles of magnets interact with the magnetic field produced around a current-carrying wire

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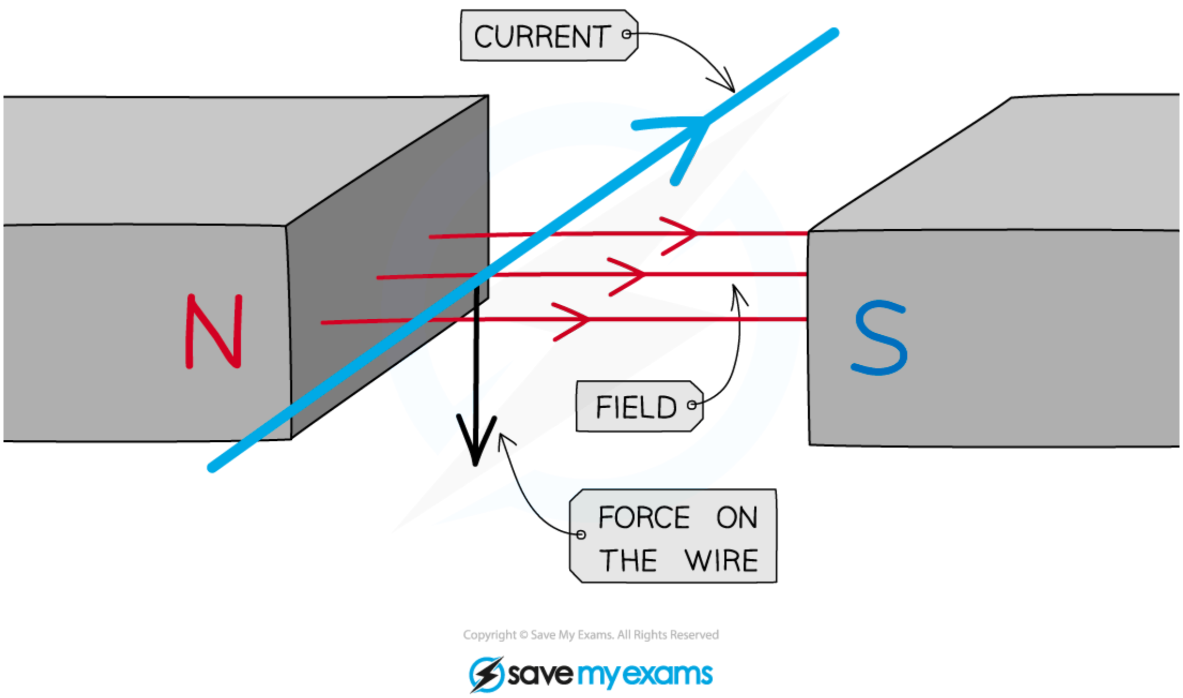

The motor effect is a result of two magnetic fields interacting to produce a force on the wire

Magnetic Forces

Higher Tier Only

- Magnetic forces are due to interactions between **magnetic fields**
  - **Stronger** magnetic fields produce **stronger** forces and vice versa
- For a current carrying conductor, the size of the force exerted by the magnetic fields can be **increased** by:
  - Increasing the amount of **current** flowing through the wire
    - This will increase the magnetic field around the wire
  - Using **stronger magnets**
    - This will increase the magnetic field between the poles of the magnet
  - Placing the wire at **90°** to the direction of the magnetic field lines between the poles of the magnet

    - This will result in the maximum interaction between the two magnetic fields
- Note: If the two magnetic fields are **parallel** there will be no interaction between the two magnetic fields and therefore **no force** produced

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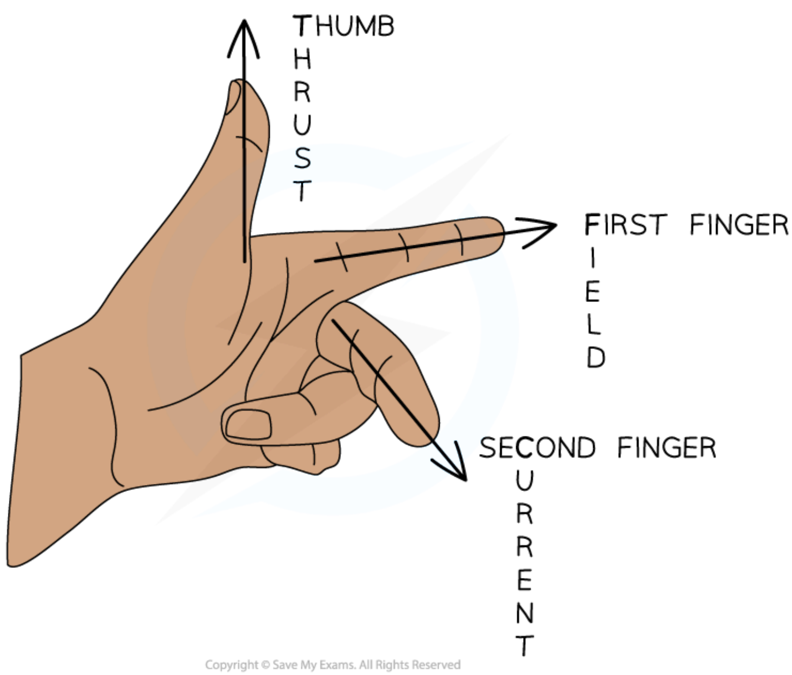
Fleming's Left Hand Rule

Fleming's Left Hand Rule

Higher Tier Only

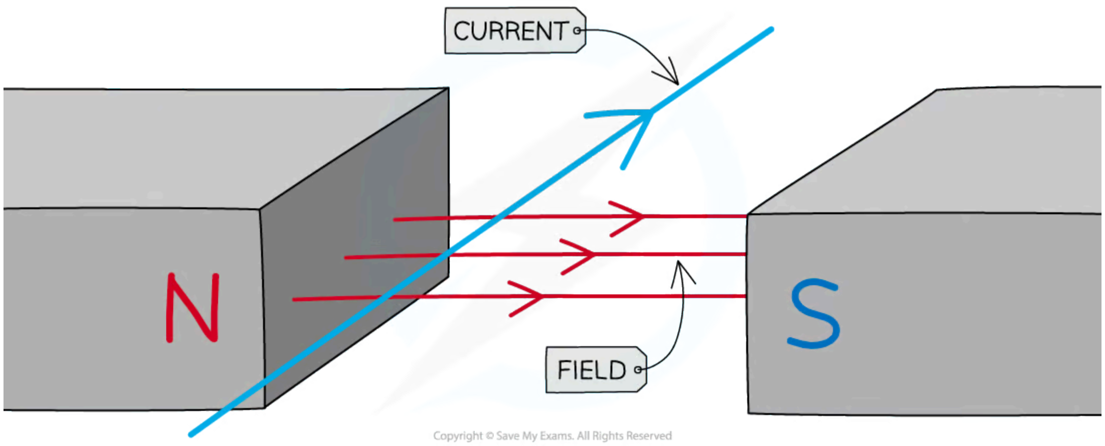
- The **direction** of the **force** (aka the **thrust**) on a current carrying wire depends on the direction of the current and the direction of the magnetic field
- All three will be **perpendicular** to each other
  - This means that sometimes the force could be into and out of the page (in 3D)
- The direction of the force (or thrust) can be worked out by using **Fleming's left-hand rule**:



Fleming's Left-Hand Rule can be used to determine directions of the force, magnetic field and current

Worked Example

Use Fleming's left-hand rule to show that if the current-carrying wire is placed into the magnetic field between the poles of the magnet, as shown below, there will be a downwards force acting on the wire



Answer:

Step 1: Determine the direction of the magnetic field

- Start by pointing your **F**irst **F**inger in the direction of the (magnetic) **F**ield.

Step 2: Determine the direction of the current

- Now rotate your hand around the first finger so that the se**C**ond finger points in the direction of the **C**urrent

Step 3: Determine the direction of the force

- The **TH**umb will now be pointing in the direction of the **TH**rust (the force)
- Therefore, this will be the direction in which the wire will move

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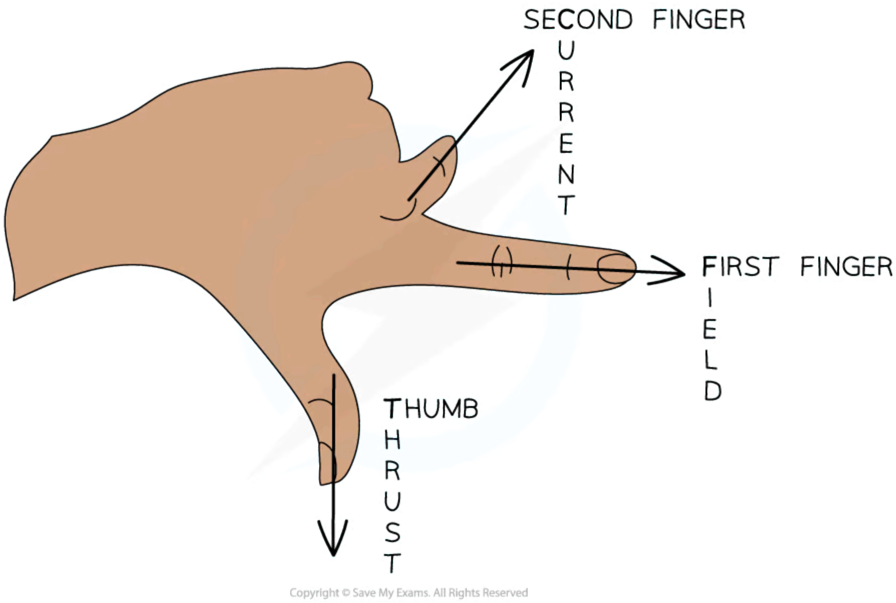

Examiner Tips and Tricks

Remember that the magnetic field is always in the direction from **North** to **South** and current is always in the direction of a **positive** terminal to a **negative** terminal. Feel free to use Fleming's left hand rule in your exam, just don't make it too obvious or distracting for other students!

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Calculating Magnetic Force

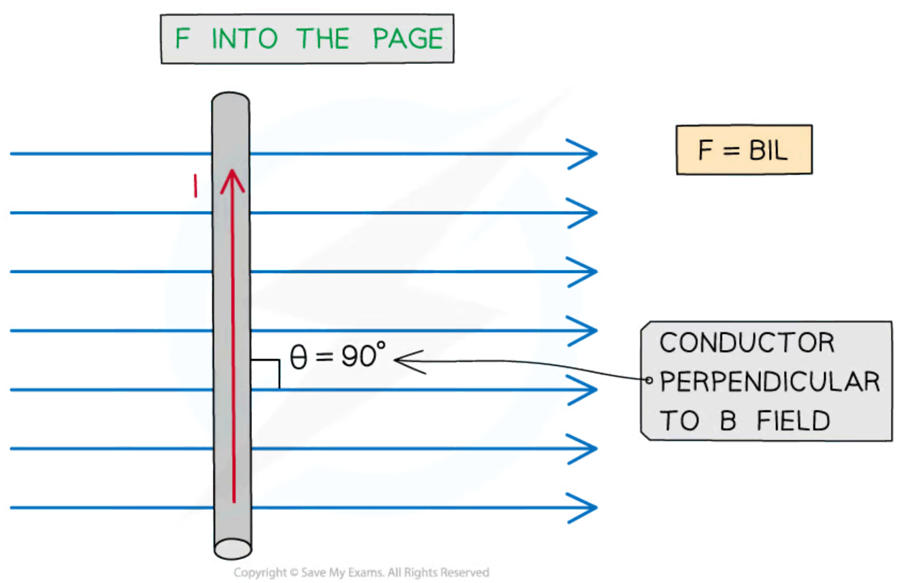
Calculating Magnetic Force on a Current-Carrying Conductor

Higher Tier Only

- The size of the force acting on a current-carrying wire in a magnetic field can be calculated using the equation:

$$F = BIL$$

- Where:
  - F = force acting on current-carrying wire in newtons (N)
  - B = magnetic flux density (which is the strength of the magnetic field) in tesla (N/A m)
  - I = current flowing through the conductor in amps (A)
  - L = length of the conductor that is in the magnetic field in metres (m)



Force on a current carrying conductor (directed into the page)

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Worked Example

A 5 cm length of wire is at 90° to the direction of an external magnetic field. When current of 1.5 A flows through the wire it experiences a force of 0.06 N from the motor effect. Calculate the magnetic flux density of the magnet.

N/A m = T

Answer:

Step 1: List the known quantities

- Length, L = 5 cm
- Current, I = 1.5 A
- Force, F = 0.06 N

Step 2: Write out the equation for the force

$$F = BIL$$

Step 3: Rearrange the equation to make B the subject

$$B = \frac{F}{IL}$$

Step 4: Convert the length to metres

$$L = 5 \text{ cm} = 0.05 \text{ m}$$

Step 5: Substitute values into the equation

$$B = \frac{0.06}{1.5 \times 0.05} = 0.8 \text{ T}$$

Examiner Tips and Tricks

You will only be expected to calculate the force when the wire is perpendicular to the field, so you won't have to worry about angles.

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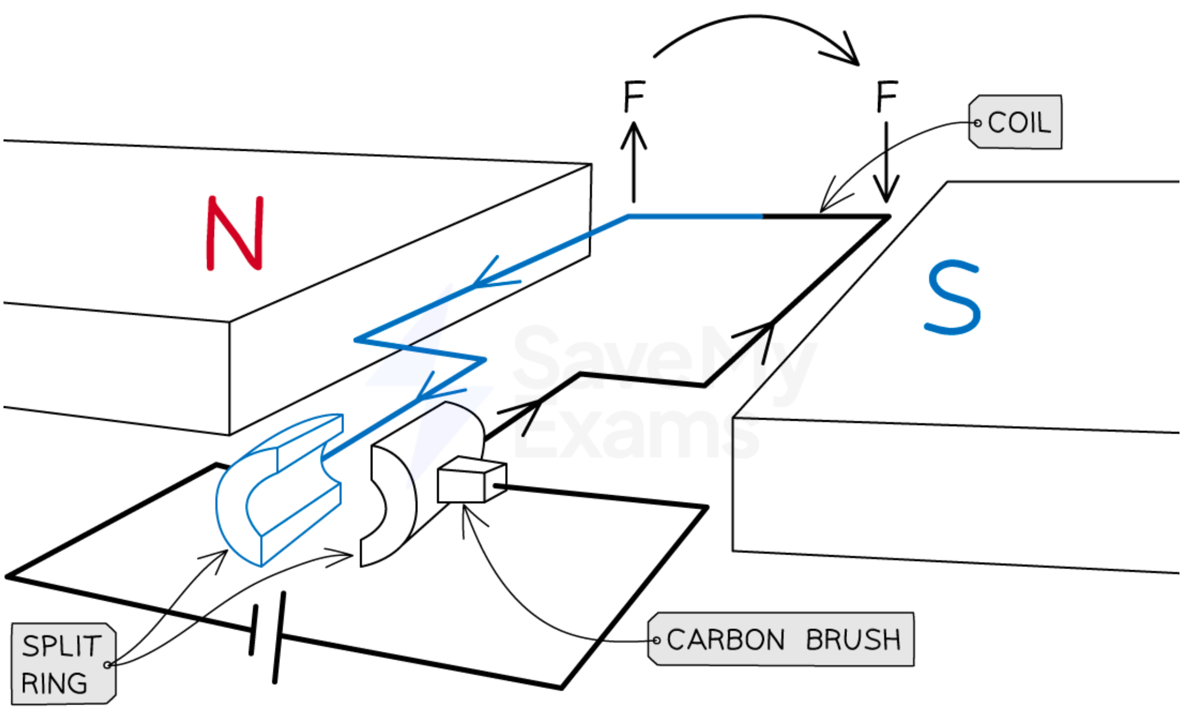
Electric Motors

Electric Motors

Higher Tier Only

- The **motor effect** can be used to create a simple **d.c.** electric motor
  - The force on a current-carrying coil is used to make it **rotate** in a single direction
- The simple d.c. motor consists of a coil of wire (which is free to rotate) positioned in a **uniform magnetic field**
- The coil of wire, when horizontal, forms a complete circuit with a cell
  - The coil is attached to a **split ring** (a circular tube of metal split in two)
  - This split ring is connected in a circuit with the cell via contact with conducting **carbon brushes**

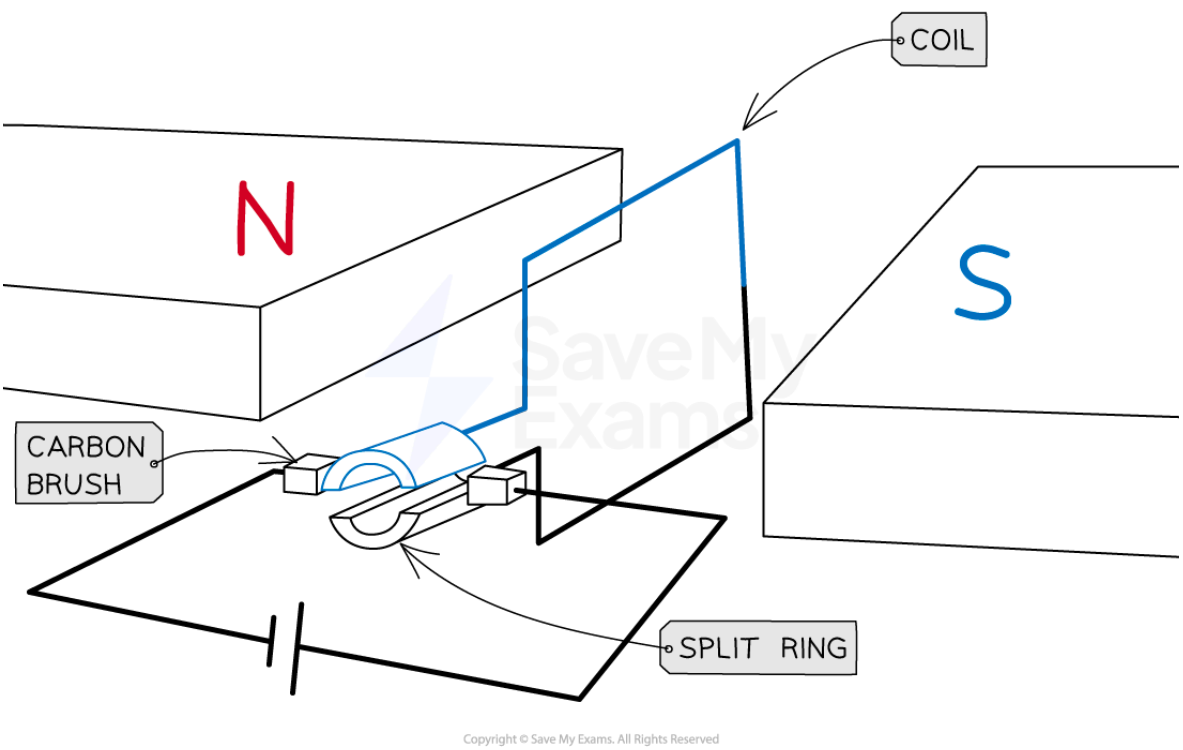
Forces on the Horizontal Coil in a D.C. Motor



Forces acting in opposite directions on each side of the coil, causing it to rotate. The split ring connects the coil to the flow of current

- Current flowing through the coil produces a magnetic field
  - This magnetic field interacts with the uniform external field, so a **force** is exerted on the wire
- Forces act in opposite directions on each side of the coil, causing it to rotate:
  - On the blue side of the coil, current travels towards the cell so the force acts upwards (using **Fleming's left-hand rule**)
  - On the black side, current flows away from the cell so the force acts downwards
- Once the coil has rotated 90°, the split ring is **no longer in contact** with the brushes
  - No current flows through the coil so no forces act

Coil in the Vertical Position



No force acts on the coil when vertical, as the split ring is not in contact with the brushes

- Even though no force acts, the momentum of the coil causes the coil to continue to rotate slightly

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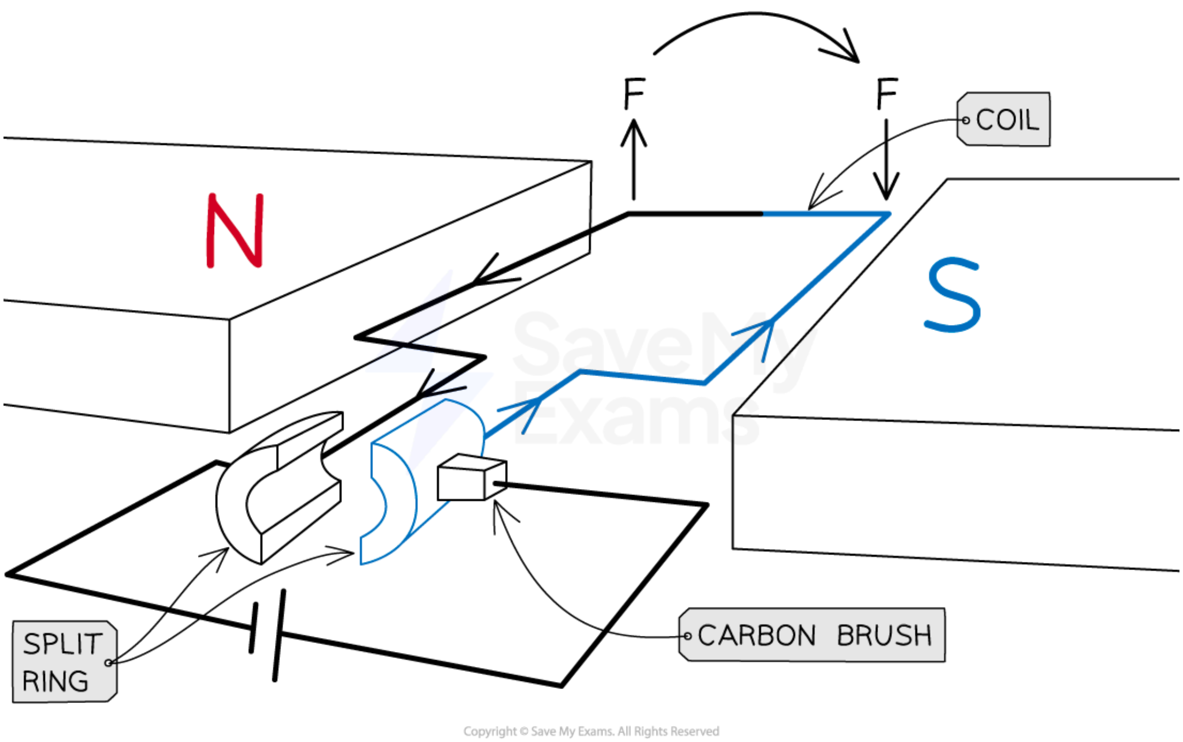
- The split ring reconnects with the carbon brushes and current flows through the coil again
  - Now the blue side is on the right and the black side is on the left
- Current still flows toward the cell on the left and away from the cell on the right, even though the coil has flipped
  - The black side of the coil experiences an upward force on the left and the blue side experiences a downward force on the right
  - The coil continues to rotate in the same direction, forming a continuously spinning motor

Forces on the Coil when Rotated 180°



Even though the coil has flipped, current still flows anticlockwise and the forces still cause rotation in the same direction

Factors Affecting the D.C Motor

- The **speed** at which the coil rotates can be increased by:
  - Increasing the **current**
  - Use a **stronger magnet**

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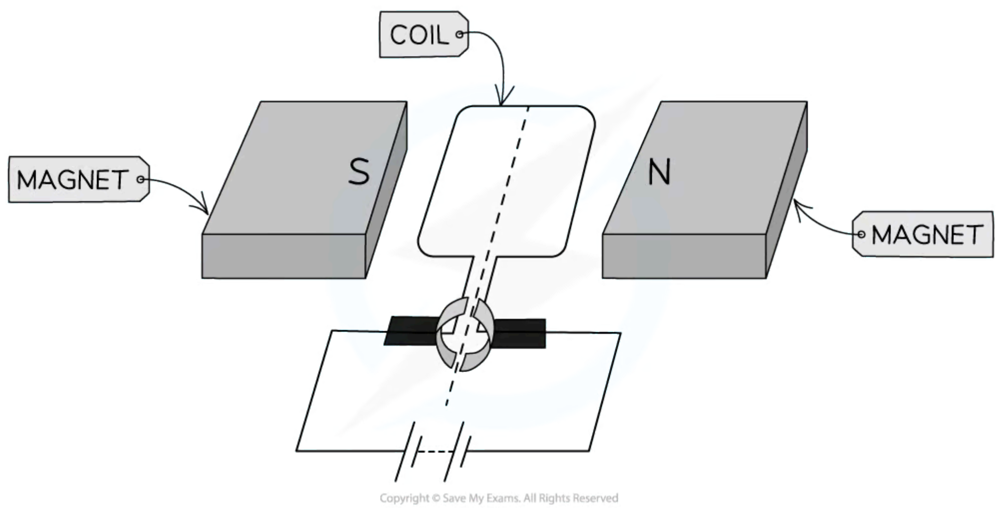
- The **direction of rotation** of coil in the d.c. motor can be changed by:
  - Reversing the direction of the **current supply**
  - Reversing the direction of the magnetic field by reversing the **poles** of the magnet
- The **force** supplied by the motor can be increased by:
  - Increasing the **current** in the coil
  - Increasing the strength of the **magnetic field**
  - Adding **more turns** to the coil

Worked Example

A d.c. motor is set up as shown below.



Determine whether the coil will be rotating clockwise or anticlockwise.

Answer:

Step 1: Draw arrows to show the direction of the magnetic field lines

- These will go from the north pole of the magnet to the south pole of the magnet

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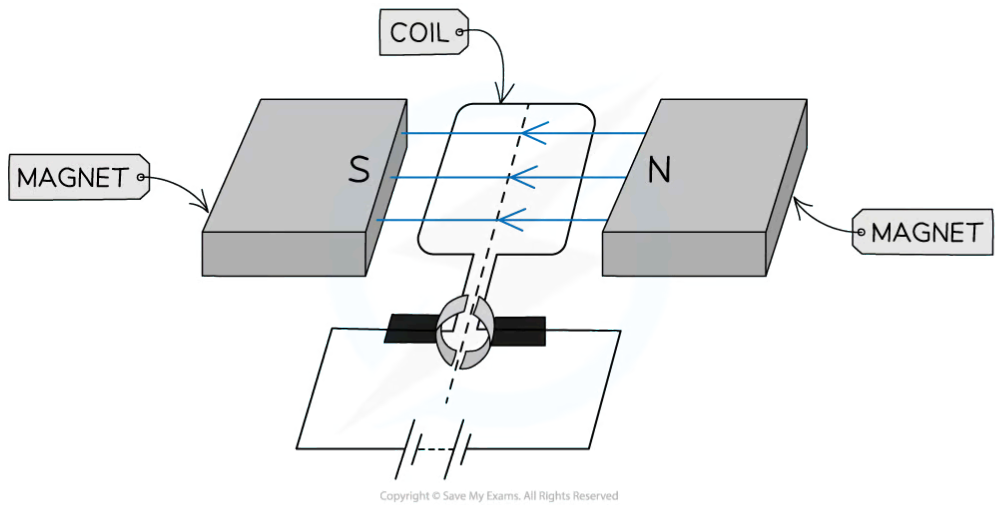
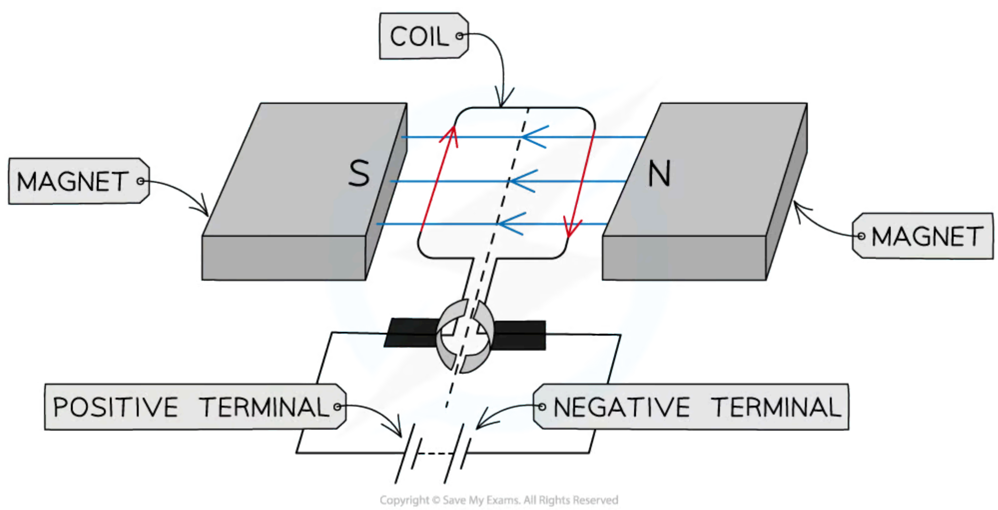


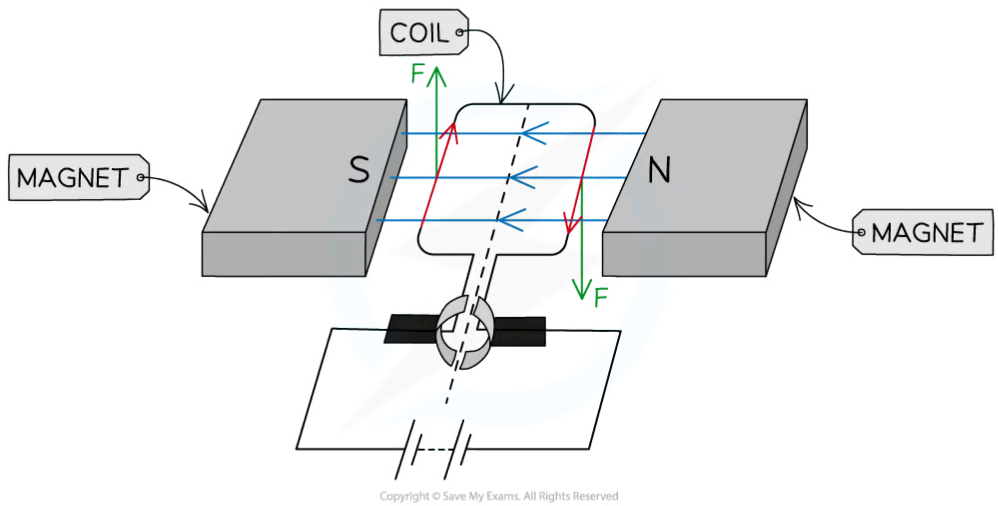
Step 2: Draw arrows to show the direction the current is flowing in the coils

- Current will flow from the positive terminal of the battery to the negative terminal



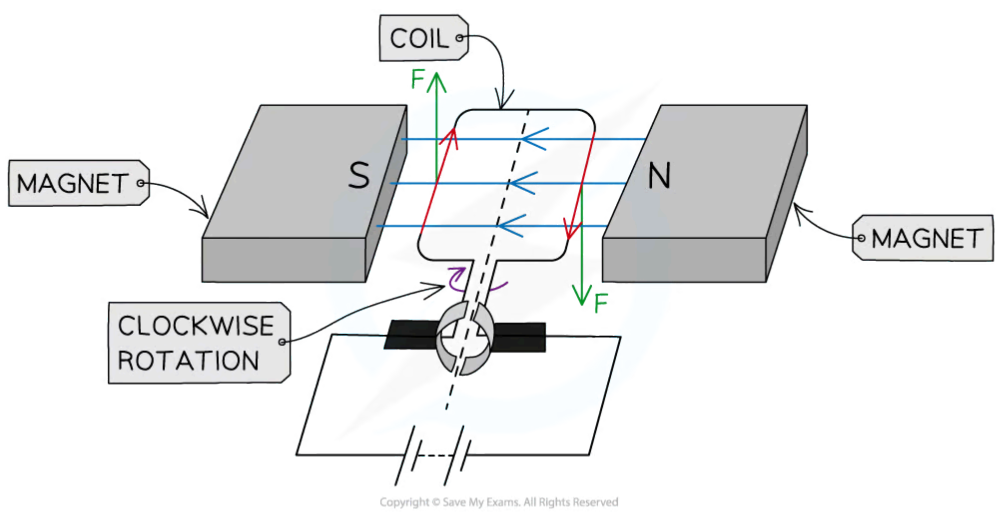
Step 3: Use Fleming's left hand rule to determine the direction of the force on each side of the coil

- Start by pointing your **F**irst **F**inger in the direction of the (magnetic) **F**ield
- Now rotate your hand around the first finger so that the se**C**ond finger points in the direction of the **C**urrent
- The **TH**umb will now be pointing in the direction of the **TH**rust (the force)



Step 4: Use the force arrows to determine the direction of rotation

- The coil will be turning **clockwise**



Examiner Tips and Tricks

It is important to remember all the steps that cause the rotation of the coil in a d.c. motor. Use Fleming's Left Hand rule to convince yourself of the direction of the force on each side of the coil, these should be in opposite directions because the directions of the current through each side are opposite.

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Additionally, don't be confused if you see the phrase 'split-ring **commutator**'. This is another way of referring to the split ring in the circuit and they mean the same thing.

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