OCR A Level Physics

Your notes

Electromagnetic Induction

Contents

Your notes

Magnetic Flux

Magnetic Flux

- Magnetic flux is a quantity which signifies how much of a magnetic field passes **perpendicularly** through an area
- For example, the amount of magnetic flux through a rotating coil will vary as the coil rotates in the magnetic field
  - It is a maximum when the magnetic field lines are **perpendicular** to the coil area
  - It is at a minimum when the magnetic field lines are **parallel** to the coil area
- The **magnetic flux** is defined as:

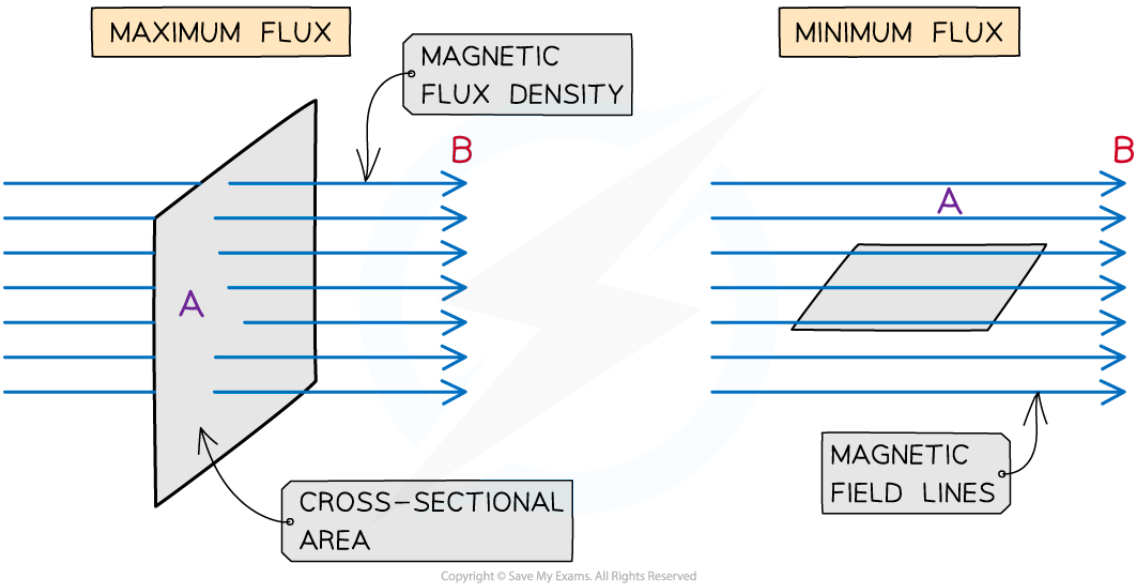
  The product of the magnetic flux density and the cross-sectional area perpendicular to the direction of the magnetic flux density

- Magnetic flux is defined by the symbol Φ (greek letter 'phi')
- It is measured in units of **Webers (Wb)**
- Magnetic flux can be calculated using the equation:

$$\Phi = BA$$

- Where:
  - Φ = magnetic flux (Wb)
  - B = magnetic flux density (T)
  - A = cross-sectional area (m^2)

Your notes

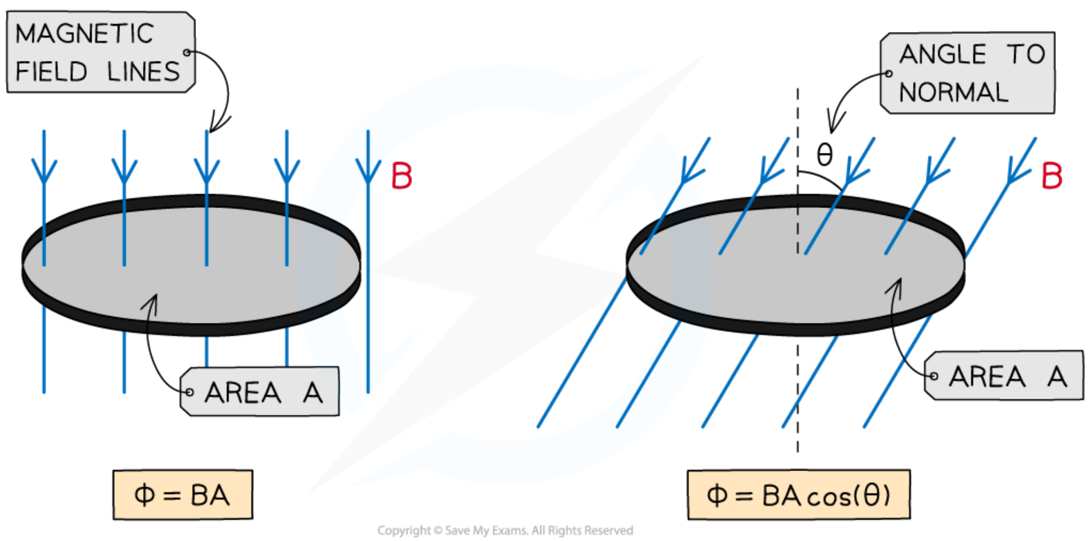


The magnetic flux is maximised when the magnetic field lines and the area through which they are passing through are perpendicular

- When magnetic flux is not completely perpendicular to the area A, then the component of magnetic flux density B perpendicular to the area is taken
- The equation then becomes:

$$\Phi = BA\cos(\theta)$$

- Where:
  - θ = angle between magnetic field lines and the line perpendicular to the plane of the area (often called the normal line) (degrees)



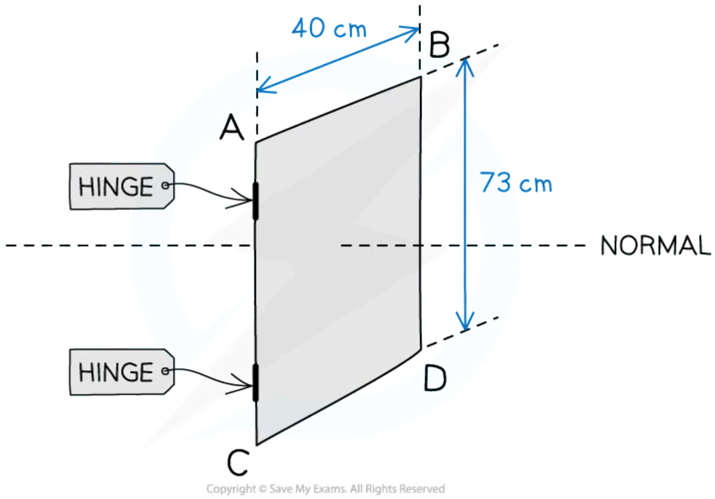
The magnetic flux increases as the angle between the field lines and plane decreases

- This means the magnetic flux is:
  - **Maximum** = BA when cos(θ) =1 therefore **θ = 0°**. The magnetic field lines are perpendicular to the plane of the area
  - **Minimum** = 0 when cos(θ) = 0 therefore **θ = 90°**. The magnetic fields lines are parallel to the plane of the area
- An e.m.f is induced in a circuit when the magnetic flux linkage changes with respect to time
- This means an e.m.f is induced when there is:
  - A changing magnetic flux density *B*
  - A changing cross-sectional area *A*
  - A change in angle *θ*

Worked Example

An aluminium window frame has a width of 40 cm and length of 73 cm as shown in the figure below

Your notes



The frame is hinged along the vertical edge AC. When the window is closed, the frame is normal to the Earth's magnetic field with magnetic flux density 1.8×10^{-5} T

a) Calculate the magnetic flux through the window when it is closed

b) Sketch the graph of the magnetic flux against angle between the field lines and the normal when the window is opened and rotated by 180°

Answer:

Part (a)

Step 1: Write out the known quantities

- Cross-sectional area, A = 40 cm × 73 cm = $(40 \times 10^{-2}) \times (73 \times 10^{-2}) = 0.292$ m^2
- Magnetic flux density, $B = 1.8 \times 10^{-5}$ T

Step 2: Write down the equation for magnetic flux

$$\Phi = BA$$

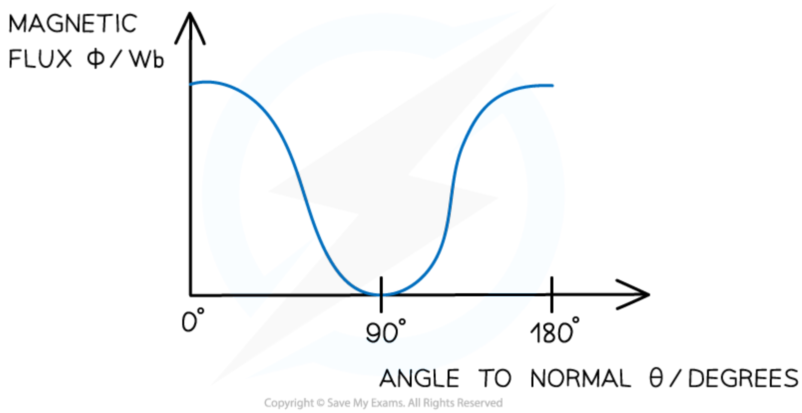
Step 3: Substitute in values

$$\Phi = (1.8 \times 10^{-5}) \times 0.292 = 5.256 \times 10^{-6} = 5.3 \times 10^{-6} \text{ Wb}$$

Part (b)

- The magnetic flux will be at a **minimum** when the window is opened by 90°
- The magnetic flux will be at a **maximum** when fully closed or opened to 180°

Your notes



Examiner Tips and Tricks

Consider carefully the value of θ, it is the angle between the field lines and the line **normal** (perpendicular) to the plane of the area the field lines are passing through.

If it helps you, drawing the normal on the area provided is a helpful way to visualise the correct angle.

Investigating Magnetic Flux

Aims of the Experiment

- The overall aim of this experiment is to determine how the magnetic flux linkage varies with the angle of rotation of a search coil
  - This is done by rotating a search coil through a uniform magnetic field created by a larger coil and recording the induced e.m.f. within it

Variables

- Independent variable = Angle between the normal to the search coil and the magnetic field lines, θ
- Dependent variable= Induced e.m.f, ε
- Control variables:
  - Area of the search coil, *A*
  - Number of loops on both coils, *N*
  - Magnetic field strength, *B*

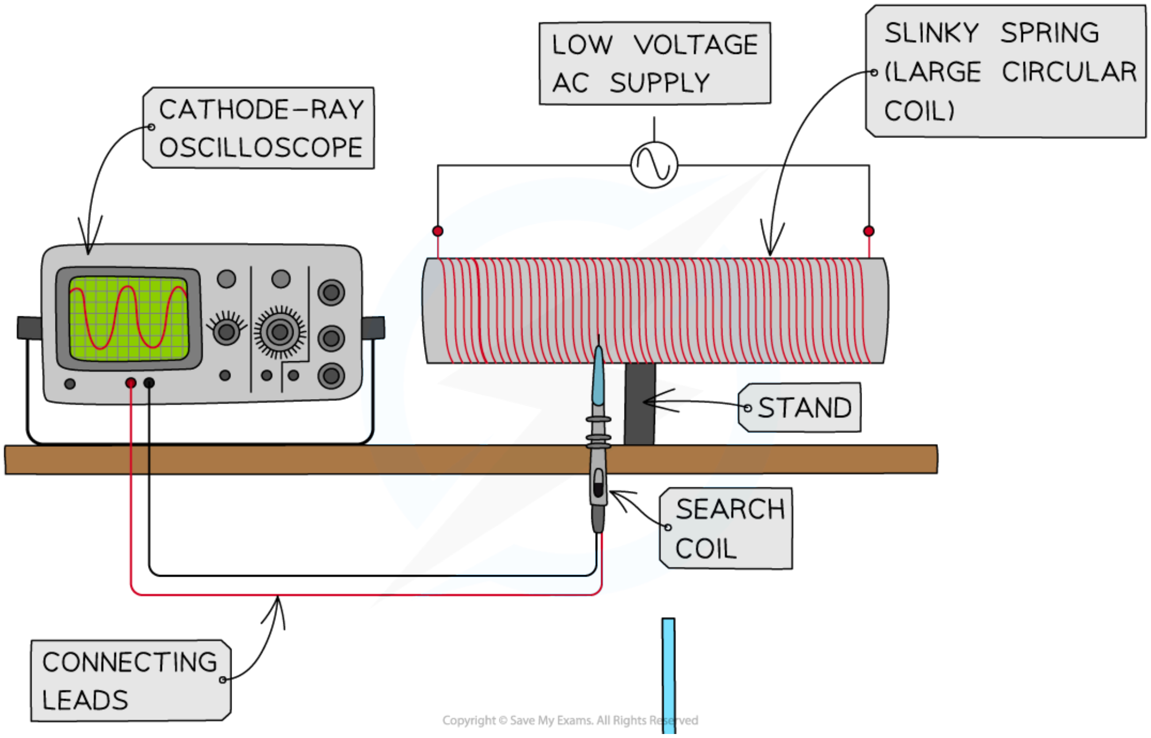
- Frequency of the power supply, f

Equipment List

Apparatus	Purpose
Cathode-ray oscilloscope (CRO)	Used to measure the induced e.m.f. in the search coil
Large circular coil	The solenoid used to create the magnetic field for the search coil
Stand (or support) for circular coil	To support the large circular coil
Low voltage 50 Hz AC supply	To create a changing magnetic field through the search coil
Connecting leads	To connect the solenoid to the CRO
Protractor	To measure the angle of rotation of the search coil
Search coil with 500-2000 turns	To rotate within the magnetic field and measure the change in e.m.f. through
(optional) Clamp stand and boss	To support the search coil

- **Resolution** of measuring equipment:
  - Protractor = 1°
  - CRO = 2 mV / div

Method


LOW VOLTAGE AC SUPPLY
SLINKY SPRING (LARGE CIRCULAR COIL)
CATHODE-RAY OSCILLOSCOPE
STAND
SEARCH COIL
CONNECTING LEADS
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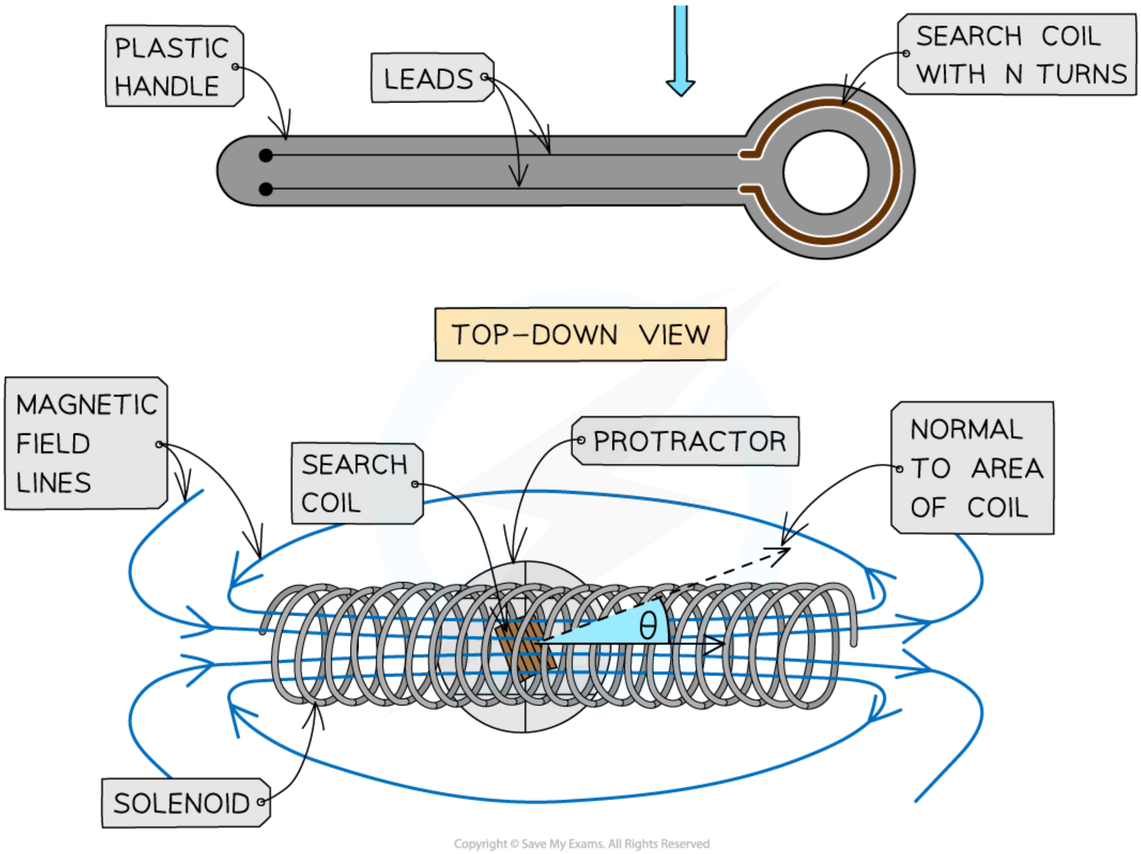


1. Arrange the apparatus as shown in the diagram.
   - The slinky spring should be connected to the alternating power supply so the flux through the search coil placed within it will be constantly changing
2. Set up the CRO so its time-base is switched off, so it only shows the amplitude of the e.m.f.
   - Adjust the voltage per division till the signal can be seen fully on the screen (eg. 10 mV / div)
3. Position the search coil so that it is halfway along the slinky spring
4. Orient the search coil so it is parallel to the slinky spring
   - The plane of its area is perpendicular to the field)
5. Record the induced e.m.f. in the search coil from the amplitude of the CRO trace
   - This should ideally be the peak-to-peak voltage (V_{pp}) which will then be halved for the peak e.m.f, ε_0
6. Rotate the search coil by 10° (in either direction) using the protractor

7. Record the new V_{pp} and repeat the procedure until the search coil is at 90° to the slinky spring

- An example table might look like this:

ANGLE BETWEEN NORMAL TO AREA OF COIL AND B FIELD LINES

FROM CRO

$\frac{V_{pp}}{2}$

ANGLE θ / DEGREES	SIN (θ)	PEAK –TO– PEAK VOLTAGE V_{pp} / V	PEAK e.m.f. ε_0 / V
0			
10			
20			
30			
40			
50			
60			
70			
80			
90			

Analysing the Results

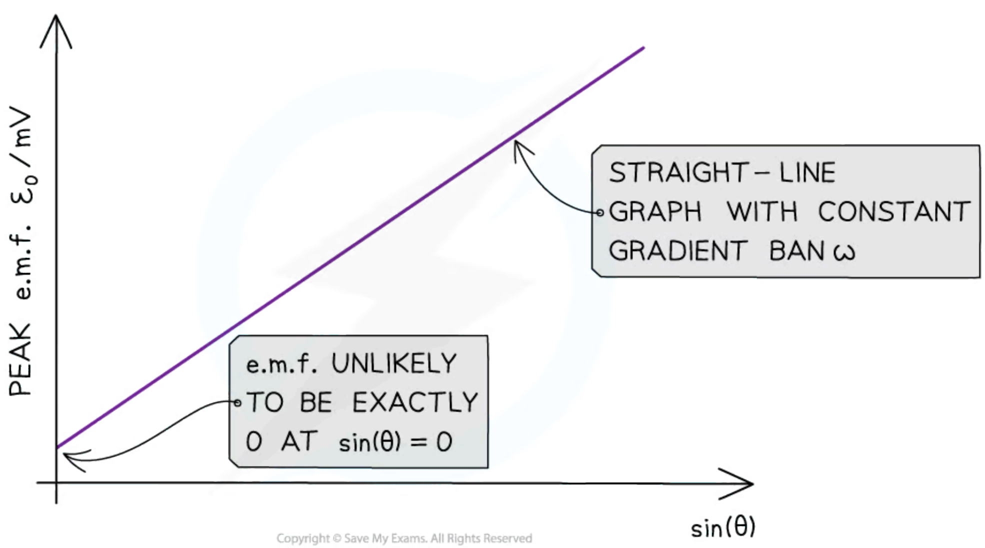
- The e.m.f. in the coil varies with the equation:

$$\varepsilon = BAN\omega \sin(\theta)$$

- Where:
  - ε = e.m.f. (V)
  - B = magnetic flux density (T)
  - A = cross-sectional area (m^2)
  - N = number of turns
  - ω = angular velocity of the rotating coil (rad s^{-1} or degrees s^{-1})
  - θ = angle between the magnetic field, B and the normal to the area, A (rads)

Your notes

- Comparing this to the straight-line equation: y = mx + c
  - y = ε
  - x = sin(θ)
  - m = *BAN*ω
  - c = 0
- Plot a graph of peak e.m.f. ε_0 against sin(θ) and draw a line of best fit
- This should be a **straight-line graph**
  - This shows that the induced e.m.f. is proportional to the cosine of the angle between the search coil and the direction of the magnetic field lines



Evaluating the Experiment

Systematic Errors:

- Reduce systematic errors by calibrating the search coil using a known magnetic field and oscilloscope
- The field lines are unlikely to be perfectly parallel and perpendicular to the area of the coil
  - Therefore, the graph is unlikely to have a y-intercept at the origin
- Read the angle from the protractor far above and from the same point every time to reduce parallax error

Random Errors:

- The experiment could be made more reliable by repeating for a full turn (θ = 360°)
- An improvement could be to use a calibrated motor to rotate the search coil at a steady rate
  - This will make the e.m.f. values more accurate
- Use blu tack to make sure the protractor stays in the same place for each reading

Safety Considerations

- Keep water or any fluids away from the electrical equipment
- Make sure no wires or connections are damaged and contain appropriate fuses to avoid a short circuit or a fire
- Don't exceed the specified current rating for the coil in order not to damage it
- The larger coil will heat up whilst the current is through it, especially if it is very thin
  - Therefore, make sure not to leave the current on for longer than necessary

Your notes

Your notes

Magnetic Flux Linkage

Magnetic Flux Linkage

- The magnetic **flux linkage** is a quantity commonly used for solenoids which are made of *N* turns of wire
- The flux linkage is defined as:

  The product of the magnetic flux and the number of turns of the coil

- It is calculated using the equation:

$$\textbf{Flux linkage} = \Phi N = BAN$$

- Where:
  - Φ = magnetic flux (Wb)
  - N = number of turns of the coil
  - B = magnetic flux density (T)
  - A = cross-sectional area (m^2)
- The flux linkage ΦN has the units of **Weber turns (Wb turns)**

Worked Example

A solenoid of circular cross-sectional radius 0.40 m and 300 turns is placed perpendicular to a magnetic field with a magnetic flux density of 5.1 mT.

Determine the magnetic flux linkage for this solenoid.

Answer:

Step 1: Write out the known quantities

- Cross-sectional area, $A = \pi r^2 = \pi(0.4)^2 = 0.503\ m^2$
- Magnetic flux density, B = 5.1 mT
- Number of turns of the coil, N = 300 turns

Step 2: Write down the equation for the magnetic flux linkage

$$\Phi N = BAN$$

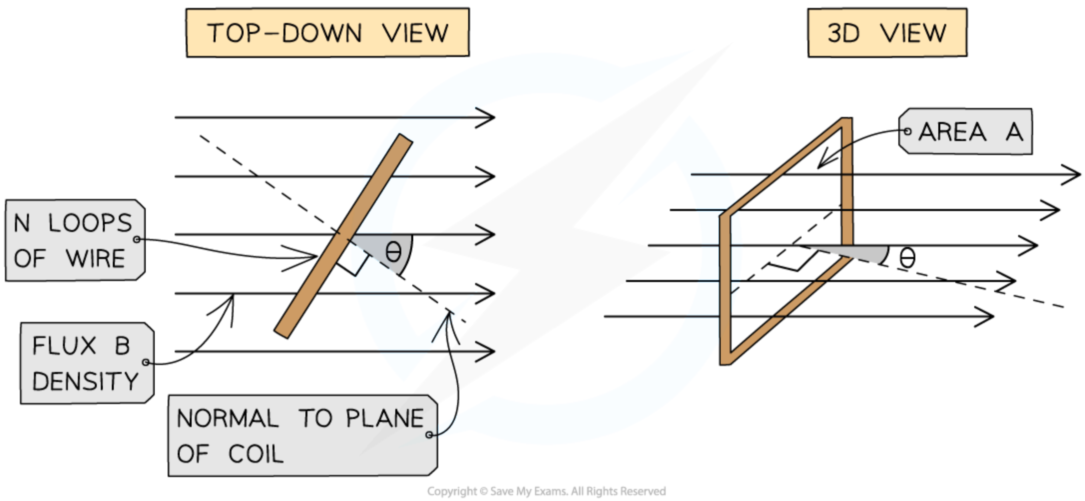
Step 3: Substitute in values and calculate

$$\Phi N = (5.1 \times 10^{-3}) \times 0.503 \times 300 = 0.7691 = 0.8 \text{ Wb turns (2 s.f)}$$

Your notes

Examiner Tips and Tricks

Just like for magnetic flux, the flux linkage through a coil may not be entirely perpendicular.



The magnetic flux linkage through a rectangular coil increases as the angle between the field lines and a normal line to the coil plane decreases

In this case, you can just substitute the equation for *B* into the equation for φ*N*, such that the flux linkage is calculated by:

$$\Phi N = BAN\cos\,\theta$$

As before, you should remember that since cos (0°) = 1, the flux linkage is a maximum when the angle θ is zero. This means the flux and coil face are perpendicular (i.e. the normal line to the coil face and the flux lines are parallel).

Your notes

Faraday's & Lenz's Laws

Faraday's Law

- Faraday's Law connects the **rate** of change of flux linkage with induced e.m.f
- It is defined in words as:

  The magnitude of the induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage

- Faraday's Law as an equation is defined as:

$$\varepsilon = \frac{\Delta(N\Phi)}{\Delta t}$$

- Where:
  - ε = induced e.m.f (V)
  - $\Delta(N\phi)$ = change in flux linkage (Wb turns)
  - Δt = time interval (s)

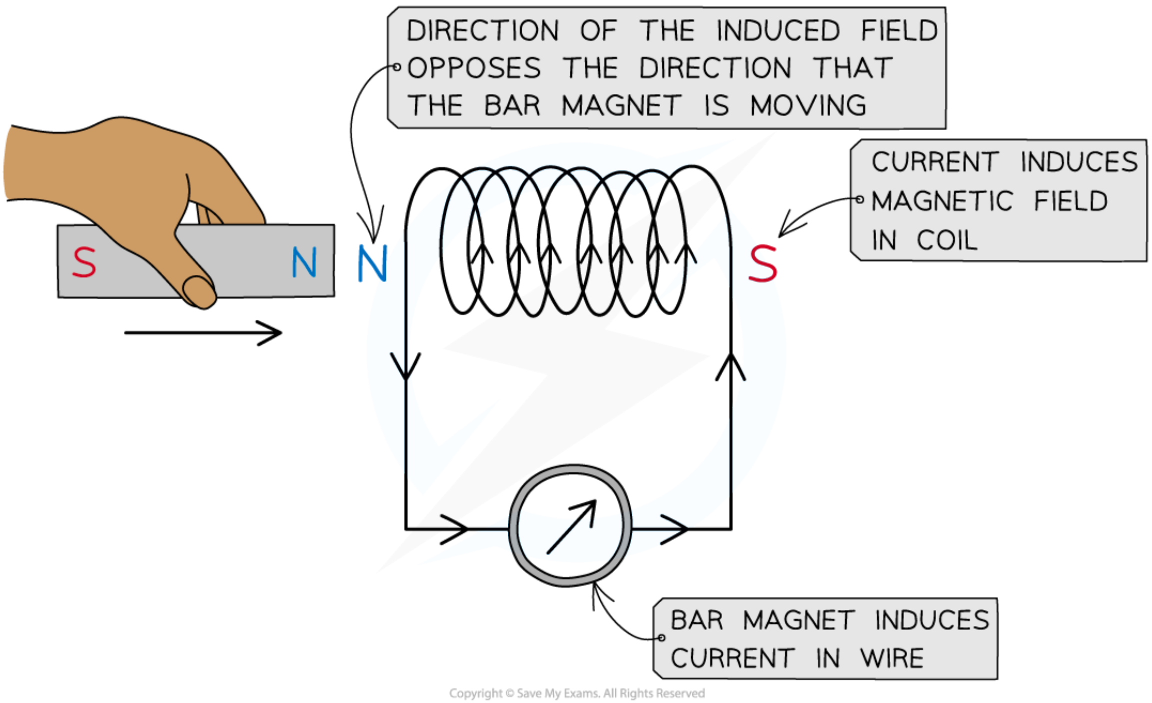
Lenz's Law

- Lenz's Law is used to predict the **direction** of an induced e.m.f. in a coil or wire
- Lenz's Law is summarised below:

  The induced e.m.f. is set up in a direction to produce effects that oppose the change causing it

- Lenz's Law can be experimentally verified using:
  - A bar magnet
  - A coil of wire
  - A sensitive ammeter

Your notes



Lenz's law can be verified using a coil connected in series with a sensitive ammeter and a bar magnet

- A known pole (either north or south) of a bar magnet is pushed into the coil
  - This induces an e.m.f. in the coil
  - The induced e.m.f. drives a current (because it is a complete circuit)
- Lenz's Law dictates:
  - The direction of the e.m.f, and hence the current, must be set up to **oppose** the incoming magnet
  - Since a **north pole** approaches the coil face, the e.m.f. must be set up to create an induced **north pole**
  - This is because two north poles will **repel** each other
- The direction of the current is therefore as shown in the image above
  - The direction of current can be verified using the right hand grip rule
  - Fingers curl around the coil in the direction of current and the thumb points along the direction of the flux lines, from north to south
  - Therefore, the current flows in an anti-clockwise direction in the image shown

- This induces a north pole, opposing the incoming magnet

Your notes

Your notes

Calculating Induced E.m.f

Calculating Induced E.m.f.

- Combining Lenz's Law into the equation for Faraday's Law is written as:

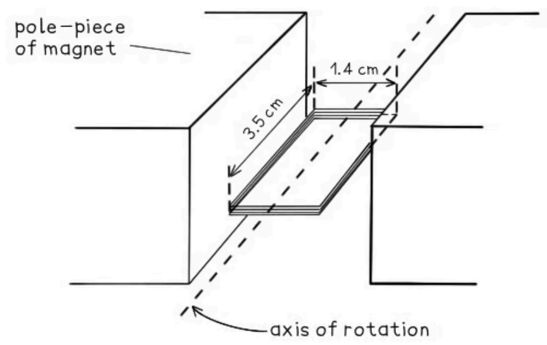
$$\varepsilon = -\frac{\Delta(N\Phi)}{\Delta t}$$

- Where
  - ε = induced e.m.f (V)
  - $\Delta(N\phi)$ = change in flux linkage (Wb turns)
  - Δt = time interval (s)
- The **negative sign** represents Lenz's Law
  - This is because it shows the induced e.m.f. ε is set up in an '**opposite direction**' to oppose the changing flux linkage
- This equation shows that the **gradient** of a graph of magnetic flux linkage against time, t, represents the **magnitude** of the induced e.m.f.
- Note: the negative sign means if the gradient is **positive**, the induced e.m.f. is **negative**
  - This is again due to Lenz's Law, which says the e.m.f. is set up to **oppose** the effects of the changing flux linkage

Worked Example

A small rectangular coil contains 350 turns of wire. The longer sides are 3.5 cm and the shorter sides are 1.4 cm.

Your notes



The coil is held between the poles of a large magnet so that it can rotate about an axis through its centre. The magnet produces a uniform magnetic field of flux density 80 mT between its poles.

The coil is positioned horizontally and then turned through an angle of 90° in a time of 0.18 s.

Calculate the magnitude of the average e.m.f. induced in the coil.

Answer:

Step 1: Write down the known quantities

- Magnetic flux density, B = 80 mT = 80×10^{-3} T
- Area, $A = 3.5 \times 1.4 = (3.5 \times 10^{-2}) \times (1.4 \times 10^{-2}) = 4.9 \times 10^{-4}$ m^2
- Number of turns, N = 350
- Time interval, Δt = 0.18 s

Step 2: Write out the equation for Faraday's law:

$$\varepsilon = \frac{\Delta(N\Phi)}{\Delta t}$$

Step 3: Write out the equation for the change in flux linkage:

- The number of turns N and the coil area A stay constant
- The flux through the coil changes as it rotates
- Therefore, the change in flux linkage can be written as:

$$\Delta(N\Phi) = NA(\Delta B)$$

Step 4: Determine the change in magnetic flux linkage

- The initial flux through the coil is zero (flux lines are parallel to the coil face)
- The final flux through the coil is 80 mT (flux lines are perpendicular to the coil face)
- This is because the coil begins horizontally in the field and is rotated 90°
- Therefore, the change in flux linkage is:

$$\Delta(N\Phi) = NA(\Delta B) = 350 \times (4.9 \times 10^{-4}) \times (80 \times 10^{-3}) = 0.014 \text{ Wb turns}$$

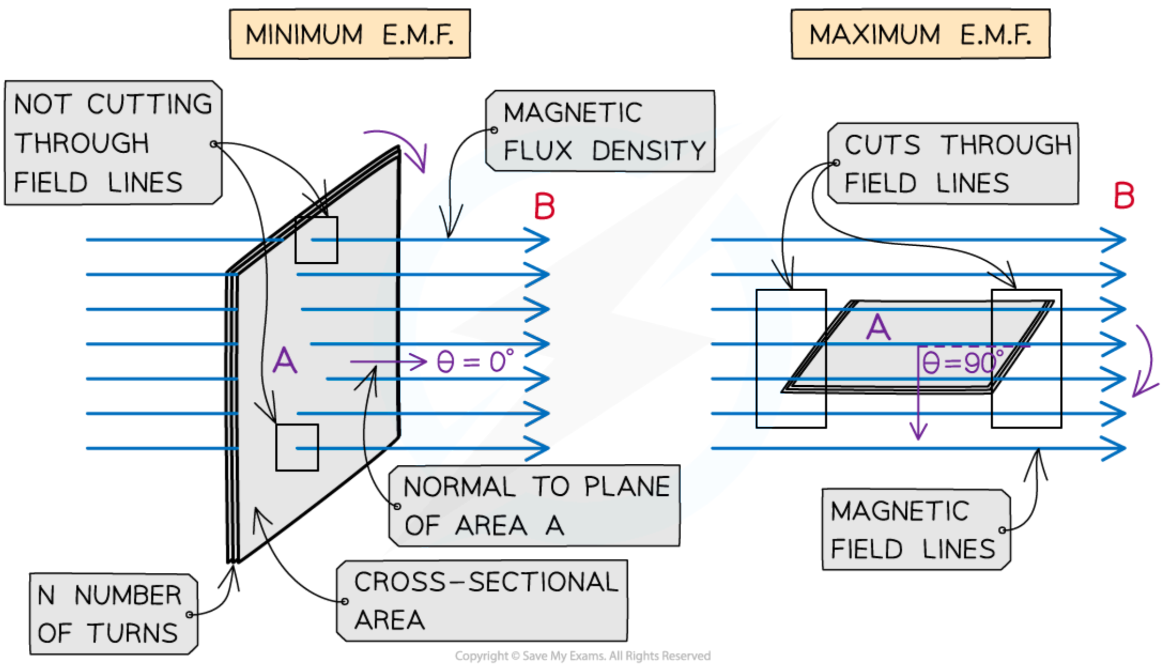
Step 5: Substitute change in flux linkage and time into Faraday's law equation:

$$\varepsilon = \frac{0.014}{0.18} = 0.076 \text{ V}$$

Your notes

EMF Inducted in a Rotating Coil

- When a coil rotates in a uniform magnetic field, the flux through the coil will vary as it rotates
- Since e.m.f is the rate of change of flux linkage, this means the e.m.f will also change as it rotates
  - The maximum e.m.f is when the coil **cuts through** the most field lines
  - The e.m.f induced is an **alternating** voltage



The maximum e.m.f is when the coil cuts through the field lines when they are parallel to the plane of the coil

- This means that the e.m.f is:
  - **Maximum** when **θ = 90°**. The magnetic field lines are parallel to the plane of the area (**or** the normal to the area is perpendicular to the field lines)
  - **0** when **θ = 0°**. The magnetic fields lines are perpendicular to the plane of the area (**or** the normal to the area is parallel to the field lines)

Your notes

- This is the **opposite** of the maximum and minimum flux through the coil
- The flux linkage can also be written as:

$$N\Phi = BAN\cos(\theta)$$

- Where the angle θ depends on the angular speed of the coil, ω:

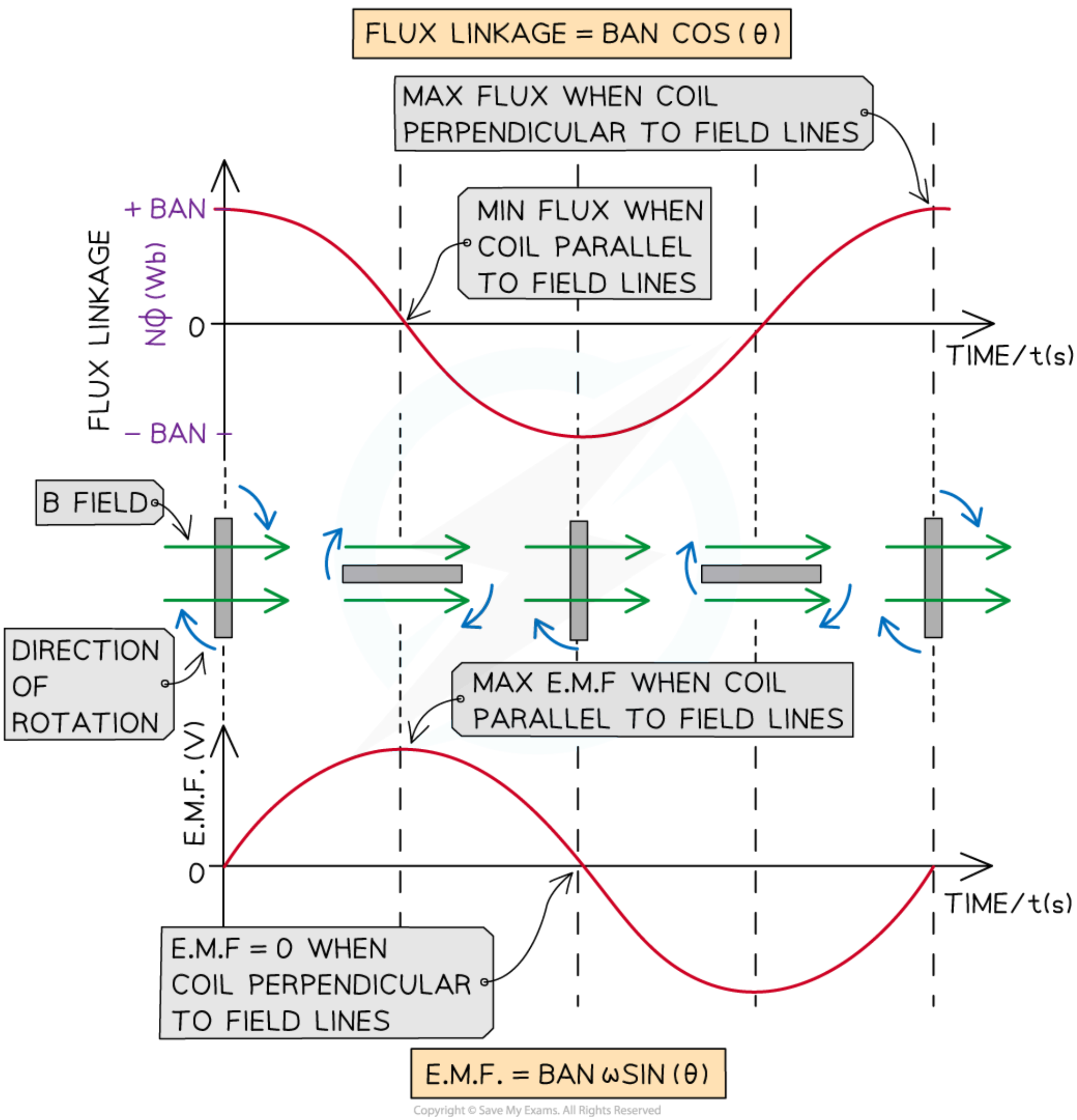
$$\theta = \omega t$$

- The induced e.m.f., ε from Faraday's Law depends on the **rate of change** of flux linkage, which means it can also be written as:

$$\varepsilon = BAN\omega\sin(\theta)$$

  - ε = e.m.f. (V)
  - B = magnetic flux density (T)
  - A = cross-sectional area (m^2)
  - N = number of turns
  - ω = angular velocity of the rotating coil (rad s^{-1})
  - θ = angle between the magnetic field, B and the normal to the area, A (rads)
- The equation shows that the e.m.f. varies **sinusoidally** and it is 90° out of phase with the flux linkage

Your notes



The e.m.f and flux linkage are 90° out of phase

Worked Example

A rectangular coil was 40 turns, each with an area of 0.5 m^2 is rotated at 42 rad s^{-1} in a uniform 3.15 mT magnetic field.

Your notes

Calculate the maximum e.m.f. induced in the coil.

Answer:

Step 1: Write the known quantities

- Number of turns, $N = 40$
- Area, $A = 0.5$ m^2
- Angular velocity, $\omega = 42$ rad s^{-1}
- Magnetic flux density, $B = 3.15$ mT $= 3.15 \times 10^{-3}$ T

Step 2: Write down the e.m.f. equation

$$\varepsilon = BAN\omega \sin(\omega t)$$

Step 3: Determine when the maximum e.m.f. will be

- The maximum e.m.f. occurs when $\sin(\omega t) = \pm 1$, or when the coil is parallel to the magnetic field

Step 4: Substitute in the values

$$\varepsilon = (3.15 \times 10^{-3}) \times 0.5 \times 40 \times 42 \times \pm 1 = \pm 2.6 \text{ V}$$

Examiner Tips and Tricks

The 'magnitude' of the e.m.f. just means its size, rather than its direction. This is often what is required in exam questions, so the minus sign in Lenz's law is not necessarily required in calculations. However, you may be expected to explain the significance of the negative sign in the equation, so be prepared to interpret it as an expression of Lenz's Law!

Remember that the greek letter delta, 'Δ', simply means 'change in'.

Remember not to get mixed up with when the e.m.f. or the flux linkage is at their maximum:

- When the plane of the coil is **perpendicular** to the field lines
  - The flux linkage is at its **maximum**
  - The e.m.f. = **0**
- When the plane of the coil is **parallel** to the field lines
  - The flux linkage is **0**
  - the e.m.f. is at its **maximum**

Since ω is in units of rads s^{-1}, make sure your calculator is in **radians** mode before doing calculations

Your notes

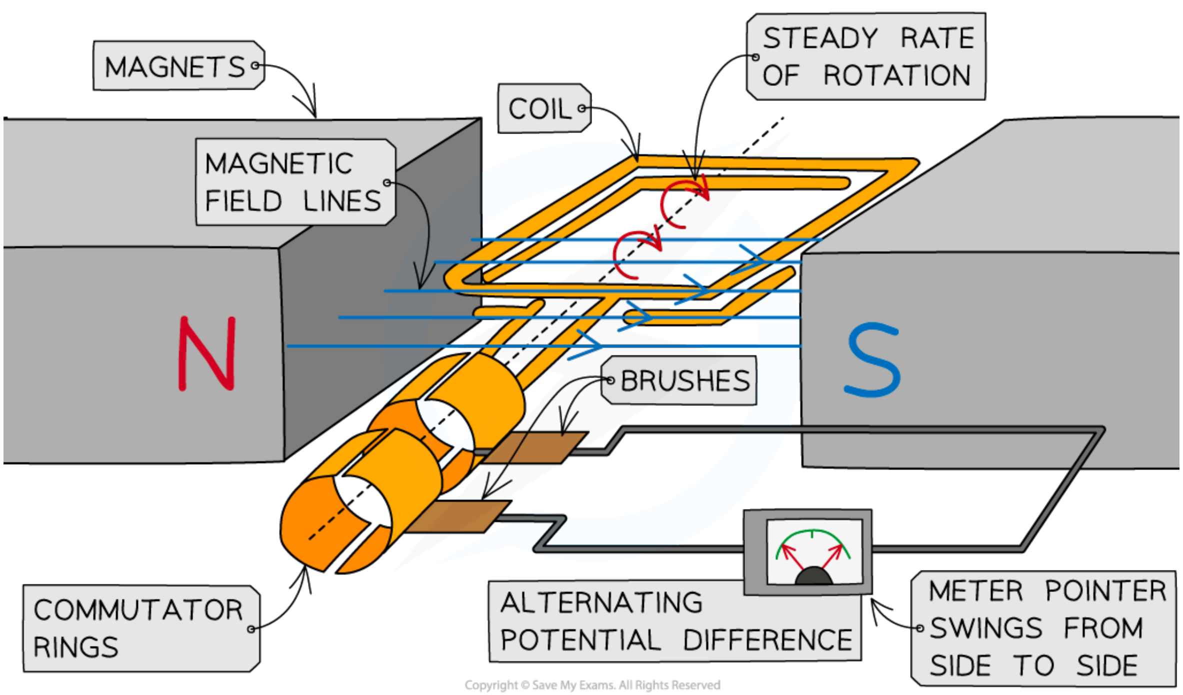
A.C Generator

A.C Generator

- If a coil of wire is rotated inside a magnetic field by an external force, an e.m.f. will be generated in the wire which causes current to flow within the coil
- The **generator effect** can be used to:
  - Generate **a.c.** in an **alternator**
  - Generate **d.c.** in a **dynamo**

Alternators

- A simple alternator is a type of generator that converts mechanical energy to electrical energy in the form of alternating current



An alternator is a rotating coil in a magnetic field connected to commutator rings

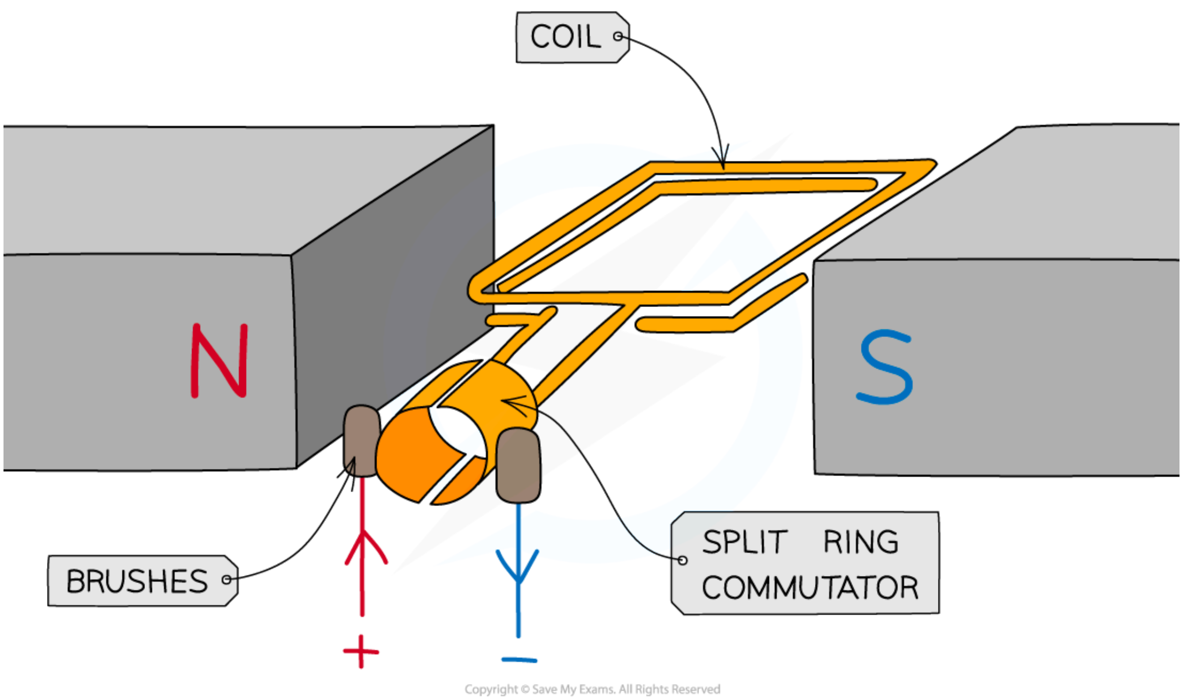
- A rectangular coil that is forced to spin in a **uniform magnetic field**
- The coil is connected to a centre-reading meter by **metal brushes** that press on two metal **slip rings** (or commutator rings)

Your notes

- The slip rings and brushes provide a continuous connection between the coil and the meter
- When the coil turns in one direction:
  - The pointer defects first one way, then the opposite way, and then back again
  - This is because the coil **cuts through** the magnetic field lines and a **potential difference,** and therefore current, is **induced** in the coil
- The pointer deflects in both directions because the current in the circuit repeatedly **changes direction** as the coil spins
  - This is because the induced potential difference in the coil repeatedly changes its direction
  - This continues on as long as the coil keeps turning in the **same** direction
- The induced potential difference and the current **alternate** because they repeatedly **change direction**

Dynamos

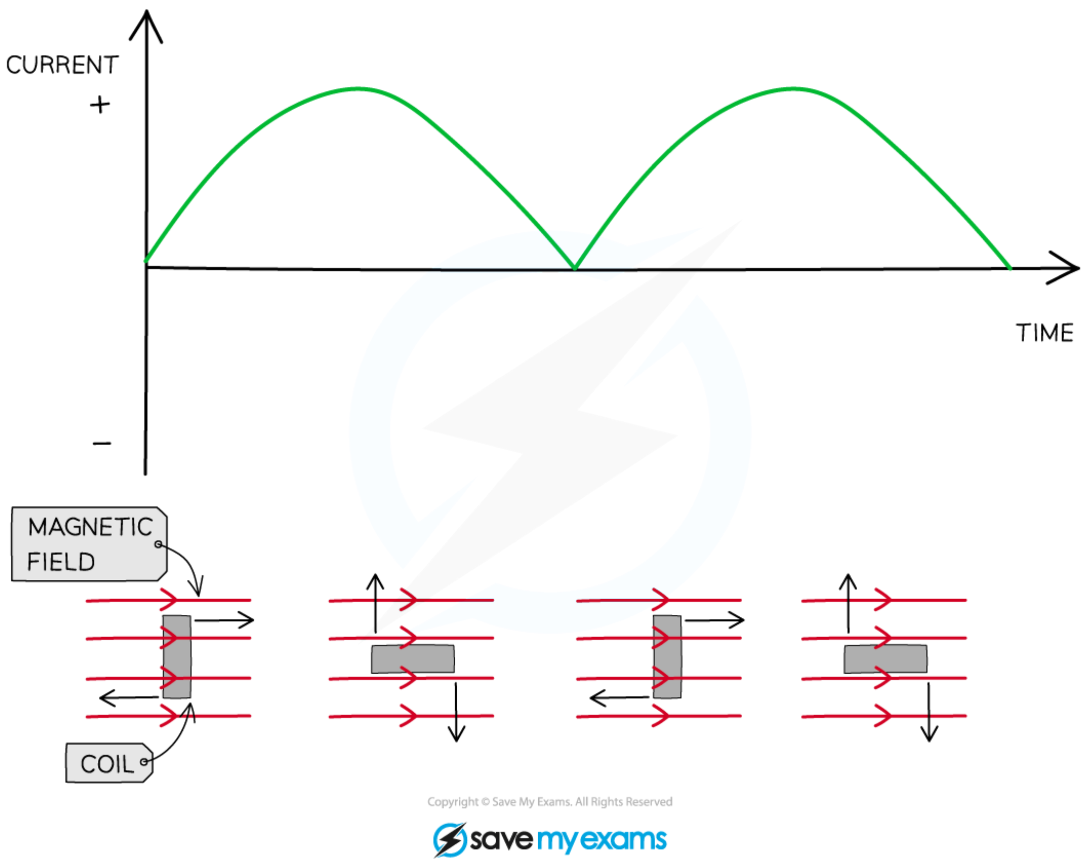
- A dynamo is a direct-current generator
- A simple dynamo is the **same** as an **alternator** except that the dynamo has a **split-ring commutator** instead of two separate slip rings



A dynamo is a rotating coil in a magnetic field connected to a split ring commutator

Your notes

- As the coil rotates, it **cuts** through the field lines
  - This **induces a potential difference** between the end of the coil
- The split ring commutator changes the connections between the coil and the brushes every half turn in order to keep the current leaving the dynamo in the **same direction**
  - This happens each time the coil is perpendicular to the magnetic field lines



D.C output from a dynamo – the current is only in the positive region of the graph

- Therefore, the induced potential difference **does not reverse** its direction as it does in the alternator
- Instead, it varies from zero to a maximum value twice each cycle of rotation, and never changes polarity (positive to negative)
  - This means the current is always **positive** (or always **negative**)

Your notes

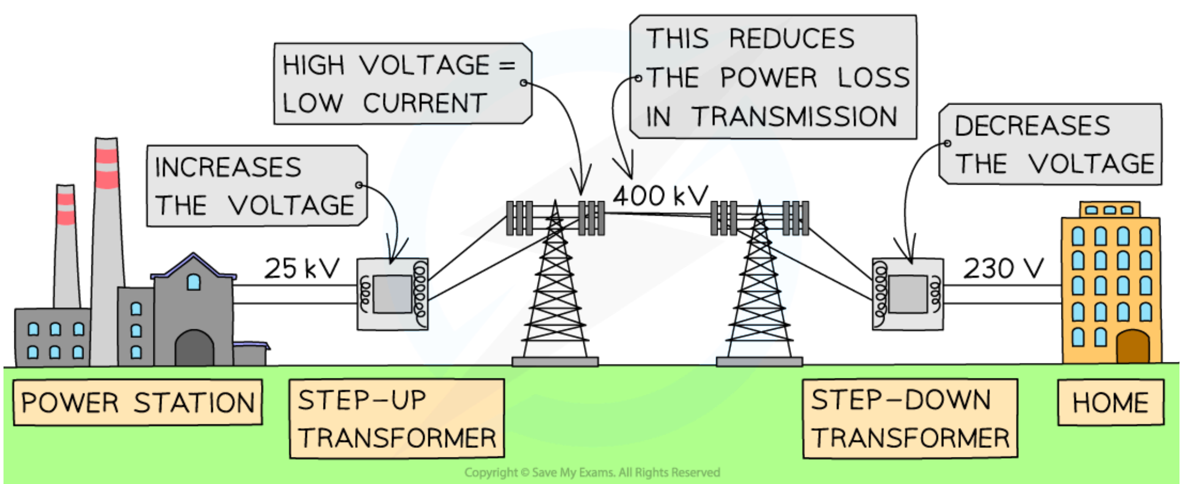
Transformers

The Ideal Transformer Equation

- A transformer is defined as:

  A device that changes high alternating voltage at low current to low alternating voltage at high current, and vice versa

- This is designed to reduce heat energy lost whilst electricity is transmitted down electrical power lines from power stations to the national grid
  - It increases the efficiency of electrical transmission
  - This is because the power dissipated by a resistor is given by $P = I^2R$
  - Therefore, reducing the current also reduces the power loss through the transmission cables
- Transformers are therefore used in the National Grid to increase efficiency of transmission.
  - Electrical power cables have a high voltage and low current due to the use of step-up transformers
  - A step-down transformer is used at a substation near people's homes and businesses to reduce the voltage and increase the current

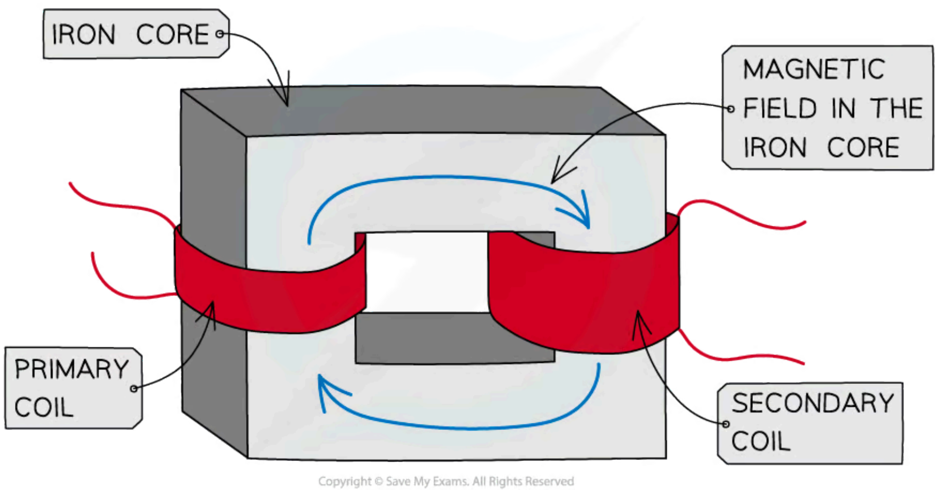


Electricity is transmitted at high voltage, reducing the current and hence power loss in the cables using transformers

- A transformer is made up of:
  - A primary coil

Your notes

- A secondary coil
- A soft iron core
- The primary and secondary coils are wound around the soft iron core
  - The soft iron core is necessary because it focuses and directs the magnetic field from the primary to the secondary coil
  - Soft iron is used because it can easily be magnetised and demagnetised



A step-up transformer has more turns in the secondary coil than primary

- In the primary coil, an alternating current producing an alternating voltage is applied
  - This creates an **alternating magnetic field** inside the iron core and therefore a changing magnetic flux linkage
- A changing magnetic field passes through to the secondary coil through the iron core
  - This results in a changing magnetic flux linkage in the secondary coil
  - Hence, from Faraday's Law, an **e.m.f. is induced**
- An e.m.f. produces an alternating output voltage from the secondary coil
  - The output alternating voltage is at the **same** frequency as the input voltage
- The magnitude of the e.m.f. is determined by the number of coils
  - A **step-up** transformer has **more coils** in the **secondary** than the primary and the **secondary voltage** is **larger** than the primary voltage

Your notes

- A **step-down** transformer has **more coils** in the **primary** than the secondary and the **secondary voltage** is **smaller** than the primary voltage

Transformer Calculations

- The transformer equation is:

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

- Where:
    - N_s = number of turns in the secondary coil
    - N_p = number of turns in the primary coil
    - V_s = output voltage from the secondary coil (V)
    - V_p = input voltage in the primary coil (V)
- There are two types of transformers:
    - **Step-up** transformer (increases the voltage of the power source) where $\mathbf{N_s > N_p}$
    - **Step-down** transformer (decreases the voltage of the power source) where $\mathbf{N_p > N_s}$
- For an **ideal transformer**, there is no electrical energy lost and it is 100% efficient
- This means the power in the primary coil equals the power in the second coil;

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

- Where:
- I_p = current in the primary coil (A)
    - I_s = output current from the secondary coil (A)

Worked Example

A step-down transformer turns a primary voltage of 0.5 kV into a secondary voltage of 100 V.

Calculate the number of turns needed in the secondary coil if the primary coil contains 3000 turns of wire.

Your notes

Answer:

Step 1: List the known quantities

- Primary voltage, V_p = 0.5 kV = 0.5×10^3 V
- Secondary voltage, V_s = 100 V
- Number of turns in the primary coil, N_p = 3000 turns

Step 2: Write down the transformer equation

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

Step 3: Rearrange for number of turns in the secondary coil

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

Step 4: Substitute in the values

$$N_s = \frac{3000 \times 100}{500} = 600 \text{ turns}$$

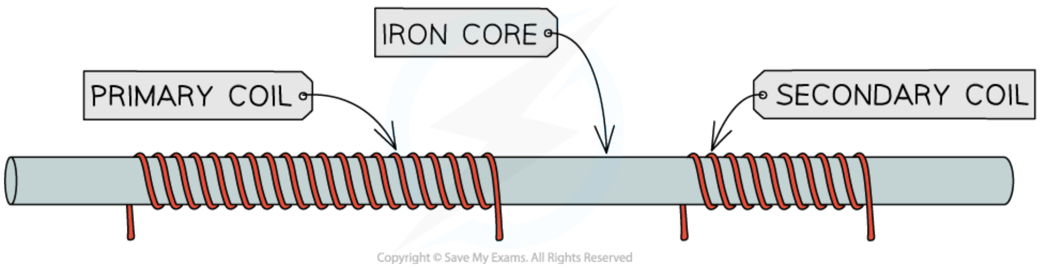
Investigating Transformers

- A simple investigation can be conducted to investigate the transformer equations

Equipment

- Iron rod
- Two 1m lengths of insulated copper wire
- A.c. power supply
- 2 multimeters set to measure a.c. voltage
- 2 multimeters set to measure a.c. current
- Crocodile clips and leads

Method



1. Wind 20 loops of copper wire around the iron rod at one end
   - Wind 10 loops around the other end, using the other piece of wire
2. Connect the first loop to the power pack using the leads and crocodile clips
   - Include a multimeter to measure a.c. voltage across the wire and a multimeter to measure a.c. current in the wire
3. Connect the multimeters to measure a.c. current and voltage to the second wire.
4. Turn on the power pack
   - Record the values of voltage and current in each coil in a suitable table
5. Keeping 20 turns in the initial coil, vary the number of coils in the output coil
   - Record the values of current and voltage for each

Analysis

- For an ideal transformer:

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

- Using the values recorded for V_p, N_p and N_s, calculate the expected value of V_s for each value
  - Compare with the record value
- Do similar with the current
- Plotting a graph of N_s against V_s should give a straight line graph as V_s increases in proportion with number of turns

Evaluation

- The iron core may heat up

- This is due to the formation of eddy currents in the core
- Transformers are often laminated
- This is where layers of iron are glued together, rather than a single block of iron being used

- Some energy will be lost due to the resistance of the wire
    - Using insulated wire minimises heating due to resistance

Examiner Tips and Tricks

In reality, transformers are around 99% efficient. We usually assume 100% efficiency in calculations. Due to this, answers to calculations should be given to 2 or maximum 3 significant figures to account for the inaccuracy.

Your notes