OCR (A) A-Level Physics

6.3 Electromagnetism

Flashcards

Define Magnetic Field

Define Magnetic Field

A region of space in which moving charged particles are subject to a magnetic force.

This force is caused by the interaction of two Magnetic Fields (there is a field around the moving charged particles which interacts with the existing Magnetic Field they are passing through).

Define Magnetic Field Line

Define Magnetic Field Line

The path which a north pole would take when placed in a Magnetic Field.

Field lines go from north to south.

How can you map field lines around a magnet?

How can you map field lines around a magnet?

You can place iron filings on a piece of paper and then put the magnet on the paper and the filings will align to the field.

You can also use a plotting compass and place it in various positions around the magnet, mark the direction of the needle at each point and connect them.

How do you represent the strength of a Magnetic Field on a diagram?

How do you represent the strength of a Magnetic Field on a diagram?

It is represented by how close together the field lines are – the closer they are, the stronger the field. (It is the **density** of the field lines, which is why **magnetic flux density** and **Magnetic Field strength** are interchangable).

Define Magnetic Flux Density

Define Magnetic Flux Density

The force per unit current per unit length on a current-carrying conductor placed in a Magnetic Field perpendicular to the field lines. (Magnetic flux per unit area).

What is the unit of Magnetic Flux Density?

What is the unit of Magnetic Flux Density?

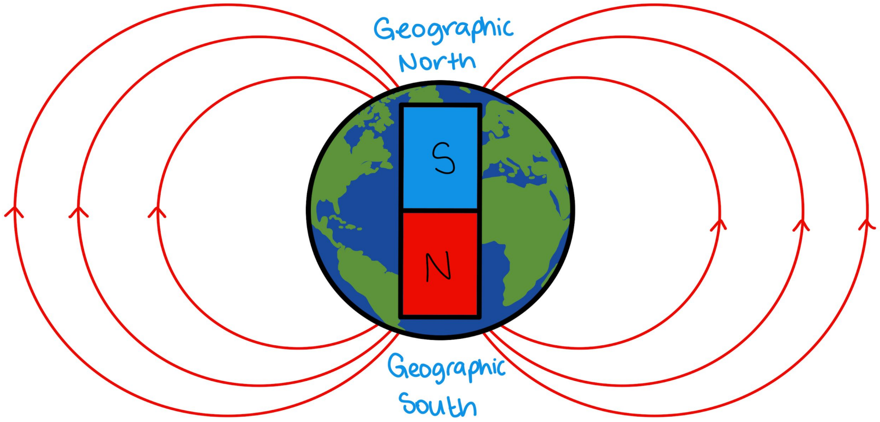
Tesla (T)

$1\ T = 1\ N\ m^{-1}\ A^{-1}$

Why does a compass point to the North Pole of the Earth?

Why does a compass point to the North Pole of the Earth?

The Earth's geographic north pole is actually the magnetic south pole, so the north pole of the compass magnet (the needle) lines up with the Earth's field and points to the magnetic south (field lines go from north to south), which is what we call the geographic north.



How do you work out the shape of the field around a current-carrying wire?

How do you work out the shape of the field around a current-carrying wire?

The right-hand thumb rule: take your right hand and make a thumbs-up shape. Point your thumb in the direction of the (conventional) current and the field goes around the wire in the direction of your fingers (from palm to tip).

How do you work out the shape of the field around a solenoid?

How do you work out the shape of the field around a solenoid?

Where the current is going **anticlockwise** around the coil is the north pole. At the south pole, the current goes clockwise. The shape of the field is then similar to a bar magnet. A good way to remember it is by the shapes of the letters:

What does the Magnetic Field around a flat, circular coil look like?

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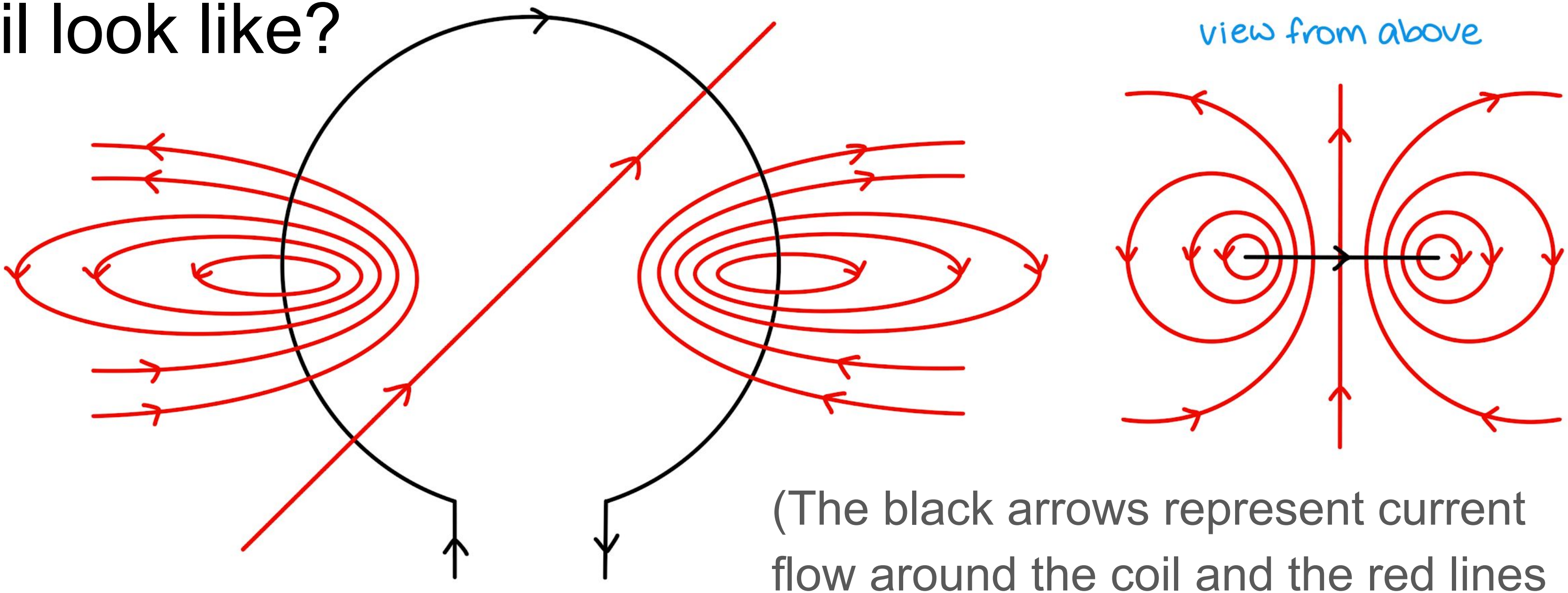


(The black arrows represent current flow around the coil and the red lines are the field lines).

Define the motor effect

Define the motor effect

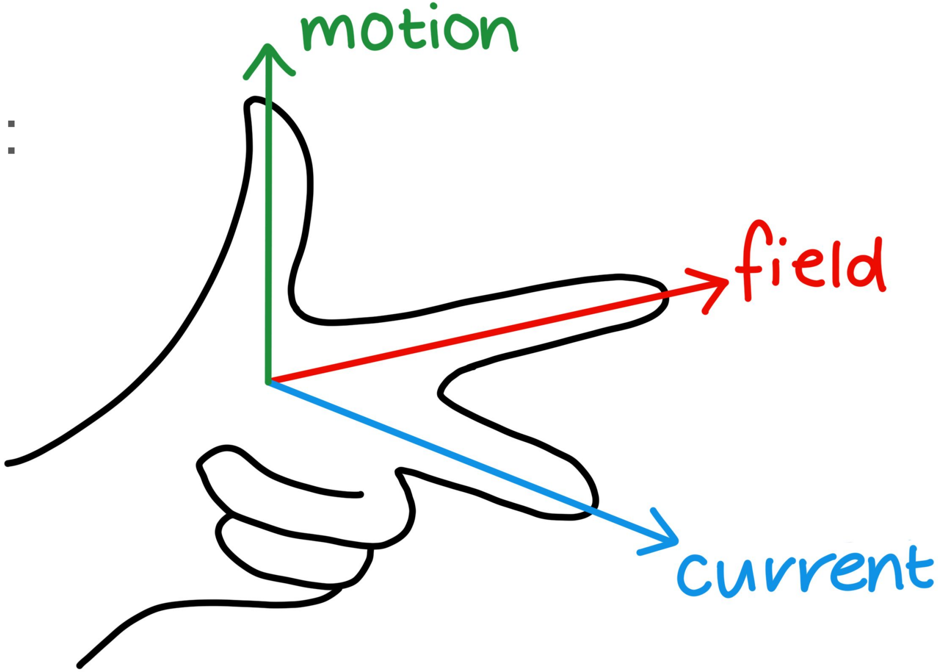
When a current-carrying conductor is placed within a Magnetic Field, it experiences a force perpendicular to the flow of current and the field lines which pushes it out of the field.

How can you predict which direction the force will push the conductor? (motor effect)

How can you predict which direction the force will push the conductor?

Using Fleming's left-hand rule:

- **F**irst finger: **F**ield lines
- Se**c**ond finger: **C**urrent (conventional)
- Thu**m**b: **M**otion



Give the formula relating magnetic force, flux density, current, length and angle between the field and the conductor

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$$F = BIL\sin\theta$$

F = Magnetic force (N)

B = Magnetic flux density (T)

I = Current in the conductor (A)

L = Length of conductor in the field (m)

θ = Angle between the field lines and the conductor (º or rad)

Describe an experiment to measure flux density

Describe an experiment to measure flux density

1. Place a horseshoe magnet on a digital balance and zero it
2. Connect rigid piece of straight wire to DC supply, variable resistor and ammeter (in series)
3. Align the wire so the force on it acts upwards (so there will be a downward force on the magnet – Newton's 3rd law)
4. Measure the length of the wire in the field
5. Record extra mass on the balance and use this to calculate force (F = mg)
6. Plot a graph of current against mass – gradient gives BL/g
    a. Since L and g are both known, B can be calculated

What does the previous experiment setup look like?

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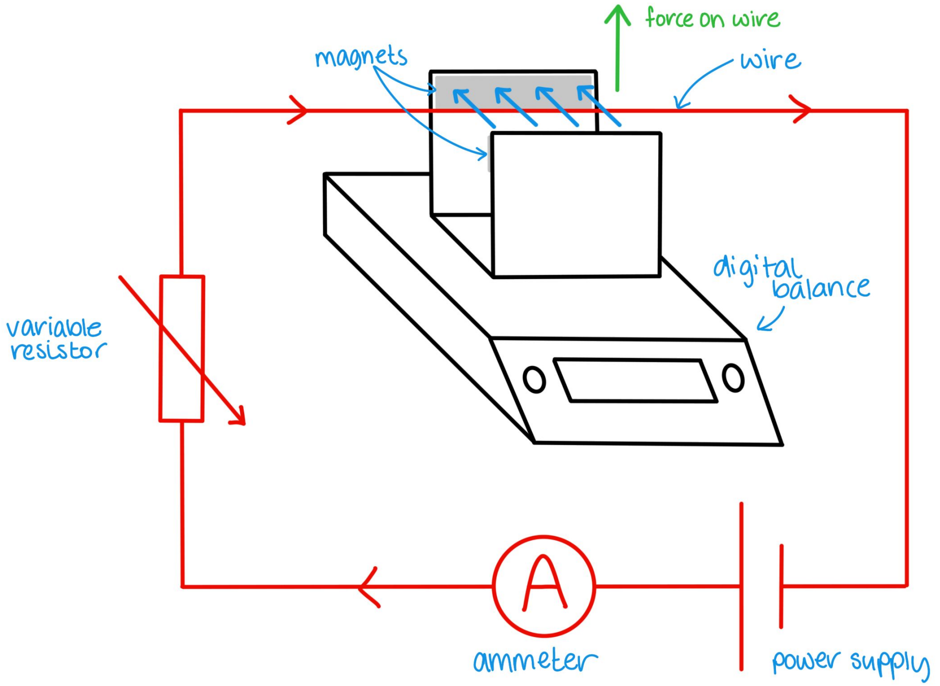


What is the formula for magnetic force on a moving charge at 90° to the field lines?

What is the formula for magnetic force on a moving charge at 90° to the field lines?

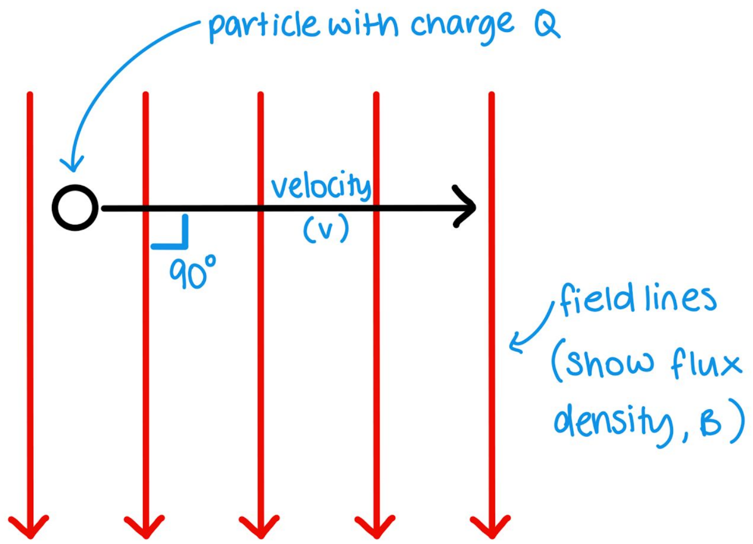
$F = BQv$

F = Force (N)

B = Magnetic flux density (T)

Q = Charge of particle (C)

v = Velocity of particle (ms^{-1})



How is $F = BQv$ derived?

How is $F = BQv$ derived?

From $F = BIL$ (for magnetic force on a conductor at 90º to field lines).

Use $I = Q/t$ and $L = vt$ (distance = speed x time).

$$F = BQvt/t$$

The t cancels out, leaving $F = BQv$

Why do charged particles move in a circular orbit in a Magnetic Field?

Why do charged particles move in a circular orbit in a Magnetic Field?

Force is always perpendicular to the velocity of the particle, so they end up being forced in a circular orbit. The particles undergo centripetal acceleration, with the centripetal force being the magnetic force.

How can you derive the formula for the radius of the circular orbit?

How can you derive the formula for the radius of the circular orbit?

Equating the formula for centripetal force and the formula for magnetic force (since they are the same thing in this context), you get $mv^2/r = BQv$.

Rearrange this and you get:

$$r = mv / BQ$$

Using $r = mv / BQ$, explain how changing the mass, velocity, flux density and charge affects the radius of the orbit

Using r = mv / BQ, explain how increasing the mass, velocity, flux density and charge affects the radius of the orbit

Increasing mass or velocity will increase the radius.

Increasing flux density or charge will decrease the radius.

What is the purpose of a velocity selector?

What is the purpose of a velocity selector?

They isolate particles of a specific velocity. This is useful for things like mass spectrometry.

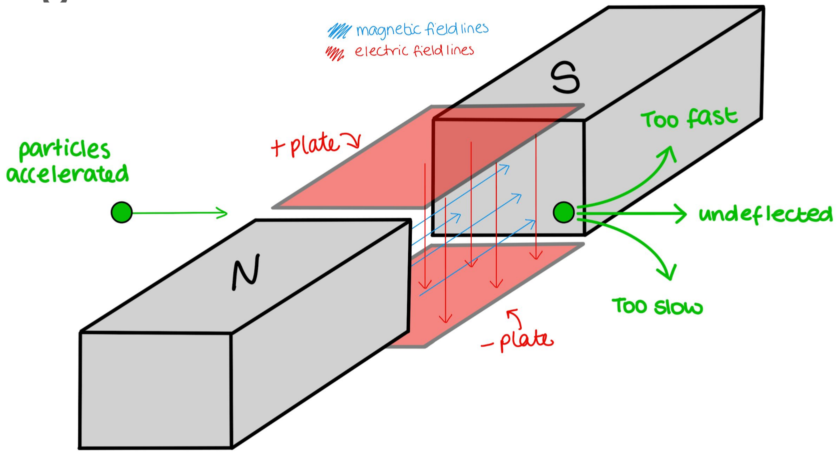
How does a velocity selector work?

How does a velocity selector work?

There are electric plates above and below so the electric force acts upwards, and there is a Magnetic Field passing through sideways so the magnetic force acts downwards. In order for the particles to pass through undeflected, the electric and Magnetic Fields must be balanced so BQv = EQ.

From this, you can derive v = E/B.

If the velocity is too fast or too slow, the particle will be deflected and not pass through.



Define Magnetic Flux

Define Magnetic Flux

The product of the magnetic flux density and the area perpendicular to the field lines. Magnetic flux is represented by the Greek letter Phi, ϕ.

What is the unit for Magnetic Flux?

What is the unit for Magnetic Flux?

Weber (Wb), where $1Wb = 1Tm^2$

What is the formula for Magnetic Flux?

What is the formula for Magnetic Flux?

$$\phi = BA\cos\theta$$

ϕ = Magnetic flux (Wb)

B = Magnetic flux density (T)

A = Area perpendicular to the field (in a coil this is the cross-sectional area) (m^2)

θ = angle between the normal to the coil and the field lines (° or rad)

Define Magnetic Flux linkage

Define Magnetic Flux linkage

The magnetic flux of an entire coil of wire. This is the product of the magnetic flux and the number of turns on the coil.

Flux linkage is also measured in Wb, and it is represented as $N\phi$.

State Lenz’s Law

State Lenz's Law

Induced emf is always in a direction so as to oppose the change that caused it.

Explain Lenz's Law in terms of energy

Explain Lenz's Law in terms of energy

Lenz's law follows the principle of the conservation of energy. If the induced emf was in a direction that aided the change which caused it, it would be creating electrical energy from nowhere.

For example, if the north pole of a bar magnet was pushed into a solenoid and that end became a south pole, it would then pull the magnet into the coil faster and field would get stronger, pulling the magnet in faster still, etc.

State Faraday’s Law

State Faraday's Law

The induced emf in a circuit is proportional to the rate of change of flux linkage throughout the circuit.

What is the formula that links Faraday’s Law and Lenz’s Law?

What is the formula that links Faraday's Law and Lenz's Law?

$$\varepsilon = -\frac{\overbrace{(\Delta N\phi)}^{\text{change of flux linkage (Wb)}}}{\Delta t}$$

induced emf (V)

change in time (s)

negative because emf acts in the opposite direction to the change that caused it → Lenz's Law

What is a search coil?

What is a search coil?

A flat coil of insulated wire connected to a galvanometer (a sensitive ammeter). It can be used to determine magnetic flux density from the current induced in the coil when it is withdrawn from a Magnetic Field.

How can you measure magnetic flux using a search coil?

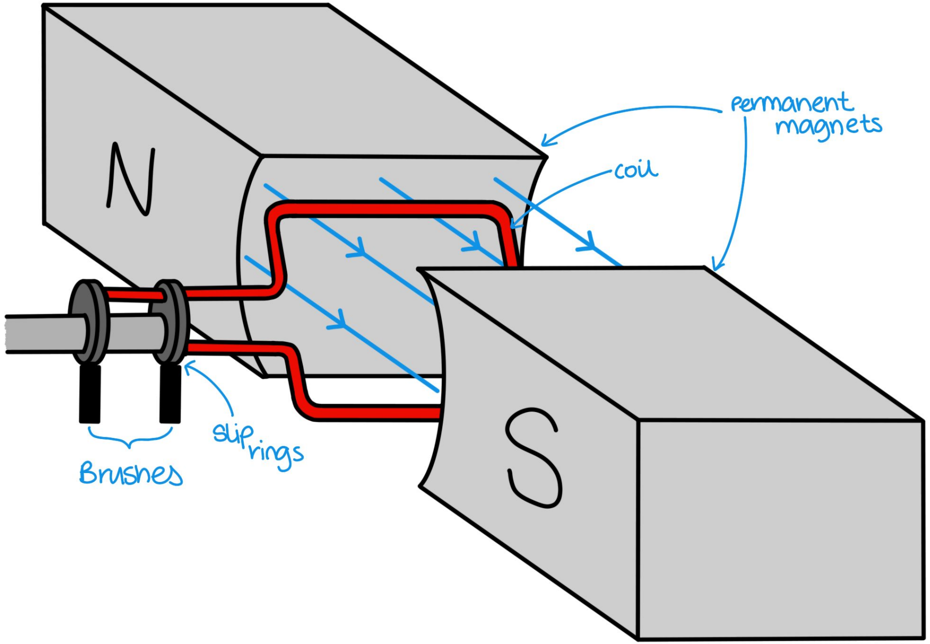
How can you measure magnetic flux using a search coil?

1. Place the coil in a Magnetic Field of known strength and pull it out again. Since $I_{max} \propto B$, you can calculate the constant of proportionality, k (therefore calibrating the coil).
2. Place the coil in the field that is to be measured and withdraw it. Use the value for k and the current to calculate the flux density.
3. Calculate magnetic flux from the flux density using $\phi = BA\cos\theta$

What is the structure of a simple A.C. generator?

What is the structure of a simple A.C. generator?

A rectangular coil which spins in a uniform Magnetic Field.



How does a simple A.C. generator work?

How does a simple A.C. generator work?

The flux linkage in the coil changes continuously, inducing an alternating current in the coil.

(A and θ change as the coil turns and $N\phi = BAN\cos\theta$)

How do emf and flux linkage vary in a simple A.C. generator? (graphs)

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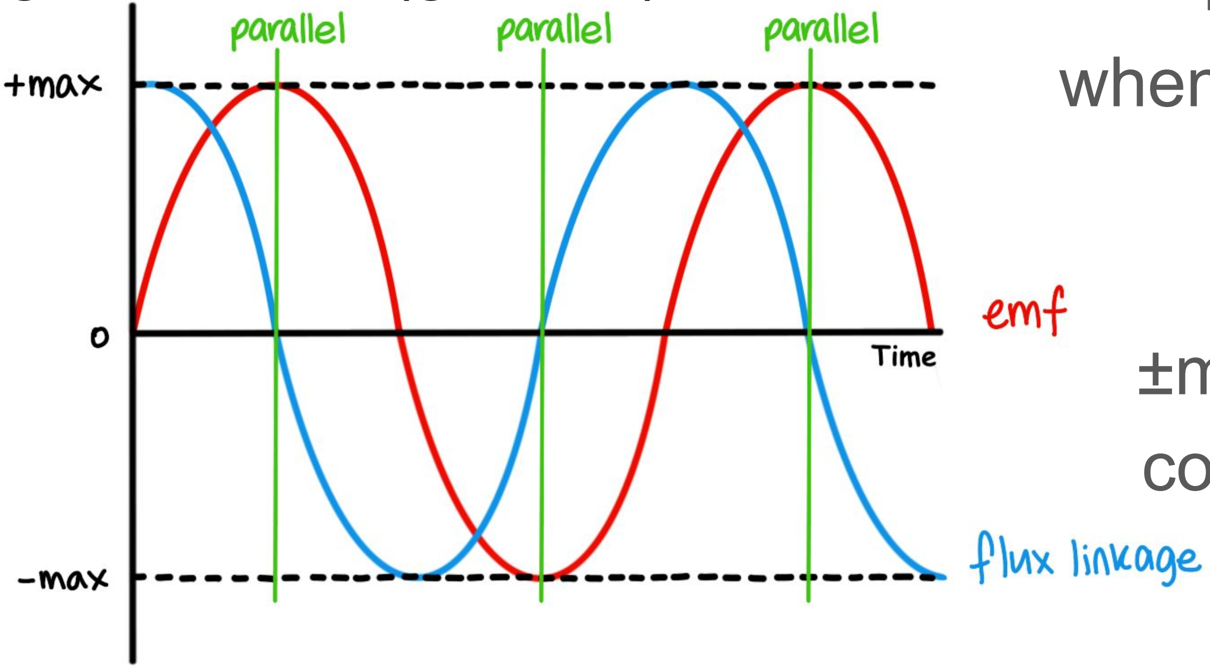


EMF is ±maximum when the coil is parallel to the field lines, whereas Nϕ is ±maximum when the coil is 90º to the field lines.

How can the peak emf of an A.C. generator be increased?

How can the peak emf of an A.C. generator be increased?

1. Increase the speed of rotation
2. Increase the magnetic flux density of the field
3. Increase the cross-sectional area of the coil
4. Increase the number of turns on the coil

What is the purpose of a transformer?

What is the purpose of a transformer?

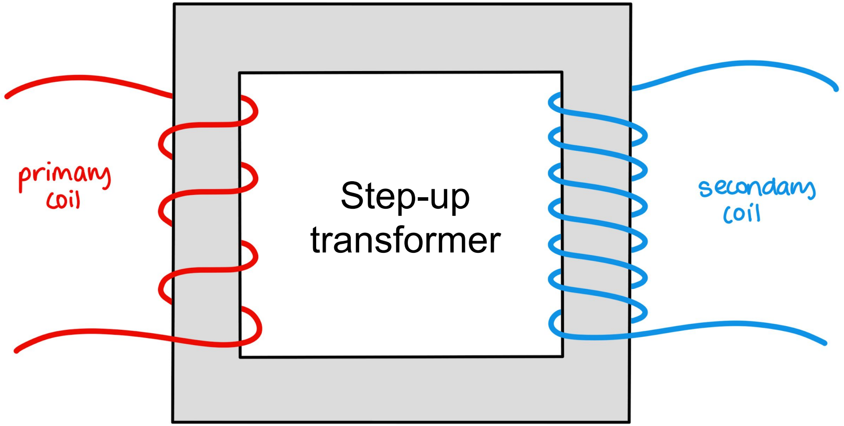
Transformers change the peak value of an alternating PD to a different value. Step-up transformers increase it, step-down transformers decrease it.

Describe the structure of a simple transformer

Describe the structure of a simple transformer

Two coils – primary coil and secondary coil – wrapped around the two sides of a laminated iron ring. For a step-up, there are more turns on the secondary coil.

For a step-down, there are more turns on the primary coil.



How does a transformer work?

How does a transformer work?

An alternating current is run through the primary coil, which induces an alternating Magnetic Field in the iron core. This, in turn, induces an alternating emf in the secondary coil.

Give the formula that relates the number of turns with the potential difference of each coil

Give the formula that relates the number of turns with the potential difference of each coil

$$V_s / V_p = N_s / N_p$$

V = potential difference

N = number of turns

$_p$ = primary coil

$_s$ = secondary coil

For an ideal transformer (100% efficient), give the formula relating potential difference and current in both coils

For an ideal transformer (100% efficient), give the formula relating potential difference and current in both coils

If efficiency = 100%, power in the primary coil = power in the secondary coil. This means $I_p V_p = I_s V_s$. Rearranging this gives $\mathbf{I_p / I_s = V_s / V_p}$ (which is also the same as N_s / N_p)

What role do transformers play in the National Grid?

What role do transformers play in the National Grid?

Step-up transformers are used to increase the voltage (and decrease current) before the electricity travels long distances. This is to reduce energy lost as heat due to resistance in the wires as the electricity passes through.

Describe an experiment to investigate the relationship $V_s / V_p = N_s / N_p$

Describe an experiment to investigate the relationship $V_s / V_p = N_s / N_p$

Vary the number of turns on each of the coils and measure the peak potential difference of each one every time. Then use the values to prove the relationship between potential difference and number of turns. It is better to use an oscilloscope than a voltmeter for an alternating pd since it is easier to see the peak value.

How can you investigate the efficiency of a transformer?

How can you investigate the efficiency of a transformer?

Measure the current in each coil with an ammeter and a variable resistor. The variable resistor is used to vary the current at a constant pd.

Use the formula P_{out} / P_{in} x100% (or I_pV_p / I_sV_s x100%) to calculate the efficiency of the transformer.