PHYSICS NOTES - ELECTRICITY & MAGNETISM

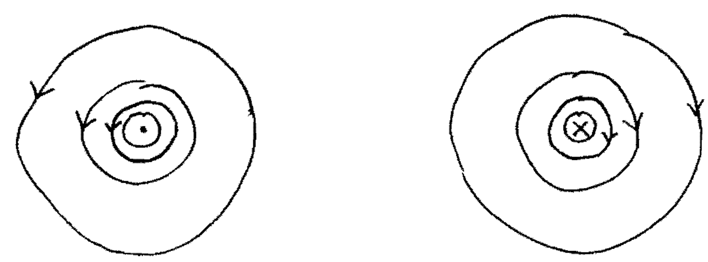
- To start with we need to understand some symbology:

Think of an arrow: if you see ⊙, it is the point of the arrow coming towards you, ie. the wire & the CONVENTIONAL CURRENT is coming towards you.

If you see ⊗, it is the arrows stabilator going away from you ie. the wire and the CONVENTIONAL CURRENT is moving away from you into the page.

- We know that if a current flow through a wire, there will be a magnetic field around the wire. We can determine the direction of this using the RIGHT HAND GRIP RULE, where the <u>THUMB</u> points in the direction of the <u>CONVENTIONAL CURRENT</u>

By the RIGHT HAND GRIP RULE

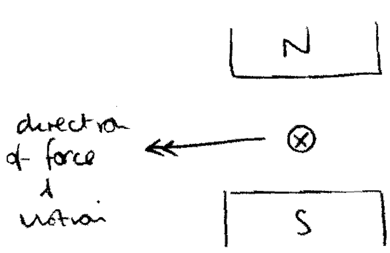


I out of page ∴ magnetic field is anti-clockwise.

I into the page magnetic field is clockwise.

THE MOTOR EFFECT

- If a current carrying wire is placed into permanent magnetic field, and the wire and the field are a 90° to each other, the wire will experience a force (motion).



Note: the current, magnetic field & force are all at 90° to each other.

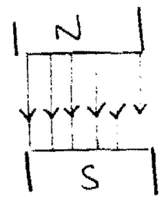
We can calculate the direction of motion using FLEMING'S LEFT HAND RULE where,

THUMB = force/motion

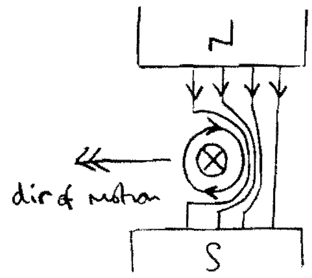
FIRST FINGER = permanent magnetic field

SECOND FINGER = Conventional Current (I)

The field between two poles normally looks like this:



When we place the current carry wire in the field, we get:

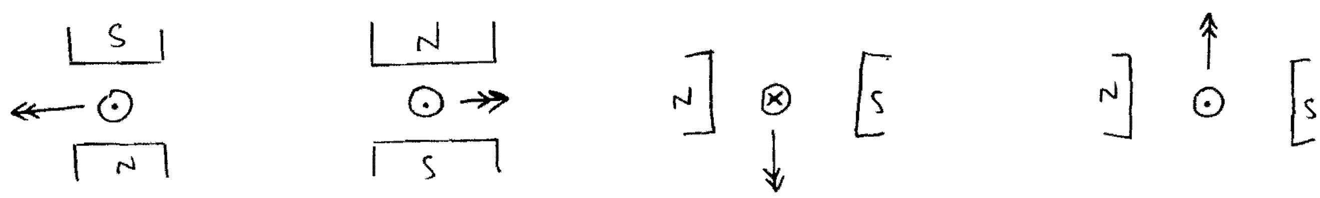


• The interaction between the two magnetic fields causes a force to be exerted on the current carrying wire.

REMEMBER: <u>FIELD LINES</u>

- graphical representation to aid with understanding
- never cross
- Away North towards South (ANTS)
- Closer together = stronger field, further apart = weaker field.
- They are continuous lines from one pole to another.

<u>Other examples.</u>



In the MOTOR EFFECT ⇒ PERMANENT MAGNETIC FIELD + CURRENT CARRYING WIRE = FORCE & MOTION

What if:

PERMANENT MAGNETIC FIELD + MOVING WIRE? ⇒ ELECTROMAGNETIC INDUCTION

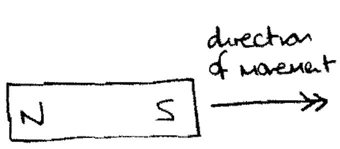
<u>ELECTROMAGNETIC INDUCTION</u>

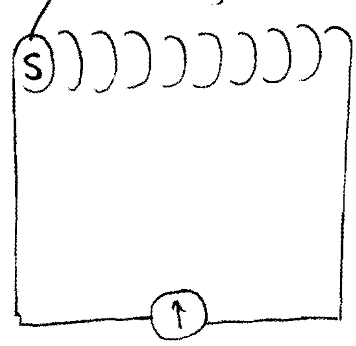
By moving a wire through a permanent magnetic field, an EMF can be induced allowing a current to flow in the wire.

<u>What is LENZ'S LAW?</u> Lenz's Law is essentially the law for the CONSERVATION OF ENERGY in electromagnetic induction.

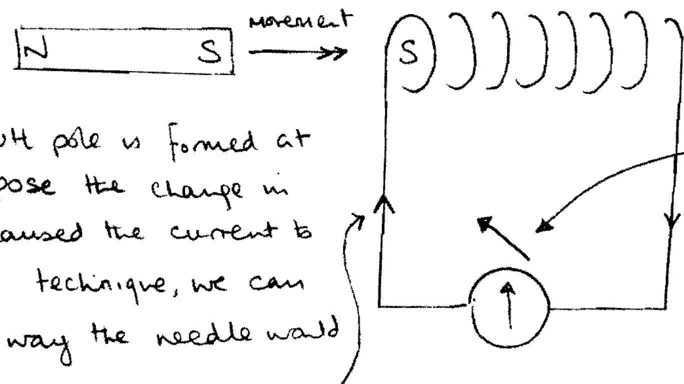
Lenz's Law states: "When a current is induced it always opposes the change in the magnetic field that caused it."

a south pole is formed to oppose the approaching South pole.



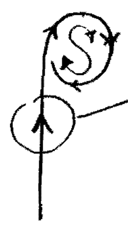


As magnet move towards solenoid, the magnetic field cuts across the solenoid, inducing an emf and allowing a current to flow. The current flows in a direction that forms a SOUTH POLE at the Left Hand Side. WORK must be done to overcome the repulsive force ∴ energy is transferred to electrical energy in the circuit.

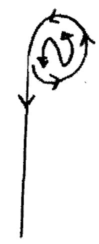


We know that a South pole is formed at the Solenoid to oppose the change in magnetic field that caused the current to flow. Using another technique, we can now work out which way the needle would move:

Current is going from right to left through the sensitive ammeter, ∴ the needle would kick to the LEFT.

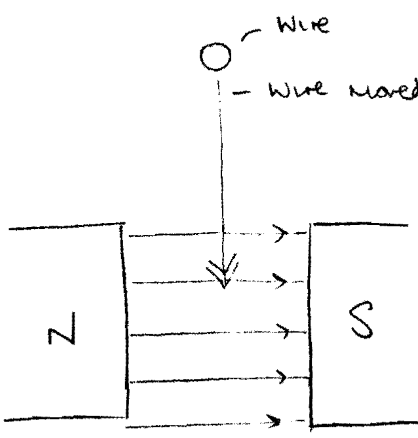


for a North Pole.



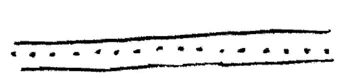
What if we used a single wire.

①



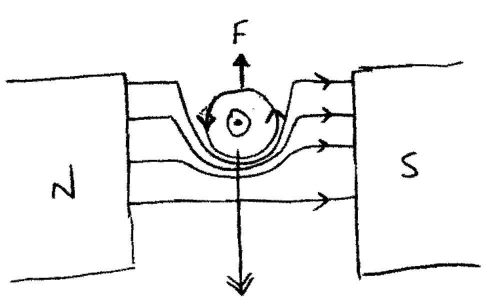
① At this stage, the wire is moving down, but it is not cutting across the field lines, therefore no emf is induced and the current does not flow.

- Imagine the wire as a line of electrons from a side on view.



② As the electron flow is down, the conventional current is upwards. Using Fleming Left Hand rules, we get the force on the charge into the page, so the conventional current is out of the page ⊙

②



Wire still moving at velocity, V

- As soon as the current flows, there is a magnetic field around the wire. We can determine the direction of this using the Right Hand Grip Rule.

- The interaction between the permanent magnetic field and the circular field around the wire leads to a force being exerted in the opposite direction to the motion of the wire. WORK has to be done to overcome this force ∴ energy is being transfered to the electrical energy of the wire → LENZ'S LAW IS OBEYED → Conservation of energy

We do not get electrical energy for nothing → work has been done overcoming the opposing force.

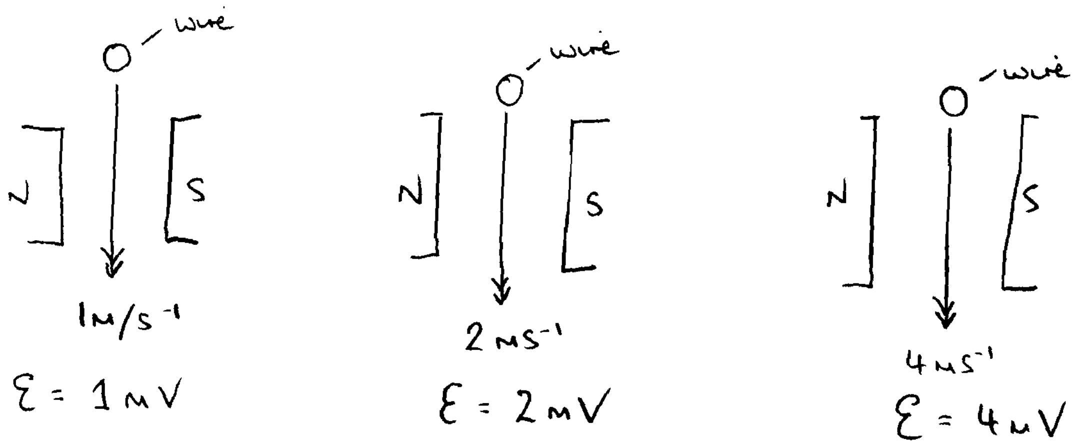
In simple terms, the [illegible] ... [illegible] the rate of change the greater the emf induced, and therefore the larger the current which flows.

This can be written as

$$\mathcal{E} \propto \frac{d\phi}{dt}$$

Emf $\propto$ rate of change of magnetic flux across the wire.

Therefore:



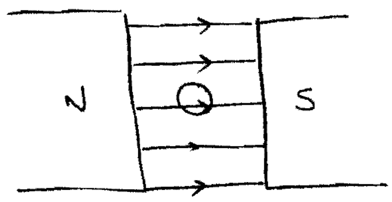
There are 3 ways to increase the Emf induced:

① As above, increase the speed of the wire moving through the field

② Use a stronger magnet <u>or</u> move the poles closer together to increase the strength of the magnetic field.

③ Make the wire into several loops, so that a greater area of wire passes between the poles. In this instance, a greater number of charge carriers (electrons) will feel a force exerted on them ∴ greater Emf and current.

④ Increase the size of the North & South Pole, such that a greater amount of wire is in the field at any given moment.



If the wire is stationary in the middle of the magnetic field, there is no changing magnetic field across the wire ∴ no emf is induced and ∴ no current flows.

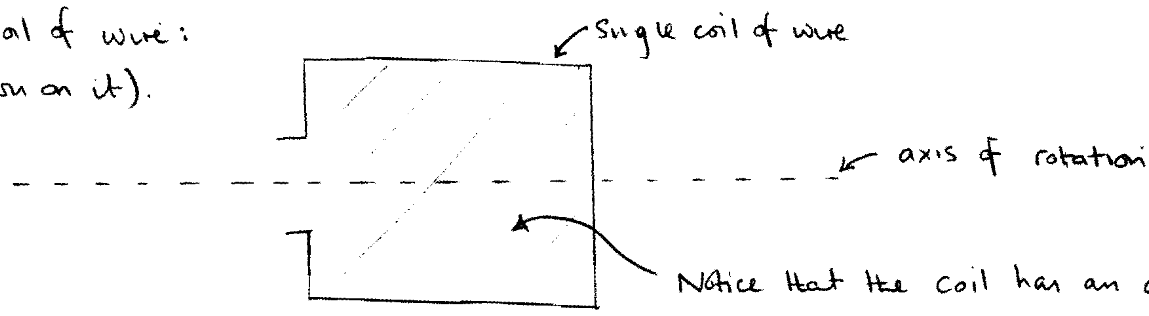
AC GENERATORS

[**WARNING**: Whilst a basic understanding of AC Generators is required for IGCSE, this section of the notes takes you beyond the required standard]

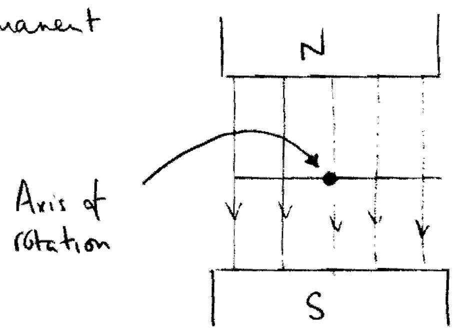
AC Generator is electromagnetic induction to produce electrical energy.

However, before we move on, we must build up from the basics.

Take a coil of wire:
(looking down on it).



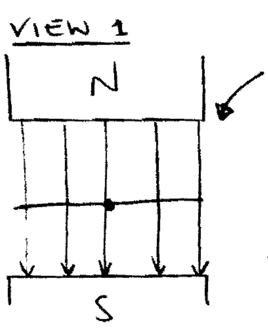
If we take the coil and place it a permanent magnetic field:



Simplified, the MAGNETIC FLUX ϕ IS:

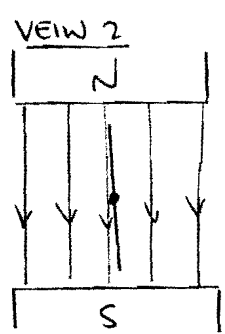
$$\phi = \text{Magnetic field strength} \times \text{Area of coil.}$$

VIEW 1



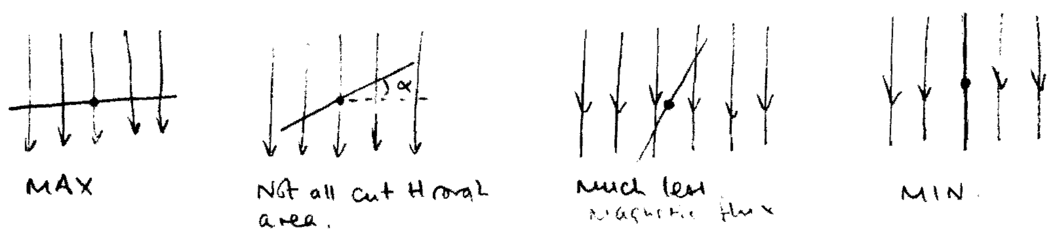
In this view, all the field lines cut through the area of the coil ∴ the MAGNETIC FLUX IS a MAXIMUM

VEIW 2

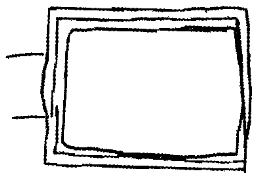


In this view, the coil has been rotated through 90°. Now no field lines cut through the area of the coil, ∴ the MAGNETIC FLUX IS a MINIMUM

As the coil rotates, there is the interim positions where the magnetic flux varies between MAXIMUM and MINIMUM.



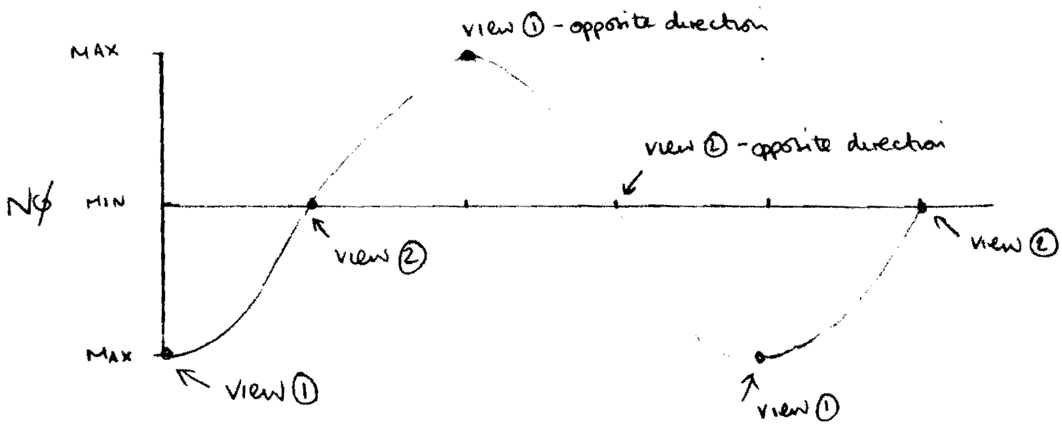
In reality, the coil is made up from many loops



Every coil contributes to the flux, therefore:

The FLUX LINKED to a coil ($N\phi$) with multiple turns is the flux through one turn (ϕ) multiplied by the number of turns (N).

We can therefore plot a graph of $N\phi$ vs. the angle of the coil.

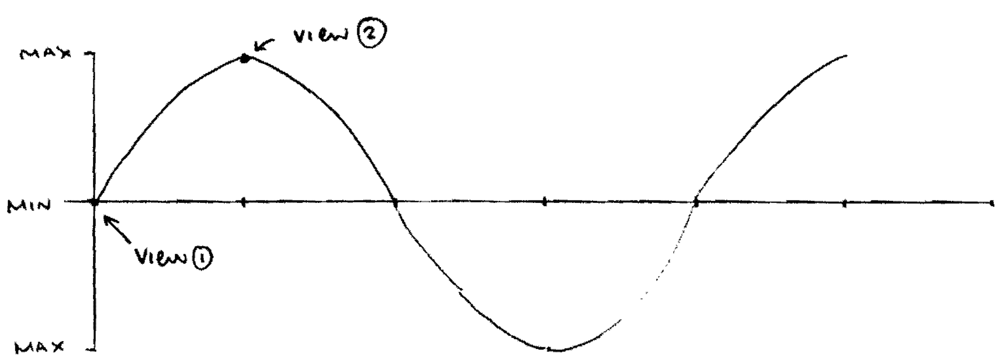


Faraday's Law of Electromagnetic Induction States that

Emf Induced $\propto$ rate of change of magnetic flux

$$\mathcal{E} \propto \frac{d N\phi}{dt}$$

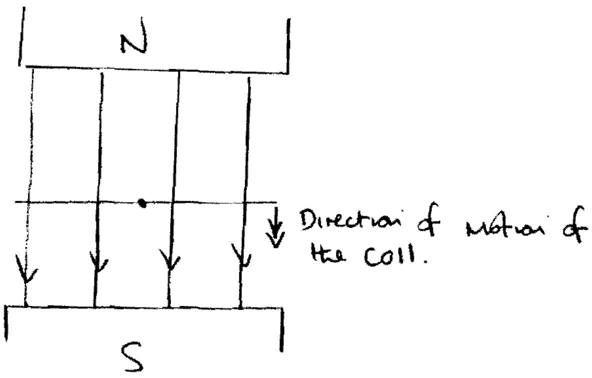
We can therefore plot the Emf Induced versus angle.



Does this make sense?

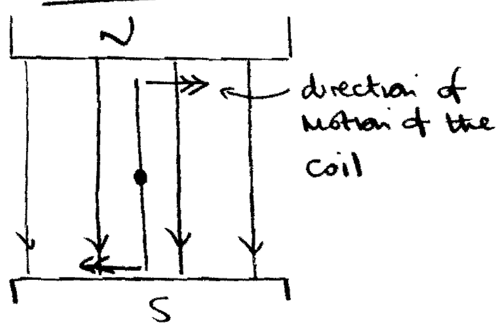
Let us revisit VIEW ① & VIEW ②.

VIEW ①



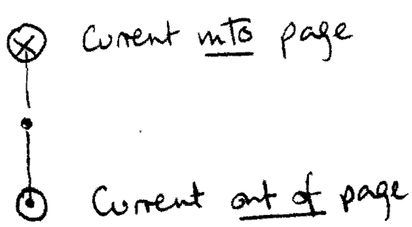
- $N\phi$ = MAXIMUM
- Emf Induced = MINIMUM i.e. zero
- On examination of the diagram, we see that the direction of the coil is PARALLEL to the field lines – by Fleming's Left Hand Rule, no current will flow. (no Emf induced to push the charge along).

VIEW ②



⇓

Using Fleming LHR (see note about LHR in Induction)

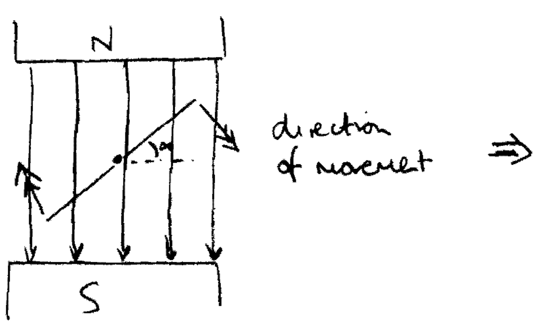


- $N\phi$ = MINIMUM
- Emf Induced = MAXIMUM
- Greatest current flowing
- On examination of the diagram, we see that the direction of the coil movement is PERPENDICULAR to the field lines – by Fleming's Left Hand Rule, a current will be flowing
- Note that:

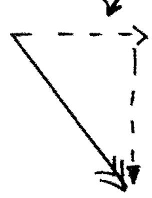
  Thumb – Force (Emf ∴ Conv Current direction)
  First Finger – Permanent field
  Second Finger – Relative motion of the positive charge

  → this is specific to electro-magnetic INDUCTION – alternatively, you can use FLEMING'S RIGHT HAND RULE for E-M Induction

What about the in between position



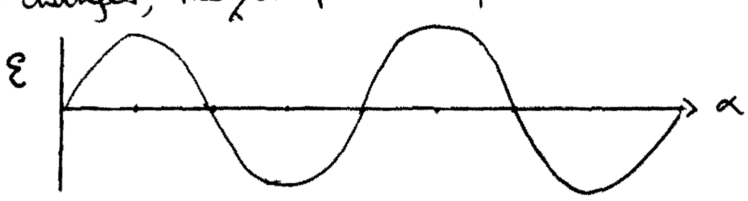
⇒



HORIZONTAL COMPONENT – still cuts across the field lines in a PERPENDICULAR manner ∴ emf induce and current flow.

← vertical component of the movement PARALLEL TO THE FIELD LINES ∴ DOES NOT CONTRIBUTE TO CURRENT

As the angle (α) changes, the vector components of the motion change giving:



AC Supply.