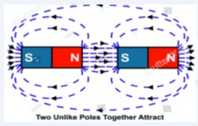
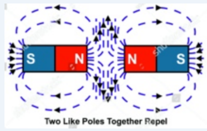
# Magnetic Fields QuickSheet    Exam Board: AQA A2    Saba Tutoring

## The Basics

- Magnetic fields are created by moving charges e.g. a moving particle or current
- Field lines, showing direction of force, are always drawn from north to south.
- Can demonstrate field patterns using iron filings or compass
- Some materials are soft i.e. can magnetise and demagnetise easily e.g. iron. When the m.field is removed, they demagnetise




## Concept 1: A current carrying conductor creates a magnetic field

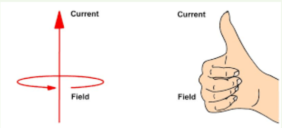
- This can either be straight conductors or solenoids (wires wrapped around a core such as iron).
- Produces electromagnets, used in scrapyards, particle accelerators.
- If alternating current is used, magnetic field alternates.

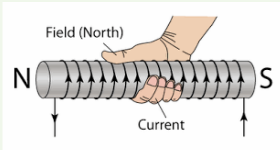
Note:-

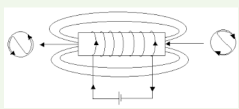
Field or Current Into Plane

Field or Current Out of Plane

| Straight Conductor | Solenoid |
|---|---|
| - Use right hand grip rule<br>- Current must be conventional! | - Use right hand grip rule, but opposite. Thumb is now north pole, fingers is current.<br>- Alternatively, if viewed from the sides, the current can be seen going clockwise (S) or anticlockwise (N)<br>North Pole – like an N<br>South Pole – like an S |



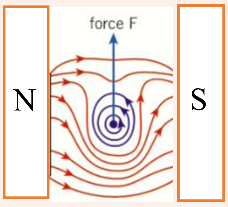



## Concept 2: A current carrying conductor within a permanent m.field experiences a force i.e. Motor Effect

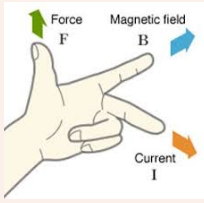
### Explanation

- The wire creates a m.field (due to concept 1).
- This interacts with the permanent m.field.
- As they are vectors, they add to create an imbalance in strength above and below the wire. This causes the force on the wire



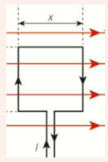

### Determining Size and Direction of Force

- The direction of the force can be determined by Flemings LHR. The direction can be switched by switching the direction of the current or the permanent m.field
- $F = BIL\sin\theta$
- Note, max force is when the wire is perpendicular to the field, there is no force if parallel.
- Experimentally, force can be measured by placing wire on weighing scale, tearing, and then applying current, *but remember weighing scales measure reaction force i.e. -ve means the force is downwards, +ve means force is upwards. Convert mass into force using W=mg*




### Torque of Motor

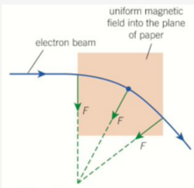
- Can calculate torque since couple (pair of coplanar antiparallel forces on both sides of wire)
- $F = BILx\sin\theta$




## Concept 3: A moving charge within a permanent m.field experiences a force causing circular motion

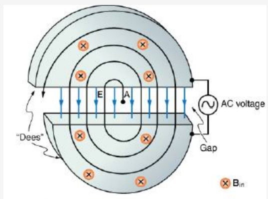
### Explanation

- According to FLHR, this force is always perpendicular to the motion of particle
- This creates circular motion.
- *Note:- the current finger in FLHR is now the direction of a +ve particle, or opposite to the direction of a -ve particle i.e. conventional*
- $F = Bqv\sin\theta$
- Equating to centripetal force: $\frac{mv^2}{r} = Bqv$
- $r = \frac{mv}{Bq} = \frac{p}{Bq}$




### Cyclotron Example

1) Particle injected in centre. An electric field accelerates the particle across the gap (F=Eq=ma)
2) Enters an m.field in the dee. This causes circular motion, bringing back into the electric field. No speed increases
3) Electric field alternates, causing acceleration towards other dee.
4) Process repeats. As particle speeds up, radius of curvature increases until eventual exit.



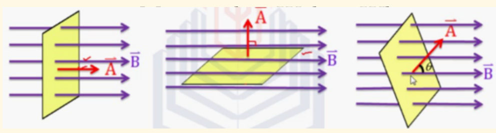

### Magnetic Flux Density, B

- Force experienced per unit length of wire carrying 1A.
- Represents magnetic field strength and is a property of magnet
- Think number of field lines per area (how dense)
- Measured in Tesla, T

x Area →

### Magnetic Flux, Ø

- $\emptyset = BA\cos\theta$
- Represents field lines acting across area.
- Note $\cos\theta$ is the effective area. When $\theta = 0$, perpendicular so max flux. When $\theta = 90$, parallel so no flux.




x Coils →

### Magnetic Flux Linkage, NØ

- $N\emptyset = BA\cos\theta$
- Represents field lines acting across area across all coils
- Measured in Weber, Wb
- Alternative unit of Weber turns used.


www.sabatutoring.co.uk
admin@sabatutoring.co.uk

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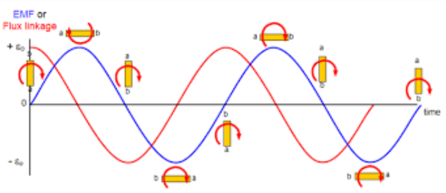
Tel: 07450376732
Mathushan Sabanayagam

## Concept 4: The EMF induced is equal to the rate of change in magnetic flux linkage i.e. Faraday's Law

- In simple terms, if the conductor experiences a changing magnetic field, an EMF is induced. If a complete circuit, a current is induced.
- This could be by relative motion between the field and the magnet, or by having a conductor in an alternating field (using an a.c electromagnet)
- $\varepsilon = -N\frac{\Delta\emptyset}{\Delta t} = -N\frac{\Delta BAcos(\theta)}{\Delta t}$
- *Important: EMF induced does not depend on flux, it depends on the change in flux i.e. the gradient of the flux graph* $\propto$ *emf induced graph*

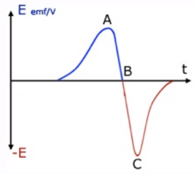
### Example 1 – Rotating Coil (A.C generator)

- A rotating coil has changing flux according to $\emptyset = \text{BA}\cos\theta = \text{BA}\cos(\omega t)$
- Therefore, the EMF is the differential (gradient)
- $\varepsilon = -N\frac{\Delta\emptyset}{\Delta t} = BANsin(\omega t)$
- Assume field going left to right. Notice when coil is vertical, $\emptyset$ is max but $\varepsilon$ is zero. When coil is horizontal, $\emptyset$ is zero but $\varepsilon$ is max. $\varepsilon$ is the gradient of $\emptyset$.
- Phase difference of $\frac{\pi}{2}$ or $90^0$. $\emptyset$ is cos graph, $\varepsilon$ is sin.



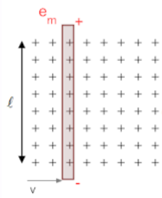

- This is what they use in energy generation. Steam /water drives a turbine, which rotates the coil

### Example 2– Dropping magnet through coil




- Increase in flux when magnet enters coil, no change within coil, and decrease in flux when exiting.
- EMF formed when entering and when exiting.
- Larger EMF when exiting due to same change in flux happening in shorter time (acceleration due to g)

### Example 3– Straight Conductor Through Field



- A straight-line conductor of length $l$ moving at velocity $v$ enters a magnetic field of flux density $B$. EMF increases when enters due to change in flux, then becomes 0 due to no change.
- $\varepsilon = Blv$. If rectangular coil $\varepsilon = NBlv$ for N coils

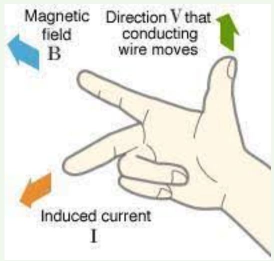
### Other Notes

- *Ways to increase EMF*: Increase velocity, increase B, increase number of coils, increase area of coil.
- *Other Examples:* Moving magnet in and out of coil (alternating voltage produced), fixed conductor with changing m.field using an ac electromagnet.

## Concept 5: The direction of the induced current is such that it opposes the change that created it i.e. Lenz's Law

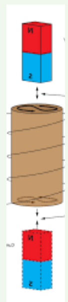
**Explanation:**

- If we take the example of motor effect, you supply a current to a conductor within a field and this produces a force which causes motion (concept 2)
- Now that there is motion of a conductor within a field, this causes EM induction which creates an induced current, i.e. a generator (concept 4)
- Lenz's Law: The induced current (and EMF) must be in the *opposite direction to the original current.* If a clockwise current causes motor effect, the induced current will be anticlockwise. Otherwise, the motor will spin faster and faster as this is a cycle, breaking conservation of energy.
- We refer to the EMF as back EMF and the induced current as eddy currents. This is why there is a -ve in $\varepsilon = -N\frac{\Delta\emptyset}{\Delta t}$
- We use Flemings Right Hand rule to determine the direction of the induced current (notice how the induced current is opposite to current in FLHR)




### Example: Dropping a Magnet into Coil

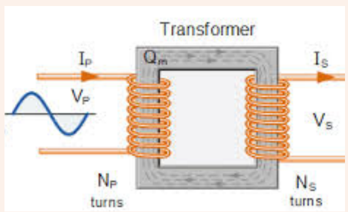
- When the magnet enters, the induced current wants to oppose the change. It is clockwise to create a South Pole at the top of the coil to repel the magnet.
- When the magnet leaves, the induced current at the bottom of the coil will be clockwise to create a South pole to prevent the magnet leaving through attraction.
- Remember, the current is ungrateful, it will be in a direction to create a field that opposes the change that created it!
- A similar case applies to moving a magnet in and out of a coil. It creates a current to generate a field to repel the magnet entering, and then when magnet is leaving, creates a current to generate a field to attract the magnet (prevent it leaving)



## Transformers

### How They Work

1) An alternating current is supplied to the primary coil. This generates an alternating field (concept 1)
2) This magnetises and demagnetises the soft iron core, causing a changing magnetic flux to be experienced by the secondary coil.
3) This induces an EMF in the secondary coil, proportional to the number of coils (concept 4). If $N_s > N_p$, then voltage increases so step-up. If $N_p > N_s$, then voltage decreases so step-up.




### Efficiency

- *Efficiency* $(P_{in}) = P_{out}$. If hundred percent efficient, $I_pV_p = I_sV_s$. Therefore, $\frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_P}$.
- I.e. stepping up voltage decreases current. We do this in transmission to reduce heat loss via heating effect as $P = I^2R$
- ***Careful:*** The secondary a.c current generates its own magnetic flux that can induce currents backwards due to Lenz's law.
- To prevent these eddy currents and back emf, we need a material that is magnetic but has high electrical resistance -> laminated iron core.
- The iron is easily magnetised and demagnetised, whilst the insulated sheets (lamination), increases the resistance, decreases eddy currents, and increases efficiency of transformer.