D4 : INDUCTION

Definition of the Amperes

↳ One ampere is defined as that current flowing in each of 2 long parallel conductors 1m apart, which results in a force of exactly $2 \times 10^{-7}\ Nm^{-1}$ of length of each conductor

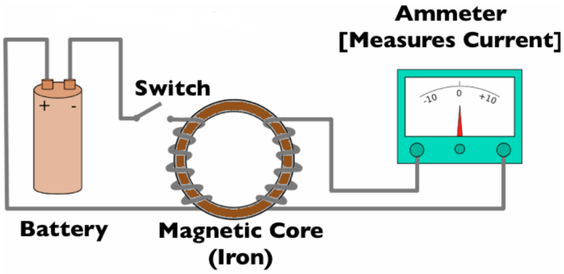
$1\ C = 1\ As$

If $I_1 = I_2 = 1A$ and 2 wires are exactly 1m apart

$\frac{F}{l} = ?$

Production of Induced EMF by Relative Motion

↳ Michael Faraday built a circuit that would produce a current in a secondary winding of a transformer by allowing a current to flow through the primary winding. The result was a magnetic field produced in the primary winding.



↳ The core intensified the magnetic field which produced a current spike in the secondary winding.

↳ Steady magnetic field does not produce current

↳ Changing magnetic field produced current

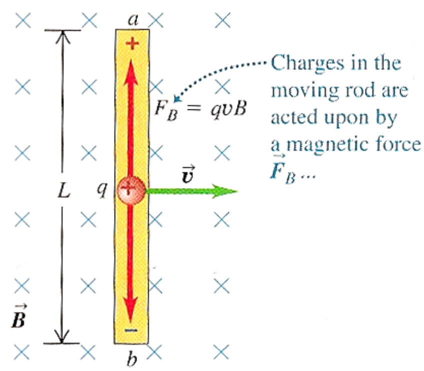
↳ This is what we called induced current

↳ wire into magnetic field, current flow through the wire

↳ If a magnet is moved quickly into a coil of wire, current is induced in the wire

↳ motion or change is required to induce an emf

Induced emf in a conductor



↳ Consider a conductor of length, L that moves with velocity, v perpendicular to a magnetic flux density or induction, B.

↳ The free-moving electron (inside a conductor) experienced on force.

$$F_B = qVB$$

↳ The force causes the electron to drift from one end of the conductor to the other. As a result, excess of electron at one end and the other end, a deficiency of electron.

$$F_E = Eq = \left(\frac{V}{\ell}\right)q$$

$$F_E = F_B$$

$$\frac{V}{\ell} \cdot q = Bqv$$

$$\mathcal{E} = B\ell v$$

$\mathcal{E}$ = induced emf (V)

B = magnetic flux density (T)

ℓ = length of conductor (m)

v = velocity of conductor ⊥ to the magnetic field (ms^{-1})

↳ As no current flowing,

Induced EMF = Potential difference

$$\mathcal{E} = B\ell v$$

↳ The motion (direction) of the induced current inside a conductor can be detected by using:

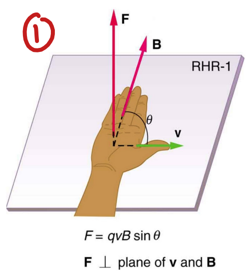
① Right hand palm

② Flemming right hand rule

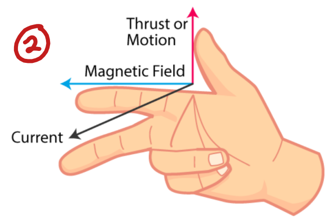
* conventional current: opposite of e^- flow
* Induced current : same as e^- flow

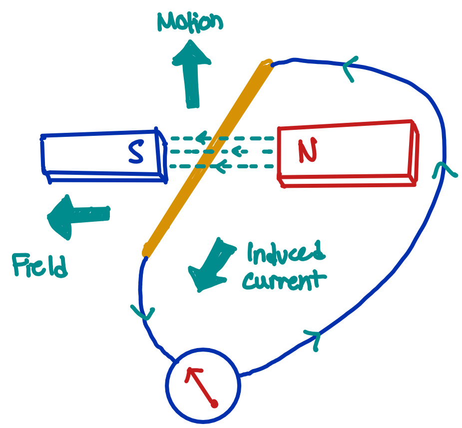
that's why pakai right

①



②





Magnetic flux & Flux linkage , Φ

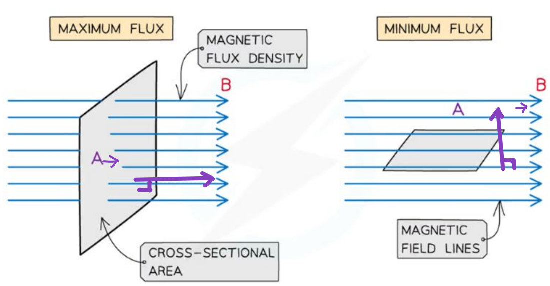
↳ Magnetic flux , Φ_B is the number of magnetic field lines passing through a given area

$\Phi_B = \vec{B} \cdot \vec{A}$

$\Phi_B = BA\cos\theta$

θ = Angle between vectors, $\vec{B}$ and $\vec{A}$

A = normal of the area



* unit : Weber (WB) @ Tm^2

Max flux:

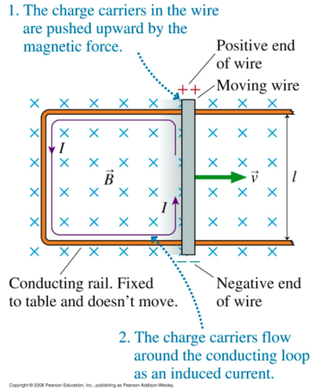
$\Phi_B = BA\cos 0^\circ$

$\Phi_B = BA$

Min flux:

$\Phi_B = BA\cos 90^\circ$

$\Phi_B = 0$



$$A = l\underbrace{v}_{\text{constant}}t$$

$$= l \times \text{distance}$$

$$\frac{A}{t} = lv$$

$$\varepsilon = Blv$$

$$= B\left(\frac{A}{t}\right) = \frac{\Phi}{t}$$

↳ For a single conductor in the magnetic flux density,

$\varepsilon \propto \frac{\Delta\Phi}{\Delta t}$ ← Faradays' law

$\varepsilon = \frac{-\Delta\Phi}{\Delta t}$ (where -1 = constant)

↳ Flux linkage, $N\Phi$ is a term used for N number of conductors (eg: solenoid), then:

$N\Phi = NBA$ $\quad\quad$ $\varepsilon = -N \times \frac{\Delta\Phi}{\Delta t}$

Faraday's Law and electromagnetic Induction

↳ Faraday's Law of induction:

The magnitude of an induced emf $\propto$ the rate of change of magnetic flux linkage

↳ If the circuit consists of N loops, all of the same area and if Φ_B is the flux through one loop, an emf is induced in every loop and Faraday's law becomes:

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

↳ moving magnetic field lines induce an emf

↳ Faster moving, larger emf

↳ more coils, more emf

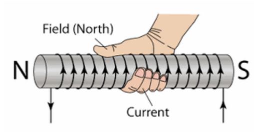
Lenz's Law

↳ Definition: The current from the induced emf will provide a magnetic field, which will always oppose the original change in the magnetic flux

$$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$$

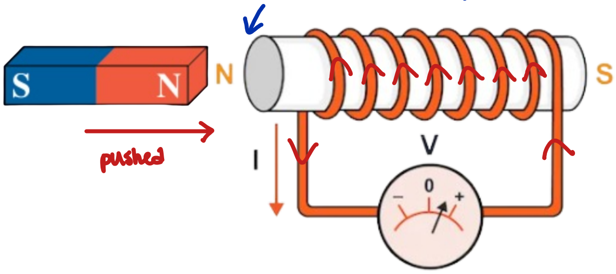
-ve sign, Lenz's Law (-1 is a constant)

Lenz's Law Applied to a Solenoid

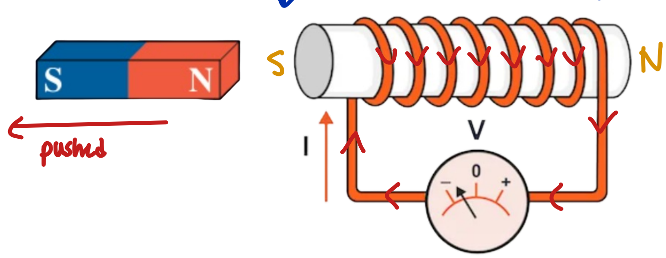


* The direction of current can be determined with Right-hand Grip Rule.

Since N pole approaches the coil face, the emf must be set up to create an induced N pole to repel the magnet bar.



Since N pole moving away from the coil face, the emf must be set up to create an induced S pole to attract the bar magnet

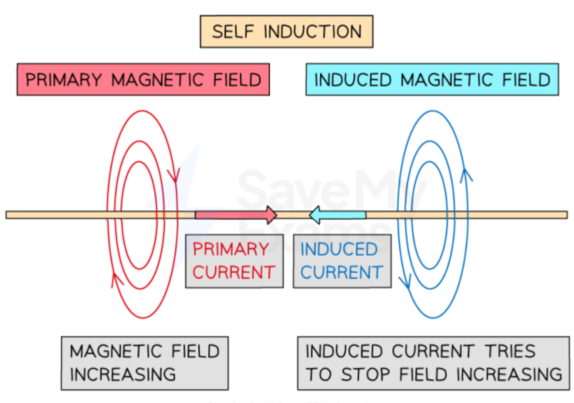


Self Induction & Mutual Induction

Self-Induction

↳ Induction within the same circuit

↳ Definition: The effect in which a change in the current tends to produce an induced emf which opposes the change of current in the same circuit



$$\text{back emf} \propto -\frac{\Delta I}{\Delta t}$$

Mutual Induction

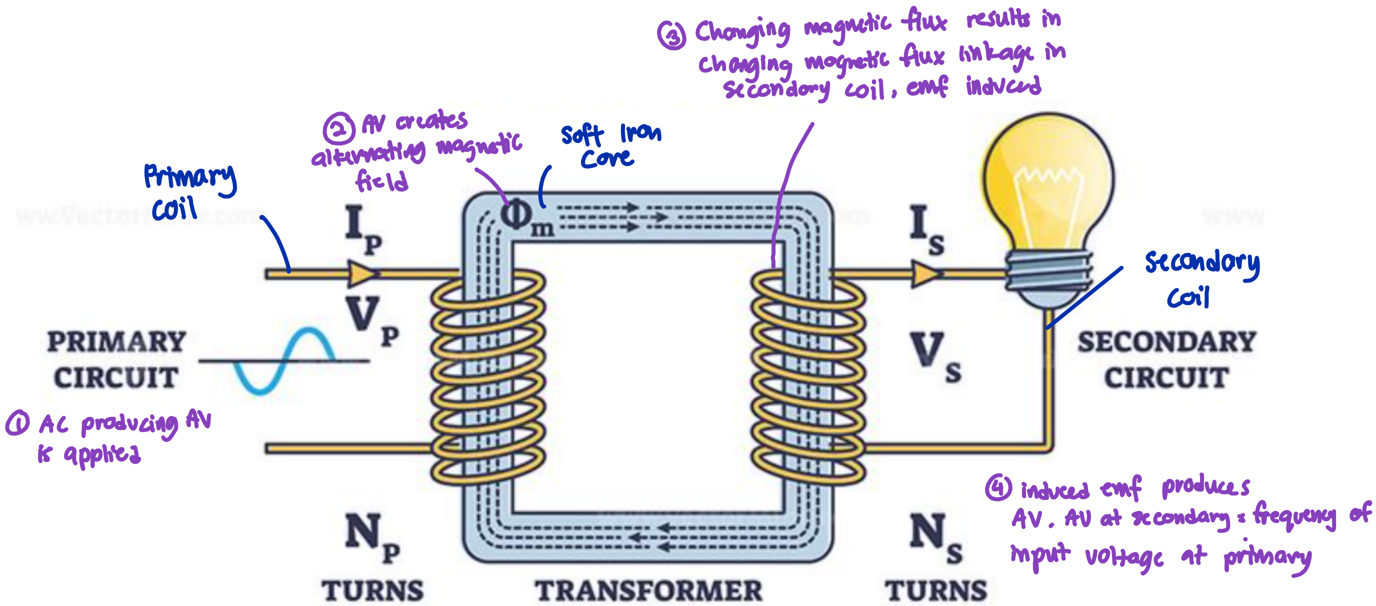
↳ Induction occurs in separate circuit from the one producing the change

↳ Definition: The effect in which a change in the current in one circuit tends to produce an induced emf which opposes the change of current in the neighbouring circuit.

↳ Application of mutual induction is Transformers.

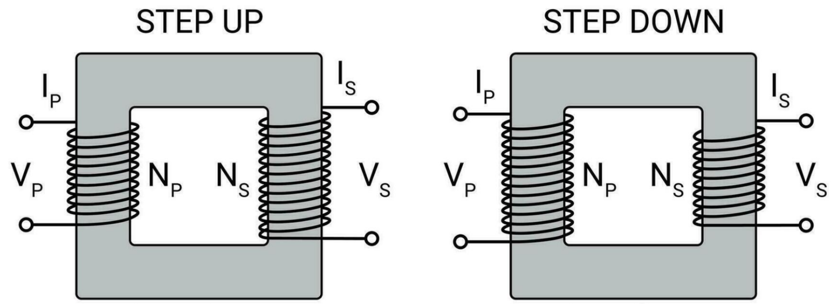
Transformers

↳ Definition : A device that changes high alternating voltage at low current to low alternating voltage at high current, and vice versa.



↳ Soft iron core – To enhance the strength of the magnetic field from the primary to the secondary coil

- Soft iron is easily magnetized and demagnetized



$N_s > N_p$ $\qquad$ $N_p > N_s$

$V_s > V_p$ $\qquad$ $V_p > V_s$

AC Generator

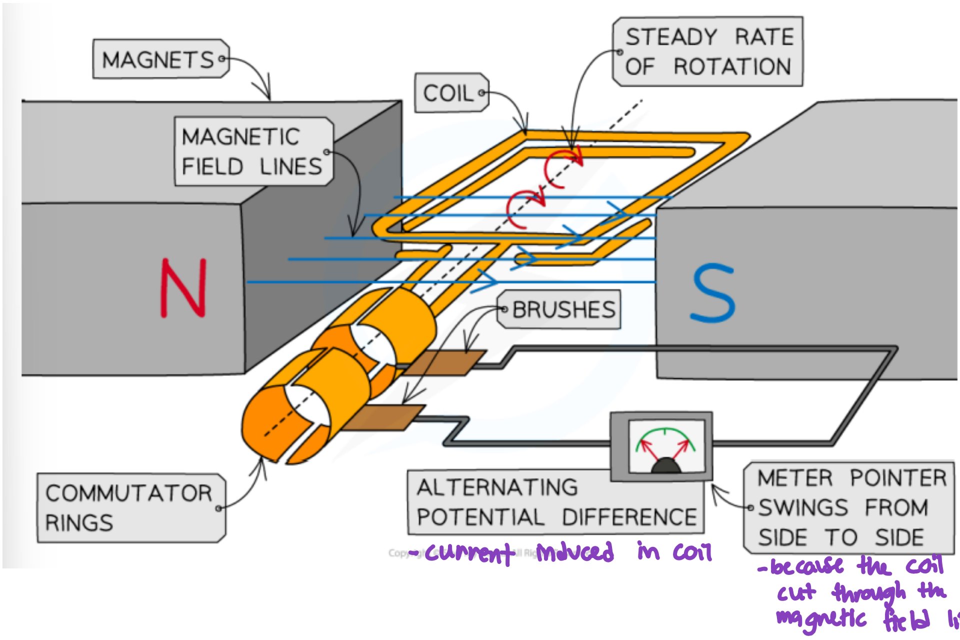
↳ An important practical result of Faraday's Law was the development of dynamo.

↳ Mechanical energy → Electrical energy (AC)

↳ AC generator:

① inverse of motor function

② consist of 2 poles



↳ The axle is turned by some mechanical means (eg: falling water, car motor belt, etc)

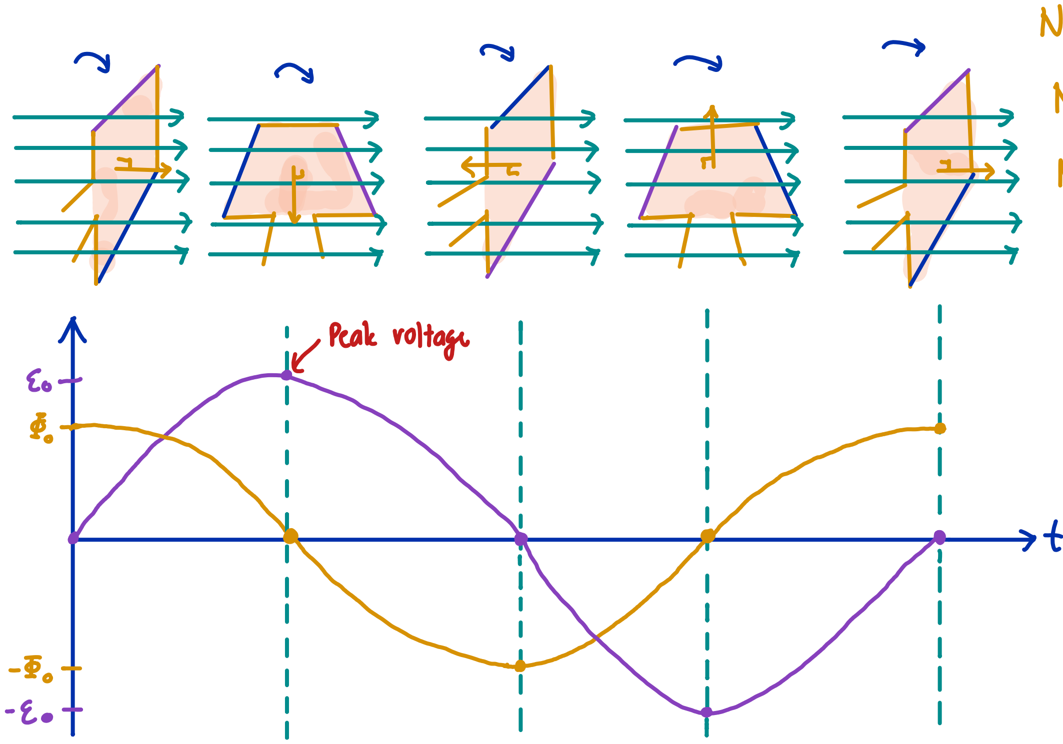
↳ The slip rings are made of metal and are insulated from each other.

How Does AC Generator Works?

↳ When the armature rotates between the poles of the magnet upon an axis ⊥ to the magnetic field, the flux which links with the armature changes continously. Due to this, an EMF is induced in the armature. This produces an electric current through the galvanometer and the slip rings and brushes.

↳ The galvanometer swings between the positive and negative values. This indicates that there is an alternating current flowing through the galvanometer.

Flux Linkage and emf in rotating coil



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

$N\Phi_0 = NBA$

$N\Phi = NBA\cos(wt)$

$N\Phi = \Phi_0\cos(wt)$

(-ve) Lenz's Law

$\mathcal{E} = \frac{-dN\Phi}{dt}$ Faraday's Law

chain rule

$\mathcal{E} = -NBA\,[-\sin(wt)\cdot w]$

$\mathcal{E} = NBA\,w\cdot\sin(wt)$

$\mathcal{E}_0 = NBA\,w$

$\mathcal{E} = \mathcal{E}_0\sin(wt)$

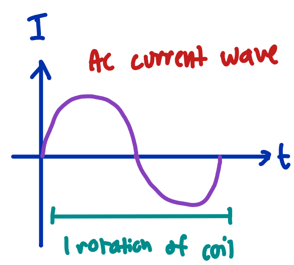
Alternating Current (AC)

- AC is an electric current which periodically reverses direction, in contrast to direct current (DC) which flows only in one direction.
- If the output of an AC generator is connected to a resistor an AC will flow.
- It can be found from:

$I = \frac{\mathcal{E}}{R}$

$I = \frac{\mathcal{E}_0\sin wt}{R}$

$I = I_0\sin wt$, where $I_0 = \frac{\mathcal{E}_0}{R}$ (peak current)



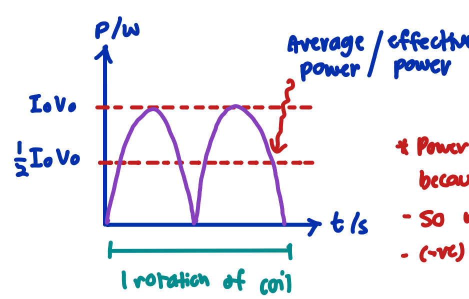
- The power generated in an AC circuit is:

$P = IV$

$P = I\mathcal{E}$

$= (I_0\sin wt)(\mathcal{E}_0\sin wt)$

$= I_0\mathcal{E}_0\sin^2(wt)$



* Power is always positive because $\mathcal{E} \propto I$
- So when $\mathcal{E}$ (-ve), I is also (-ve)
- (-ve) and (-ve) is (+ve)