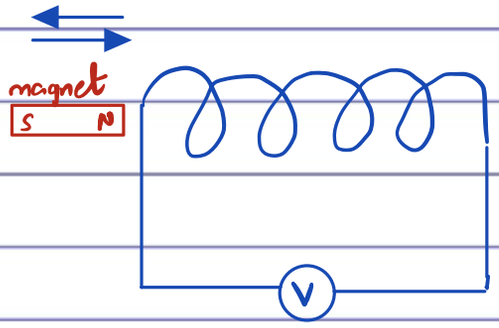
→ Topic: Electromagnetic Induction: Date:

Faraday's law of Electromagnetic Induction



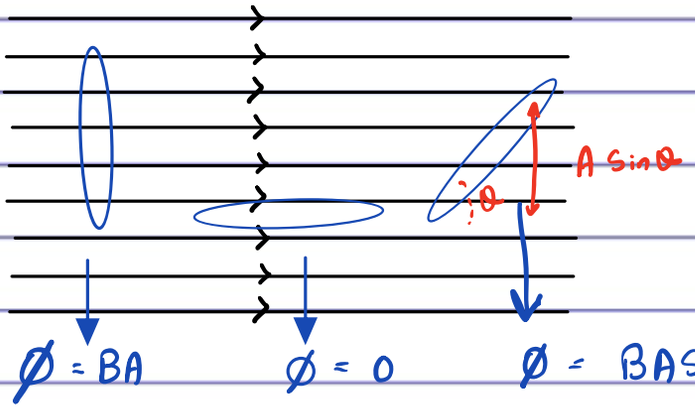
→ If magnet was pushed in a deflection was observed in one direction.

→ magnet is pulled out deflection was observed in opposite direction.

Faraday's law: The rate of change of magnetic flux induces EMF.

Magnetic Flux density: alternate name of magnetic field strength measured in Tesla (T)

Magnetic flux: denoted by symbol $\emptyset$, it is a product of magnetic flux density and area of the coil through which field is passing. provided area is perpendicular to the field.



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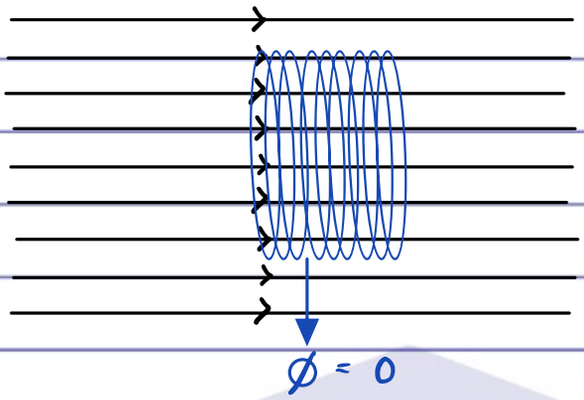
Magnetic flux linkage: If your coil consists of a large number of turns for eg (N no of turns), then cutting effect is called magnetic flux linkage



$\emptyset = NBA$

$\emptyset$ is measured in = Tm^2

B = Tesla

A = m^2

Tm^2 → Weber (W_b)

Faraday: Induced EMF is equal to rate of change of magnetic flux

$$E = \frac{\text{Change in magnetic flux}}{\text{time}} \Rightarrow \frac{\Delta \emptyset}{t}$$

$$E_{mf} = \frac{\emptyset f - \emptyset i}{t} \quad \text{or} \quad E = \frac{d\emptyset}{dt}$$

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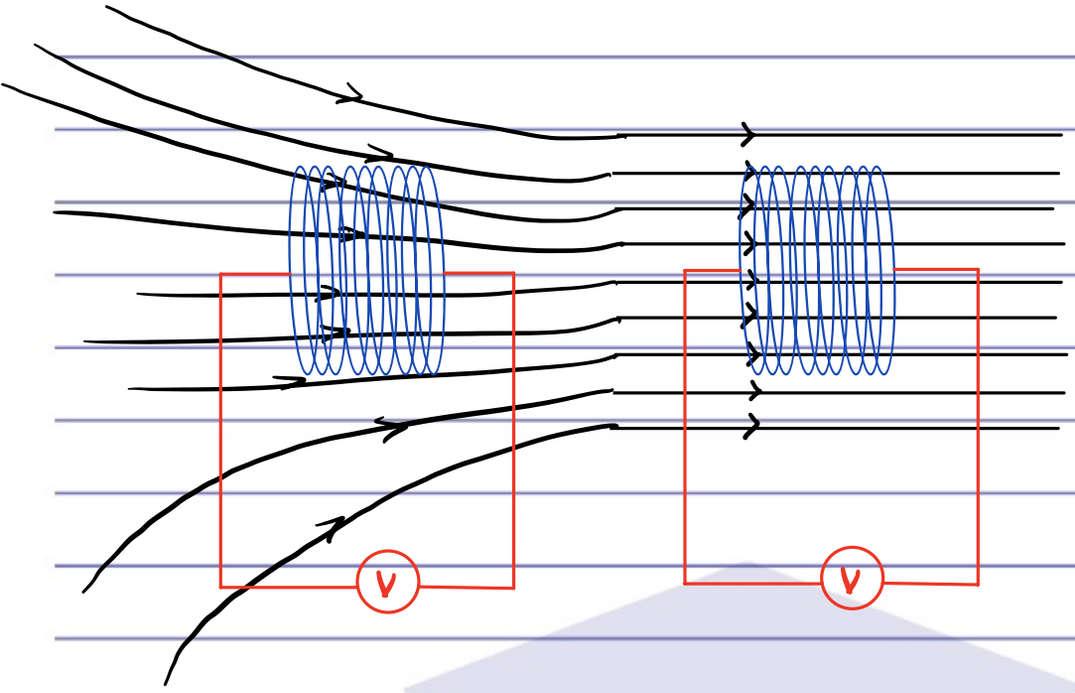
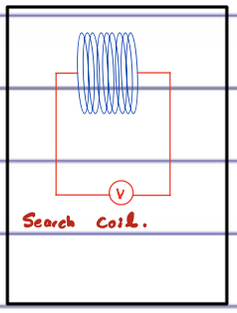
Case 1





Calculate the Induced EMF

$A = 8\,cm^2$

$B_i = 70\,mT$

$B_f = 180\,mT$

$N = 500\,turns$

$t = 0.1\,s$

$$E = \frac{\Phi_f - \Phi_i}{t}$$

$$= \frac{NB_f A - NB_i A}{t}$$

=

=

$= 0.44\,V$

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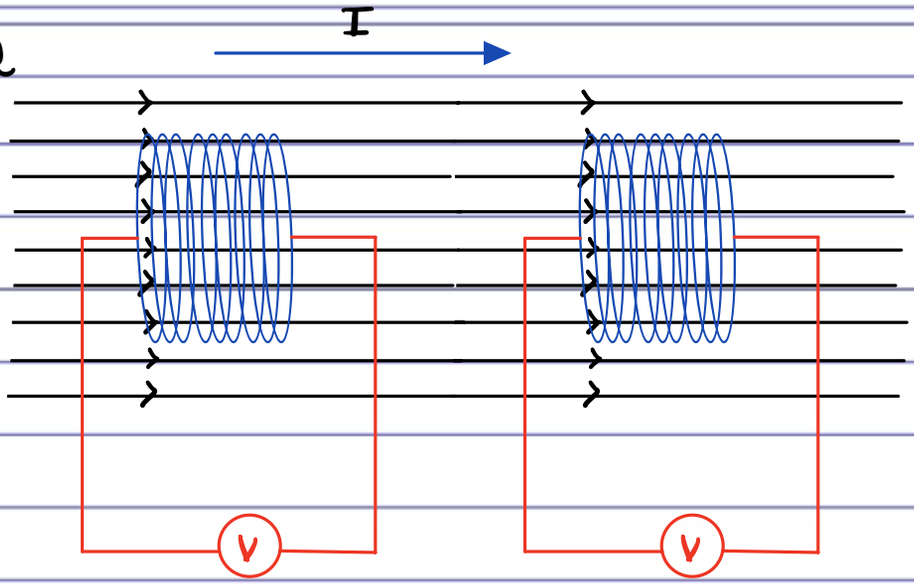
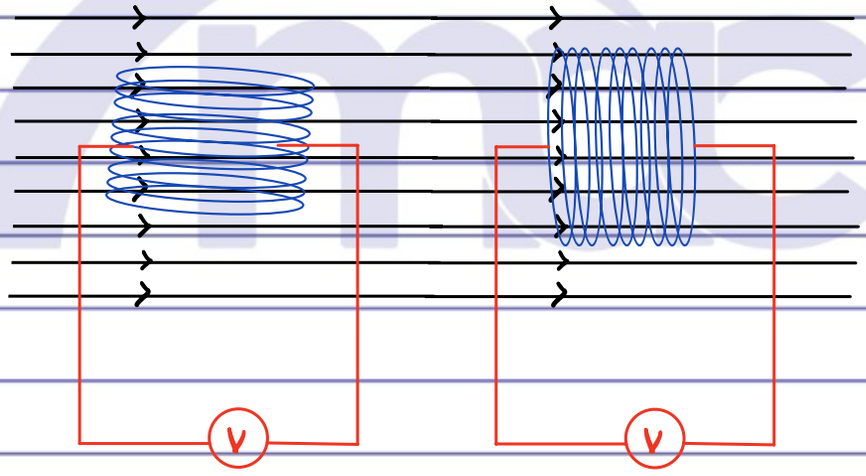
Case 2



Induced EMF = 0V (No change in magnetic flux)

Case 3 Coil rotated through 90°



$\phi_i = 0$ $\phi_f = NBA$

$$E = \frac{NBA - 0}{t}$$

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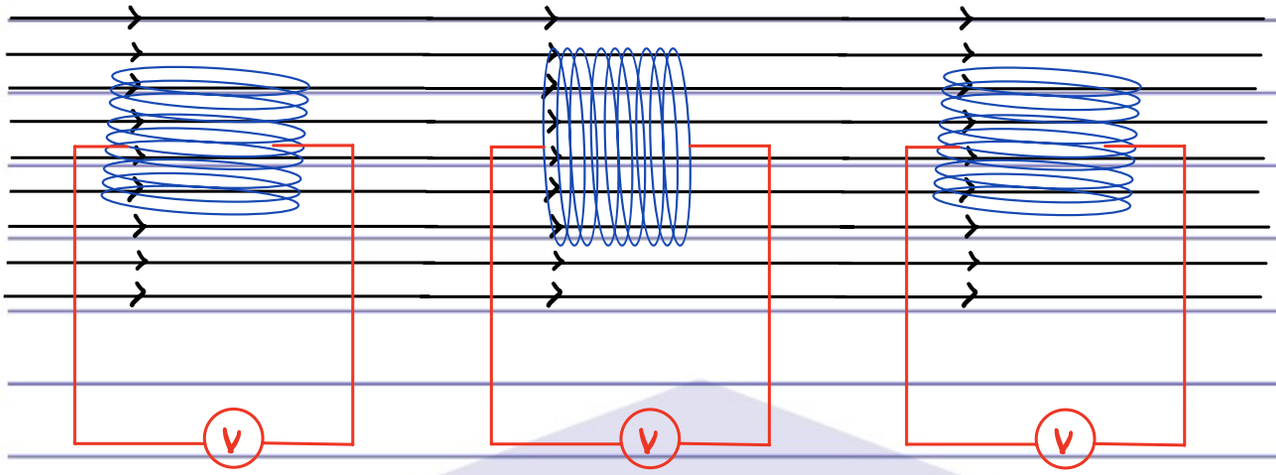
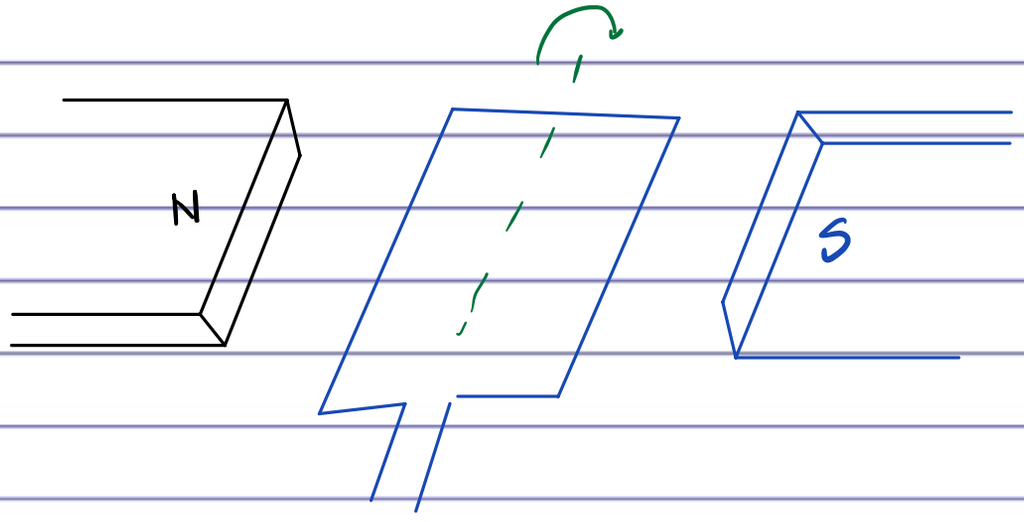
Case 4 = rotating 180°



$0° \longrightarrow 90°$ $90° \longrightarrow 180°$

$$E = \frac{2NBA}{t}$$

⇒ This concept was used in the concept of an AC generator



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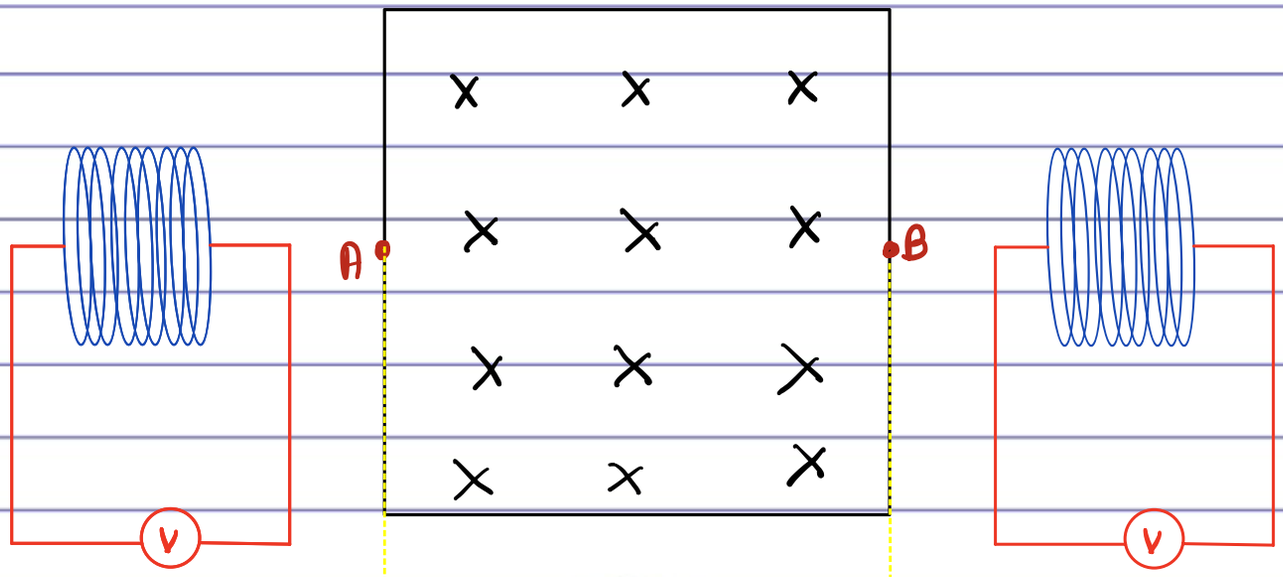
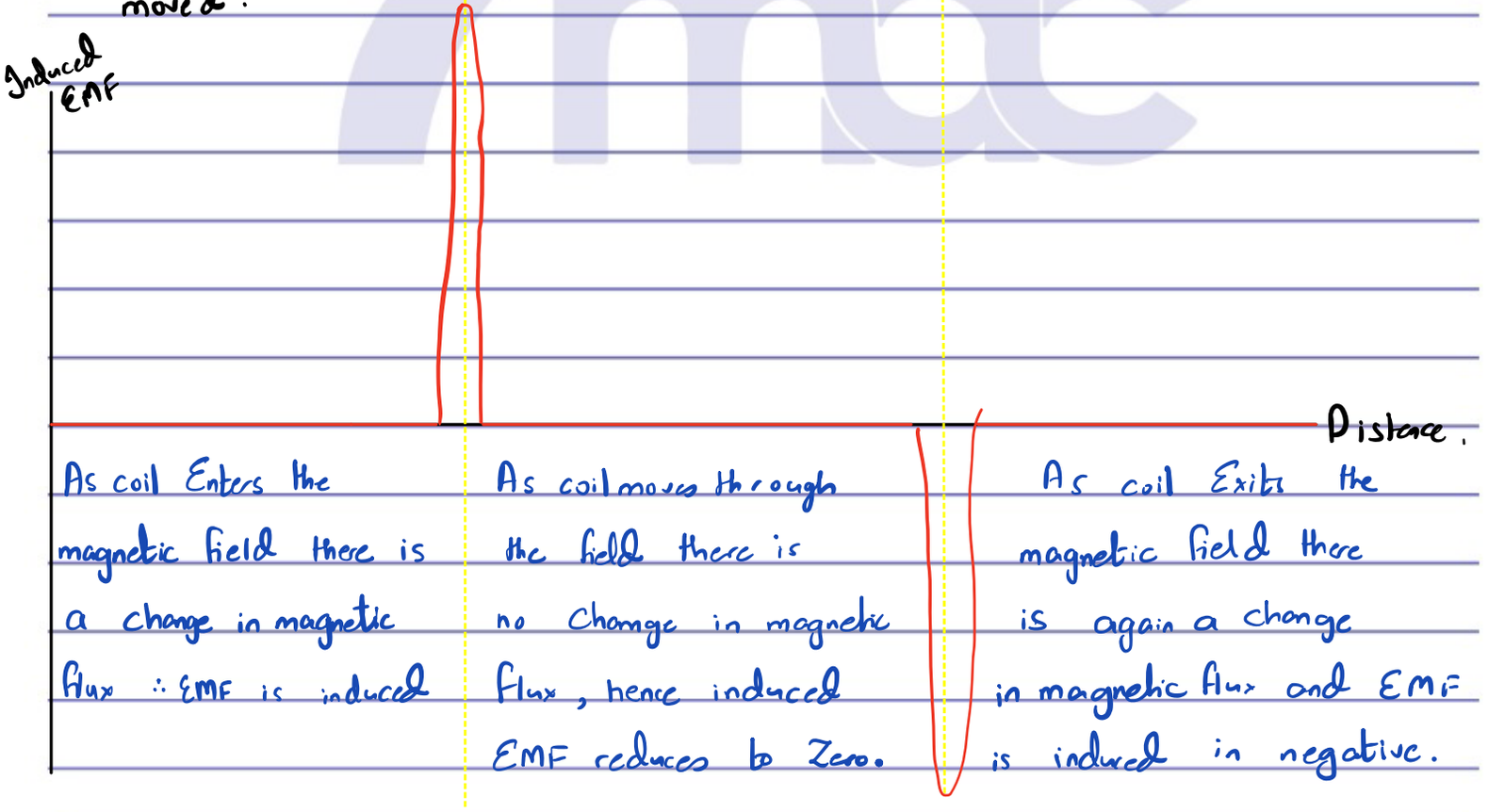


Left Right

As the coil rotates from left to Right sketch a graph of How induced EMF varies with distance moved.



As coil Enters the magnetic field there is a change in magnetic flux ∴ EMF is induced

As coil moves through the field there is no Change in magnetic flux, hence induced EMF reduces to Zero.

As coil Exits the magnetic field there is again a change in magnetic flux and EMF is induced in negative.

→ It is used to determine direction of induced EMF

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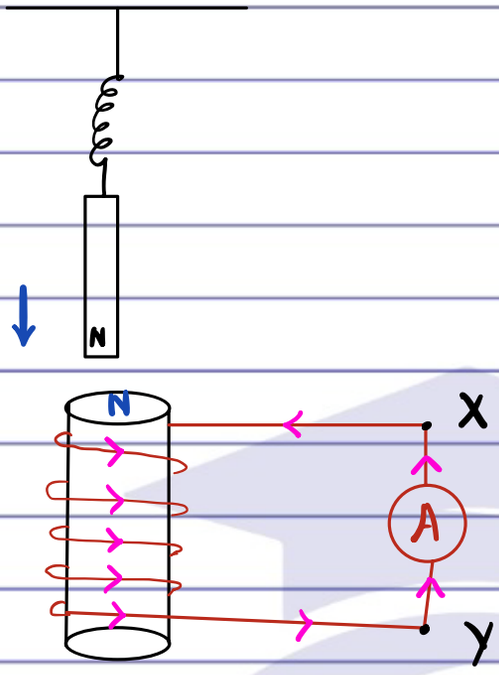
⇒ Lenz's law:— Induced EMF is such that it always opposes the change that produces it.

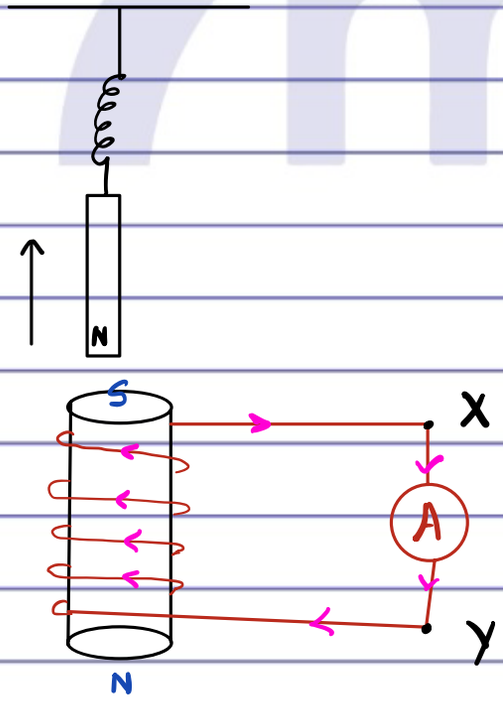
⇒ This is another application of right hand grip rule.
⇒ Place thumb towards North pole and curl of fingers give direction of current.

1



In Fig 1 when North is pushed in Current flows From Y to X and induced current opposes motion of the magnet.

2



In Fig 2 when magnet moves out South pole is induced and hence Current flow from X to Y

Purpose: To Help determine direction of Induced current.

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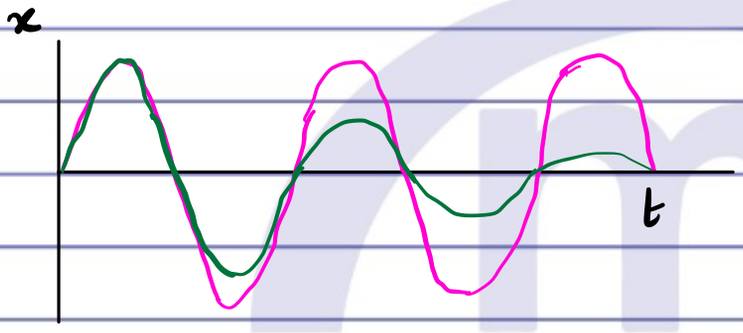
→ If a graph of Displacment x against time (t) is plotted for a motion of a magnet, it can be realized that, after a few oscillations, the amplitude will decrease continuously until the magnet stops completely. i.e we can say oscillations are subjected to light damping.

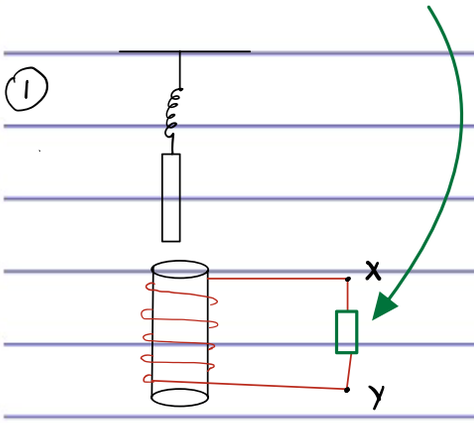
Reason of Damping: ∴ As the magnet enters the coil (fig ①) its mechanical Energy is used up in overcoming repulsive forces b/w like poles and as it moves out away from the solenoid. (fig 2) its mechanical Energy is wasted in overcoming the attractive forces b/w unlike poles. Hence graphical representation is given below.



— free oscillations.
— light damping

How can we reduce the damping effect.

⇒ Place the Resistor in the solenoid circuit



⇒ Due to Resistor the induced current which flows in the solenoid circuit will decrease

⇒ According to lenz's law induced current opposes the change causing it ∴ if induced current decreases the degree of opposition also decreases.

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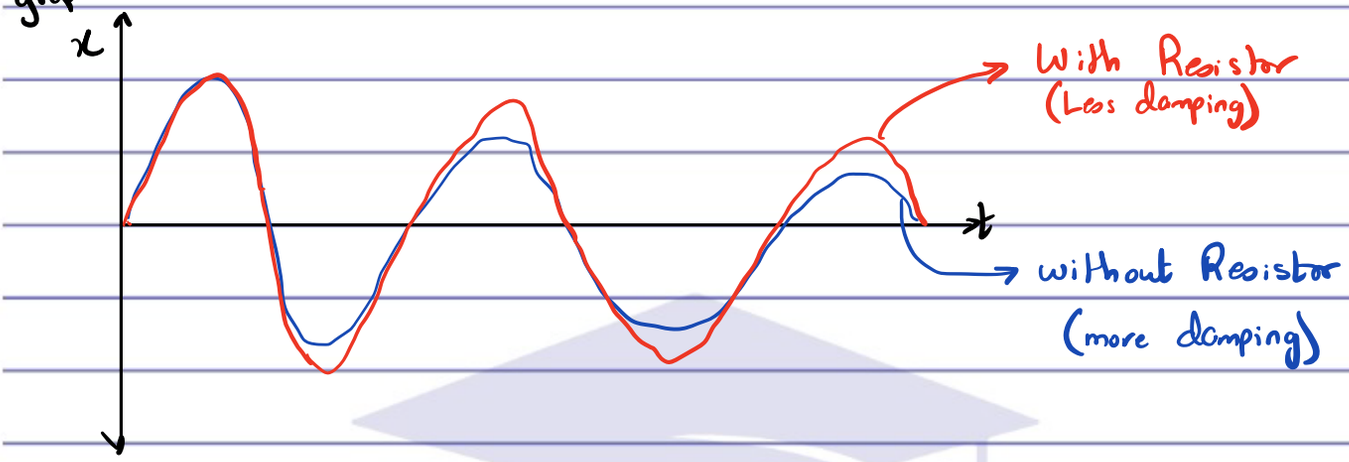
Less opposition means Less energy of the oscillating magnet is wasted ∴ more energy is left available for oscillations to continue hence oscillation will now last for a longer duration of time.

graph



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Till now :

1) Faraday's law $E = \frac{\Delta \phi}{t}$ OR $\mathcal{E} = \frac{d\phi}{dt}$

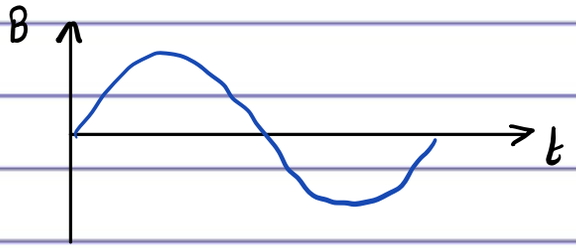
2) Lenz's law Induced EMF always opposes the change that causes it

Faraday's + Lenz's law

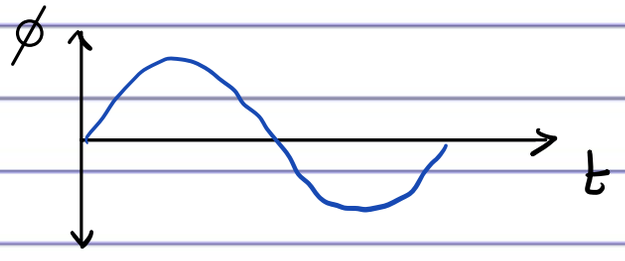
$E = -\frac{d\phi}{dt}$ due to lenz's law.

⇒ Whenever you are doing numerical calculations you can ignore the -ve sign hence just the formula $E = \frac{d\phi}{dt}$ or $E = \frac{\Delta \phi}{t}$

⇒ For graphical purposes you have to take -ve sign into account. for e.g



i) Sketch graph of magnetic flux vs time



Based on $\phi = BA$ and $\phi = NBA$ $\phi \propto B$

graph of ϕ must be in phase of the graph of B

Same shape.

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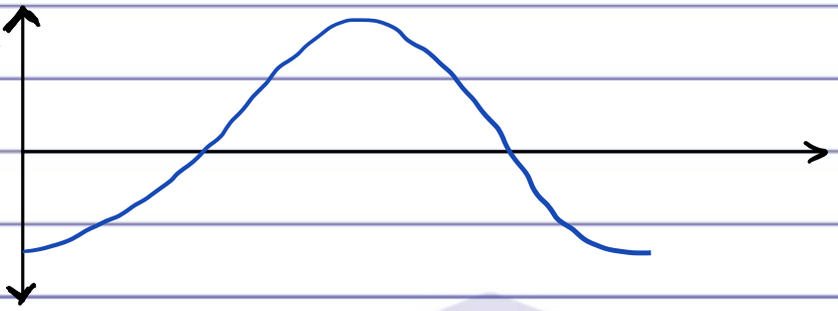
ii) Sketch the graph of induced EMF (E) vs time (t)

$$E = \frac{-d\phi}{dt}$$ ["negative gradient of graph of ϕ vs t gives Induced emf E"]

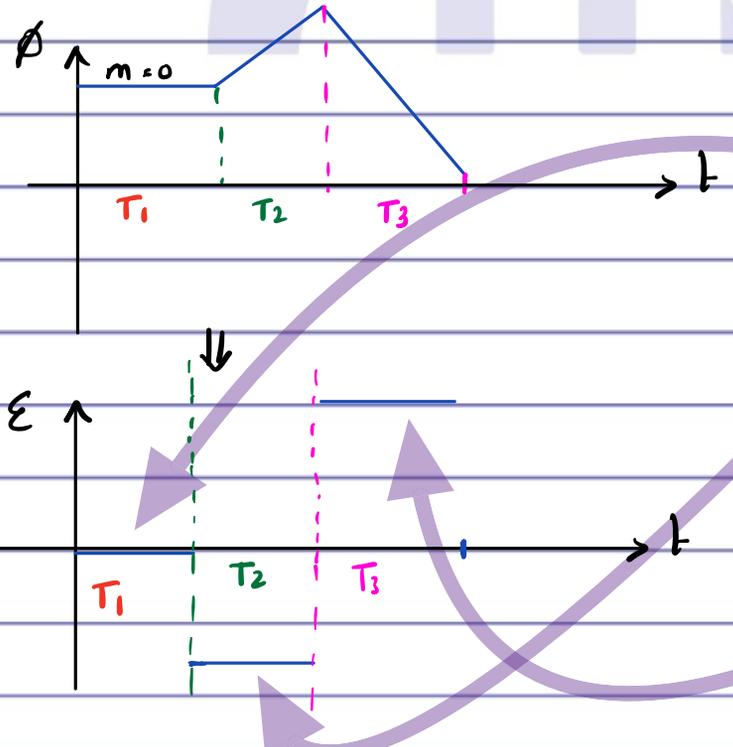


Orignal ϕ graph is a Sine function. if you differentiate the graph you would get Cosine fuction so

since $E = \frac{-d\phi}{dt}$ {negative gradient of graph of ϕ vs t gives induced EMF E}

Example 2 :

$$\mathcal{E} = \frac{-d\phi}{dt}$$



1) For T_1 change in ϕ is zero hence $m = 0$ therefore graph is drawn on the x axis for $\mathcal{E}$ against T

2) For T_2 Since gradient is +ve and constant and $\mathcal{E} = \frac{-d\phi}{dt}$ so it is drawn in negative.

3) For T_3 Since gradient is -ve and constant graph is drawn in positive

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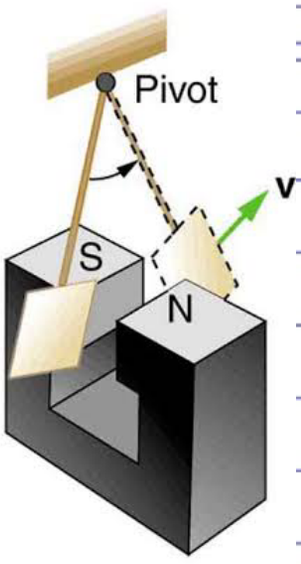

(c)

* Two magnetic Poles are placed as shown.
* A metal sheet (A) is made to oscillate b/w the magnets.

i) Explain why emf is induced in the metal sheet.

Ans: As the metal sheet oscillates, there is a continous change in cutting effect/magnetic flux (b/w field lines & metal sheet A). This according to faraday's law induces emf in the metal sheet.

(ii) Explain why you would expect the metal sheet to stop oscillating after some time?

* The rate of change of magnetic flux induces emf in the metal sheet (A) this gives rise to the flow of induced current. (This current is called Eddy current)
* According to lenz's law this induced current/eddy current opposes the motion of the metal plate by applying a resistive force and damping occurs.
* Energy is wasted (as heat) in overcoming this damping effect ∴ metal sheets stop oscillating after some time.

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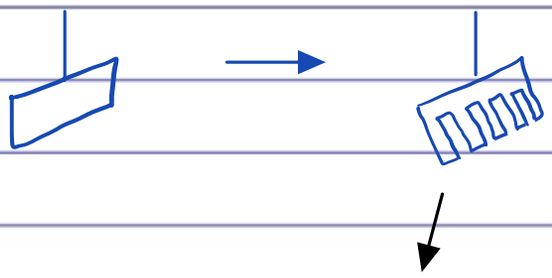
ii) What can be done to reduce this opposition/damping effect i.e what change if done to the arrangement will allow the metal sheet to oscillate for a longer duration.

$R \propto \frac{l}{A}$



⇒ Slices

⇒ Lamination of metal sheet

⇒ This causes length of metal to increase by reducing the Area

⇒ The metal sheet must be laminated (we are creating air gaps with the solid metal)

Length will increase Area will decrease combine effect cause. Resistance to increase. ∴ Eddy current will reduce and more Energy will be there for oscillations, of the metal plate ∴ more Energy avalible for oscillation to continue for a longer duration of time.

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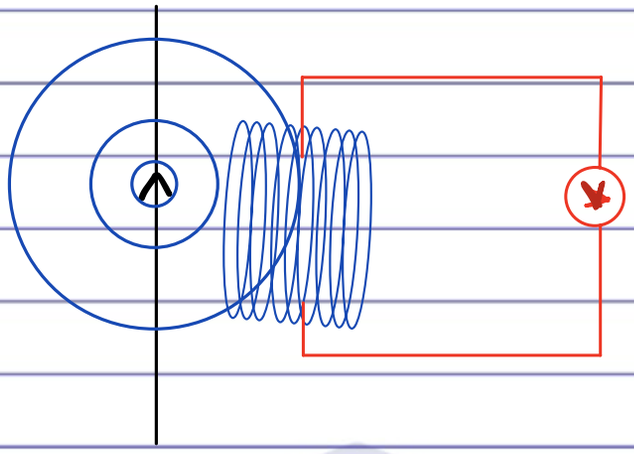
⇒ The diagram shows a long straight current carrying wire. A search coil is positioned close to the wire as indicated.



⇒ Suggest why voltmeter donot give any reading:

⇒ There is no change in magnetic flux ∴ No EMF is induced in the search coil.

Suggest three changes that can be made that would cause voltmeter to give a deflection.

① dc ⟶ ac

② Move the search coil left & right i.e move it closer to the wire and away from the wire.

③ Start rotating the search coil about its axis

advantage = due to rotation at one instance plane of the search coil will be perpendicular to the field which will give maximum cutting effect. However at some other instant plane will be parallel hence zero cutting effect will be established.

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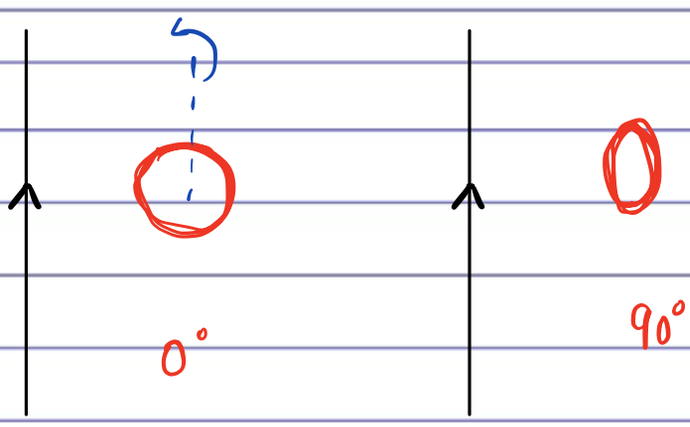
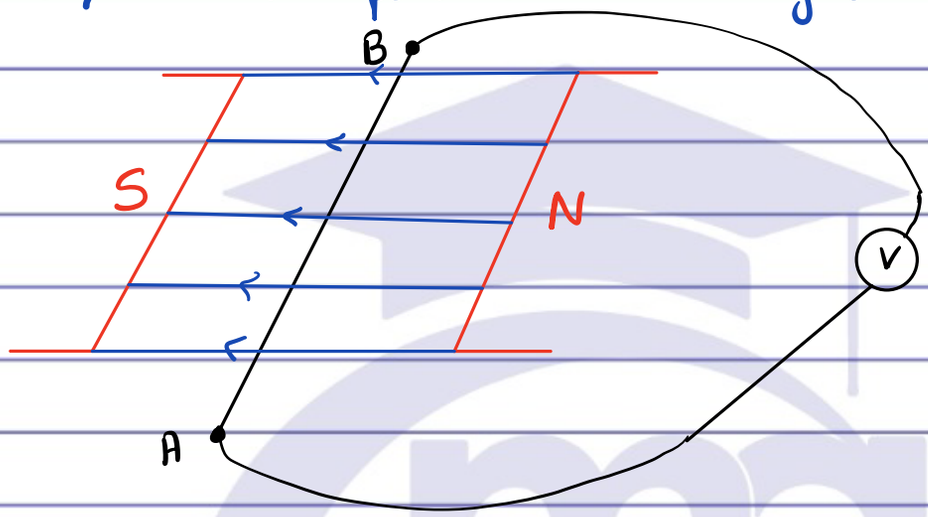


* Formula for calculating induced EMF across a wire / Conductor positioned in a magnetic field.



* Strength of magnetic field = B (Tesla)

* length of wire AB {b/w the magnetic field} = L (m)

* Speed of wire = V m/s

- When wire is at rest or moveing left and right no emf will be induced. (As wire is moving parallel)

- Wire is moving at V m/s in the vertical plane (up & down) (EMF will be induced as field and movement is perpendicular)

Formula for this EMF is $E = BLV$

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