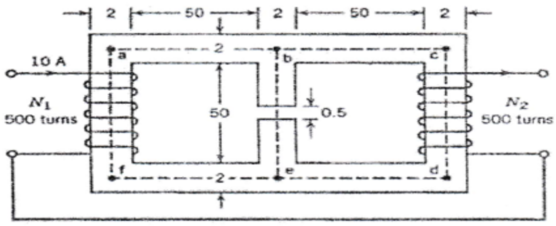
Chapter - 1 (8 marks, Theory + Numericals)

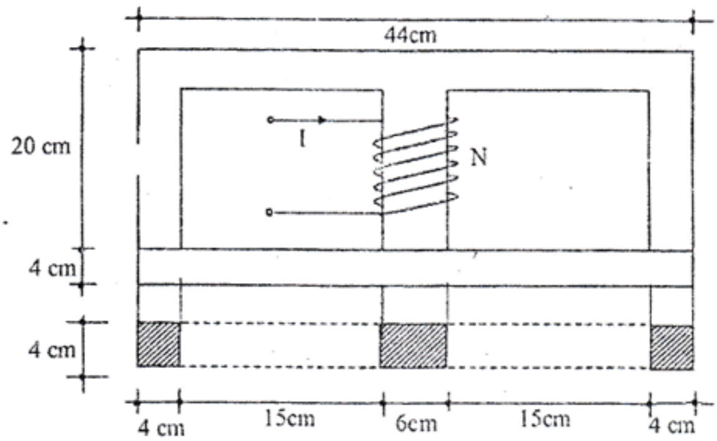
State Ohm's law for magnetic circuit. For the given magnetic circuit, neglecting magnetic leakage and fringing, calculate air gap flux, flux density and magnetic field intensity at the air gap. Given that relative permeability of ferromagnetic material is 1200 and all dimensions are in cm. [2+6]



Define the term magneto motive force and magnetizing force for magnetic circuit. A ring has mean diameter of 21 cm and a cross sectional area of 10 cm^2. The ring is made up of semicircular section of cast iron and cast steel, with each joint having a reluctance equal to an air gap of 0.2 mm. Find the ampere turns required to produce a flux of 0.8 m Wb. The relative permeability of cast steel and cast iron are 800 and 166 respectively. [8]

1. a) What are reluctance and permeance in the magnetic circuits? Derive their expressions in any type of magnetic circuits. [8]

   b) For the Magnetic circuit shown below, calculate the Amp-turn (NI) required to establish a flux of 0.75 wb in the central limb. Given that μ_r = 4000 for iron core. [8]



An iron ring of 0.15 meter diameter and 0.001 m^2 in cross section with a saw cut 2 mm wide is wound with 300 turns of wire. The gap flux density is 1 Tesla. The relative permeability of the iron is 800. Determine the exciting current and inductance. [8]

a) An iron ring of mean length 1.2m and cross sectional area of 0.005 m^2 is wound with a coil of 900 turns. If a current of 2A in the coil produces a flux density of 1.2T in the iron ring, calculate: (i) The mmf (ii) Total Flux in the ring (iii) The magnetic field strength (iv) The relative permeability of iron at this flux density. [8]

A ring of iron has a mean diameter of 15 cm, a cross section of 1.5 cm^2 and has a radial air gap of 0.5 mm cut in it. It is uniformly wound with 1500 turns of insulated wire and a current of 1.2A produces a flux of 0.1mWb across the air gap. Calculate the relative permeability of iron on the assumption that there is no magnetic leakage. [8]

Explain the losses, which occur when magnetic materials are subjected to an alternating flux. How can we reduce these losses practically? [5+3]

What do you mean by

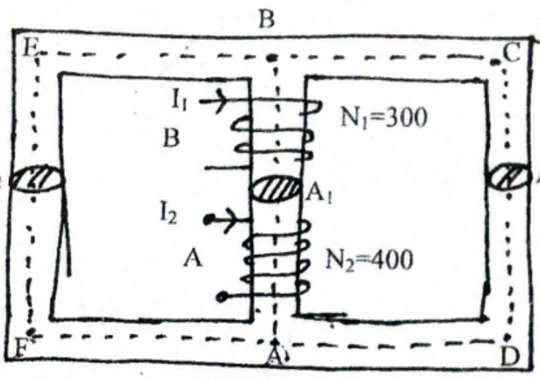
1. a) A steel ring of 12 cm mean radius and of circular cross-section 1 cm in radius has an air gap of 2 mm length. It is wound uniformly with 550 turns of wire carrying 3A of current. The air gap takes 60% of total magnetomotive force. Find the total reluctance. [5]

   b) Explain hysteresis and eddy current losses in electrical machines. Prove that hysteresis loss in a magnetic material is equal to the area of hysteresis loop. [5]

   c) Explain the following: [2×3]

   (i) Faraday's laws of electromagnetic induction
   (ii) Fleming's right and left hand rules

1. a) For magnetic circuit shown in figure below, find out the current to be passed through coil B so that magnetic flux in CD section is 2 mWb. Given $\mu_r = 1000$ [8]



Given:

$I_2 = 3$ Amp, $A_1 = 6\ cm^2$, $A2 = 3\ cm^2$

AB = CD = EF = 20 cm

BC = AD = BE = AF = 20 cm

1. a) Define coercitivity and retaintivity with the help of BH curve. [6]

b) A magnetic circuit consists of a circular iron core having mean length of 10 cm and cross sectional area of 100 square mm. The air gap is 2 mm and the core has 600 turns of winding. Calculate the magnitude of current to be passed through the winding to produce air gap flux of 1 tesla (permeability of iron = 4000) [10]

A ring of 30 cm mean diameter is made up of round iron rod 2.5 cm in diameter. A saw cut of 1 mm is made on the ring. It is uniformly wound with 500 turns of wire. Calculate the current required by the exciting coil to produce a total flux of 4m Wb. Assume a relative permeability of iron at this flux density as 800.

a) An iron ring has a mean length of 2m and cross-sectional area of 0.01 m^2. It has a radial air gap of 4 mm. The ring is wound with 250 turns. What dc current would be needed in the coil to produce a flux of 0.8 Weber in the air gap? Assume that $\mu r = 400$.

[8]

b) An iron ring of mean diameter 100cm and cross sectional area 10cm^2 is wound with 1000 turns and has $\mu_r = 2000$. Compute (i) reluctance (ii) flux produced when the current through the coil is 1A (iii) Flux in the ring if a saw cut of 1mm length is made, the current through the coil remaining the same. [8]

1. a) A rectangular iron core is shown in figure 1. It has a mean length of magnetic path of [illegible] cm, cross-section of (2 cm × 2 cm), relative permeability of 1400 and an air-gap of 5 mm cut in the core. The three coils carried by the core have number of turns, $N_a = 335$, $N_b = 600$ and $N_c = 600$; and the respective currents are 1.6 A, 4 A and 3 A. The directions of the currents are as shown in the figure. Find the flux in the air-gap. [6]

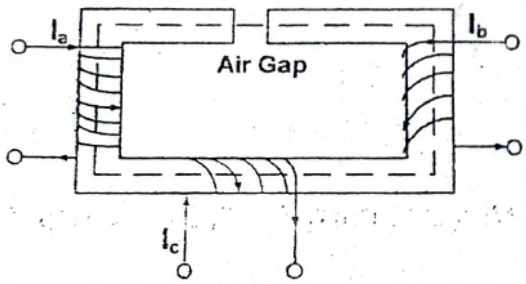
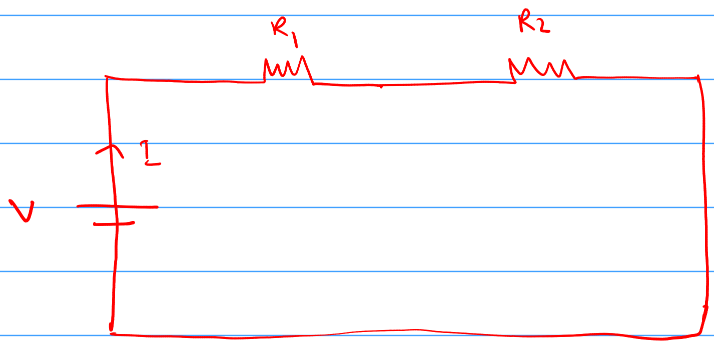


Figure 1

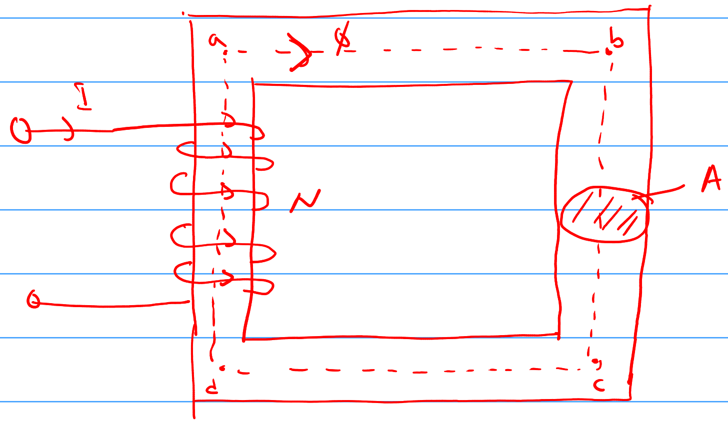
b) State Faraday's Laws of electromagnetic induction. Distinguish between statically induced emf and dynamically induced emf. [6

Magnetic circuits : series and parallel magnetic circuits



electric ckt (path followed by electric current)

magnetic circuits

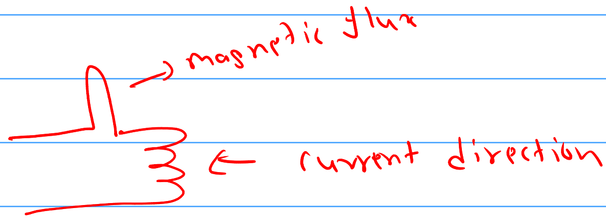


→ the path followed by the magnetic flux is known as magnetic circuit.

let us suppose we have an iron core with cross sectional area A. coil having N number of turns is wounded on the iron core and current I is flowing in through the coil.

A current carrying coil will always produce a magnetic flux (ϕ).

The direction of the magnetic flux is given by right hand screw rule.



So, flux is (↑) is above direction

Here, L = length of magnetic circuit path = a-b-c-d-a

N = no of turns of coil

Ohm's law for magnetic ckt (IOE)

magnetic flux density $\boxed{(B) = \mu_0 \mu_r H}$ —(i)

magnetic field Intensity

$$B = \frac{\phi}{A} \quad (wb/m^2, T)$$

$$H = \frac{NI}{L} \quad (\text{turns } A/m)$$

$\mu_0 = 4\pi \times 10^{-7}$ absolute permeability

μ_r = relative permeability

$\mu = \mu_0 \mu_r$

From (i)

$$B = \mu_0 \mu_r H$$

or, $$\frac{\phi}{A} = \mu_0 \mu_r \frac{NI}{L}$$

or, $$\phi = \mu_0 \mu_r \frac{NIA}{L}$$

or, $$\boxed{\phi = \frac{NI}{\left(\frac{L}{\mu_0 \mu_r A}\right)}} \longleftrightarrow I = \frac{V}{R}$$

This is ohm's law for magnetic ckt

NI = mmf (responsible for pushing the magnetic flux in the magnetic ckt)

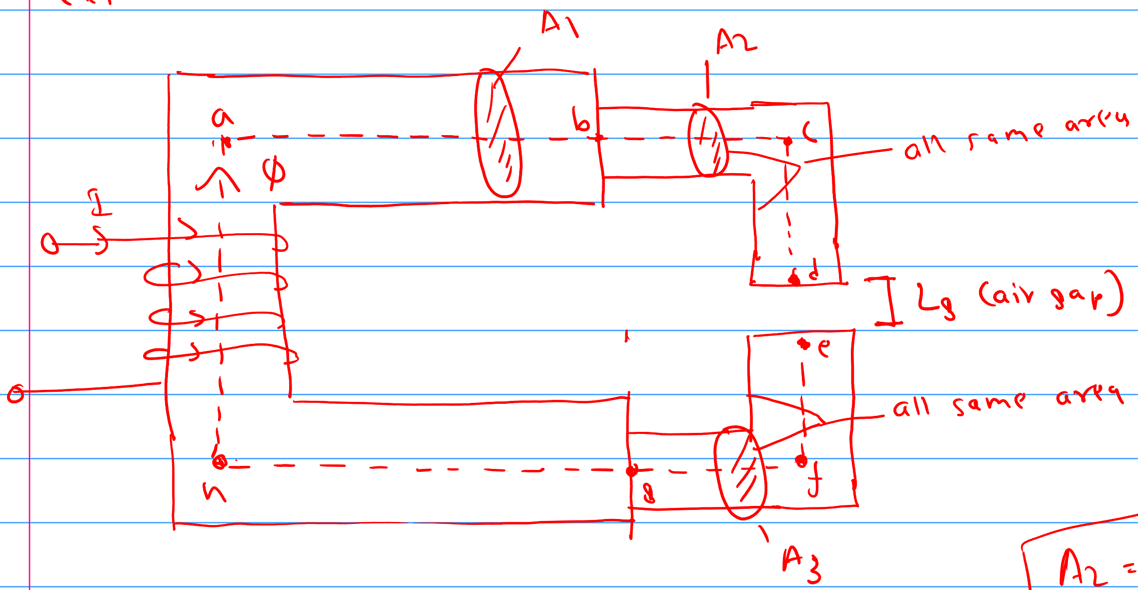
$$\frac{l}{\mu_0 \mu_r A} = \text{Reluctance}$$

$\therefore$ $$\boxed{\phi = \frac{mmf}{Reluctance}}$$ $$I = \frac{V}{R}$$

This is the comparision between ohms law in electrical and magnetic ckt.

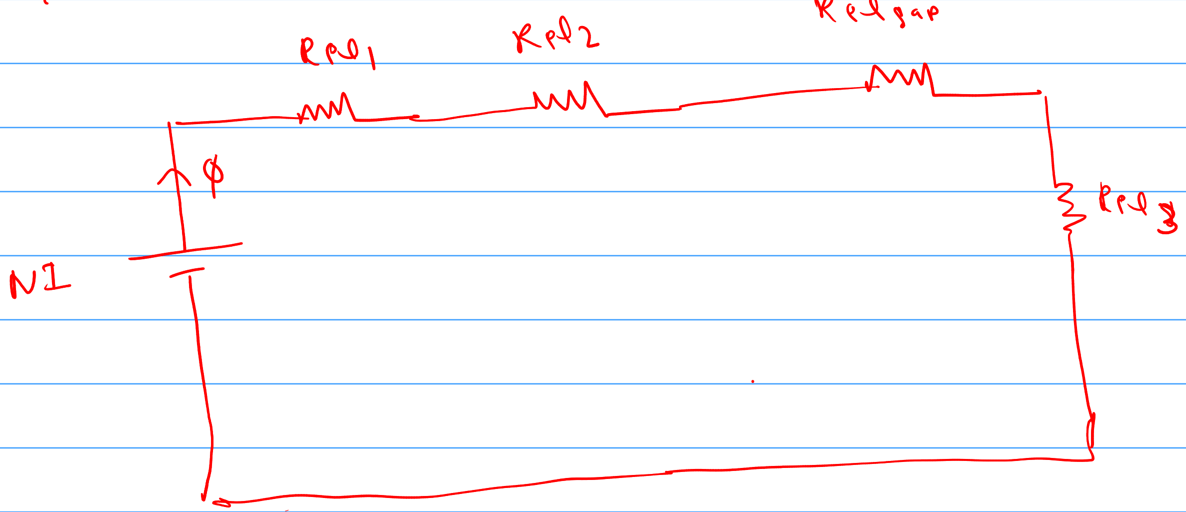
Series Magnetic ckt

→ same magnetic flux passes through various elements of mag ckt.



$$\boxed{A_2 = A_3}$$

Equivalent ckt



$$\phi = \frac{mmf}{\text{Reluctance equivalent}}$$

$$Rel = \frac{l}{\mu_0 \mu_r A}$$

$$Rel_1 = \frac{l_{g-h-a-b}}{\mu_0 \mu_{r_1} A_1}, \quad Rel_2 = \frac{l_{b-c-d}}{\mu_0 \mu_{r_2} A_2}$$

$$Rel_3 = \frac{l_{e-f-g}}{\mu_0 \mu_{r_3} A_3}$$

(since $A_2 = A_3$ 2 bata also ϕ goes to 3 without loss)

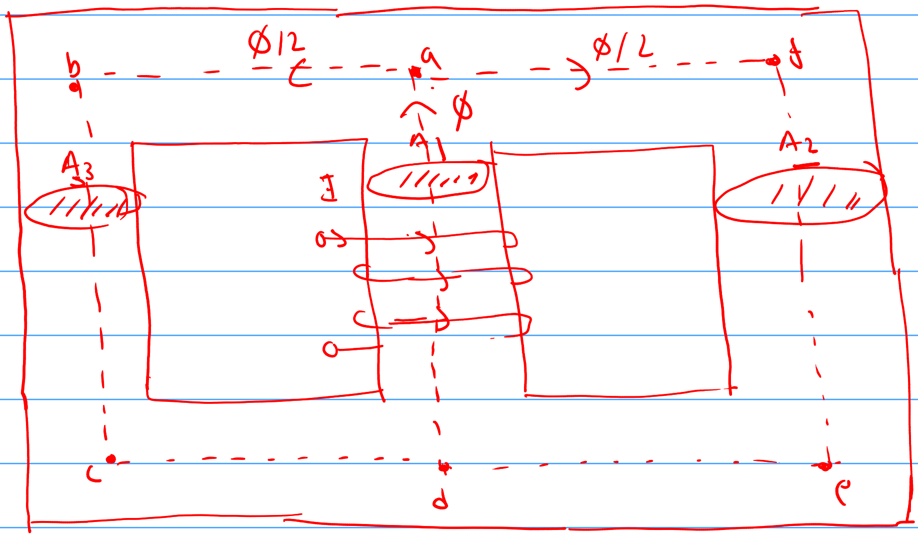
$$Rel_{gap} = \frac{l_{gap}}{\mu_0 \cdot 1 \cdot A_2}$$ [$\mu_r = 1$] for air gap

(A_2 or A_3 depends on the direction of flux, here ϕ is from 2-3 so area is A_2)

$$\phi = \frac{NI}{R_{el\ equivalent}} = \frac{NI}{R_{el_1} + R_{el_2} + R_{el_3} + R_{el\ gap}}$$

Parallel magnetic ckt

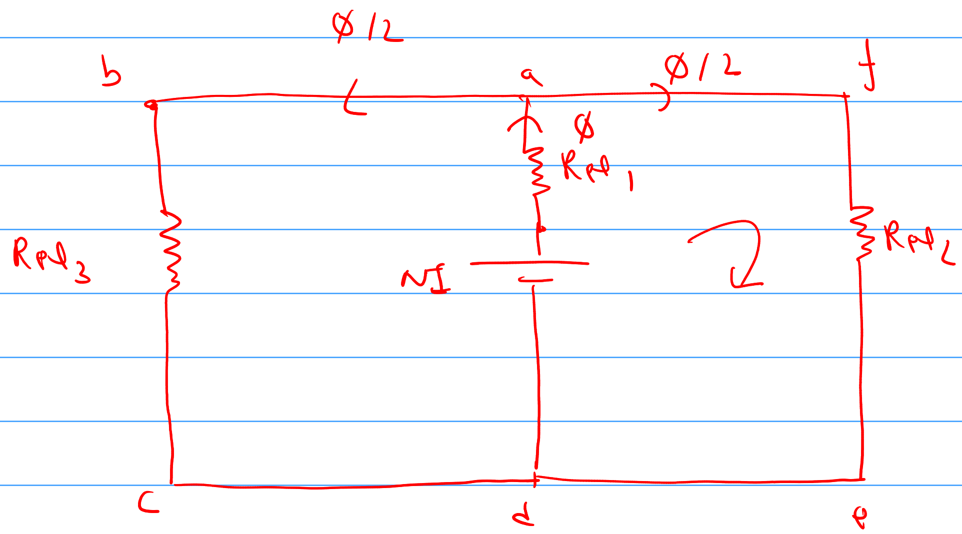
→ if ϕ provided by mmf (NI) divides into two or more parallel paths.



$(A_2 = A_3)$

Since $(A_2 = A_3)$ ϕ is divided into $\phi/2$

Equivalent ckt



KVL in right loop

$$NI = \phi \times Rel_1 + \frac{\phi}{2} Rel_2 \quad — (i)$$

$$Rel_1 = \frac{l_{d-a}}{\mu_0 \mu_{r_1} A_1} \qquad Rel_2 = \frac{l_{a-f-e-d}}{\mu_0 \mu_{r_2} A_2}$$

$$Rel_3 = \frac{l_{a-b-c-d}}{\mu_0 \mu_{r_3} A_3}$$

From (i)

$$NI = \phi \left[Rel_1 + \frac{Rel_2}{2} \right]$$

$$\therefore \phi = \frac{NI}{\left[Rel_1 + \frac{Rel_2}{2} \right]}$$

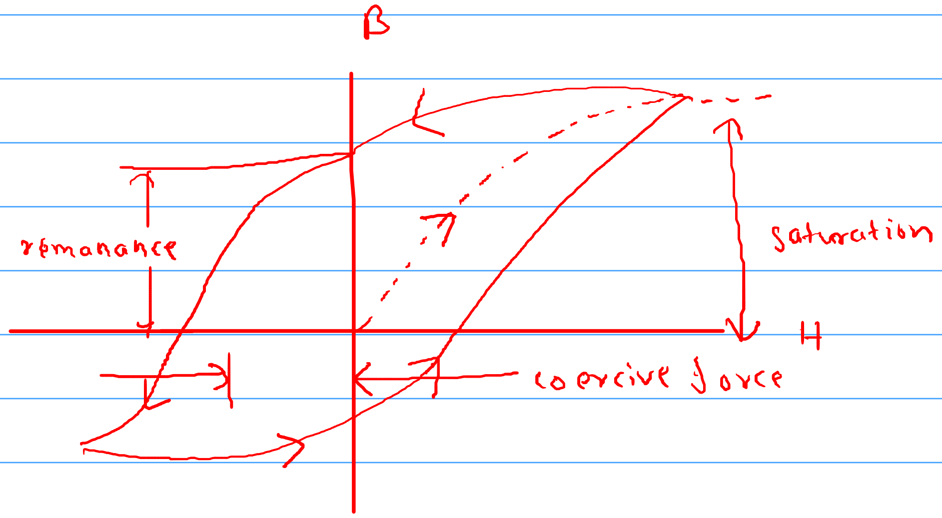
Similarities between magnetic and electric ckt (IOE)

① Both follow ohm's law

$I = V/R \qquad \phi = NI/Rel$

(ii) path followed by electric current is known as electric ckt, path followed by magnetic flux is known as magnetic circuit.

Hysteresis loop (IOE)



→ A hysteresis loop is a graphical representation that shows the relationship between an external magnetic field and the magnetization of a ferromagnetic material.

→ When a ferromagnetic material is unmagnetized and an external magnetic fileld (H) is applied, the material becomes magnetized, increasing the magnetic flux density (B). This is shown by initial rising curve.

→ When material is fully magnetized, increasing it further does not increase B significantly. The point where the curve flattens is called saturation.

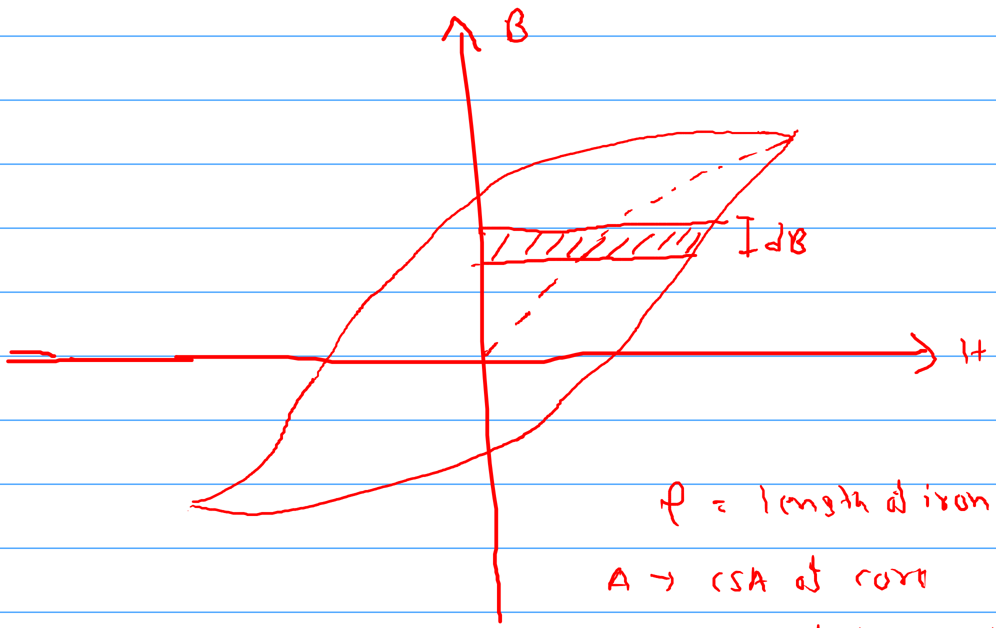
→ When the external magnetic field (H) is reduced to zero, the material retains some magnetization (B). This is called remanence or retentivity.

→ To demagnetize the material completely, a reverse magnetic field (H) must be applied. The strength of the reverse field needed to bring B to zero is called the coercive force or coercivity.

→ When the reverse field continues to increase, the material becomes magnetized in the opposite direction, reaching saturation in the opposite direction. Reversing the field again causes the loop to repeat, forming the characteristic hysteresis loop.

→ During the process of forming a hysteresis loop there's some energy loss to neutralize residual magnetic flux.

→ The area of the hysteresis loop is proportional to hysteresis loss or energy loss per unit volume. (IOE)



l = length of iron core

A → CSA of core

N → no of turns in the coil

When current is passed through winding ϕ is produced. let ϕ be the magnetic flux produced by the core then,

According to Faraday's law of EMF

$$e = N\frac{d\phi}{dt}$$

or $$e = N\frac{d(BA)}{dt} \qquad \left(\phi = BA,\ B = \frac{\phi}{A}\right)$$

or, $$e = NA\frac{dB}{dt} \qquad (A \to \text{const}) \quad \text{—— (i)}$$

$$\text{Power }(P) = e \times I \qquad (V \times I)$$

$$= \cancel{N}A\frac{dB}{dt} \times \frac{Hl}{\cancel{N}}$$

$$\left(H = \frac{NI}{l},\ I = \frac{Hl}{N}\right)$$

$$P = AHl\frac{dB}{dt} \quad \text{—— (ii)}$$

Total energy spent in small interval of time dt is :-

$$dw = P \times dt \qquad \left(P = \frac{w}{t} \right)$$

or $$dw = AH\varphi \frac{dB}{dt} dt$$

or $$dw = AH\varphi \, dB \quad \text{—— (iii)}$$

Now, total energy lost in a complete cycle

$$W = \oint dw$$

$$= \oint AH\varphi \, dB$$

$$= A\varphi \oint H \, dB$$

$$\therefore \frac{W}{A\varphi} = \oint H \, dB$$

energy loss per unit volume = area under hysteresis curve.

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magnetic hysteresis → The phenomenon of B lagging behind the magnetizing force (H) in a magnetic material is known as magnetic hysteresis.

Comparision

	Soft mag material	hard mag material
①	can be easily magnetized and demagnetized.	difficult to demagnetize once magnetized.
②	hysteresis loop area is small.	hysteresis loop area is large.
③	Suitable for temporary magnetism	suitable for permanent magnetism.

Hysteresis loss

→ During the process of forming a hysteresis loop ther's some energy loss to neutralize residual magnetic flux. This energy loss is known as hysteresis loss.

Eddy current loss

→ When a magnetic material is exposed to a changing magnetic field, it induces circulating current (eddy currents) within the material. These currents causes I^2R losses leading to energy dissipation as heat.

Steps to reduce Eddy current loss

→ laminating the core using thin insulated sheets insted of a solid core.

→ Using high resistivity materials

→ using ferrites in high-frequency applications, as they have low electrical conductivity.

Faraday's law of EMI

① 1st law : whenever the magnetic flux linkage in a conductor changes w.r.t. time an emf is induced on the conductor.

magnetic flux linkage (ψ) $= N\phi$

② 2nd law : The magnitude of emf induced is equal to the rate of change of magnetic flux linkage.

i.e $$e = \frac{d\psi}{dt} = \frac{Nd\phi}{dt}$$

The magnetic flux linkage could be changed in two two different ways. Therefore emf can be produced in two different ways.

① Statically induced emf

→ EMF induced in a stationary conductor due to a time-varying magnetic field.

→ The magnetic flux changes because the magnetic field strength or direction varies over time, while the conductor remains stationary.

$$\boxed{e = N\frac{d\phi}{dt}}$$

Types:

→ Self-Induced EMF : Occurs in a coil when its own current changes

→ Mutually Induced EMF : arises in a nearby coil due to changing current in another coil.

eg : Transformers, Inductors in ckt's

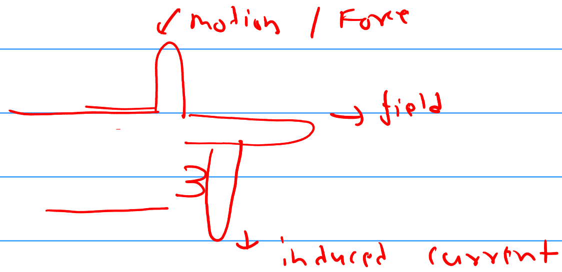
② Dynamically Induced EMF

→ emf generated by the motion of a conductor through a static magnetic field.

→ The conductor "cuts" magnetic flux lines, altering flux linkage. The field is constant but the conductor motion (translation, rotation) causes flux change.

$\boxed{e = Blv}$ volts

Direction : Fleming's right hand rule



eg: Generators, moving wires in a magnetic field

Fleming left hand rule → same but instead of generator it explains motor action.

Force on current carrying conductor: $\boxed{F = BIl}$

Self inductance

→ It is a property of circuit, typically coil or solenoid where a change in electric current flowing through it induces an emf in the same circuit.

Coefficient of self inductance (L)

∴ $L = \frac{\phi}{I}$

if N turns in a coil

$$\boxed{L = \frac{N\phi}{I}} \quad \text{— (i)}$$

From Ohm's law

$$\phi = \frac{mmf}{reluctance} = \frac{NI}{\frac{l}{\mu_0 \mu_r A}}$$

or,

$$\frac{LI}{N} = \frac{NI}{\left(\frac{l}{\mu_0 \mu_r A}\right)} \qquad \left(\phi = \frac{LI}{N} \right) \text{---(i)}$$

or,

$$L = \frac{N^2 \mu_0 \mu_r A}{l}$$

$$\therefore \boxed{L = \frac{N^2 \mu_0 \mu_r A}{l}}$$

→ This shows that L does not depend upon the diameter of the winding wire.

Note : $\boxed{\text{Permeance} = \frac{1}{\text{Reluctance}}}$