Basic Electrical Engg – EE102

(Lecture Notes-Magnetic Circuits & Transformers)

Topics Covered (Part-2)

- Composite Magnetic Circuits
- Magnetic Leakage and Fringing
- Kirchhoff's Laws for Magnetic Circuits
- Solution of Magnetic Circuits
- Significance of Airgap in Magnetic Circuits
- Magnetization Characteristics
- Experimental Determination of B-H Curve
- Hysteresis Loss, Eddy Current Loss

- Electromagnetic Induction, Fleming's Right Hand Rule
- Self Inductance, Mutual Inductance, Coefficient of Coupling
- Dot Convention, Coupled Coils in Series
- Numerical Examples

References & Further Reading

- Vincent Del Toro, Electrical Engineering Fundamentals, Prentice-Hall of India Private Limited.
- Edward Huges, Electrical and Electronic Technology, Pearson Education Limited.
- Rajendra Prasad, Fundamentals of Electrical Engineering, PHI Learning Private Limited.
- Basic Electrical Engineering (Available online : https://nptel.ac.in/ content/ storage2/ courses/108105053/ pdf/L-21(TB)(ET)%20((EE)NPTEL).pdf
- Magnetic Circuits (Available online : https://ocw.mit.edu/ zcourses/electrical-engineering-and-computer-science/6-007-electromagnetic-energy-from-motors-to-lasers-spring-2011/lecture-notes/MIT6_007S11_lec11.pdf

Composite Magnetic Circuits

Magnetic circuits → Two or more magnetic materials → non-homogeneous magnetic circuits → composite magnetic circuits.

Specimen A → mean length l_1, crosssectional Area a_1

Specimen B → l_2, a_2

$$S_A = \frac{l_1}{\mu_1 a_1}$$

$$S_B = \frac{l_2}{\mu_2 a_2}$$

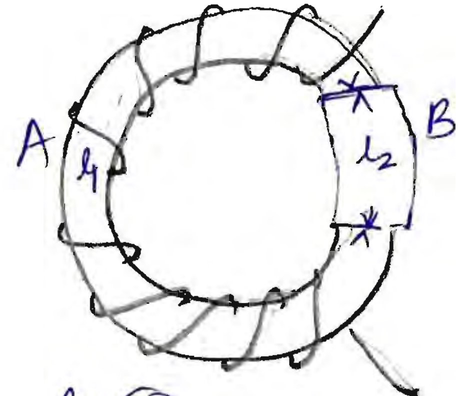


Fig (a)

Composite magnetic ckt.

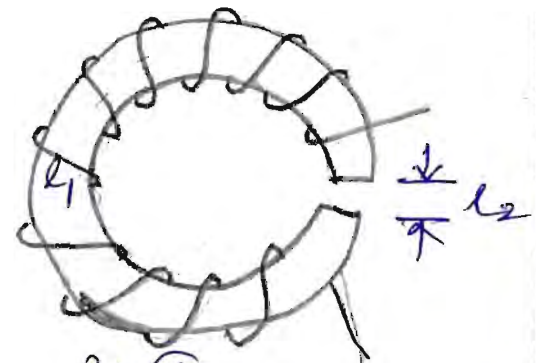


Fig (b).

Iron core with Airgap.

If the second material is air $\mu_2 = \mu_0$.

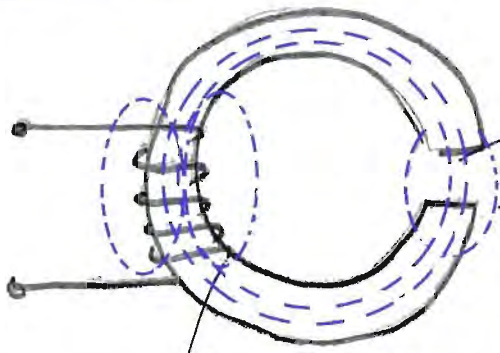
$$S_B = \frac{l_2}{\mu_0 a_2}$$

$\therefore$ Total Reluctance $S = S_A + S_B = \frac{l_1}{\mu_1 a_1} + \frac{l_2}{\mu_2 a_2}$

$$\text{Total flux } \varphi = \frac{mmf}{Reluctance} = \frac{NI}{\frac{l_1}{\mu_1 a_1} + l_2/\mu_2 a_2}$$

But $\mu_1 >> \mu_0$ $\therefore$ $S_A << S_B$ or $S \simeq S_B$.

Magnetic leakage and Fringing



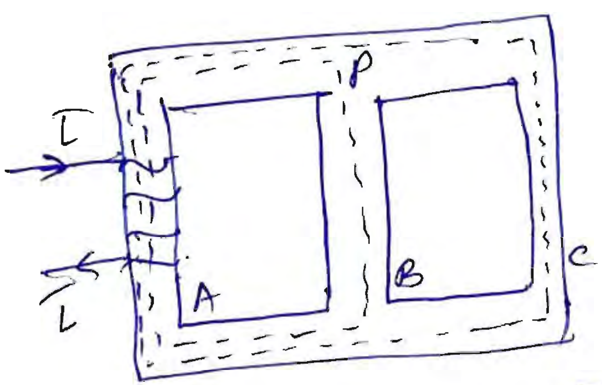
Bulging out → Fringing

↑ area of cross section.

∴ ↓ B.

longer ~~A~~ Gap → more fringing

Kirchhoff's Laws for magnetic circuits



Let H & l for

limb A →	H_a	l_a
limb B →	H_b	l_b
" C →	H_c	l_c

Coil carries current I, creates mmf NI which creates φ → At junction P, φ divides → limb B & limb C

∴ mmf of coil $= H_a l_a + H_b l_b$.

or " $= H_a l_a + H_c l_c$.

First Law : The flux entering a junction in a magnetic circuit is equal to the flux leaving the junction.

Second Law -
In a closed magnetic circuit, the algebraic sum of the product of magnetic field strength and length of the flux path of each part of the circuit is equal to the resultant mmf.

Solution of magnetic circuit

$\phi = BA$	flux, ϕ	$B = \phi/A$
$B = \mu_0\mu_r H$	flux density, B	$H = B/\mu_0\mu_r$
$H = \frac{F}{l}$	Field strength, H	$F = Hl$
	MMF, F	$I = F/N$
$F = NI$	Current, I	

(1) Start from one end of this chain → Do calculation and move to the other end.

(2) Series – ||el combination of reluctances can be carried out as in case of series-||el comb. Resistances.

Significance of Airgap in Magnetic Circuit

~~S ↑ with air~~ ① S of airgap ↑ as compared to magnetic material

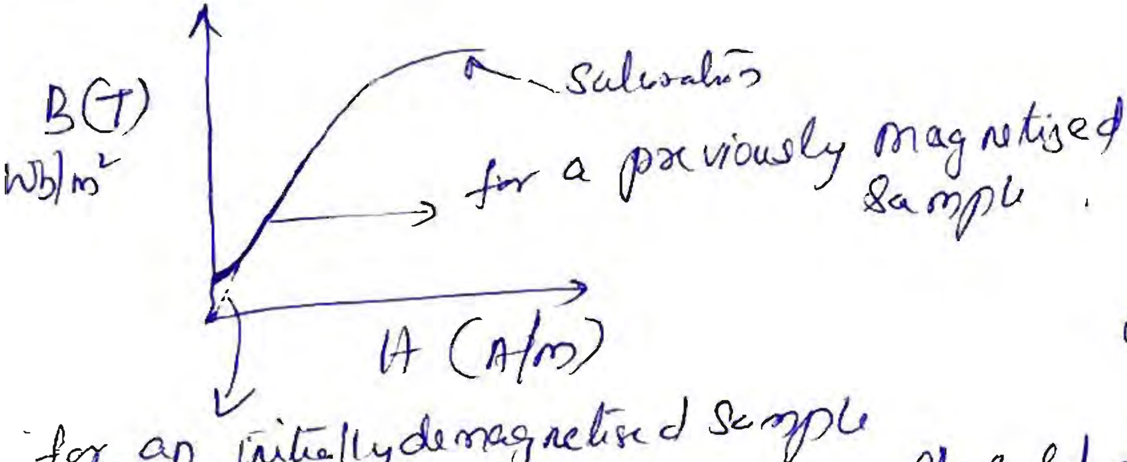
② More magnetizing current is required to create a given B.

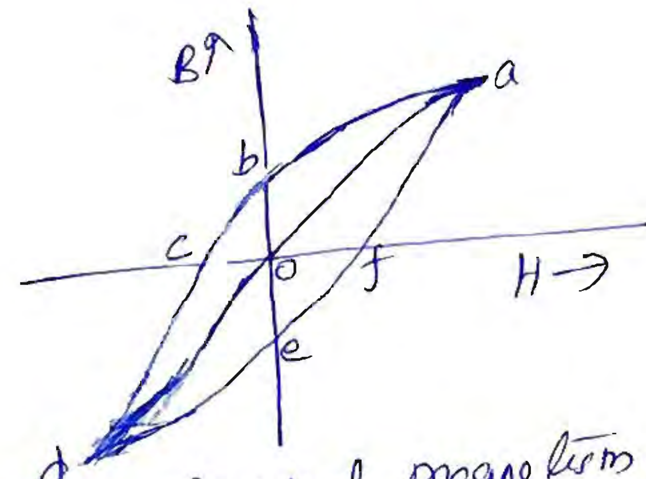
Magnetic circuits invariably contain airgaps → Why.

→ To allow an object to move in the air ~~gap~~ gap. (motors, relays)

→ To prevent saturation of the magnetic circuit → or make the magnetization characteristics more linear.

Magnetization characteristics





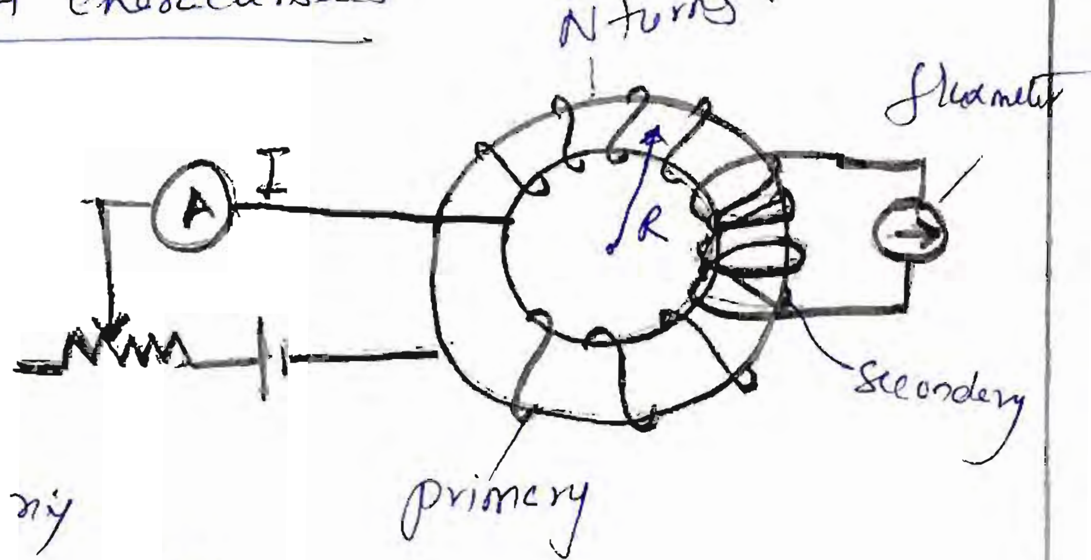
Ob, Oe → Residual magnetism / flux density.

OC → Coercive force

If a & d are at saturation then .Ob → Remanence / Retentivity

OC → Coercivity

Experimental Determination of B-H characteristics



B-H curve of iron specimen

A thin closed ring is cut from the specimen →

primary winding → N-turns uniformly distributed over the ring

secondary winding → fluxmeter is connected to it.

If I is the current in primary winding, $H = \frac{NI}{l}$ when $l = 2\pi R$.

H can be varied by varying I, H → creates flux

Due to change in magnetic flux, emf is induced in the secondary

Fl meter is calibrated to read the value of B

from I → H

emf induced → B → fluxmeter

Hysterisis loss

A ferromagnetic material

→ While being magnetised stores energy (EM)

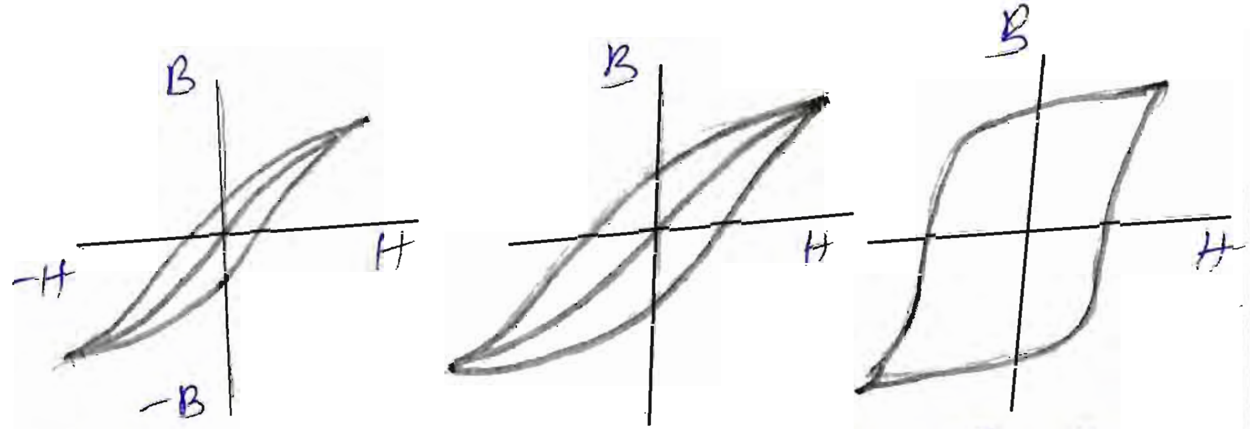
→ On being demagnetised releases energy (ED)

But some energy is absorbed by the material in each cycle of magnetisation due to hysterisis

∴ ED < EM

→ The difference (EM−ED) is dissipated as heat and is called hysterisis loss.

→ The Area of hysterisis loop indicates the hysterisis loss.



(a) Soft iron (b) Hard steel (c) Ferrite

Coercive force → 40000 A/m Alnico (Al, Ni, Co, Fe, Cu)

~~3A~~ 3 A/m → mumetal (iron, nickel, cu, molybdenum.

Hysteresis loss

$P_h = k_h v f B_{max}^{\eta}$ watts

k_h - constant for a given material

$v \rightarrow$ volume of specimen (m^3)

$f \rightarrow$ frequency

$B_{max} \rightarrow$ Max. flux density (T)

$\eta \rightarrow 1.5$ to 2.5 (steinmetz constant)

$\eta \rightarrow (1.6)$

Eddy current loss

When the current in the coil of an electromagnet changes, an emf is induced in the iron core and circulating current flows in the core $\rightarrow$ wastage of energy and heating of core.

$\rightarrow$ eddy ct $\rightarrow$ Lenz's $\rightarrow$ ~~eto~~ oppose the cause.

~~change in~~

If ferromagnetic material used is a good conductor, $R\downarrow$, eddy ct $\uparrow$, losses $\uparrow$

$\rightarrow$ magnetic core $\rightarrow$ laminations to $\uparrow R$ thus $\downarrow$ eddy ct $\rightarrow \downarrow$ eddy ct losses.

$P_e = K_e B_m^2 f^2 t^2 \times$ Volume.

or $P_e = K_e B_m^2 f^2$

t - Thickness of lamination.

B_m - max. flux density

K_e - constant $\rightarrow$ material.

$f \rightarrow$ frequency.