

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

$$B = \frac{\phi}{A} \text{ Wb/m}^2 \text{ (or) T}$$

$$B = \mu H$$

where ; \$H \rightarrow\$ magnetic field

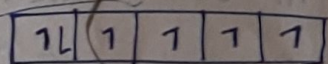
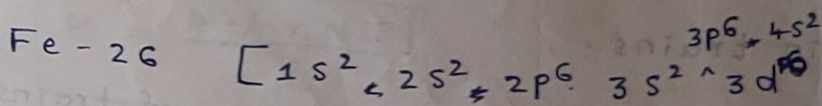
$$H = \frac{NI}{l} \text{ A/m}$$

We can measure magnetic flux density.

\$M \rightarrow\$ Magnetisation

(Dipole moment per unit volume)

$$M = \frac{p}{V} \text{ A/m}$$



Electron spin is the origin of magnetism.

Unpaired electrons contribute to magnetism

Ex : Fe, Co, Ni

Relation Between \$BH\$ & \$M\$;

$$B = \mu H = \mu_0 \mu_r H \rightarrow (1)$$

$$B = (\mu_0 (M + H)) \rightarrow (2)$$

$$(1) = (2)$$

$$\mu_0 (M + H) = \mu_0 \mu_r H$$

$$\chi = \frac{M}{H}$$

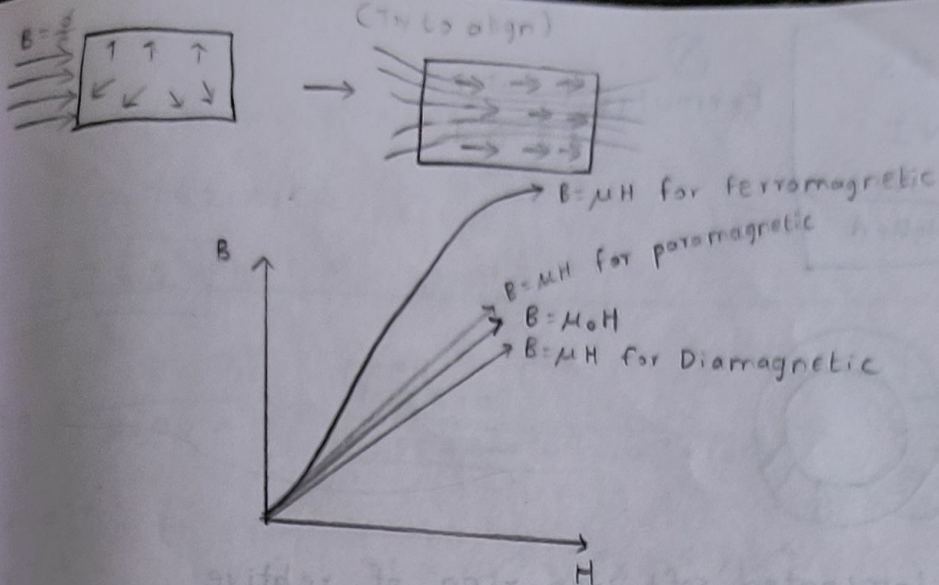
$$\mu_r = \frac{M + H}{H}$$

$$\mu_r = 1 + \frac{M}{H}$$

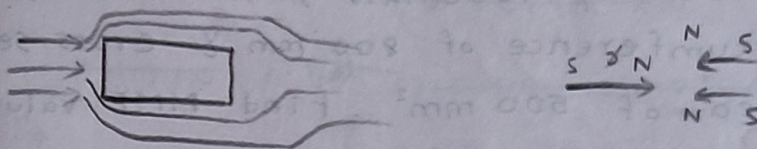
$$\therefore \mu_r = 1 + \chi$$

$$(or) \chi = \mu_r - 1$$

Magnetic susceptibility

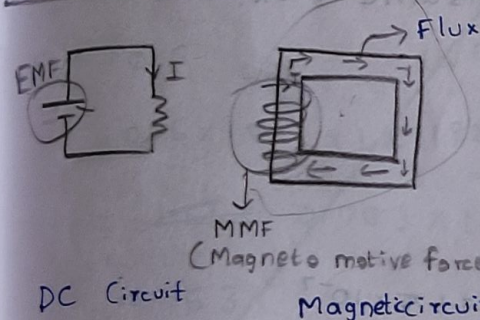


* Copper at low temp - Diamagnetic material.



* Diamagnetic material has paired electrons.

* $\chi = -ve$ (Diamagnetic)



$S \rightarrow$ Reluctance

(Resistance in electrical circuit = Reluctance in magnetic circuit)

R

S

I

ϕ

$$E = IR$$

Similarly: $MMF = \phi S$

$$MMF = F$$

$$MMF = N \cdot I$$

WKT: $B = \frac{\phi}{A}$

$$\phi = BA$$

$$= \mu H A$$

$$= \mu_0 \mu_r H A$$

$$\phi = \frac{\mu_0 \mu_r N I}{l} A$$

$$\phi = \frac{\mu_0 \mu_r F}{l}$$

$$F = \phi \frac{l}{\mu_0 \mu_r A}$$

(or)

$$F = \phi S$$

$$\therefore S = \frac{l}{\mu_0 \mu_r A}$$

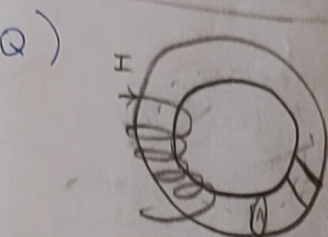
$$S \propto \frac{1}{\mu_r}$$

$$F = \oint S$$

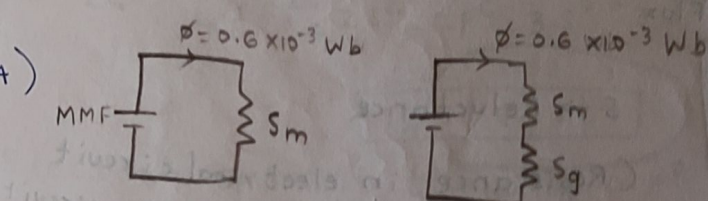
$$F = NI$$

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

Formulas



- Q) A laminated soft iron-ring of relative permeability 1000 ~~mm~~, has a mean circumference of 800 mm & cross-sectional area of 500 mm². Find MMF value to get a Flux of 0.6 m Wb. If a small air-gap of 1.2 mm is present in the ring, then how much MMF has to be given to maintain the same flux.



Given: $\mu_r = 1000$

$$A = 500 \times 10^{-6} \text{ m}^2$$

$$l = 800 \times 10^{-3} \text{ m}$$

$$\phi = 0.6 \times 10^{-3} \text{ Wb}$$

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

WKT:

$$S_m = \frac{l}{\mu_0 \mu_r A} = \frac{800 \times 10^{-3}}{4\pi \times 10^{-7} \times 1000 \times 500 \times 10^{-6}}$$

$$= \frac{800}{12.56 \times 1000 \times 500} \times 10^{-3} \times 10^7 \times 10^6$$

$$= 1.2738 \times 10^{-4} \times 10^{-3} \times 10^7 \times 10^6$$

$$= 1.2738 \times 10^6 \times 10^6$$

$$= 1.27 \times 10^6 \text{ A/Wb}$$

$$F = \phi S$$

$$= 0.6 \times 10^{-3} \times 1.27 \times 10^6$$

$$= 0.762 \times 10^3$$

$$F \approx 762 A$$

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

$$= \frac{1.2 \times 10^{-3}}{12.56 \times 10^{-6} \times 500 \times 10^{-7} \times 10^{-6}}$$

In air
 $\mu_r = 1$

$$= 1.91 \times 10^{-3} \times 10^7 \times 10^6 \times 10^{-4}$$

$$= 1.9108 \times 10^6 \text{ A/Wb}$$

$$= \cancel{0.001910 \times 10^6}$$

$$= \cancel{1.910 \text{ A Wb}^{-1}} = \cancel{0.001910 \times 10^6 \text{ A/Wb}}$$

$$S = S_m + S_g$$

$$= 1.27 \times 10^6 + 1.910 \times 10^6 = 1.27 + 0.001910 \times 10^6$$

$$= 1.271910 \times 10^6 \text{ A/Wb}$$

$$F = \phi S$$

$$= 0.6 \times 10^{-3} \times 1.271910 \times 10^6$$

$$= \cancel{0.763} \times 10^3$$

$$F = 763$$

$$S = S_m + S_g$$

$$= 1.27 \times 10^6 + 1.91 \times 10^6$$

$$= 3.18 \times 10^6 \text{ A turns/Wb}$$

$$F = \phi S$$

$$= 0.6 \times 10^{-3} \times 3.18 \times 10^6$$

$$= 1.908 \times 10^3$$

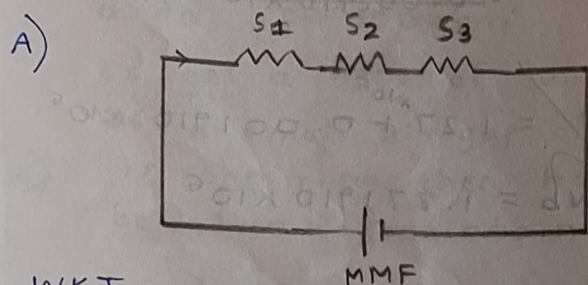
$$F \approx 1908 A$$

27/11/24

Q) A series magnetic circuit comprises of three sections, $l_1 = 80 \text{ mm}$ with cross-sectional Area of 60 mm^2 , $l_2 = 70 \text{ mm}$ and $A = 80 \text{ mm}^2$, $l_3 \rightarrow \text{Air gap}$ $l = 0.5 \text{ mm}$ and $A = 60 \text{ mm}^2$. Determine the current necessary in a coil of 4000 turns wound on a section to produce a flux density of 0.7 Tesla in the air gap. Neglect magnetic leakage.

For Section (1) $H = 415 \text{ A/m}$

For Section (2) $H = 285 \text{ A/m}$



WKT:

$$H = \frac{NI}{l}$$

For Section 1: $NI = H \times l$

$$= 415 \times 80 \times 10^{-3}$$

$$= 33200 \times 10^{-3}$$

$$NI = 33.2$$

For Air Gap: $\mu_r = 1$, $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$.
(Section 3)

$$S_3 = \frac{l_3}{\mu_0 \mu_r A}$$

$$= \frac{0.5 \times 10^{-3}}{4 \times 3.14 \times 10^{-7} \times 60 \times 10^{-6}}$$

$$= 6.634819 \times 10^{-4} \times 10^{-3} \times 10^{13}$$

$$= 6.6348 \times 10^6$$

$$S_3 = 6634819 \text{ At/Wb}$$

(\therefore Flux Density is different for different section. Flux in the section)

For Section 1 :

$$B_1 = \mu_0 \mu_{r1} \cdot H$$

$$B_1 = 4\pi \times 10^{-7} \times \mu_{r1} \times 415$$

$$0.7 = 12.56 \times 415 \times 10^{-7} \times \mu_{r1}$$

$$\mu_{r1} = \frac{0.7}{12.56 \times 415} \times 10^7$$

$$\mu_{r1} = 1.342 \times 10^{-4} \times 10^7 = 1342$$

$$S_1 = \frac{l}{\mu_0 \mu_{r1} A} = \frac{80 \times 10^{-3}}{4\pi \times 10^{-7} \times 1342 \times 60 \times 10^{-6}}$$
$$= 7.9103 \times 10^{-5} \times 10^{-3} \times 10^{13}$$
$$= 7.91036 \times 10^5$$

$$S_1 = 791036 \text{ At/Wb}$$

WKT: $B_1 = \frac{\phi}{A_1}$

$$0.7 = \frac{\phi}{60 \times 10^{-6}}$$

$$\phi = 0.7 \times 60 \times 10^{-6}$$

$$\phi = 42 \times 10^{-6} \text{ Wb}$$

For Section 2 :

$$B_2 = \frac{\phi}{A_2} = \frac{42 \times 10^{-6}}{80 \times 10^{-6}} = 0.525 \text{ T}$$

$$B_2 = \mu_0 \mu_{r2} H_2$$

$$0.525 = 4 \times 3.14 \times 10^{-7} \times \mu_{r2} \times 285$$

$$\mu_{r2} = \frac{0.525}{12.56 \times 285} \times 10^7$$

$$= 1.467 \times 10^7 \times 10^{-4}$$

$$\mu_{r2} = 1467$$

$$S_2 = \frac{l_2}{\mu_0 \mu_{r2} A}$$

$$= \frac{70 \times 10^{-3}}{4 \times 3.14 \times 10^{-7} \times 1467 \times 80 \times 10^{-6}}$$

$$= 4.748 \times 10^{-5} \times 10^{-3} \times 10^{13}$$

$$= 4.74884 \times 10^5$$

$$S_2 = 474884 \text{ A/Wb}$$

$$S = S_1 + S_2 + S_3$$

$$= 791036 + 474884 + 6634819$$

$$= 7900739 \text{ A/Wb}$$

$$\phi = 42 \times 10^{-6} \text{ Wb}$$

$$F = \phi S$$

$$= 42 \times 10^{-6} \times 7900739$$

$$= 331.83 \text{ A turns}$$

Since

$$F = NI$$

$$331.8 = 4000 \times I$$

$$I = \frac{331.8}{4000}$$

$$I = 0.082 \text{ A}$$

* Copper Loss occurs due to $I^2 R$ in the transformer winding.

* Iron loss occurs due to variation of flux density in the transformer core.