

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

$$B = \frac{\mu_0 \Phi}{A} \quad \text{Wb/m}^2 \quad (\text{Cor})$$

where;  $H \rightarrow$  magnetic field

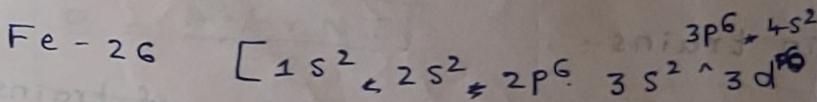
$$H = \frac{NI}{l} \text{ A/m}$$

We can measure magnetic flux density.

$M \rightarrow$  Magnetisation

(Dipole moment per unit volume)

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



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Electron spin is the origin of magnetism.

Unpaired electrons contribute to magnetism

Ex : Fe, Co, Ni;

Relation Between  $BH$  &  $M$  ;

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

$$B = (\mu_0 (M + H)) \rightarrow ②$$

$$① = ②$$

Magnetic susceptibility

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

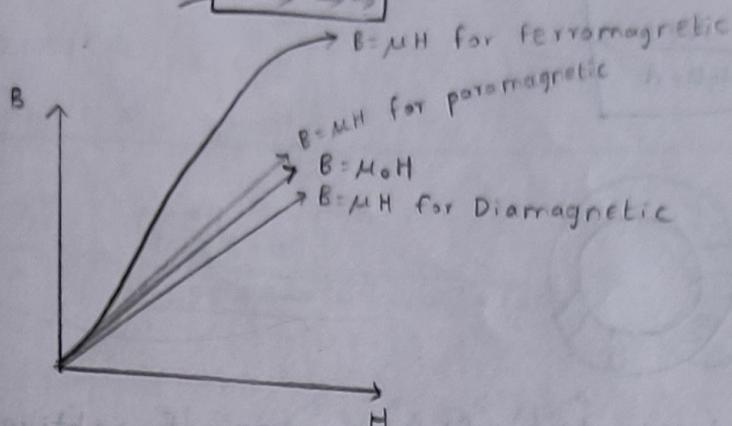
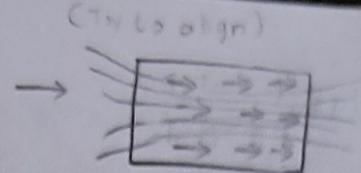
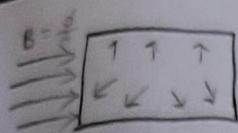
$$\chi = \frac{M}{H}$$

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

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

$$\therefore \boxed{\mu_r = 1 + \chi}$$

$$(\text{Cor}) \quad \boxed{\chi = \mu_r - 1}$$

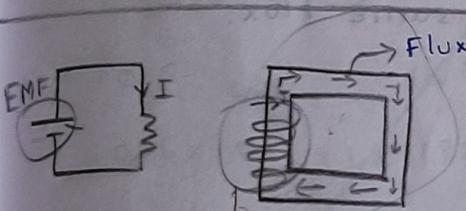


\* Copper at low temp - Diamagnetic material.



\* Diamagnetic material has paired electrons.

\*  $\chi = -ve$  (Diamagnetic)



$S \rightarrow$  Reluctance

(Resistance in electrical circuit  
= Reluctance in magnetic circuit)

DC Circuit

R

I

S

Φ

$$E = IR$$

Similarly :  $MMF = \Phi S$

$$MMF = F$$

$MMF = N \cdot I$

WKT:  $B = \frac{\Phi}{RA}$

$$\Phi = BA$$

$$= \mu H A$$

$$= \mu_0 \mu_r H A$$

$$\Phi = \frac{\mu_0 \mu_r NI}{l} A$$

$$\Phi = \frac{\mu_0 \mu_r AF}{l}$$

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

(or)

$F = \Phi S$

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

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

$$F = \phi S$$

$$F = NI$$

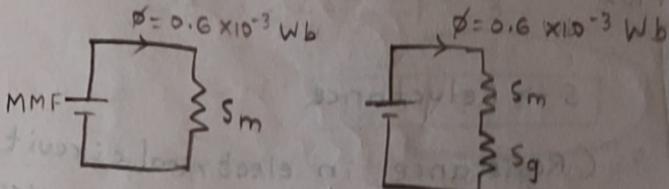
$$S = \frac{l}{\mu_0 \mu_r A}$$

~~Formulas~~

Q)



- Q) A laminated soft iron-ring of relative permeability 1000, has a mean circumference of 800 mm & cross-sectional area of 500 mm<sup>2</sup>. Find MMF value to get a Flux of 0.6 mWb. 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 :  $\mu_r = 1000$        $\mu_0 = 4\pi \times 10^{-7}$   
 $A = 500 \times 10^{-6} \text{ m}^2$   
 $l = 800 \times 10^{-3} \text{ m}$   
 $\phi = 0.6 \times 10^{-3} \text{ Wb}$

NKT :

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

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

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

$$= 1.2738 \times 10^4 \times 10^1 \times 10^6$$

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

$$F = \phi S$$

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

$$= 0.762 \times 10^3$$

$$F \approx 762 \text{ A}$$

$$S_g = \frac{l}{\mu_0 \mu_r A} = \frac{1.2 \times 10^{-3}}{12.56 \times 10^{-6} \times 500 \times 10^{-7} \times 10^{-6}}$$

In air

$$\mu_r = 1$$

$$= \frac{1.91 \times 10^{-3} \times 10^7 \times 10^6 \times 10^{-4}}{1.9108 \times 10^6}$$

$$= 0.001910 \times 10^6$$

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

$$S = S_m + S_g$$

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

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

$$F = \phi S$$

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

$$= 0.763 \times 10^3 \times 1.271910 \times 10^6$$

$$F = 763$$

$$S = S_m + S_g$$

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

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

$$F = \phi S$$

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

$$= 1.908 \times 10^3$$

$$F \approx 1908 \text{ A}$$

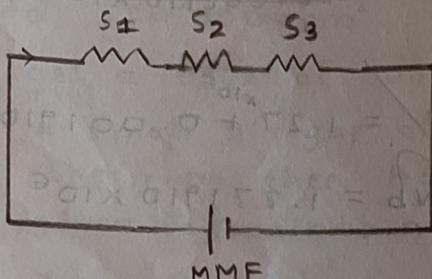
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Q) A series magnetic circuit comprises of three sections, <sup>(1)</sup>  $\ell = 80 \text{ mm}$  with cross-sectional Area of  $60 \text{ mm}^2$ , <sup>(2)</sup>  $\ell = 70 \text{ mm}$   $A = 80 \text{ mm}^2$ , <sup>(3)</sup>  $\ell = 0.5 \text{ mm}$  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)  $H = 285 \text{ A/m}$

A)



WKT :

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

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

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

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

$$NI = 33.2$$

$\therefore$  Flux Density is different for different sections  
Flux in the section

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

$$S_3 = \frac{\ell_3}{\mu_0 \mu_r A}$$

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

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

$$= 6.6348 \times 10^6$$

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

For Section 1 :

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

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

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

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

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

$$S_1 = \frac{l_1}{\mu_0 \mu_{r1} A_1} = \frac{80 \times 10^{-3}}{4\pi \times 10^{-7} \times 1342 \times 60 \times 10^{-6}}$$
$$= 7.9103 \times 10^{-5} \times 10^{-3} \times 10^{13}$$
$$= 7.91036 \times 10^5$$

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

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 :

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

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

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

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

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

$$\mu_{r2} = 1467$$

$$S_2 = \frac{l_2}{\mu_0 \mu_{r_2} A}$$

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

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

$$= 4.74884 \times 10^5$$

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

$$S = S_1 + S_2 + S_3$$

$$= 791036 + 474884 * 6634819$$

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

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

$$F = \phi S$$

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

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

Since

$$F = N I$$

$$331.8 = 4000 \times I$$

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

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

\* 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.