BASICS OF ELECTRICAL AND ELECTRONICS ENGINEERING

UNIT-2 MAGNETIC CIRCUITS

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BASIC CONCEPTS :

Magnetic circuit :- The closed path followed by magnetic flux is called Magnetic circuit.

Magnetic flux :- Total number of magnetic lines of force existing in a particular magnetic field is called Magnetic flux. Denoted by ϕ and units are webers.

Magnetic lines of force :- Imaginary lines of force which travel from North to South pole outside the magnet & from South to North pole inside the magnet are called Magnetic lines of force.

Magnetic field :- The region (or) space around magnet within which influence of magnet can be experienced is called Magnetic field.

Magnetic flux density (B) : It is defined as magnetic flux per unit area. It is denoted by B. Units are weber/m^2 (or) Tesla.

$$\boxed{B = \frac{\phi}{a}}$$

Magnetic field strength (or) Magnetic field intensity H :-

It is defined as force experienced by unit north pole at a point in magnetic field.

It can also be defined as magnetomotive force (MMF) per unit length of magnetic circuit.

$$\boxed{H = \frac{MMF}{Length} = \frac{NI}{l}}$$

Units : Ampere-turn / meter

COULOMB'S LAWS OF MAGNETIC FORCE :

FIRST LAW : It states that "Like poles repel each other and unlike poles attract each other."

SECOND LAW : The force between two magnetic poles is directly proportional to product of their pole strengths and inversely proportional to square of distance between them.

$$F = K\frac{m_1 m_2}{d^2} \quad \text{where } K = \frac{1}{4\pi\mu_0\mu_r}$$

where K is constant

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

$m_1, m_2 \rightarrow$ pole strengths

$d \rightarrow$ distance between them.

PERMEABILITY OF FREE SPACE (or) VACUUM :-

It is defined as the ratio of magnetic flux density 'B_0' in air (or) vacuum to magnetic field strength (or) intensity.

* It is denoted by μ_0 and its value is constant.
* Mathematically it can be expressed as

$$\mu_0 = \frac{B_0}{H} = 4\pi \times 10^{-7} \text{ H/m}$$

RELATIVE PERMEABILITY :-

It is defined as the ratio of flux density produced in a medium other than free space (or) vacuum 'B' to flux density produced in free space B_0, under the influence of same magnetic field strength.

* It is denoted by μ_r and has no units.
* Mathematically, it can be expressed as

$$\mu_r = \frac{B}{B_0}$$

NOTE: For free space (or) Vacuum $\boxed{\mu_r = 1}$

MAGNETOMOTIVE FORCE (MMF) :- It is defined as the product of no. of turns of the coil and current flowing in the coil.

* Mathematically it can be expressed as $M.M.F = NI$
* Its units is Ampere-turns (AT).
* It can also be defined as the force responsible for production of flux in a magnetic circuit.
* It can also be defined as the work done in moving a unit magnetic pole once around magnetic circuit.

RELUCTANCE :- It is defined as the opposition that magnetic circuit offers to magnetic flux.

- It is denoted by S.
- Its unit is AT/wb
- It is directly proportional to length of magnetic circuit and inversely proportional to area of cross-section.

$$S \propto \frac{l}{a} \Rightarrow S = K\frac{l}{a}$$

where $K = \frac{1}{\mu} \Rightarrow \boxed{S = \frac{l}{\mu_0 \mu_r a}}$

- It can also be defined as ratio of MMF to magnetic flux.

$$\text{Reluctance } S = \frac{MMF}{\phi}$$

PERMEANCE :- It is reciprocal of Reluctance.

It can be also defined as the measure of ease with which flux can pass the material.

- Its unit is wb/AT

RELATION BETWEEN MMF, MAGNETIC FLUX & RELUCTANCE

We know that

$$B = \frac{\phi}{a} \rightarrow (1)$$

$$H = \frac{B}{\mu} \rightarrow (2)$$

$$H = \frac{NI}{l} \rightarrow (3)$$

$$S = \frac{l}{\mu_0 \mu_r a} \rightarrow (4)$$

Substitute (1) in (2)

$$H = \frac{B}{\mu} = \frac{\phi}{\mu a}$$

$$\Rightarrow H = \frac{\phi}{\mu_0 \mu_r a} \rightarrow (5)$$

Substitute 5 in 3

$$\frac{\phi}{\mu_0 \mu_r a} = \frac{NI}{l}$$

$$\Rightarrow \phi = \frac{NI}{\frac{l}{\mu_0 \mu_r a}} = \frac{NI}{S}$$

$$\therefore \boxed{\text{Magnetic flux} = \frac{\text{MMF}}{\text{Reluctance}}}$$

RELATION BETWEEN B AND H :

We know

$B = \frac{\phi}{a} \rightarrow (1)$ $\quad H = \frac{NI}{l} \rightarrow (2)$ $\quad \phi = \frac{NI}{S} \rightarrow (3)$

Substitute 3 in 1

$B = \frac{NI}{Sa} \rightarrow (4)$ But we know

$S = \frac{l}{\mu_0 \mu_r a} \rightarrow (5)$

Substitute 5 in 4

$$B = \frac{NI}{a} \times \frac{\mu_0 \mu_r a}{l} \Rightarrow B = \frac{NI}{l} \times \mu_0 \mu_r$$

$\therefore B = \mu_0 \mu_r \cdot H$ [From 2]

$$\therefore \boxed{B = \mu H}$$

COMPARISON BETWEEN ELECTRIC AND MAGNETIC CIRCUITS :-

SIMILARITIES

ELECTRIC CIRCUIT	MAGNETIC CIRCUIT
The closed path for electric current is called Electric circuit.	The closed path for magnetic flux is called Magnetic circuit.
EMF is driving force	MMF is driving force
There is current I in electric circuit measured in Amperes (A)	There is flux ϕ in magnetic circuit measured in Webers (wb).
The flow of electrons decides current in conductor.	The no. of magnetic lines of force decides flux.
Resistance opposes flow of I	Reluctance opposes magnetic flux ϕ
Resistance $R = \rho \frac{l}{a}$	Reluctance $S = \frac{l}{\mu_0 \mu_r a}$
Current $I = \frac{\text{EMF}}{\text{Resistance}}$	Magnetic flux $\phi = \frac{\text{MMF}}{\text{Reluctance}}$
Current density $J = \frac{I}{a}$ A/m²	Flux density $B = \frac{\phi}{a}$ wb/m²
Electromotive Force	Magnetomotive Force
Voltage drop = IR	MMF drop = ϕS
Electric field intensity $E = \frac{V}{d}$	Magnetic field intensity $H = \frac{NI}{l}$
Conductance is reciprocal of Resistance	Permeance is reciprocal of Reluctance.
Conductivity is property to allow current to pass through	Permeability is property to allow magnetic flux to pass through

DISSIMILARITIES

ELECTRIC CIRCUIT	MAGNETIC CIRCUIT
In electric circuit, current actually flows.	Truly speaking, magnetic flux does not flow.
There are many materials like air, PVC, synthetic resin etc which can be used as insulators from which current cannot pass.	There is no magnetic insulator as flux can pass through all materials.
Energy must be supplied to electric circuit to maintain flow of current.	Energy is required to create magnetic flux, but not to maintain it.
Electric lines of force are not closed.	Magnetic lines of force are closed lines

SERIES MAGNETIC CIRCUITS:

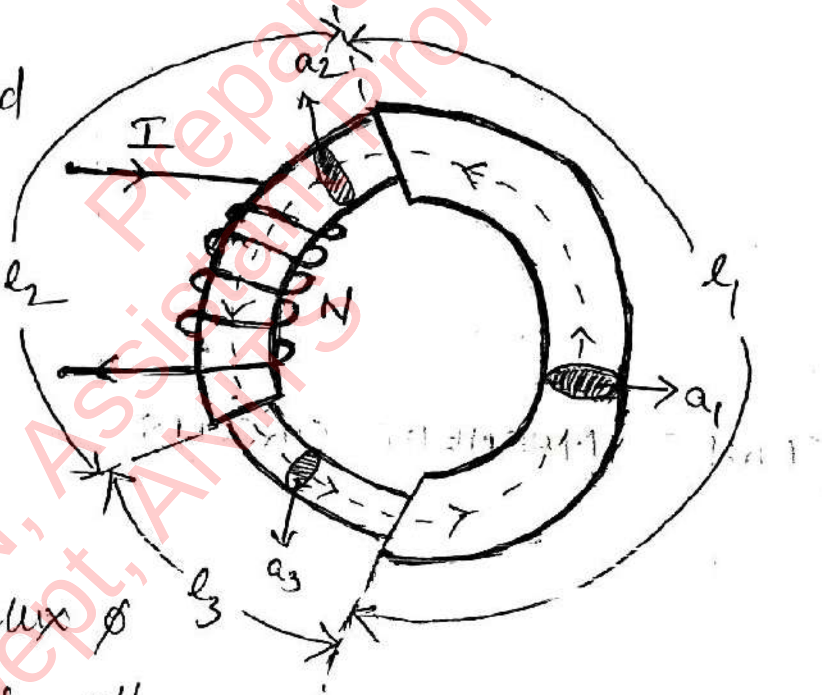
* In practice, magnetic circuit may be composed of various materials of different permeabilities, of different lengths and of different cross-sectional areas.
* Such a circuit is called COMPOSITE MAGNETIC CIRCUIT.
* When such parts are connected one after the other, the circuit is called SERIES MAGNETIC CIRCUIT.

CASE I :-

Let us consider a composite magnetic circuit consisting of three different magnetic materials of different lengths, areas of cross-section and absolute permeabilities.

Considering a circular ring as shown made up of different materials of lengths l_1, l_2 and l_3, cross-sectional areas a_1, a_2 and a_3 and absolute permeabilities μ_1, μ_2 and μ_3.

Let a coil be wound on ring has N turns carrying a current of I amperes.



The total MMF available is NI

This will set up flux ϕ which is same through all three elements of the circuit.

Since three parts of the circuit are in series, total reluctance is equal to sum of reluctances of individual parts.

We know

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

$$\text{Total Reluctance} = \frac{l_1}{a_1 \mu_0 \mu_{r_1}} + \frac{l_2}{a_2 \mu_0 \mu_{r_2}} + \frac{l_3}{a_3 \mu_0 \mu_{r_3}}$$

We know

$$\text{Total flux} = \frac{\text{Total MMF}}{\text{Total Reluctance}}$$

$$\text{Total MMF} = (\text{Total flux}) \times (\text{Total Reluctance})$$

$$NI = \phi \left[\frac{l_1}{a_1 \mu_0 \mu_{r_1}} + \frac{l_2}{a_2 \mu_0 \mu_{r_2}} + \frac{l_3}{a_3 \mu_0 \mu_{r_3}} \right]$$

$$NI = \left(\frac{\phi}{a_1 \mu_0 \mu_{r_1}} \times l_1 \right) + \left(\frac{\phi}{a_2 \mu_0 \mu_{r_2}} \times l_2 \right) + \left(\frac{\phi \times l_3}{a_3 \mu_0 \mu_{r_3}} \right)$$

But we know

$$B = \frac{\phi}{a}$$

So,

$$NI = \left(\frac{B_1}{\mu_0 \mu_{r_1}} \times l_1 \right) + \left(\frac{B_2}{\mu_0 \mu_{r_2}} \times l_2 \right) + \left(\frac{B_3}{\mu_0 \mu_{r_3}} \times l_3 \right)$$

But we know

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

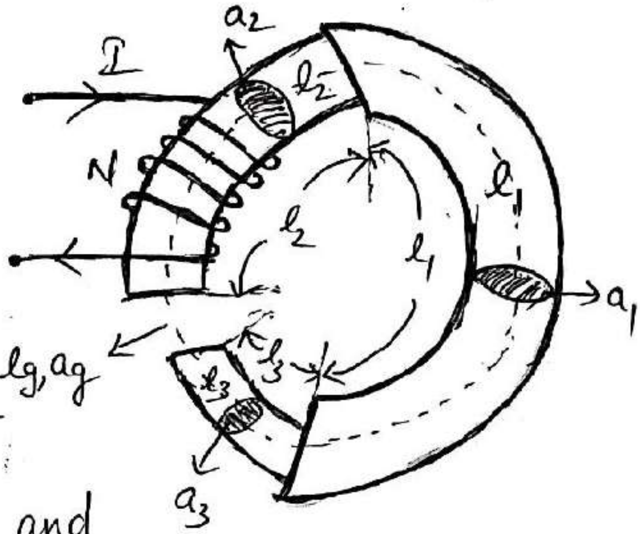
Therefore.

$$NI = H_1 l_1 + H_2 l_2 + H_3 l_3$$

$$\boxed{\text{TOTAL MMF} = H_1 l_1 + H_2 l_2 + H_3 l_3}$$

CASE 2:-

Let us once again consider a composite magnetic circuit consisting of three different magnetic materials of different lengths, areas of cross-section and absolute permeabilities along with AIR GAP.



Consider a circular ring as shown made up of different materials of lengths l_1, l_2 and l_3, cross-sectional areas a_1, a_2 and a_3 & absolute permeabilities μ_1, μ_2 and μ_3. Also let length of air gap be l_g and area of cross-section of air gap be a_g.

Let a coil be wound on ring having N turns carrying a current of I amperes.

Total MMF available is NI

This will set up flux ϕ which is same through all parts of circuit.

Since all parts are in series, total Reluctance is equal to sum of reluctances of individual parts.

We know

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

Also for air, $\mu_r = 1$

$$\text{Total Reluctance} = \frac{l_1}{a_1 \mu_0 \mu_{r_1}} + \frac{l_2}{a_2 \mu_0 \mu_{r_2}} + \frac{l_3}{a_3 \mu_0 \mu_{r_3}} + \frac{l_g}{\mu_0 a_g}$$

We know

$$\text{Total flux} = \frac{\text{Total MMF}}{\text{Total Reluctance}}$$

$$\text{Total MMF} = (\text{Total flux}) \times (\text{Total Reluctance})$$

$$NI = \phi \left[\frac{l_1}{a_1 \mu_0 \mu_{r_1}} + \frac{l_2}{a_2 \mu_0 \mu_{r_2}} + \frac{l_3}{a_3 \mu_0 \mu_{r_3}} + \frac{l_g}{\mu_0 a_g} \right]$$

But we know

$$B = \frac{\phi}{a}$$

So

$$NI = \left(\frac{B_1}{\mu_0 \mu_{r_1}} \times l_1 \right) + \left(\frac{B_2}{\mu_0 \mu_{r_2}} \right) l_2 + \left(\frac{B_3}{\mu_0 \mu_{r_3}} \right) l_3 + \frac{B_g l_g}{\mu_0}$$

But we know

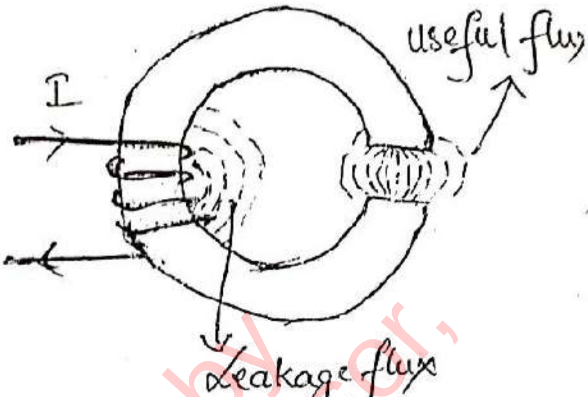
$$B = \mu H = \mu_0 \mu_r H$$

Therefore

$$NI = H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g$$

$$\boxed{\text{TOTAL MMF} = H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g}$$

LEAKAGE FLUX :- The flux that does not follow desired path in a magnetic field is called LEAKAGE FLUX.



* In most of practical magnetic circuits, a large part of flux path is through magnetic material & remainder part of flux path is through air.
* The flux in air gap is known as USEFUL FLUX because it can be utilised for various useful purposes.
* Total flux produced by coil does not pass through air gap as some of it leaks through the air surrounding iron. These flux lines are called leakage flux.

Let ϕ_i = Total flux produced (iron ring)

ϕ_g = Useful flux across air gap.

$\therefore$ Leakage flux $\phi_{leak} = \phi_i - \phi_g$.

Leakage coefficient/factor $\lambda = \dfrac{\text{Total flux}}{\text{Useful flux}} = \dfrac{\phi_i}{\phi_g}$

$$\therefore \boxed{\lambda = \frac{\phi_i}{\phi_g}}$$

Note: Useful flux passing across air gap tends to bulge outwards, thereby increasing effective area of gap and reducing flux density. This effect is known as FRINGING. Longer air gap, greater is fringing & vice-versa.

BASIC CONCEPTS: Tutorials on Magnetic Circuits

1. A coil is wound uniformly with 300 turns over a steel ring of relative permeability 900 having mean circumference of 40 cm and a cross-sectional area of 5 cm^2. If the coil has a resistance of 100Ω and is connected to 250V dc supply. Calculate i) MMF ii) Magnetic field strength iii) Total flux iv) Reluctance v) Permeance

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Sol: Given $N = 300$

$\mu_r = 900$

$l = 40\,cm = 40\times10^{-2}\,m$

$a = 5\,cm^2 = 5\times10^{-4}\,m^2$

$R = 100\Omega$

$V = 250V$

i) Current $I = \frac{V}{R} = \frac{250}{100} = 2.5A$

$MMF = NI = 300\times2.5 = 750\,AT \Rightarrow \boxed{MMF = 750\,AT}$

ii) Magnetic field strength $H = \frac{NI}{l}$

$\Rightarrow H = \frac{750}{40\times10^{-2}} = 1875\,AT/m \Rightarrow \boxed{H = 1875\,AT/m}$

iii) Magnetic flux density $B = \mu_0\mu_r H$ and $B = \frac{\phi}{a}$

$\Rightarrow B = 4\pi\times10^{-7}\times900\times1875 = 2.12\,Wb/m^2$

$\therefore B = \frac{\phi}{a} \Rightarrow \phi = B\times a = 2.12\times5\times10^{-4} = 10.6\times10^{-4}\,wb$

Total flux $\boxed{\phi = 10.6\times10^{-4}\,wb}$

iv) Reluctance $S = \frac{MMF}{Flux} = \frac{750}{10.6 \times 10^{-4}} = 70.75 \times 10^{4}$ AT/wb

$\therefore \boxed{S = 70.75 \times 10^{4} \text{ AT/wb}}$

v) Permeance $= \frac{1}{Reluctance} = \frac{1}{70.75 \times 10^{4}} = 1.4 \times 10^{-6}$ wb/AT

$\therefore \boxed{\text{Permeance} = 1.4 \times 10^{-6} \text{ wb/AT}}$

(2) An iron ring has cross-sectional area of 400 mm^2 and a mean diameter of 25 cm. It is wound with 500 turns. If relative permeability is 250, find total flux set up in ring. coil resistance is 474Ω and supply voltage is 240V.

Sol: coil current $I = \frac{V}{R} = \frac{240}{474} = 0.506$ A

Given diameter $d = 25$ cm $= 25 \times 10^{-2}$ m

Mean length $l = 2\pi r = \pi d = \pi \times 25 \times 10^{-2}$ m

Magnetic field intensity $H = \frac{NI}{l} = \frac{500 \times 0.506}{\pi \times 25 \times 10^{-2}}$

$\therefore H = 322.13$ AT/m

Magnetic flux density $B = \mu_0 \mu_r H = 4\pi \times 10^{-7} \times 250 \times 322.13$

$\therefore B = 0.101$ wb/m^2

Total flux $\phi = B \times a = 0.101 \times 400 \times 10^{-6}$

$\boxed{\phi = 40.48 \times 10^{-6} \text{ wb}}$

(3) An iron ring of circular cross-sectional area of $3\ cm^2$ and mean diameter of 20 cm is wound with 500 turns of wire & carries a current of 2.09A to produce magnetic flux of 0.5 mwb in the ring. Determine relative permeability.

Sol: Mean length $l = 2\pi r = \pi d = \pi \times 20 \times 10^{-2} = 0.628\ m$

Reluctance $S = \frac{l}{\mu_0 \mu_r a}$ and $S = \frac{MMF}{Flux}$

$$\therefore S = \frac{NI}{\phi} = \frac{500 \times 2.09}{0.5 \times 10^{-3}} = 2 \times 10^{6}\ AT/wb$$

But $S = \frac{l}{\mu_0 \mu_r a} \Rightarrow \mu_r = \frac{l}{\mu_0 a S}$

$$\therefore \mu_r = \frac{0.628}{4\pi \times 10^{-7} \times 3 \times 10^{-4} \times 2 \times 10^{6}} = 797$$

$$\therefore \boxed{\mu_r = 797}$$

(4) A coil of 1000 turns is wound uniformly over a wooden ring with mean circumference of 2m and a uniform sectional area of $0.025\ cm^2$. If coil is carrying a current of 2A, Calculate i) MMF ii) Magnetic field intensity iii) Magnetic flux density iv) Total flux.

Sol: Given $N = 1000$

$l = 2m$

$a = 0.025\ cm^2 = 0.025 \times 10^{-4}\ m^2$

$I = 2A$

i) $MMF = NI = 1000 \times 2 = 2000\ AT \Rightarrow \boxed{MMF = 2000\,AT}$

ii) $H = \frac{NI}{l} = \frac{2000}{2} = 1000\ AT/m \Rightarrow \boxed{H = 1000\ AT/m}$

iii) Wood is non-magnetic material $\mu_r = 1$

Magnetic flux density $B = \mu_0 \mu_r H = \mu_0 H$

$\therefore B = 4\pi \times 10^{-7} \times 1000 = 1.256 \times 10^{-3}\ T \Rightarrow \boxed{B = 1.256 \times 10^{-3}\ T}$

iv) Magnetic flux. $\phi = B \times a = 1.256 \times 10^{-3} \times 0.025 \times 10^{-4}$

$\therefore \boxed{\phi = 3.14 \times 10^{-9}\ wb}$

5) A coil of 600 turns is wound uniformly on a ring of non-magnetic material of cross sectional area of $200\ mm^2$ and a mean circumference of 500 mm. If the current in coil is 4A, determine i) Magnetic field strength ii) Magnetic flux density. iii) Magnetic flux.

Sol Given $N = 600$, $a = 200\,mm^2 = 200 \times 10^{-6}\ m^2$, $I = 4A$, $\mu_r = 1$

$l = 500mm = 500 \times 10^{-3}\ m$,

i) $H = \frac{NI}{l} = \frac{600 \times 4}{500 \times 10^{-3}} = 4800\ AT/m \Rightarrow \boxed{H = 4800\ AT/m}$

ii) $B = \mu H = \mu_0 H = 4\pi \times 10^{-7} \times 4800 = 6.03 \times 10^{-3}\ T$

$\therefore \boxed{B = 6.03 \times 10^{-3}\ T}$

iii) $B = \frac{\phi}{a} \Rightarrow \phi = B \times a = 6.03 \times 10^{-3} \times 200 \times 10^{-6}$

$\Rightarrow \boxed{\phi = 1.26 \times 10^{-6}\ wb}$

⑥ An iron ring of cross-sectional area 6 cm² is wound with 100 turns and has saw cut of 2mm. Calculate magnetising current required to produce a flux of 0.1 mWb if mean length is 30 cm and relative permeability is 470. (Previous Q-paper)

Sol: We know

$$NI = H_i l_i + H_g l_g = \frac{B l_i}{\mu_0 \mu_r} + \frac{B l_g}{\mu_0}$$

$$B = \frac{\phi}{a} = \frac{0.1\times10^{-3}}{6\times10^{-4}} = 0.167\,T$$

$$NI = \frac{0.167\times30\times10^{-2}}{4\pi\times10^{-7}\times470} + \frac{0.167\times2\times10^{-3}}{4\pi\times10^{-7}} = 84.83 + 265.8 = 350.63\ \text{AT}$$

$$I = \frac{350.63}{N} = \frac{350.63}{100} = 3.5A \Rightarrow \boxed{I = 3.5A}$$

⑦ A magnetic flux density of 1.2 T is required in 2mm air gap of an electromagnet having iron path 1m long. Calculate MMF required, assuming relative permeability to be 1500.

Sol: We know

$$NI = H_i l_i + H_g l_g = \frac{B l_i}{\mu_0 \mu_r} + \frac{B l_g}{\mu_0}$$

$$NI = \frac{1.2\times1}{4\pi\times10^{-7}\times1500} + \frac{1.2\times2\times10^{-3}}{4\pi\times10^{-7}}$$

$$NI = 637 + 1910 = 2547\ \text{AT}$$

$$\therefore \boxed{\text{MMF required } (NI) = 2547\ \text{AT}}$$

(8) An iron ring has mean diameter of 15 cm, cross-sectional area of 20 cm^2 and a radial gap 0.5 mm cut in it. It is uniformly wound with 1500 turns and a magnetising current of 1A produces a flux of 1 mWb. Calculate i) Relative permeability and ii) Reluctance

Sol. Air-gap ampere-turns :-

$$H_g l_g = \frac{B}{\mu_0} l_g = \frac{\phi}{\mu_0 a} l_g = \frac{1\times10^{-3} \times 0.5\times10^{-3}}{4\pi\times10^{-7}\times 20\times10^{-4}}$$

$$\therefore \boxed{H_g l_g = 199 \text{ AT}}$$

Total ampere-Turns: $NI = 1500\times1 = 1500$ AT

Iron-path ampere-turns :

$H_g l_g + H_i l_i = NI \Rightarrow H_i l_i = NI - H_g l_g = 1500 - 199$

$$\therefore \boxed{H_i l_i = 1301 \text{ AT}}$$

But, $H_i l_i = \frac{B}{\mu_0 \mu_r} l_i = \frac{\phi}{\mu_0 \mu_r a} l_i = \frac{1\times10^{-3}\times(\pi\times d)}{4\pi\times10^{-7}\times\mu_r\times20\times10^{-4}}$

$$\therefore 1301 = \frac{1\times10^{-3}\times\pi\times15\times10^{-2}}{4\pi\times10^{-7}\times\mu_r\times20\times10^{-4}}$$

$$\Rightarrow \mu_r = \frac{1\times10^{-3}\times\pi\times15\times10^{-2}}{4\pi\times10^{-7}\times1301\times20\times10^{-4}}$$

$$\therefore \boxed{\mu_r = 144}$$

ii) Reluctance of air gap $S_g = \frac{l_g}{a\mu_0}$

$$S_g = \frac{0.5\times10^{-3}}{20\times10^{-4}\times 4\pi\times10^{-7}} \Rightarrow \boxed{S_g = 1.99\times10^5 \text{ AT/wb}}$$

Reluctance of iron part

$$S_i = \frac{l_i}{a\mu_0\mu_r} = \frac{\pi\times15\times10^{-2}}{20\times10^{-4}\times4\pi\times10^{-7}\times144}$$

$$\boxed{S_i = 13.01\times10^5 \text{ AT/wb}}$$

Total Reluctance $S = S_i + S_g = (1.99+13.01)\times10^5$

$$\boxed{S = 15\times10^5 \text{ AT/wb}}$$

(9) A ring composed of three sections. The cross-sectional area is $0.001\ m^2$ for each section. Mean arc length are $l_a = 0.3m$, $l_b = 0.2m$ & $l_c = 0.1m$. An air-gap length of 0.1mm is cut in the ring. Relative permeabilitie for sections a, b and c are 5000, 1000 and 10,000 resp. Flux in air gap is 7.5×10^{-4} wb. Find

i) mmf ii) current if coil has 100 turns iii) Reluctances of all sectio

Sol: Area $a = 0.001\ m^2$

$l_a = 0.3m$, $l_b = 0.2m$, $l_c = 0.1m$, $l_g = 0.1\times10^{-3}m$

$\mu_{ra} = 5000$, $\mu_{rb} = 1000$, $\mu_{rc} = 10,000$, $\phi = 7.5\times10^{-4}$ wb

iii) Reluctance $S = \frac{l}{\mu_0\mu_r a}$

The ring contains 3 sections

Reluctance of section 'a' of ring

$$\text{Reluctance } S_a = \frac{l_a}{\mu_0 \mu_{r_a} a} = \frac{0.3}{4\pi\times10^{-7}\times5000\times0.001}$$

$$\Rightarrow \boxed{S_a = 47746.5}$$

Reluctance of section 'b' of ring

$$S_b = \frac{l_b}{\mu_0 \mu_{r_b} a} = \frac{0.2}{4\pi\times10^{-7}\times1000\times0.001}$$

$$\Rightarrow \boxed{S_b = 159155}$$

Reluctance of section 'c' of ring

$$S_c = \frac{l_c}{\mu_0 \mu_{r_c} a} = \frac{0.1}{4\pi\times10^{-7}\times10{,}000\times0.001}$$

$$\Rightarrow \boxed{S_c = 7957.74}$$

Reluctance of air gap $S_g = \frac{l_g}{\mu_0 a} = \frac{0.1\times10^{-3}}{4\pi\times10^{-7}\times0.001}$

$$\Rightarrow \boxed{S_g = 79577.5}$$

Total Reluctance $S_T = S_a + S_b + S_c + S_g = 47746.5 + 159155 + 7957.74 + 79577.5$

$$\Rightarrow \boxed{S_T = 294436.74}$$

i) Total mmf = (Total flux) x (Total Reluctance)

$$= 7.5\times10^{-4}\times294436.74$$

$$\Rightarrow \boxed{(MMF)_{Total} = 220.82 \text{ AT}}$$

ii) $(MMF)_{Total} = NI \Rightarrow I = \frac{MMF}{N} = \frac{220.82}{100} \Rightarrow \boxed{I = 2.2A}$

(10) An iron ring has a cross-section of $3 cm^2$ and a mean diameter of 25 cm. An air-gap of 0.4mm has been cut across the section of the ring. The ring is wound with a coil of 200 turns through which a current of 2A is passed. If total magnetic flux is 0.24mWb, find relative permeability of iron, assuming no leakage.

Sol: Flux density $B = \frac{\phi}{a} = \frac{0.24\times10^{-3}}{3\times10^{-4}} = 0.8\ Wb/m^2$

Ampere turns for iron ring:

$$(NI)_{Iron} = H_i l_i = \frac{B}{\mu_0\mu_r}\times l_i = \frac{0.8\times\pi\times25\times10^{-2}}{4\pi\times10^{-7}\mu_r}$$

$$\therefore (NI)_{Iron} = \frac{500{,}000}{\mu_r}\ AT$$

Ampere turns for air gap:-

$$(NI)_{Air\ gap} = H_g l_g = \frac{B}{\mu_0}\times l_g = \frac{0.8\times0.4\times10^{-3}}{4\pi\times10^{-7}}$$

$$\therefore (NI)_{Air\ gap} = 255\ AT$$

Total Ampere-turns required $= (NI)_{Iron} + (NI)_{Air\ gap}$

$$(NI)_{Total} = \frac{500\,000}{\mu_r} + 255$$

But Total Ampere turns is also equal to NI

$$(NI)_{Total} = NI = 200\times2 = 400\ AT$$

$$\therefore \frac{500\,000}{\mu_r} + 255 = 400$$

$$\Rightarrow \frac{500\,000}{\mu_r} = 145$$

$$\Rightarrow \boxed{\mu_r = 3448.27}$$

(11) A mild steel ring of 30 cm mean circumference has a cross-sectional area of 6 cm² and has a winding of 500 turns. The ring is cut so as to provide an air gap of 1mm in magnetic circuit. It is found that a current of 4A in winding, produces flux density of 1T in air-gap. Find relative permeability of mild steel.

Sol: Ampere turns required for mild steel ring:

$$(NI)_{steel} = H_{steel} l_{steel} = \frac{B}{\mu_0 \mu_r} \times l_{steel}$$

$$\therefore (NI)_{steel} = \frac{1}{4\pi \times 10^{-7} \times \mu_r} \times 30 \times 10^{-2} = \frac{0.238 \times 10^{6}}{\mu_r} \text{ AT}$$

Ampere-turns required for air-gap:

$$(NI)_{Air\ gap} = H_g l_g = \frac{B}{\mu_0} \times l_g = \frac{1}{4\pi \times 10^{-7}} \times 1 \times 10^{-3}$$

$$\therefore (NI)_{Air\ gap} = 795.7 \text{ AT}$$

$$\text{Total mmf} = NI = 500 \times 4 = 2000 = (NI)_{steel} + (NI)_{Air\ gap}$$

$$\Rightarrow \frac{0.238 \times 10^{6}}{\mu_r} + 795.7 = 2000$$

$$\Rightarrow \frac{0.238 \times 10^{6}}{\mu_r} = 1204.3$$

$$\Rightarrow \mu_r = \frac{0.238 \times 10^{6}}{1204.3}$$

$$\therefore \boxed{\mu_r = 197.6}$$

*(12) A circular iron ring has a mean circumference of 1.5 m and a cross-sectional area of 0.01 m^2. A saw-cut of 4 mm wide is made in ring. Calculate magnetising current required to produce flux of 0.8 mWb in air-gap if ring is wound with coil of 175 turns. Assume relative permeability of iron is 400 and leakage factor 1.25. (Previous Q-paper) (6)

Sol:- Air-gap ampere-turns :-

$$H_g l_g = \frac{B_g}{\mu_0} l_g = \frac{\phi_g}{\mu_0 a} l_g = \frac{0.8\times10^{-3}\times 4\times10^{-3}}{4\pi\times10^{-7}\times 0.01}$$

$$\therefore \boxed{H_g l_g = 254.6 \text{ AT}}$$

Iron-path ampere-turns :-

$$H_i l_i = \frac{B_i}{\mu_0 \mu_r} l_i = \frac{\phi_i}{\mu_0 \mu_r a} l_i = \frac{(\lambda \phi_g)\, l_i}{\mu_0 \mu_r\, a}$$

$$\Rightarrow H_i l_i = \frac{(\lambda \phi_g) l_i}{\mu_0 \mu_r a} = \frac{1.25\times 0.8\times10^{-3}\times 1.5}{4\pi\times10^{-7}\times 400\times 0.01}$$

$$\therefore \boxed{H_i l_i = 298.4 \text{ AT}}$$

$$\therefore NI = H_g l_g + H_i l_i = 254.6 + 298.4 = 553$$

$$I = \frac{553}{175} = 3.16 \text{ A}$$

$$\therefore \boxed{I = 3.16\text{A}}$$

(13) A magnetic circuit consists of three parts in series of uniform cross-sectional area. They are:

PART-A :- Length of 80 mm, Cross-section area of $50\ mm^2$

PART-B :- Length of 60 mm, Cross-sectional area of $90\ mm^2$

PART-C :- Air-gap length of 0.5 mm, cross-sectional area of $150\ mm^2$

A coil of 4000 turns is wound on PART-B and flux density in air-gap is $0.3\ wb/m^2$. Assuming relative permeability to be 1300, estimate current in coil.

Sol:

Flux in circuit $\phi = B_g a_g = 0.3 \times 150 \times 10^{-6} = 4.5 \times 10^{-5}$ wb

PART-A Ampere-turns :-

$$H_A l_A = \frac{B_A}{\mu_0 \mu_r} l_A = \frac{\phi}{\mu_0 \mu_r a_A} l_A = \frac{4.5 \times 10^{-5} \times 80 \times 10^{-3}}{4\pi \times 10^{-7} \times 1300 \times 50 \times 10^{-6}}$$

$$\therefore \boxed{H_A l_A = 44.07\ AT}$$

PART-B Ampere-turns :-

$$H_B l_B = \frac{B_B}{\mu_0 \mu_r} l_B = \frac{\phi}{\mu_0 \mu_r a_B} l_B = \frac{4.5 \times 10^{-5} \times 60 \times 10^{-3}}{4\pi \times 10^{-7} \times 1300 \times 90 \times 10^{-6}}$$

$$\therefore \boxed{H_B l_B = 18.4\ AT}$$

PART-C Ampere-turns :-

$$H_c l_c = \frac{B_c}{\mu_0} l_c = \frac{\phi}{\mu_0 a_c} l_c = \frac{4.5 \times 10^{-5}}{4\pi \times 10^{-7} \times 150 \times 10^{-6}}$$

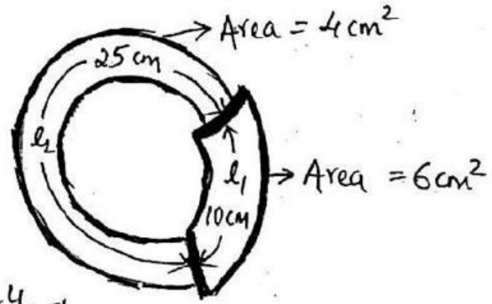
$$\therefore \boxed{H_c l_c = 119.3\ AT}$$

$$NI = H_A l_A + H_B l_B + H_c l_c = 44.07 + 18.4 + 119.3 = 181.77\ AT$$

$$\therefore I = \frac{181.77}{N} = \frac{181.77}{4000}$$

$$\therefore \boxed{I = 45.4\ mA}$$

(14) The ring shaped core shown in figure is made of material having relative permeability 1000. Flux density in thicker section is 1.5T. If current through coil is not to exceed 0.5A, find number of turns.



Sol:

Flux in thicker section

$$\phi = B \times a = 1.5 \times 6 \times 10^{-4}$$

$$\therefore \phi = 9 \times 10^{-4}\,wb$$

Flux in magnetic circuit $= 9 \times 10^{-4}\,wb$

Ampere turns for thicker section :-

$$(MMF)_{Thick} = H_{Th} l_{Th} = \frac{B_{th}}{\mu_0 \mu_r} l_{th} = \frac{1.5}{4\pi \times 10^{-7} \times 1000} \times 10 \times 10^{-2}$$

$$\Rightarrow \boxed{(MMF)_{Thick} = 119.4\ AT}$$

Ampere turns for thin section :-

$$(MMF)_{Thin} = H_T l_T = \frac{B_T}{\mu_0 \mu_r} l_T = \frac{\phi_T}{\mu_0 \mu_r a_T} \times l_T = \frac{9 \times 10^{-4} \times 25 \times 10^{-2}}{4\pi \times 10^{-7} \times 1000 \times 4 \times 10^{-4}}$$

$$\Rightarrow \boxed{(MMF)_{Thin} = 448\ AT}$$

Total MMF $= (MMF)_{thick} + (MMF)_{thin} = 119.4 + 448$

But Total mmf $= NI$

$$\therefore NI = 567.4 \Rightarrow N = \frac{567.4}{I} = \frac{567.4}{0.5}$$

$$\therefore \boxed{N = 1135}$$

(15) A steel ring 30 cm mean diameter and of circular section 2cm in diameter has an air gap 1mm long. It is wound uniformly with 600 turns of wire carrying current of 2.5A. Find (i) Total mmf (ii) Total Reluctance (iii) Flux. Neglect magnetic leakage. Iron path takes 40% of total mmf.

Sol:

i) Total mmf $= NI = 600 \times 2.5 = 1500$ AT

ii) $(MMF)_{Iron} = 40\%$ of $1500 = \frac{40}{100} \times 1500 = 600$ AT

$(MMF)_{Air\ gap} = 1500 - 600 = 900$ AT

We know (Flux) x (Reluctance) = (MMF)

(9)

$\therefore$ MMF $\propto$ Reluctance

$$\frac{(MMF)_{Iron}}{(MMF)_{Air\ gap}} = \frac{(Reluctance)_{Iron}}{(Reluctance)_{Air\ gap}} = \frac{600}{900} = 0.67$$

$\therefore (Reluctance)_{Iron} = 0.67\ (Reluctance)_{Air\ gap}$

We know

$$(Reluctance)_{Air\ gap}\ S_g = \frac{l_g}{\mu_0 a_g} = \frac{1\times10^{-3}}{4\pi\times10^{-7}\times\pi\times(1\times10^{-2})^2}$$

$\boxed{S_g = 2.5\times10^6 \text{ AT/wb}}$ $\Rightarrow S_{iron} = 0.67\times2.5\times10^6$

$\Rightarrow \boxed{S_{iron} = 1.675\times10^6 \text{ AT}}$

Total Reluctance $S_T = S_{iron} + S_{Air\ gap}$

$= 2.5\times10^6 + 1.675\times10^6$

$\Rightarrow \boxed{S_T = 4.175\times10^6 \text{ AT/wb}}$

iii) Total flux $\phi = \frac{\text{Total MMF}}{\text{Total Reluctance}} = \frac{1500}{4.175\times10^6}$

$\Rightarrow \boxed{\phi = 0.36 \text{ mWb}}$

(16) A cast steel ring with relative permeability of 300 has circular cross-section of 3cm in diameter and a mean circumference of 80 cm. The ring is uniformly wound with coil of 600 turns. Estimate current required to produce a flux of 0.5 mWb in the ring.

Sol Given $\mu_r = 300$, $d = 3\,cm = 3\times10^{-2}\,m$, $N = 600$

$l = 80\,cm = 80\times10^{-2}\,m$, $\phi = 0.5\times10^{-3}\,wb$.

Area of cross-section $a = \frac{\pi}{4}d^2 = \frac{\pi}{4}\times(3\times10^{-2})^2$

$\Rightarrow a = 7.068\times10^{-4}\,m^2$

We know $NI = Hl = \frac{Bl}{\mu_0\mu_r} = \frac{\phi l}{\mu_0\mu_r a}$

$$\therefore NI = \frac{0.5\times10^{-3}}{4\pi\times10^{-7}\times300\times7.068\times10^{-4}} = 1.5\times10^{3}\ AT$$

$$\therefore I = \frac{1.5\times10^{3}}{600} = 2.5A \Rightarrow \boxed{I = 2.5A}$$

*** (17) An iron ring of cross-section area of $10\,cm^2$ is wound with 1500 turns has a saw cut of 3mm air gap. Calculate magnetising current required to produce flux of 0.25 wb if mean length is 50cm and relative permeability of 470. Leakage factor is 1.2. (Previous Q-paper)

Sol. Given $a = 10\ cm^2 = 10\times10^{-4} m^2$, $N = 1500$

$l_g = 3mm = 3\times10^{-3} m$, $l_i = 50\ cm = 50\times10^{-2} m$

$\mu_r = 470$, $\lambda = 1.2$, $\phi_g = 0.25\ wb$

$$NI = H_i l_i + H_g l_g$$

Air-gap ampere-turns :

$$H_g l_g = \frac{B_g}{\mu_0} l_g = \frac{\phi_g\, l_g}{\mu_0\, a_g} = \frac{0.25\times 3\times10^{-3}}{4\pi\times10^{-7}\times10\times10^{-4}}$$

$$\therefore \boxed{H_g l_g = 596.83\times10^{3}\ AT}$$

Iron-path ampere-turns : Note: $\phi_i = \lambda\phi_g$

$$H_i l_i = \frac{B_i}{\mu_0\mu_r} l_i = \frac{\phi_i l_i}{\mu_0\mu_r a_i} = \frac{(\lambda\phi_g)\, l_i}{\mu_0\mu_r a_i}$$

$$H_i l_i = \frac{1.2\times0.25\times50\times10^{-2}}{4\pi\times10^{-7}\times470\times10\times10^{-4}} = 254\times10^{3}\ AT.$$

$$\therefore \boxed{H_i l_i = 254\times10^{3}\ AT}$$

$$NI = H_i l_i + H_g l_g = 254\times10^{3} + 596.8\times10^{3} = 850.8\times10^{3}\ AT$$

$$I = \frac{850.8\times10^{3}}{1500} = 567.22\ A$$

$$\therefore \boxed{I = 567.22\ A}$$

(18) An iron ring of cross-sectional area of 10 cm^2 is wound with a wire of 1500 turns has a saw cut of 2mm gap. Calculate magnetising current required to produce a flux of 20mWb if mean length of magnetic path 40 cm and relative permeability of 400. (11)

Sol: Ampere turns required for air-gap :-

$$(NI)_{Air\text{-}gap} = H_g l_g = \frac{B_g}{\mu_0} l_g = \frac{\phi_g}{\mu_0 a} l_g$$

$$(NI)_{Air\,gap} = \frac{20\times10^{-3}}{4\pi\times10^{-7}\times10\times10^{-4}} \times 2\times10^{-3} \Rightarrow \boxed{(NI)_{Air\text{-}gap} = 31830.98\ AT}$$

Ampere-turns required for iron path :-

$$(NI)_{Iron} = H_i l_i = \frac{B_i}{\mu_0\mu_r} l_i = \frac{\phi_i}{\mu_0\mu_r a} l_i$$

$$(NI)_{Iron} = \frac{20\times10^{-3}}{4\pi\times10^{-7}\times400\times10\times10^{-4}} \times 40\times10^{-2}$$

$$\boxed{\begin{aligned}\phi_g &= \phi_i = 20mWb\\ a_g &= a_i = 10\times10^{-4} m^2\end{aligned}}$$

$$\therefore \boxed{(NI)_{Iron} = 15915.49\ AT}$$

Total ampere turns $(NI)_T = (NI)_{Air\,gap} + (NI)_{Iron}$.

$$NI = 31830.98 + 15915.49 = 47746.47$$

Magnetising current $I = \frac{(NI)_T}{N} = \frac{47746.47}{1500}$

$$\therefore \boxed{I = 31.83\ A}$$

19. Calculate permeability (μ) of an iron when current taken by exciting coil of 600 turns is 1.2 Amps. The mean circumference of ring is 100π cm. and its cross-sectional area is $12\ cm^2$. Total flux produced is 1 mWb. (12)

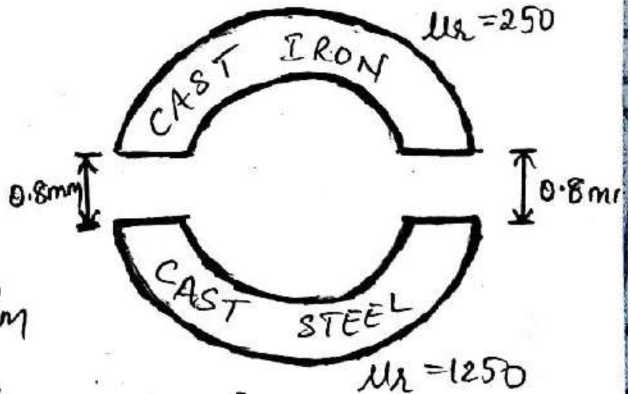
Sol: We know

$$(NI)_{Iron} = H_i l_i = \frac{B}{\mu} l_i = \frac{\phi}{\mu a} l_i$$

$$\Rightarrow \mu = \frac{\phi}{NIa} l_i = \frac{1\times10^{-3} \times 100\pi}{600\times1.2\times12\times10^{-4}}$$

$$\therefore \boxed{\mu = 0.36}$$

20. A metal ring of mean circumference 90 cm is made up of two semi circular pieces of cast iron and cast steel separated by two pieces of copper strip 0.8 mm thick. The relative permeability of cast iron and cast steel may be taken as 250 and 1250 respectively at operating flux density of $0.8\ wb/m^2$. Calculate exciting current required if number of turns in coil is 450.



Sol: Air gap:-

$$H = \frac{B}{\mu_0} = \frac{\phi}{\mu_0 a}$$

$$\therefore H = \frac{0.8}{4\pi\times10^{-7}} = 636.62\times10^{3}\ AT/m$$

Total air gap length $= 2\times0.8\times10^{-3}\ m = 1.6\times10^{-3}\ m$

Ampere turns required $(AT)_{Airgap} = Hl = 636.62\times10^{3}\times1.6\times10^{-3}$

$$\therefore \boxed{(AT)_{Air\text{-}gap} = 1018.592\ AT}$$

Cast Steel :-

$$H = \frac{B}{\mu_0 \mu_r} = \frac{0.8}{4\pi \times 10^{-7} \times 1250} = 509.3 \text{ AT/m}$$

$l = 45 \text{ cm} = 45 \times 10^{-2} \text{ m}$

Ampere turns required $(AT)_{\text{Cast Steel}} = Hl = 509.3 \times 45 \times 10^{-2}$

$$\therefore \boxed{(AT)_{\text{Cast Steel}} = 229.185 \text{ AT}}$$

Cast Iron :-

$$H = \frac{B}{\mu_0 \mu_r} = \frac{0.8}{4\pi \times 10^{-7} \times 250} = 2546.48 \text{ AT/m}$$

$l = 45 \text{ cm} = 45 \times 10^{-2} \text{ m}$

Ampere turns required $(AT)_{\text{Cast Iron}} = Hl = 2546.48 \times 45 \times 10^{-2}$

$$\therefore \boxed{(AT)_{\text{Cast Iron}} = 1145.916 \text{ AT}}$$

Total ampere turns required

$$(AT)_{\text{Total}} = (AT)_{\text{Air gap}} + (AT)_{\text{Cast Steel}} + (AT)_{\text{Cast Iron}}$$

$$NI = 1018.592 + 229.185 + 1145.916$$

$$NI = 2393.69$$

$$I = \frac{2393.69}{N}$$

$$\therefore \boxed{I = 5.31 \text{ A}}$$

21. An iron ring of cross section 1cm x 4cm has effective iron path of 100 cm. An air gap of 0.5 mm has been made in the ring. The ring is wound with 1500 turns, through which a current of 1A is passed. If total flux produced is 0.5 mWb, find relative permeability of iron and Reluctance of magnetic circuit.

Sol: Given $l_i = 100\,cm = 100 \times 10^{-2}\,m$

$l_g = 0.5\,mm = 0.5 \times 10^{-3}\,m$

$a = 4\,cm^2 = 4 \times 10^{-4}\,m^2$

$N = 1500$, $I = 1A$, $\phi = 0.5 \times 10^{-3}\,Wb.$

Air-gap ampere turns :-

$$H_g l_g = \frac{B_g}{\mu_0} l_g = \frac{\phi}{\mu_0 a} l_g = \frac{0.5 \times 10^{-3} \times 0.5 \times 10^{-3}}{4\pi \times 10^{-7} \times 4 \times 10^{-4}}$$

$$\therefore \boxed{H_g l_g = 497.36\ AT}$$

Iron-path ampere-turns :-

$$NI = H_g l_g + H_i l_i \Rightarrow H_i l_i = NI - H_g l_g$$

$$\therefore H_i l_i = (1500 \times 1) - (497.36) = 1002.64\ AT$$

But $H_i l_i = \dfrac{B}{\mu_0 \mu_r} l_i = \dfrac{\phi}{a \mu_0 \mu_r} l_i$

$$\therefore 1002.64 = \frac{0.5 \times 10^{-3} \times 100 \times 10^{-2}}{4 \times 10^{-4} \times 4\pi \times 10^{-7} \times \mu_r}$$

$$\Rightarrow \mu_r = \frac{100 \times 10^{-2} \times 0.5 \times 10^{-3}}{4 \times 10^{-4} \times 4\pi \times 10^{-7} \times 1002.64}$$

$$\therefore \boxed{\mu_r = 992}$$

ii) Total Reluctance $S = S_i + S_g$

Iron-part: $S_i = \dfrac{l_i}{\mu_0 \mu_r a} = \dfrac{100\times10^{-2}}{4\pi\times10^{-7}\times 992\times 4\times10^{-4}}$

$$\therefore \boxed{S_i = 2\times10^{6}\ \text{AT/wb}}$$

Air-gap part: $S_g = \dfrac{l_g}{\mu_0 a} = \dfrac{0.5\times10^{-3}}{4\pi\times10^{-7}\times 4\times10^{-4}}$

$$\therefore \boxed{S_g = 994.7\times10^{3}\ \text{AT/wb}}$$

$$S = S_i + S_g = (2\times10^{6}) + (994.7\times10^{3})$$

$$\therefore \boxed{S = 3\times10^{6}\ \text{AT/wb}}$$

(26) A ring of area $10\ \text{cm}^2$, length 50 cm long, produces a flux density of 0.5 T in air gap of length 6 mm long and $20\ \text{cm}^2$ in area. Calculate ampere turns required. Assume relative permeability is 1800.

Sol://

$$NI = H_i l_i + H_g l_g = \frac{B}{\mu_0\mu_r} l_i + \frac{B}{\mu_0} l_g$$

$$\therefore NI = \frac{0.5\times 50\times10^{-2}}{4\pi\times10^{-7}\times1800} + \frac{0.5\times6\times10^{-3}}{4\pi\times10^{-7}}$$

$$NI = 110.52 + 2387.32$$

$$\boxed{NI = 2497.84\ \text{AT}}$$

PRACTICE SUMS

1. An iron ring has mean diameter of 25 cm and a cross-sectional area of 4 sq.cm. It is wound with a coil of 1200 turns. An air-gap of 1.5 mm width is cut in the ring. Determine current required in coil to produce a flux of 0.48mWb in air-gap, if relative permeability of iron is 800. Neglect leakage and fringing.

2. A magnetic circuit has cross-sectional area of 5 sq. cm, and a length of 25 cm. A coil of 100 turns is wound uniformly around magnetic circuit. When a current in the coil is 2A, flux is 0.3 Wb, calculate
(i) Magnetizing force
(ii) Relative permeability
(iii) Magnetic flux density.

3. A magnetic ring has mean circumference of 1.5 m and is 0.01 sq.m cross-section area. It is wound with 200 turns and a saw cut of 4 mm wide is made in the ring. Calculate magnetizing current required to produce a flux of 0.8 mWb in air-gap. Assume relative permeability is 400 and leakage coefficient as 1.3.

4. A steel magnetic circuit has a uniform cross-sectional area of 4 sq.cm and a length of 50 cm. A coil of 250 turns is wound uniformly over magnetic circuit. When the current in the coil is 5 A, total flux is 0.6 mWb, calculate (i) Magnetic field strength and (ii) Relative permeability of steel.

5. An iron ring of mean length 30 cm, has an air gap of 2mm, and a winding of 200 turns. If permeability of iron core is 300, when a current of 1A flows through coil, find flux density.

6. A mild steel ring has a cross-sectional area of 500 sq.m, and a mean circumference of 400 mm having a coil of 200 turns wound uniformly around it. Calculate (i) Reluctance (ii) current required to produce a flux of 800 micro Wb in the ring. Assume relative permeability is 380.

7. A magnetic circuit consists of an iron ring of mean circumference 80 cm with cross sectional area of 12 sq.cm. A current of 2 A in the magnetic coil of 200 turns produce a total flux of 1.2 mWb in the iron. Calculate (i) the flux density in the iron (ii) absolute and relative permeabilty of iron (iii) relactance

8. The air-gap in a magntic circuit is 1.5 mm long and 2500 sq.mm in cross-sectional area. Calculate (i) Reluctance of air-gap and (ii) MMF required to set up a flux of 800 micro Wb in the air-gap.

9. An iron ring has a mean diameter of 15 m, a cross sectional of 20 sq. cm and a radial gap of 0.5 mm cut in it. It is uniformly wound with 1500 turns, a magnetizing current of 1A, which produces a magnetic flux of 1mWb. Calculate (i) Reluctance and (ii) Relative permeability.

10. A coil of 100 turns is wound uniformly over a insulator ring with a mean circumference of 2m and a uniform sectional area of 0.025 cm 2 . If the coil carrying a current of 2A.Calculate i) the MMF of the circuit, ii) Magnetic field intensity iii) flux density and iv) the total flux.

11.A steel ring of 25cm mean diameter and of circular cross-section 3cm in diameter has an air gap of 1.5mm length. It is wound uniformly with 750 turns of wire carrying a current of 2.1A. Calculate (i) Magnetomotive force, (ii) Flux density in air gap (iii) Magnetic flux (iv) relative permeability of steel ring (v) Total reluctance. Assume that iron part takes about 35% of the total magneto-motive force.

12. A coil of 500 turns is wound uniformly over a wooden ring having a mean circumference of 50 cm and a cross sectional area of 500 sq.mm .If the current through the coil is 3Amps, calculate a) the magnetic field strength, b) the flux density and c) the total flux

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