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POSTAL BOOK PACKAGE 2025

ELECTRICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

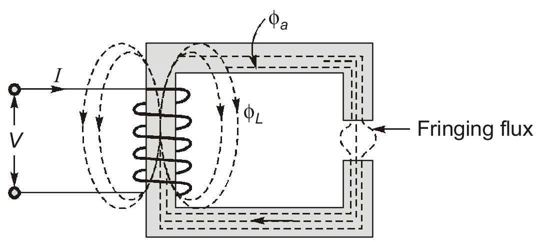
ELECTRIC MACHINES

1 CHAPTER Magnetic Circuits, Electromechanical Energy Conversion

Q.1 Explain the difference between fringing flux and leakage flux.

Solution:

Consider the magnetic circuit given below:



Of the total flux generated by the coil, some flux ϕ_L does not follow the intended path of the magnetic circuit. This flux cannot be used for any purpose. This flux is called as the leakage flux.

When the flux enters the airgap, it acquires a bulging shape. The amount of the bulging is direction proportional to the length of the airgap. Bulging increases, the effective area of the airgap and reduces flux density in it. This effect is called as fringing and the flux in the bulge is called as fringing flux.

Q.2 In an electromagnetic relay, functional relation between the current in the exciting coil, the position of armature x and the flux linkage Ψ is given by

$$i = 2\Psi^3 + 3\Psi(1 - x + x^2), \quad x > 0.5$$

Find the force on the armature as a function of Ψ.

Solution:

$$i = 2\Psi^3 + 3\Psi\,(1 - x + x^2)$$

Field energy stored,

$$W_f(\Psi, x) = \int_0^{\Psi} i(\psi)\,d\Psi = \int_0^{\Psi} [2\Psi^3 + 3\Psi(1 - x + x^2)]\,d\Psi = \frac{2\Psi^4}{4} + 3\frac{\Psi^2}{2}(1 - x + x^2)$$

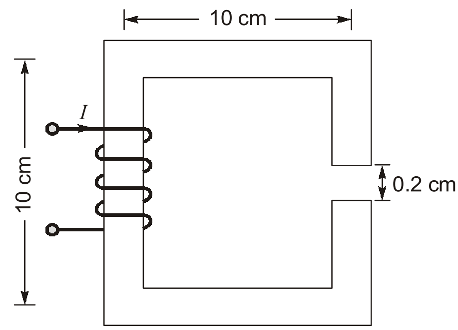
Magnetic force is given by,

$$\therefore \qquad f_e = \frac{\partial W_f(\Psi, x)}{dx} = -\frac{\partial}{x}\left[\frac{\Psi^4}{2} + \frac{3\Psi^2}{2}(1 - x + x^2)\right]$$

$$= -\left[0 + \frac{3\Psi^2}{2}(0 - 1 + 2x)\right] = \frac{3\Psi^2}{2}(1 - 2x)$$

For $x > 0.5$, f_e is negative, therefore f_e acts to decrease the field energy stored at constant flux linkage.

Q.3 The magnetic circuit shown below has uniform cross-sectional area and air gap of 0.2 cm. The mean path length of the core is 40 cm. Assume that leakage and fringing fluxes are negligible. When the core relative permeability is assumed to be infinite, the magnetic flux density computed in the air gap is 1 tesla. With same Ampere-turns, if the core relative permeability is assumed to be 1000 (linear), then determine the flux density in the air gap.



Solution:

Air gap length, $l_{ag} = 0.2$ cm,

Mean length of magnetic path, $l_m = 40$ cm

Given, $B_0 = 1$ Tesla

$$\phi = \frac{\text{mmf}}{\Re}$$

For same mmf, $\phi \propto \frac{1}{\Re}$

In case-1: $\Re_1 = \frac{l_m}{\mu_0 A} = \frac{l_{ag}}{\mu_0 A} + \frac{l_m}{\mu_0 \mu_r A}$

As $\mu_r = \infty$

$\therefore$ $\Re_1 = \frac{0.2 \times 10^{-2}}{\mu_0 A}$

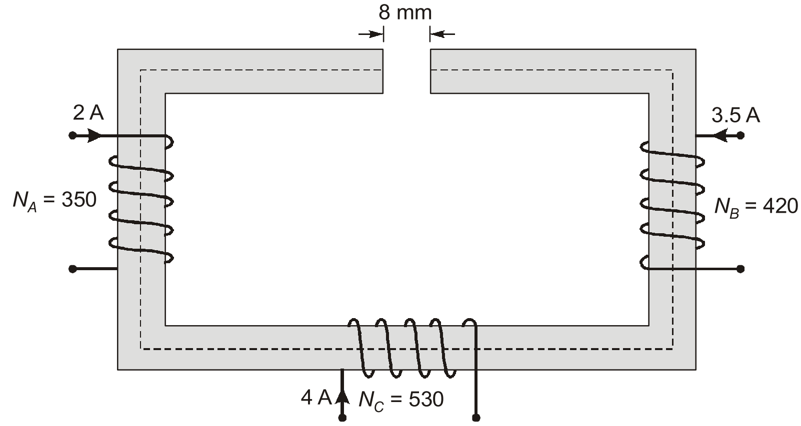
In case-2: $\Re_2 = \frac{l_{ag}}{\mu_0 A} + \frac{l_m}{\mu_0 \mu_r A} = \frac{0.2 \times 10^{-2}}{\mu_0 A} + \frac{40 \times 10^{-2}}{1000 \mu_0 A} = \frac{0.24 \times 10^{-2}}{\mu_0 A}$

As, flux, $\phi = BA$, for uniform cross section area, $\phi \propto B$

Therefore, $B \propto \frac{1}{\Re}$

$\therefore$ $B_2 = \frac{B_1 \times \Re_1}{\Re_2} \Rightarrow B_2 = \frac{0.2 \times 10^{-2} / \mu_0 A}{0.24 \times 10^{-2} / \mu_0 A} = 0.833$ T

Q.4 An iron core has mean length of a magnetic circuit of 120 cm, cross-section of 4 cm × 4 cm and relative permeability of 2470. A cut of size 8 mm in the core has been made. The three coils, *A*, *B* and *C* on the core have number of turns 350, 420 and 530 respectively and the respective currents flowing are 2 A, 3.5 A and 4 A. The direction of currents is shown in figure below. Find the air gap flux. Neglecting of flux.



2 CHAPTER Transformers

Q.1 **The emf per turn for a single phase, 2310/220 V, 50 Hz transformer is approximately 13 volts. Calculate the number of primary and secondary turns.**

Solution:

$$\text{Emf per turn } E_t = 13 \text{ volts}$$

$$\text{Number of secondary turns} = \frac{\text{Secondary voltage}}{E_t}$$

$$\therefore \qquad N_2 = \frac{220}{13} = 16.92$$

Now the number of turns can not be a fraction, therefore, $N_2 = 17$ (nearest whole number). For $N_2 = 17$, Number of primary turns

$$N_1 = N_2\left(\frac{V_1}{V_2}\right) = 17\left(\frac{2310}{220}\right) = 178.5$$

This shows that N_2 can not be equal to 17 turns. The other nearest integers are 16 or 18. It is preferable to take $N_2 = 18$.

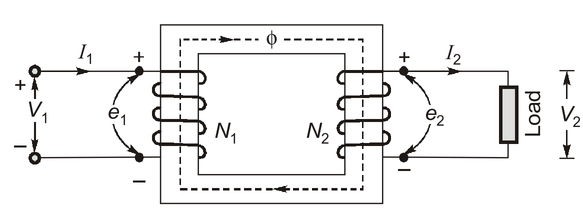
$$\therefore \qquad N_1 = 18(10.5) = 189 \text{ turns}$$

Thus the required values of N_1 and N_2 are 189 and 18 turns respectively.

Q.2 **Derive an expression for the emf induced in a transformer winding. Show that emf per turn in primary is equal to emf per turn in secondary.**

Solution:

Supply voltage = V_1
Emf induced in primary winding = e_1
Current in primary winding = I_1
Magnetic flux = f
Turns in primary winding = N_1
Turns in secondary winding = N_2
Emf induced in secondary winding = e_2
Current in secondary winding = I_2
Voltage across load = V_2



When sinusoidal voltage applied to primary winding, a sinusoidal flux is set up in the iron core which links both windings.

Sinusoidal flux variation, $\quad f = f_{max} \sin\omega t$

where, f_{max} is the maximum value of the magnetic flux.

The emf e_1 induced in the primary winding by the alternating flux.

$$e_1 = N_1 \frac{d\phi}{dt} \quad \text{(magnitude)}$$

The direction of induced emf can be determine by Lenz's law,

$$e_1 = N_1 \frac{d}{dt}(\phi_{max} \sin \omega t) = N_1 \omega \phi_{max} \cos \omega t$$

$$e_1 = E_{1,max} \cos \omega t = E_{1,max} \sin(\omega t + 90°)$$

where, $E_{1(max)}$ is the maximum value of induced emf.

The emf induced in primary winding is 90° ahead by the core flux.

Rms value of emf e_1 induced in primary winding,

$$E_1 = \frac{E_{1,max}}{\sqrt{2}} = \frac{N_1 \omega \phi_{max}}{\sqrt{2}}$$

$$E_1 = \frac{N_1 (2\pi f) \phi_{max}}{\sqrt{2}} = \sqrt{2} \pi f N_1 \phi_{max} = 4.44 \, f N_1 \phi_{max} \quad \ldots(i)$$

Similarly, emf induced in secondary winding,

$$e_2 = N_2 \frac{d\phi}{dt} = N_2 \omega \phi_{max} \cos \omega t = N_2 \omega \phi_{max} \sin(\omega t + 90°)$$

$$e_2 = E_{2,max} \sin(\omega t + 90°)$$

Rms value of emf e_2 induced in secondary winding,

$$E_2 = \frac{E_{2,max}}{\sqrt{2}} = \frac{N_2 \omega \phi_{max}}{\sqrt{2}} = \frac{N_2 (2\pi f) \phi_{max}}{\sqrt{2}}$$

$$E_2 = \sqrt{2} \pi f N_2 \phi_{max} = 4.44 f N_2 \phi_{max} \quad \ldots(ii)$$

From equation (i) and (ii) we get

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad \text{or} \quad \frac{E_1}{N_1} = \frac{E_2}{N_2} = \text{emf per turn}$$

i.e. emf per turn in primary winding is equal to emf per turn in secondary winding.

Q.3 A single-phase, 50 Hz, three winding transformer is rated at 2200 V on HV side with 250 turns. Two secondary winding are each 200 kVA with 550 V and 220 V. When the rated current flows in the two secondaries at 0.6 lag and *upf* respectively, find primary current.

Solution:

Winding	Voltage	Turns	V_A	Current
Primary	V_P = 2200 V	N_P = 250	S_P	I_P
Secondary	V_S = 550 V	N_S	S_S = 200 KVA	I_S
Tertiary	V_T = 220 V	N_T	S_T = 200 KVA	I_T

Calculate current in secondary:

$$550 \times |I_S| = 200 \times 10^3$$

$$\Rightarrow \quad |I_S| = 363.64 \text{ A}$$

$$\therefore \quad I_s = 363.64 \angle -\cos^{-1} 0.6 \quad [\because \text{Power factor is 0.6 lagging}]$$

$$\Rightarrow \quad I_s = 363.64 \angle -53.13° \text{ A}$$

Calculate turns in secondary:

$$\Rightarrow \quad \frac{V_P}{V_s} = \frac{N_P}{N_s}$$

$$\Rightarrow \quad \frac{2200}{550} = \frac{250}{N_s} \Rightarrow N_s = 62.5$$