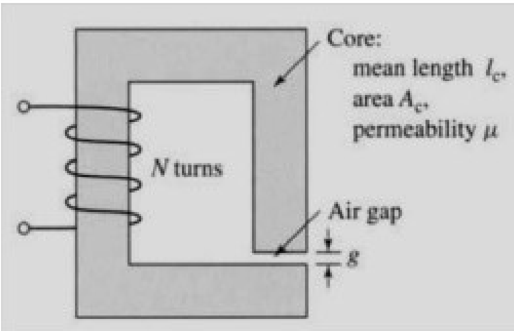
1.9 Solved Problems

Eg .No.1

A magnetic circuit with a single air gap is shown in Fig. 1.24. The core dimensions are:

Cross-sectional area $A_c = 1.8 \times 10^{-3}$ m^2, Mean core length $l_c = 0.6$ m

Gap length $g = 2.3 \times 10^{-3}$ m , $N = 83$ turns



Assume that the core is of infinite permeability and neglect the effects of fringing fields at the air gap and leakage flux. (a) Calculate the reluctance of the core R_e and that of the gap R_g. For a current of i = 1.5 A, calculate (b) the total flux ϕ, (c) the flux linkages λ of the coil, and (d) the coil inductance L.

Solution:

$$R_c = 0 \quad \text{since} \quad \mu \to \infty \qquad R_g = \frac{g}{\mu_0 A_c} = \frac{2.3\times10^{-3}}{4\pi\times10^{-7}\times1.8\times10^{-3}} = 1.017\times10^6 \text{ A/Wb}$$

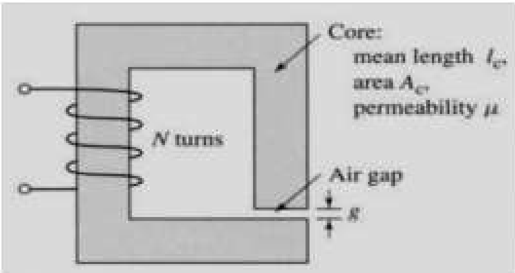
$$\phi = \frac{Ni}{R_c + R_g} = \frac{83\times1.5}{1.017\times10^6} = 1.224\times10^{-4} \text{ Wb}$$

$$\lambda = N\phi = 1.016\times10^{-2} \text{ Wb}$$

$$L = \frac{\lambda}{i} = \frac{1.016\times10^{-2}}{1.5} = 6.773 \text{ mH}$$

Eg .No.2

Consider the magnetic circuit of with the dimensions of Problem 1.1. Assuming infinite core permeability, calculate (a) the number of turns required to achieve an inductance of 12 mH and (b) the inductor current which will result in a core flux density of 1.0 T.



Solution:

$$L = \frac{N^2}{R_g} = 12\times10^{-3}\ \text{mH} \quad \Rightarrow \quad N = \sqrt{12\times10^{-3}\times1.017\times10^{6}} = 110.47 \quad \Rightarrow \quad N = 110\ \text{turns}$$

$$B_c = B_g = 1.0\ \text{T} \quad \Rightarrow \quad \phi = B_g A_c = 1.8\times10^{-3}\ \text{Wb}$$

$$i = \frac{\lambda}{L} = \frac{N\phi}{L} = \frac{110\times1.8\times10^{-3}}{12\times10^{-3}} = 16.5\ \text{A}$$

Eg.No.3

In the magnetic circuit of Fig. E1.3*a*, the relative permeability of the ferromagnetic material is 1200. Neglect magnetic leakage and fringing. All dimensions are in centimeters, and the magnetic material has a square cross-sectional area. Determine the air gap flux, the air gap flux density, and the magnetic field intensity in the air gap.

Solution

The mean magnetic paths of the fluxes are shown by dashed lines in Fig. E1.3*a*. The equivalent magnetic circuit is shown in Fig. E1.3*b*.

$$F_1 = N_1 I_1 = 500 \times 10 = 5000 \text{ At}$$

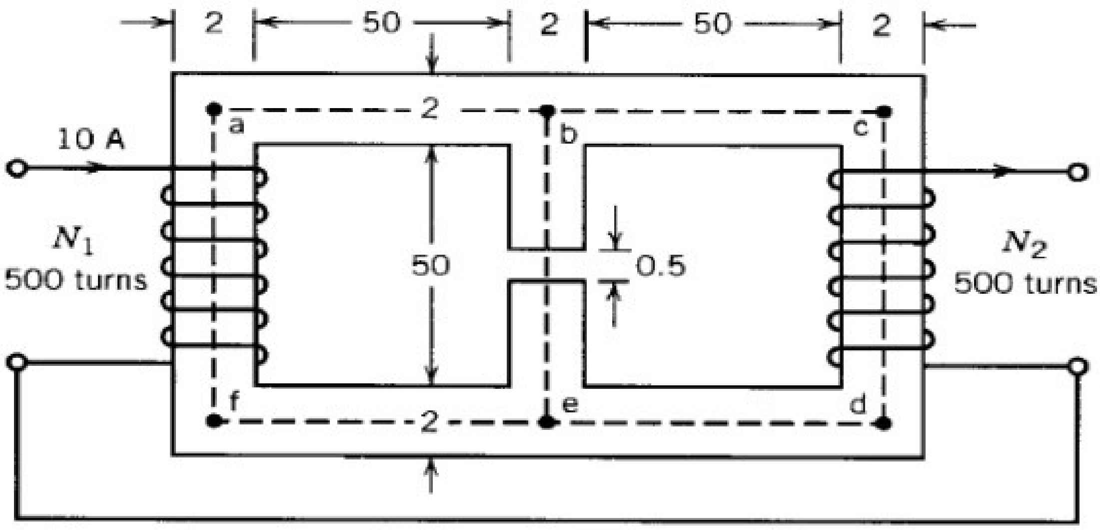
$$F_2 = N_2 I_2 = 500 \times 10 = 5000 \text{ At}$$

$$\mu_c = 1200\mu_0 = 1200 \times 4\pi 10^{-7}$$

$$\mathcal{R}_{bafe} = \frac{l_{bafe}}{\mu_c A_c}$$

$$= \frac{3 \times 52 \times 10^{-2}}{1200 \times 4\pi 10^{-7} \times 4 \times 10^{-4}}$$

$$= 2.58 \times 10^6 \text{ At/Wb}$$



From symmetry

$$\mathcal{R}_{\text{bcde}} = \mathcal{R}_{\text{bafe}}$$

$$\mathcal{R}_{\text{g}} = \frac{l_{\text{g}}}{\mu_0 A_{\text{g}}}$$

$$= \frac{5 \times 10^{-3}}{4\pi 10^{-7} \times 2 \times 2 \times 10^{-4}}$$

$$= 9.94 \times 10^{6} \text{ At/Wb}$$

$$\mathcal{R}_{\text{be(core)}} = \frac{l_{\text{be(core)}}}{\mu_c A_c}$$

$$= \frac{51.5 \times 10^{-2}}{1200 \times 4\pi 10^{-7} \times 4 \times 10^{-4}}$$

$$= 0.82 \times 10^{6} \text{ At/Wb}$$

The loop equations are

$$\Phi_1(\mathcal{R}_{\text{bafe}} + \mathcal{R}_{\text{be}} + \mathcal{R}_{\text{g}}) + \Phi_2(\mathcal{R}_{\text{be}} + \mathcal{R}_{\text{g}}) = F_1$$

$$\Phi_1(\mathcal{R}_{\text{be}} + \mathcal{R}_{\text{g}}) + \Phi_2(\mathcal{R}_{\text{bcde}} + \mathcal{R}_{\text{be}} + \mathcal{R}_{\text{g}}) = F_2$$

$$\Phi_1(13.34 \times 10^{6}) + \Phi_2(10.76 \times 10^{6}) = 5000$$

$$\Phi_1(10.76 \times 10^{6}) + \Phi_2(13.34 \times 10^{6}) = 5000$$

The air gap flux density is

$$B_{\text{g}} = \frac{\Phi_{\text{g}}}{A_{\text{g}}} = \frac{4.134 \times 10^{-4}}{4 \times 10^{-4}} = 1.034 \text{ T}$$

The magnetic intensity in the air gap is

$$H_{\text{g}} = \frac{B_{\text{g}}}{\mu_0} = \frac{1.034}{4\pi 10^{-7}} = 0.822 \times 10^{6} \text{ At/m}$$

Eg.no.5

Eg.No.4

For the magnetic circuit of Fig. 1.9, $N = 400$ turns.
Mean core length $l_c = 50$ cm.
Air gap length $l_g = 1.0$ mm
Cross-sectional area $A_c = A_g = 15$ cm^2
Relative permeability of core $\mu_r = 3000$
$i = 1.0$ A

Find

(a) Flux and flux density in the air gap.
(b) Inductance of the coil.

Solution

(a)

$$\mathcal{R}_c = \frac{l_c}{\mu_r \mu_0 A_c} = \frac{50 \times 10^{-2}}{3000 \times 4\pi\, 10^{-7} \times 15 \times 10^{-4}}$$
$$= 88.42 \times 10^3 \text{ AT/Wb}$$

$$\mathcal{R}_g = \frac{l_g}{\mu_0 A_g} = \frac{1 \times 10^{-3}}{4\pi 10^{-7} \times 15 \times 10^{-4}}$$
$$= 530.515 \times 10^3 \text{ At/Wb}$$

$$\Phi = \frac{Ni}{R_c + R_g}$$
$$= \frac{400 \times 1.0}{(88.42 + 530.515)10^3}$$

$$B = \frac{\Phi}{A_g} = \frac{0.6463 \times 10^{-3}}{15 \times 10^{-4}} = 0.4309 \text{ T}$$

b)

$$L = \frac{N^2}{\mathcal{R}_c + \mathcal{R}_g} = \frac{400^2}{(88.42 + 530.515)^{10^3}}$$
$$= 258.52 \times 10^{-3} \text{ H}$$

or $$L = \frac{\lambda}{i} = \frac{N\Phi}{i} = \frac{400 \times 0.6463 \times 10^{-3}}{1.0}$$
$$= 258.52 \times 10^{-3} \text{ H} \quad \blacksquare$$