HW2: Magnetic Circuits – Solution

Problem 1:

$$\tilde{\mathcal{F}}_1 = N_1 I_1 = (80)(12) = 960 \text{ At}$$

$$\mathcal{R}_1 = \frac{g_1}{\mu_0 A_1} = \frac{5 \times 10^{-3}}{(4\pi \times 10^{-7})(5 \times 10^{-4})} = 7.958 \times 10^{6} \text{ At/wb}$$

$$\mathcal{R}_2 = \frac{g_2}{\mu_0 A_2} = \frac{5 \times 10^{-3}}{(4\pi \times 10^{-7})(5 \times 10^{-4})} = 7.958 \times 10^{6} \text{ At/wb}$$

$$\mathcal{R}_3 = \frac{g_3}{\mu_0 A_3} = \frac{10 \times 10^{-3}}{(4\pi \times 10^{-7})(10 \times 10^{-4})} = 7.958 \times 10^{6} \text{ At/wb}$$

$$\mathcal{R}_t = \mathcal{R}_1 + \frac{\mathcal{R}_2 \mathcal{R}_3}{\mathcal{R}_2 + \mathcal{R}_3} = 11.937 \times 10^{6} \text{ At/wb}$$

$$\Phi_1 = \frac{N_1 I_1}{\mathcal{R}_t} = \frac{960}{11.937 \times 10^{6}} = 80.4 \times 10^{-6} \text{ Wb}$$

$$\Phi_2 = \Phi_3 = \frac{1}{2} \Phi_1 = 40.2 \times 10^{-6} \text{ Wb}$$

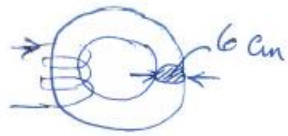
$$B_1 = \frac{\Phi_1}{A_1} = \frac{80.4 \times 10^{-6}}{5 \times 10^{-4}} = 0.161 \text{ T}$$

$$B_2 = \frac{\Phi_2}{A_2} = \frac{40.2 \times 10^{-6}}{5 \times 10^{-4}} = 0.080 \text{ T}$$

$$B_3 = \frac{\Phi_3}{A_3} = \frac{40.2 \times 10^{-6}}{10 \times 10^{-4}} = 0.040 \text{ T}$$

Problem 2:

$$l = \pi d_m = \pi * 25 = 78.64 \text{ cm}$$



$$A = \pi \frac{6^2}{4} = 28.27 \text{ cm}^2$$

(a) $$B = \frac{1.7 \times 10^{-3}}{28.27 \times 10^{-4}} = 0.6 \text{ T}$$

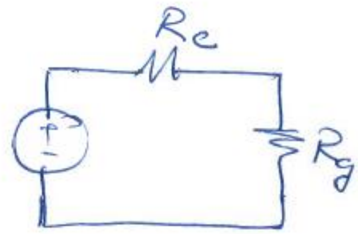
From table $H = 600 \text{ AT/m}$

so

$$NI = H \cdot l \Rightarrow I = \frac{600 \times 78.64 \times 10^{-2}}{600}$$

$$I = \underline{0.7864} \text{ A}$$

(b) Same Φ & B



$$H_c = 600 \text{ AT/m}$$

$$l_c = 78.64 \text{ cm}$$

$$H_g = \frac{B}{\mu_0} = \frac{0.6}{4\pi 10^{-7}} = 477.5 \times 10^{3} \text{ AT/m}$$

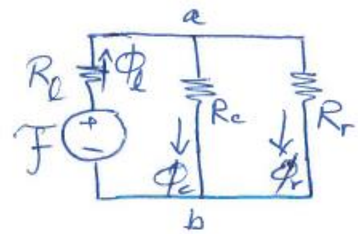
$$l_g = 2 \times 10^{-3} \text{ m}$$

$$NI = H_g l_g + H_c l_c = 1427 \text{ A.T}$$

$$I = \frac{1427}{600} = 2.378 \text{ A}$$

Problem 3:

$\Phi_c = 0.36\ mWb$



$$B_c = \frac{\Phi_c}{A} = \frac{0.36\times10^{-3}}{4\times10^{-4}} = 0.9\ Wb/m^2$$

$H_c = 150\ AT/m$ (from B-H Curve)

$$A.T_{ab} = H_c l_c = 150\times0.06 = 9\ A.T \quad (l_c = 4+1+1 = 6\ Cm)$$

$$= H_r l_r = H_r * (6+6+6)10^{-2}$$

$$\therefore H_r = \frac{9}{18\times10^{-2}} = 50\ A.T$$

$\therefore B_r$ (Corresponding Value from B-H curve) $= 0.35\ wb/m^2$

$$\therefore \Phi_r = B_r A_r = 0.35\times4\times10^{-4} = 0.14\ m\,Wb$$

$$\therefore \Phi_\ell = \Phi_c + \Phi_r = 0.36 + 0.14 = 0.5\ mWb$$

$$\therefore B_\ell = \frac{\Phi_\ell}{A} = \frac{0.5\times10^{-3}}{4\times10^{-4}} = 1.25\ Wb/m^2$$

$\therefore H_\ell = 500\ AT/m$ (from B-H curve)

$$\therefore H_\ell l_\ell = 500\times(6+6+6)\times10^{-2} = 90\ A.T$$

$$\therefore \mathcal{F}_1 = H_\ell l_\ell + H_c l_c = 90 + 9 = 99\ AT = NI$$

$$\therefore I = \frac{99}{300} = 0.33\ A$$

Problem 4:

For Constant B

$P_h \propto f$ i.e. $P_h = A \cdot f$ where A is constant

$P_e \propto f^2$ i.e. $P_e = B \cdot f^2$ where B is Constant

At $f = 60\ Hz$

$1800 = A * 60 + B * 60^2$ ①

At $f = 90\ Hz$

$3000 = A * 90 + B * 90^2$ ②

Multiplying 3 by eq. (1) & 2 by eq. (2), then Subtract eq (1) from eq. (2) yields

$-600 = -5400 B \Rightarrow B = \frac{6}{54} = \frac{1}{9}$

$\therefore A = \frac{1800 - B \times 60^2}{60} = \frac{1800 - 400}{60} = \frac{1400}{60} = \frac{140}{6}$

$A = \frac{70}{3} = 23.33$

Hence, At $f = 60\ Hz$: $P_h = \frac{70}{3} \times 60 = 1400 W$

$P_e = \frac{1}{9} \times 60^2 = 400 W$

At $f = 90\ Hz$: $P_h = \frac{70}{3} \times 90 = 2100 W$

$P_e = \frac{1}{9} \times 90^2 = 900 W$