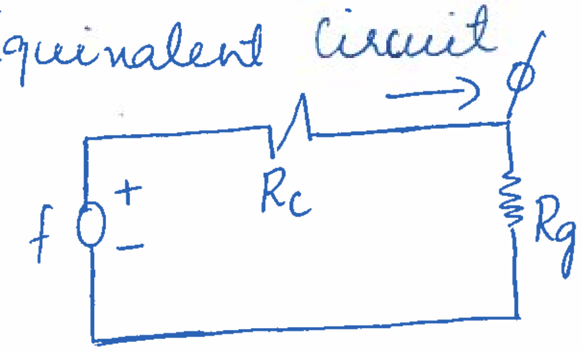
PROBLEM # 1

Solution :- (a)

Equivalent circuit



$$R_{eq} = R_c + R_g$$

$$= \frac{l_c}{\mu_c A_c} + \frac{l_g}{\mu_0 A_g} \quad \text{———} (1)$$

$l_g = 0.1 \times 10^{-3}\, m$

$A_g = A_c = 16 \times 10^{-4}\, m^2$

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

$$= \frac{(40 \times 10^{-2} - 0.1 \times 10^{-3})}{\mu_0 \times 50{,}000 \times 16 \times 10^{-4}} + \frac{0.1 \times 10^{-3}}{\mu_0 \times 16 \times 10^{-4}}$$

$$R_{eq} = 3977.87 + 49735.9 = 53713.7 \ At/wb$$

As $F = Ni = \phi R_{eq}$

$\boxed{\phi = BA}$

$$\Rightarrow i = \frac{(1.5 \times 16 \times 10^{-4}) \times 53713.7}{350}$$

1) $\boxed{i = 0.3683\ A}$

2) $\phi = B_g \cdot A_g$ $\quad \because \boxed{A_c = A_g}$

$B_g = 1.5T$

$$= 1.5 \times 16 \times 10^{-4}$$

$\boxed{\phi = 2.4\, m\, wb}$

(b)

$$A_{g_{new}} = A_g + 0.05 \times A_g$$

$$A_{g_{new}} = (1+0.05)A_g = 1.05 \times 16 \times 10^{-4}$$

$$A_{g_{new}} = 1.68 \times 10^{-3} \, m^2$$

$$l_{c_{new}} = 40 - 0.05 = 39.95 \, cm = 39.95 \times 10^{-2} \, m$$

$$\boxed{l_{c_{new}} = 39.95 \times 10^{-2} \, m}$$

From ①, we can write

$$\boxed{l_g = 0.05 \, cm}$$

$$\boxed{l_{g_{new}} = 0.05 \times 10^{-2} \, m}$$

$$R_{eq} = \frac{l_{c_{new}}}{\mu_c A_c} + \frac{l_{g_{new}}}{\mu_0 A_{g_{new}}}$$

$$R_{eq} = \frac{39.95 \times 10^{-2}}{\mu_0 \times 50{,}000 \times 16 \times 10^{-4}} + \frac{0.05 \times 10^{-2}}{\mu_0 \times 1.68 \times 10^{-3}} = 240811.61$$

$$i = \frac{B_{gap} \times A_{gap_{new}} \times \text{Reluctance } (R)}{N}$$

$$= \frac{1.5 \times 1.68 \times 10^{-3} \times 240811.61}{350}$$

1) $i = 1.7338 \, A$

2) $\phi = B_g \cdot A_{g_{new}}$

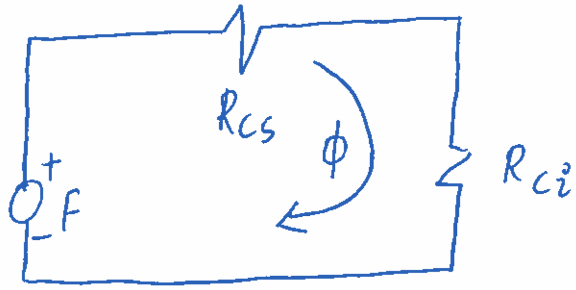
$$= 1.5 \times 1.68 \times 10^{-3}$$

$$\boxed{\phi = 2.52 \, mWb}$$

PROBLEM #2

Solution

Magnetic equivalent Circuit



$$F = Ni = 350 \times 1.2 = 420$$

$$\boxed{F = 420 \text{ A.t}}$$

$$R_{cs} = \frac{l_{cs}}{\mu_{cs} A_{cs}} = \frac{20 \times 10^{-2}}{800 \times 4\pi \times 10^{-7} \times 16 \times 10^{-4}}$$

$$\boxed{R_{cs} = 124339.7 \text{ A.t/Wb}}$$

$$R_{ci} = \frac{l_{ci}}{\mu_{ci} A_{ci}} = \frac{20 \times 10^{-2}}{250 \times 4\pi \times 10^{-7} \times 16 \times 10^{-4}}$$

$$\boxed{R_{ci} = 397887.3 \text{ A.t/Wb}}$$

$$\Longrightarrow R_{eq} = R_{cs} + R_{ci}$$

$$R_{eq} = 522227.05 \text{ At/Wb}$$

$$F = Ni = \phi R_{eq}$$

$$\Rightarrow \phi = \frac{F}{R_{eq}} = \frac{420}{522270.05}$$

1)

$$\boxed{\phi = 8.042 \times 10^{-4}\ Wb}$$

2) $\lambda = N\phi = 350 \times 8.042 \times 10^{-4}$

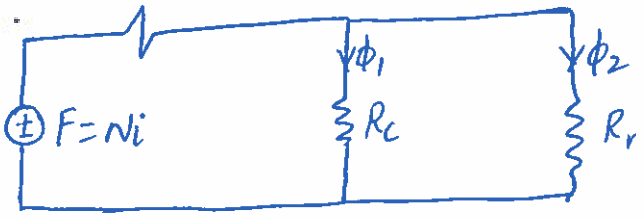
$$\boxed{\lambda = 0.2814\ Wb.turn.}$$

3) $B = \phi / A = \dfrac{8.042 \times 10^{-4}}{16 \times 10^{-4}}$

$$\boxed{B = 0.502\ T}$$

PROBLEM # 3

Solution ①



②
$$\phi_2 = 0.625 \times 10^{-3} \text{ weber}$$

$$\mu_{cs} = 1.11 \times 10^{-3} \text{ wb/A·t m}$$

$$H_2 = \frac{B_2}{\mu_{cs}}, \quad \text{where } B_2 = \frac{\phi_2}{A_2}$$

$$B_2 = \frac{0.625 \times 10^{-3}}{(2.5)^2 \times 10^{-4}} = 1 \text{ wb/m}^2$$

$$\therefore H_2 = \frac{1}{1.11 \times 10^{-3}} = 900.9 \text{ At/m.}$$

and $F_2 = H_2 \times \ell_2 = 900.9 \times 0.25$

$$\boxed{F_2 = 225.22 \text{ A·t}}$$

$$\boxed{F_2 = F_1 = 225.22 \text{ A·t}}$$
(Parallel circuit)

(cs = cast steel)

3) $\phi_1 = 0.906\,m\,Wb$,

$$\phi = \phi_1 + \phi_2 = (0.625 + 0.906) \times 10^{-3} = 1.531\ mWb$$

$$B_{left} = \frac{\phi}{A} = \frac{1.531 \times 10^{-3}}{(2.5)^2 \times 10^{-4}} = 2.4496\ Wb/m^2$$

$$H_{left} = \frac{B_{left}}{\mu_{cs}} = \frac{2.4496}{1.11 \times 10^{-3}} = 2206.8\ At/m.$$

$$\mathcal{F}_{left} = H_{left} \times l_{left} = 2206.8 \times 0.25$$

$$F_{left} = 551.71\ A.t$$

$$F_{total} = F_{left} + F_{central} \quad (\because F_1 = F_2)$$

$$F_{total} = 551.71 + 225.22 = 776.93\ A.t$$

$$I_{needed} = \frac{F_{total}}{N} = \frac{776.93}{500}$$

$$I_{needed} = 1.553\,A$$

4) $P = VI = (300 \times 1.553)$

$$P = 465.9\ W$$

PROBLEM # 4

Solution (a) As permeability of material

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

and relative permeability

$$\mu_r = \frac{\mu}{\mu_0} \; ; \; \mu_0 = 4\pi \times 10^{-7}$$

1) $H = 250$ A.t/m

$B = 1.2\,T$ (From graph)

$\mu = B/H = 1.2/250 = 0.0048$ H/m

and $\boxed{\mu_r = \frac{\mu}{\mu_0} = \frac{0.0048}{4\pi \times 10^{-7}} = 3819.7}$

Similarly

2) $H = 500$ A.t/m

$B = 1.40\,T$ (From graph)

$$\mu = \frac{1.40}{500} = 0.0028 \text{ H/m}$$

$$\boxed{\mu_r = \mu/\mu_0 = \frac{0.0028}{4\pi \times 10^{-7}} = 2230}$$

(b) As $B = \phi / A$

$= \frac{0.012}{0.015}$

$B = 0.8\,T$

∵ $\phi = 0.012\,Wb$
$A = 150\,cm^2$
$A = 0.015\,m^2$
$l_c = 55\,cm$
$l_c = 0.55\,m$

$\Rightarrow H = 115\,A\,turns/m$ (from graph) (Figure 4)

Magnetomotive force $\longrightarrow$ $F = Ni = Hl_c$

$= 115 \times 0.55$

$F = 63.25\,A\,turns$

and $i = \frac{F}{N} = \frac{63.25}{200}$

1) $\boxed{i = 0.316\,A}$

2) $\mu = \frac{B}{H} = \frac{0.8}{115} = 0.00696\,H/m$

$\mu_r = \frac{\mu}{\mu_0} = \frac{0.00696}{4\pi \times 10^{-7}}$

$\boxed{\mu_r = 5540}$

Reluctance $\longrightarrow$ 3) $R = \frac{F}{\phi} = \frac{63.25}{0.012} = 5270\,A.t/wb.$

$\boxed{R = 5270\,At/wb}$

PROBLEM # 5

Solution

(a) $W_h = xy \times$ (area of hysteresis loop)

where x & y are scale factors

$W_h = 9 \times 0.1 \times 250$

$= 225$ J/m³/cycle.

At $f = 50$ Hz

Hysteresis loss $= V_{core} \times W_h \times f$

$P_h = 0.16 \times 225 \times 50$

$P_h = 1800$ W

Eddy-current loss = Iron losses − Hysteresis losses.

$P_e = 2170 - 1800$

$P_e = 370$ W

(b) Similarly

At $f = 60$ Hz

$P_h = 1800 \times 60/50 = 2160$ W

$P_e = 370 \times (60/50)^2 = 533$ W

Total Iron losses $= 2160 + 533$

Total Iron losses $= 2690$ W

(c)

$P_h = K_h \times B_{max}^{n} f$

$P_h = 30 \times (1.3)^2 \times 50$

$P_h = 2535$ W

Eddy - current losses can be ~~mini~~ reduced by using

1. Laminations
2. Material of higher resistivity.