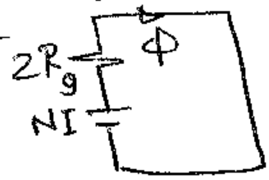
Kafrelsheikh university
Faculty of Engineering
Elect Engineering Dept.
2^{nd} year (2007) 2016/2017
Energy Conversion

Date 22-5-2017
Time allowed: 3 H
Full mark: 90
Accademic Code: EPM2204

Answer model (2017)

Q1: ⓐ → Magnetic Flux density B (wb/m²) (6 Marks)
It is the flux passing through the unit area (A) of the plane prependicular to the flux path ∴ $B = \Phi / A$ Tesla
The more general relation is $\Phi = \int_s B \cdot dA$
→ Magnetic flux intensity H (AT/m)
It is the force experienced by a north pole of one weber at a certain point. It is proportional to flux density $H = \frac{B}{\mu}$ ∴ $H = \frac{NI}{\ell}$
→ ~~It is mmf per unit length of mag. path~~ (14 marks)

ⓑ
ⓘ $NI = 2H_g \ell_g \Rightarrow 1000 * 8 = 2 * \frac{B_g * 0.5 * 10^{-2}}{4\pi * 10^{-7}}$



$\Rightarrow B_g = 1.005\,T$

ⓘⓘ when the rotor replaced by PM (6 marks)

∵ $\Phi_g = \Phi_m$
$A_g B_g = A_m B_m \Rightarrow B_g = B_m \cdot \frac{A_m}{A_g} \rightarrow ①$

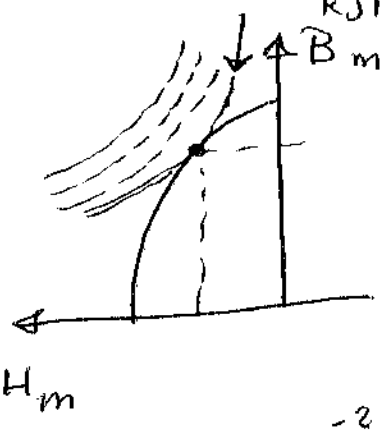
∵ $\Sigma Ni = 0.0$ ∴ $\Sigma Ni = \Sigma H\ell$ (8 marks)
∴ $0.0 = H_m \ell_m + 2H_g \ell_g \Rightarrow H_g = -\frac{H_m \ell_m}{2\ell_g}$

∴ $B_g = \frac{-\mu_0 H_m \ell_m}{2\ell_g} \longrightarrow ②$

By multiplying eqn ① by ② ⇒

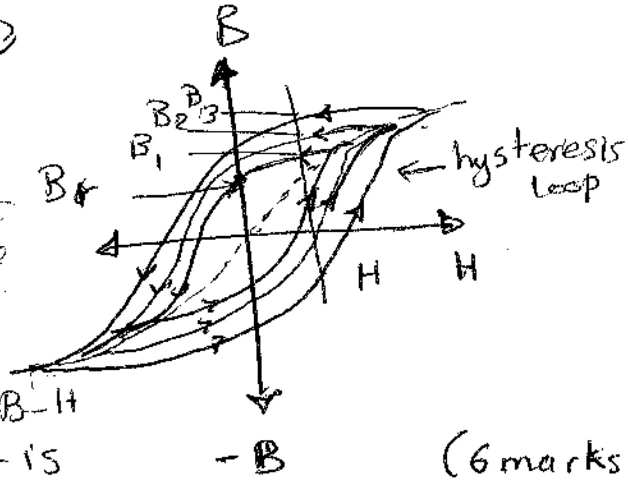
$B_g^2 = \left(-\frac{\mu_0 H_m \ell_m}{2\ell_g}\right) * \left(B_m \cdot \frac{A_m}{A_g}\right)$

$B_g^2 = \frac{-\mu_0 (H_m B_m)(A_m \ell_m)}{2(A_g \ell_g)}$



$\Rightarrow V_{P.M} = A_m \cdot \ell_m = \frac{2(A_g \ell_g) B_g^2}{\mu_0 (-H_m B_m)} \Rightarrow V_{P.M} = \frac{2 * (0.5 * 0.2 * 10^{-2}) * 1.00}{4\pi * 10^{-7} (40 * 10^3)}$

Q2 (a): magnetic hystresis



It means that B–H relation, when increasing H, is differet from that when decreasin H. The differen ce depends on the max. value of H

For ac excitation, the complet B–H relation during one cycle of current is known as hysteresis loop

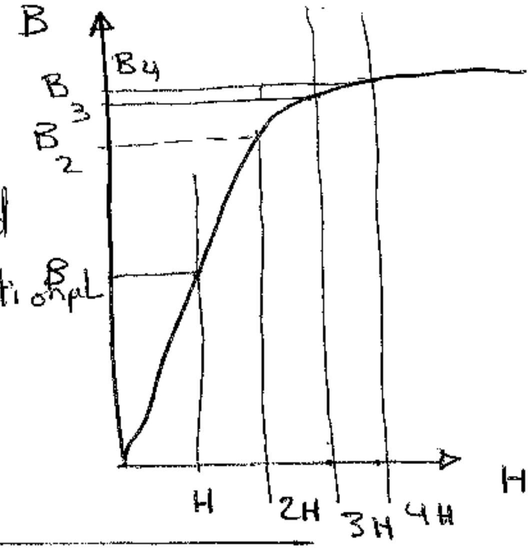
(6 marks)

→ The B–H curve is multi-valued and it depends on

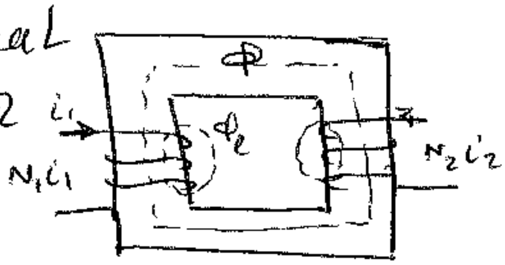
- material type
- B an H max

magnetic saturation

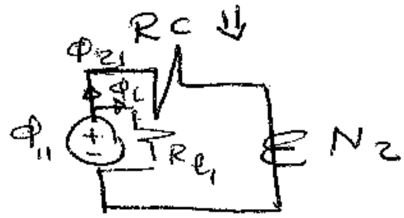
It means that beyond a certain limit, the increas in the magnetic field intensity H does not result in a proportional increase in the flux density B as shown in Fig.



(b) To determine the self and mutual inductances of coil 1 and coil 2 using superposition theory:-



$i_1 = 2$ and $i_2 = 0$-0 ⇒



$\Phi_{11} = \Phi_{l_1} + \Phi_{21}$

$\Phi_{11} = \dfrac{N_1 i_1}{R_{eq_1}}$, $P_{11} = \dfrac{1}{R_{eq1}} = \dfrac{1}{R_c} + \dfrac{1}{R_l}$

$\therefore \Phi_{11} = N_1 i_1 \cdot P_{11} \longrightarrow (1)$

$\Phi_{l_1} = N_1 i_1 P_{l1}$, $P_{l1} = \dfrac{1}{R_l}$

$\Phi_{21} = N_1 i_1 P_{21}$, $P_{21} = \dfrac{1}{R_c}$

$\therefore \Rightarrow P_{11} = \dfrac{1}{R_{eq_1}} = P_{21} + P_{l_1}$

$$L_{11} = \frac{N_1\Phi_{11}}{i_1} = \frac{N_1^2 \cancel{i_1} P_{11}}{\cancel{i_1}} = N_1^2 P_{11}$$

$$L_{21} = \frac{N_2\Phi_{21}}{i_1} = \frac{N_2 N_1 \cancel{i_1}}{\cancel{i_1}} P_{21} = N_1 i_1 P_{21}$$

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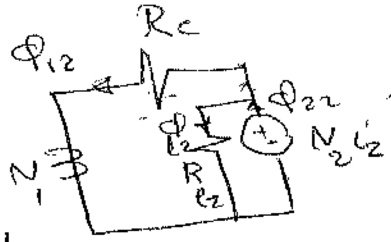
when $i_1 = 0.0$, $i_2 = \checkmark$



$$\Phi_{22} = \Phi_{l_2} + \Phi_{12}$$

$$\Phi_{22} = \frac{N_2 i_2}{Req_2} = N_2 i_2 P_{22}, \quad P_{22} = \frac{1}{Req_2} = \frac{1}{R_{l_2}} + \frac{1}{R_c}$$

$$\Phi_{l_2} = \frac{N_2 i_2}{R_{l_2}} = N_2 i_2 P_{l_2}, \quad P_{l_2} = \frac{1}{R_{l_2}}$$

$$\Phi_{12} = \frac{N_2 i_2}{R_c} = N_2 i_2 P_{12}, \quad P_{12} = \frac{1}{R_c} = P_{21}$$

$$\Rightarrow P_{22} = P_{12} + P_{l_2}$$

$$L_{22} = \frac{N_2 \Phi_{22}}{i_2} = N_2^2 P_{22}$$

$$L_{12} = \frac{N_{\cancel{1}} \Phi_{12}}{i_2} = N_1 N_2 P_{12}$$

$$\therefore L_{11} L_{22} = N_1^2 P_{11} N_2^2 P_{22}$$

$$= N_1^2 N_2^2 (P_{l_1} + P_{21})(P_{l_2} + P_{12}), \quad P_{12} = P_{21} \text{ (Linear magnetic circuit)}$$

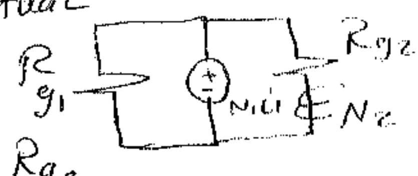
$$= \underbrace{N_1^2 N_2^2 P_{12}^2}_{L_{12}^2 \,\to\, M^2} \underbrace{\left(\frac{P_{l_1}}{P_{12}} + 1\right)\left(\frac{P_{l_2}}{P_{12}} + 1\right)}_{1/K^2}$$

$\Rightarrow M \to$ mutual inductance, ($K \to$ Coupling coefficient) $(0 \leq K \leq 1)$

$$\Rightarrow M = K\sqrt{L_{11} L_{22}}$$

(C) $N_1 = 250$ turns, $N_2 = 500$ turns, $A_{g_1} = A_{g_2} = 10\ cm^2$, $R_c = 0.0$

To Calculate Self inductance and mutual using superposition Theory



$i_1 = \checkmark$, $i_2 = 0.0$

$\Phi = N_1 i_1 / R_{eq}$, $Req_1 = R_{g_1} \parallel R_{g_2}$

$L_{11} = \frac{\lambda_{11}}{i_1} = \frac{N_1 \phi_{11}}{i_1} = \frac{N_1^2 \cancel{i_1}}{R_{eq1} \cancel{i_1}}$ (4)

$$R_{g_1} = \frac{l_{g_1}}{\mu_0 A_g} = \frac{0.5 * 10^{-3}}{4\pi * 10^{-7} * 10^{-3}} = 397887.36 \text{ AT/wb}$$

$$R_{g2} = \frac{1 * 10^{-3}}{4\pi * 10^{-7} * 10^{-3}} = 795774.7 \text{ At/wb}$$

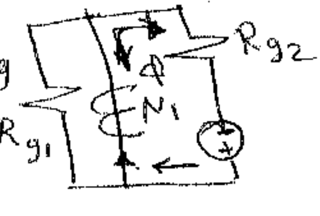
$$R_{eq_1} = 265258.24 \text{ AT/m}$$

$$\therefore L_{11} = \frac{N_1^2}{R_{eq_1}} = \frac{(250)^2}{265258.24} = 0.2356 \text{ H}$$

$$L_{21} = \frac{\Phi_{21} * N_2}{i_1} = \frac{N_1 \cancel{i_1}}{R_{g2} \cancel{i_1}} * N_2 = \frac{N_1 N_2}{R_{g2}} = \frac{250 * 500}{795774.7} = 0.157 \text{ H}$$

$\Rightarrow$ let $i_1 = 0.0$, $i_2 = \ldots$

R_{g_1} will be Shorted by the middle leg



$$\Rightarrow \Phi_{22} = \frac{N_2 i_2}{R_{eq_2}}, \quad R_{eq_2} = R_{g2}$$

$$\therefore L_{22} = \frac{N_2 \phi_{22}}{i_2} = \frac{N_2 \cdot N_2 \cancel{i_2}}{R_{eq_2} \cancel{i_2}} = \frac{N_2^2}{R_{g2}} = \frac{(500)^2}{795774.7} = 0.314 \text{ H}$$

$$L_{12} = \frac{\Phi_{21} N_1}{i_2} = \frac{N_2 \cancel{i_2}}{R_{g2}} \cdot \frac{N_1}{\cancel{i_2}} = \frac{N_1 N_2}{R_{g2}} = 0.157 \text{ H}$$

$$L_{12} = L_{21} = 0.157 \text{H}$$

(ii) $e_1 = \frac{d\lambda_1}{dt} = \frac{d}{dt}(L_{11} i_1 + L_{12} i_2)$, L_{11}, $L_{12} \to$ Constant

$$= L_{11} \frac{di_1}{dt} + L_{12} \frac{di_2}{dt}$$

$e_2 = \frac{d\lambda_2}{dt} = \frac{d}{dt}(L_{21} i_1 + L_{22} i_2)$, L_{22}, $L_{21} \to$ Constant

$$= L_{21} \frac{di_1}{dt} + L_{22} \frac{di_2}{dt}$$

when $i_1 = 5 \cos wt \Rightarrow \frac{di_1}{dt} = 5w \sin wt$

$i_2 = 2 \text{ A} \Rightarrow \frac{di_2}{dt} = 0.0$

$$\therefore e_1 = L_{11} \frac{di_1}{dt} = 0.235 * (-5 * 2\pi * 50) \sin wt$$

$$=$$

$$e_1 = L_{21} \frac{di_1}{dt} = 0.157(-5 * 2\pi * 50) \sin wt$$

$$W_1 = \frac{1}{2} L_{11} i_1^2 + M i_1 i_2 + \frac{1}{2} L_{22} i_2^2$$