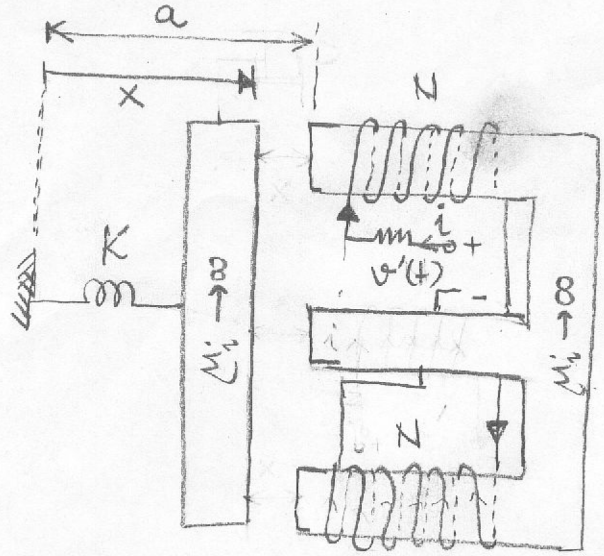
PRINCIPLES OF ENERGY CONVERSION SECOM MIDTER EXAM

Dr. Salih FADIL

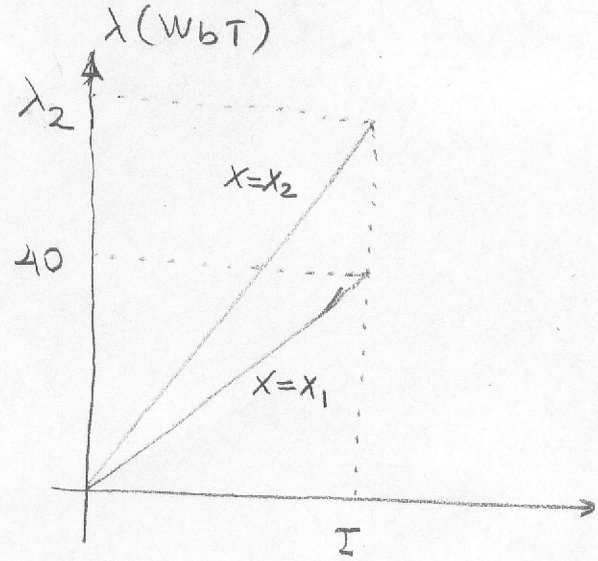
May 03, 2010

#1)



An electromagnet, wich has a uniform cross-sectio's A m^2, is shown on the figure. Write the necassarry differential equatio's set, wich governs the motion of the electromagnet. The differential equation set should be written in such a way that, one can integrate them by using an appropriate software for a given initial values.

#2)



Suppose that the movable part of the above system, shown in the figure, moves from a positio's $X=X_1$ to $X=X_2$ very slowly so that the current remains constant at 2A. If 60 J is given to the conservative system from electric input during the movement.

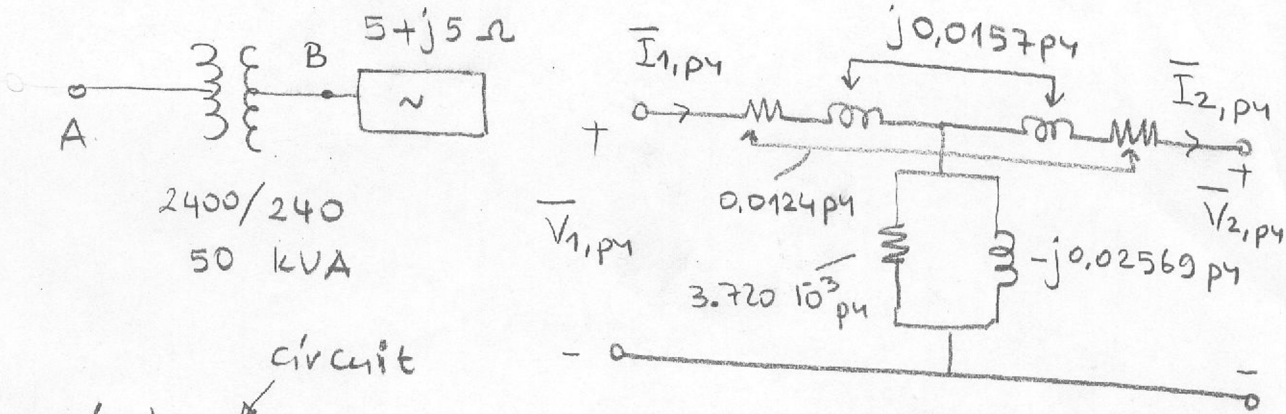
a) Calculate λ_2 value

b) Calculate the stored magnetic energies at $X=X_1$ and $X=X_2$ positions, also change of stored magnetic energy in the magnetic field

c) Calculate the energy converted to mechanical energy.

SEE BACK

#3)



The pu equivalent circuit given on the right hand side on the above belongs to 2400/240 V, 50 kVA transformer that is given on the left hand side on the above figure.

a) Draw the actual equivalent circuit referred to LV side of the transformer.

b) If $\bar{V}_A = 2400 \angle 0^\circ$ V, calculate $\bar{V}_B$. Ignore the shunt magnetization branch of the transformer in your calculation.

PRINCIPLES OF ENERGY CONVERSION SECOND MIDTERM EXAM SOLUTION MANUAL

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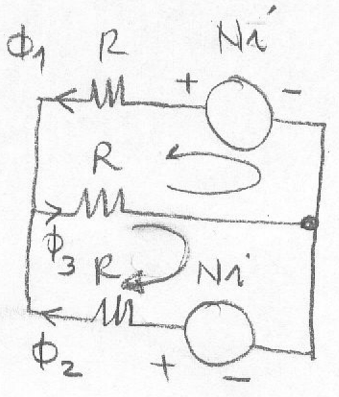
#1)



$$-Ni + \Phi_1 R + \Phi_3 R = 0$$
$$-Ni + \Phi_2 R + \Phi_3 R = 0$$

$$\frac{Ni}{R} = \Phi_1 + \Phi_3 \qquad \Phi_2 + \Phi_1 = \Phi_3$$
$$\frac{Ni}{R} = \Phi_2 + \Phi_3$$

$$\frac{2Ni}{R} = 2\Phi_3 + \Phi_3 = 3\Phi_3 \qquad \Phi_3 = \frac{2Ni}{3R}, \quad \Phi_1 = \Phi_2 = \frac{Ni}{R} - \frac{2Ni}{3R} = \frac{Ni}{3R}$$

$$\Phi_1 = \Phi_2 = \phi = \frac{Ni}{3R}, \quad \Phi_3 = 2\phi = \frac{2Ni}{3R}$$

$$f_e = -\left\{\frac{1}{2}\Phi_1^2\frac{dR}{dx} + \frac{1}{2}\Phi_2^2\frac{dR}{dx} + \frac{1}{2}\Phi_3^2\frac{dR}{dx}\right\} = -\frac{dR}{dx}\frac{1}{2}\left[\Phi_1^2 + \Phi_1^2 + \Phi_3^2\right]$$

$$R = \frac{a-x}{\mu_0 A}, \quad \frac{dR}{dx} = -\frac{1}{\mu_0 A}$$

$$f_e = \frac{1}{2\mu_0 A}\left[\frac{(Ni)^2}{9R^2} + \frac{(Ni)^2}{9R^2} + \frac{4(Ni)^2}{9R^2}\right] = \frac{1}{\cancel{2}\mu_0 A}\,\frac{\overset{3}{\cancel{6}}(Ni)^2}{\underset{3}{\cancel{9}}R^2}$$

$$\boxed{f_e = \frac{(Ni)^2}{\mu_0 A\, 3R^2}} = \frac{(Ni)^2}{3\cancel{\mu_0 A}\frac{(a-x)^2}{\cancel{(\mu_0 A)^2}_{\mu_0 A}}} = \frac{(Ni)^2\mu_0 A}{3(a-x)^2} = \frac{1}{2}\frac{dL(x)}{dx}\cancel{i}^2$$

$$\boxed{\frac{dL(x)}{dx} = \frac{2}{3}\frac{N^2\mu_0 A}{(a-x)^2}} \longrightarrow dL(x) = -\frac{2\mu_0 A N^2}{3}(a-x)^{-2}(-dx)$$

$$L(x) = -\frac{2\mu_0 A N^2}{3}\,\frac{-1}{(a-x)} \qquad L(x) = \frac{2\mu_0 A N^2}{3(a-x)}$$

$$M \frac{d^2x}{dt^2} + Kx = f_e = \frac{1}{2} \frac{dL(x)}{dx} i^2$$

$$v' = iR + L(x) \frac{di}{dt} + i \frac{dL(x)}{dx} \cdot \frac{dx}{dt}$$

$$\frac{dx}{dt} = y$$

$$\frac{dy}{dt} = \frac{1}{M} \left[\frac{1}{2} \frac{dL(x)}{dx} i^2 - Kx \right]$$

$$\frac{di}{dt} = \frac{1}{L(x)} \left[v' - iR - i \frac{dL(x)}{dx} \cdot y \right]$$

where

$$L(x) = \frac{2\mu_0 A N^2}{3(a-x)}, \quad \frac{dL(x)}{dx} = \frac{2\mu_0 A N^2}{3(a-x)^2}$$

initial conditions should be given

$$x(0) = x_0$$
$$y(0) = y_0$$
$$i(0) = i_0$$

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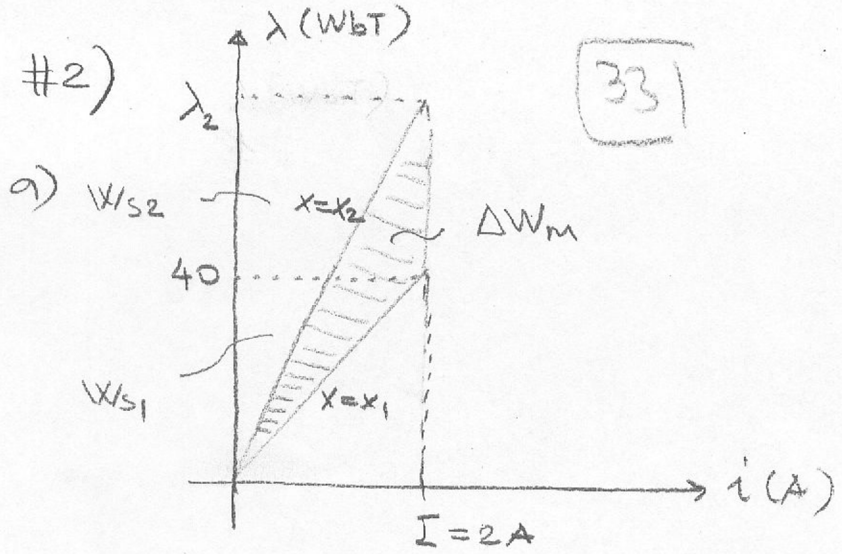
#2)



a) $\Delta W_e = \int_{\lambda=\lambda_1}^{\lambda_2} i \, d\lambda = I \int_{\lambda=\lambda_1}^{\lambda_2} d\lambda = I(\lambda_2 - \lambda_1) = 60$

$2(\lambda_2 - 40) = 60$ $\boxed{\lambda_2 = 40 + 30 = 70 \text{ J.}}$

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b) Stored magnetic energy at $x = x_1$

$W_{s_1} = \frac{1}{2} 40 \times 2 = 40$ J.

$W_{s2} = \frac{1}{2} 70 \times 2 = 70$ J.

$\Delta W_s = 70 - 40 = 30$ J.

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c) For motor operation;

$\Delta W_e = \Delta W_s + \Delta W_m$

$\Delta W_m = \Delta W_e - \Delta W_s = 60 - 30 = 30 = \frac{1}{2} \Delta W_e$ J.

From the figure (shaded area)

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$\frac{1}{\cancel{2}} \times 70 \times \cancel{2} - \frac{1}{\cancel{2}} 40 \times \cancel{2} = 30$ J.

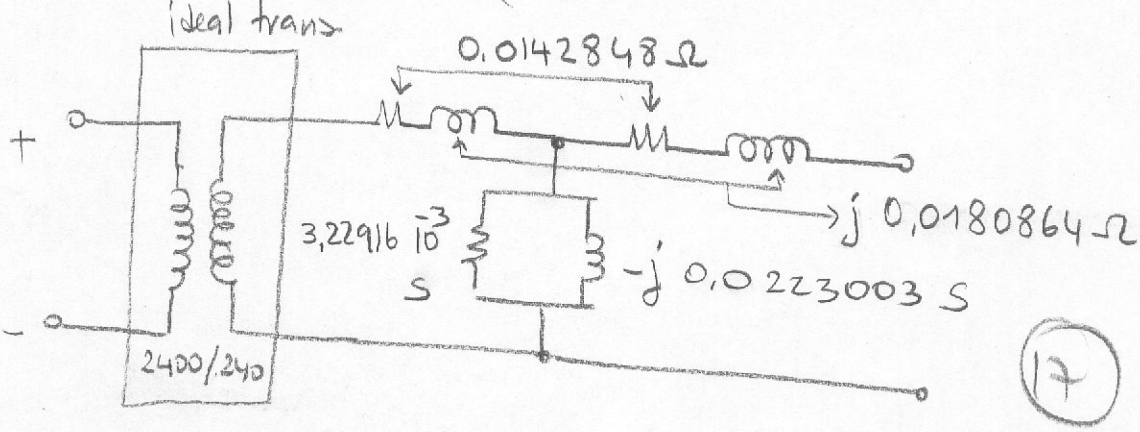
#3)

a) $Req_{LV} = 0{,}0124 \dfrac{(240)^2}{50\ 10^3} = 0{,}0142848\ \Omega$

$Xeq_{LV} = 0{,}0157 \dfrac{(240)^2}{50\ 10^3} = 0{,}0180864\ \Omega$

$Gc_{LV} = 3.720\ 10^{-3} \dfrac{50\ 10^3}{(240)^2} = 3.22916\ 10^{-3}\ S$

$B_{m_{LV}} = 0{,}02569 \dfrac{50\ 10^3}{(240)^3} = 0{,}0223003\ S.$



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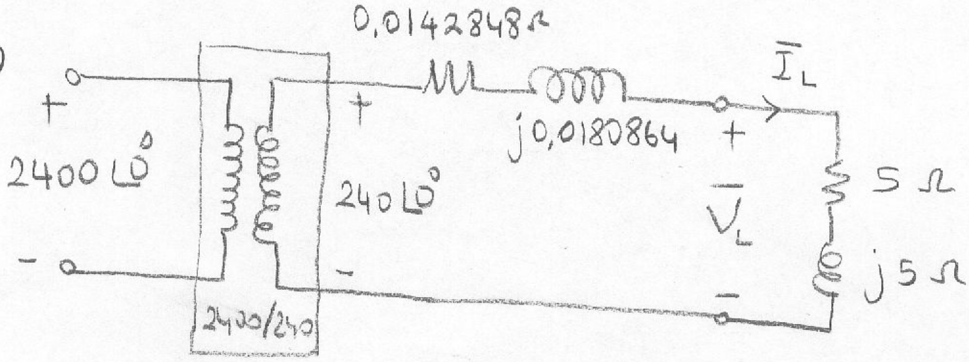
b)



$$\bar{V}_B = 240 \angle 0^\circ \frac{5 + j5}{5{,}0142848 + j5{,}0180864} = 240 \frac{7.071067 \angle 45^\circ}{7.093958 \angle 45.0217}$$

$\bar{V}_B = 239.225 \angle -0.0217$ volt

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