University of Jordan
Dept. of Elect. Engg.

Electric Drives (0943582)
Mid Examination

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Time:75Minutes

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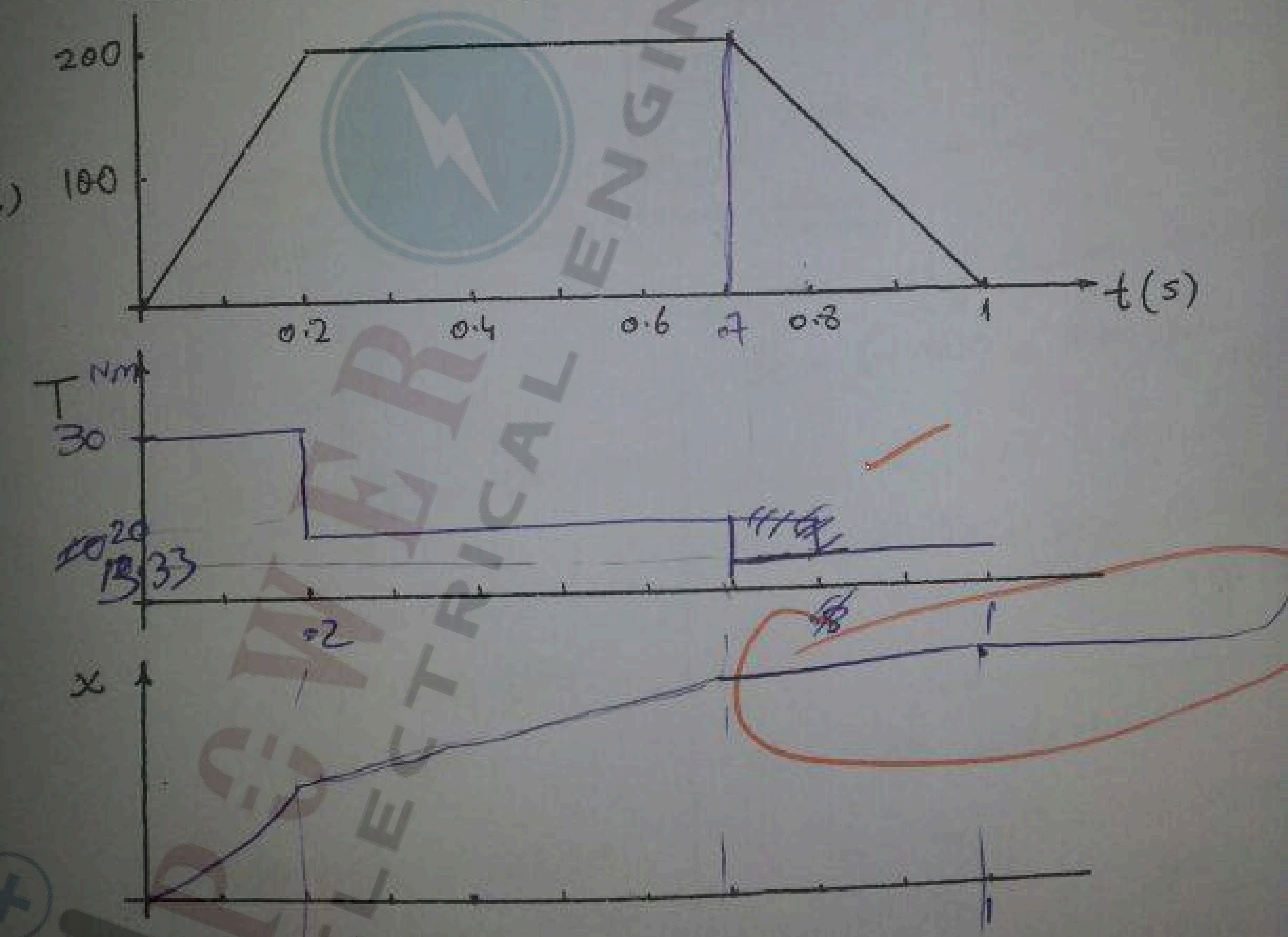
1. Given the speed variation with time for certain load. Draw the variation of th Torque and position with time. Given that the constant torque is 20Nm and th motor load inertia J= 0.01kgm^2. **4marks**



$T_e = T_L + J\frac{d\omega}{dt}$

$t = 0 \rightarrow .2$

for $t = 1 \rightarrow \infty$

$\frac{d\omega}{dt} = 0 \rightarrow$

$T_e = T_L = 20$

3. A 300 V dc shunt motor drives a certain load at a speed of 1000 rpm. The armature resistance = 0.5Ω and the field current = 2A. The motor draws a total current of 82A. The load torque is proportional to square of the speed. The speed control for this motor is performed by field current control. Calculate the field current to drive the load at 1200rpm. What is the value of the armature current then?

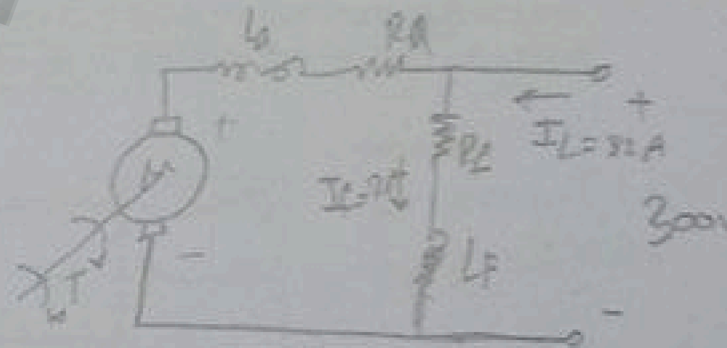
6marks

$V_T = 300\,V$ $\quad T_L = k n^2$

$n_1 = 1000$ rpm

$R_a = 0.5\,\Omega$

$I_{f_1} = 2\,A$



* find I_{f_2} at $n_2 = 1200$ rpm

$I_{a_1} = I_L - I_{f_1} = 82 - 2 = 80\,A$

$V_T = E_{a_1} + I_{a_1} R_{a_1}$

$E_{a_1} = 300 - (80) \times 0.5 = 260\,V$

$T_1 = k\phi I_{a_1}$

$T = k\omega^2$

1

4. A dc. Separately excited motor is driving a load torque composed of two components as given in the equation:

$$\boxed{T = 25 + 0.1\,\omega^2}$$

The armature circuit of the motor is connected to a full-wave, ac/dc SCR converter. he input voltage to the converter is 300V (rms). The armature resistance of the motor is 5 Ω, and the field constant (kϕ) is 2.5 V sec. Assume that the armature current is always ontinuous. Calculate the range of the triggering angle to operate the motor at a speed nge of 0 to 600 rpm.

6marks

at $\omega_m = \frac{600 * 2\pi}{60} = 62.9$ rad/sec

$\frac{T}{k\phi}$

$\alpha = \cos^{-1}\left[\frac{\pi}{2V_{max}}(R_a * I_{av} + k\phi\right.$

$\alpha = \cos^{-1}\left[\frac{\pi}{2 * \sqrt{2} * 300}\right.(.5 * (\frac{25 + .1}{2.5}$

$\alpha = \cos^{-1}\left(3.7 * 10^{-3}\right.\left(.5 * (168.26)\right)$

$\alpha = 26.73$ for $\omega = 62$

for $\omega = 0$

$\alpha = \cos^{-1}\left[\frac{\pi}{2\sqrt{2} * 300}\right.\left[.5\frac{(25)}{2.5}\right.$

Q3 $I_a = 82 - 2 = 80\,A$ $\longrightarrow$ $E_{a_1} = 300 - 80\left(\frac{1}{2}\right) \approx 260$ volt

$T = K\phi I_a \Longrightarrow \frac{I_{F_2}}{I_{F_1}} \frac{I_{a_2}}{I_{a_1}} = \left(\frac{n_2}{n_1}\right)^2$

$\left(\frac{1200}{1000}\right)^2 = \frac{I_{F_2}\, I_{a_2}}{I_{F_1}\, I_{a_1}}$ $\Longrightarrow$ $E_a = K\phi\omega$

$I_{F_1} \to 2$, $I_{a_1} \to 80$

$\frac{E_{a_2}}{260} = \frac{I_{F_2}}{2} * \frac{1200}{1000}$ ~~E_{a_2}~~

$E_{a_2} = 300 - I_{a_2}\left(\frac{1}{5}\right)$ $\Longrightarrow$ $I_{a_2} = 1.39\,A$

$I_{a_2} = 165\,A$ X

4. A dc. Separately excited motor is driving a load torque composed of two components as given in the equation:

$$T = 25 + 0.1\,\omega^2$$

The armature circuit of the motor is connected to a full-wave, ac/dc SCR converter. The input voltage to the converter is 300V (rms). The armature resistance of the motor is 0.5 Ω, and the field constant (kϕ) is 2.5 V sec. Assume that the armature current is always continuous. Calculate the range of the triggering angle to operate the motor at a speed range of 0 to 600 rpm.

6marks

$R_a = 0.5\,\Omega$

$K\phi = 2.5$ V sec

continuous I_a

6

$T = K\Phi I_A$

at $n_1 = 0$

$T_1 = 25 + 0.1 \times (0)^2 = 25$ N.m

$I_{A_1} = \frac{T}{K\Phi} = \frac{25}{2.5} = 10$ A

$E_{A_1} = K\Phi\,\omega_1 = 0$

$\boxed{\frac{2 V_{max}}{\pi} \cos(\alpha) = E_A + R_A I_A}$

$\frac{2 \times 300 \times \sqrt{2}}{\pi} \cos(\alpha) = 0 + 0.5 \times 10$

$270.1 \cos(\alpha) = 5$

$\alpha_1 = \cos^{-1}\left(\frac{5}{270.1}\right) = 88.93^\circ$

at $n_2 = 600$ rpm

$\omega_2 = 600 \times \frac{2\pi}{60} = 62.83$ rad/sec

$T_2 = 25 + 0.1 \times (62.83)^2 = 419.8$ Nm

$I_{A2} = \frac{T_2}{K\phi} = \frac{419.8}{2.5} = 167.92$ A

$E_{A2} = K\phi\,\omega_2 = 2.5 \times 62.83 = 157.1$ V

$\frac{2 \times 300\sqrt{2}}{\pi} \cos(\alpha) = 157.1 + 0.5 \times 167.92$

$270.1 \cos(\alpha) = 241.06$

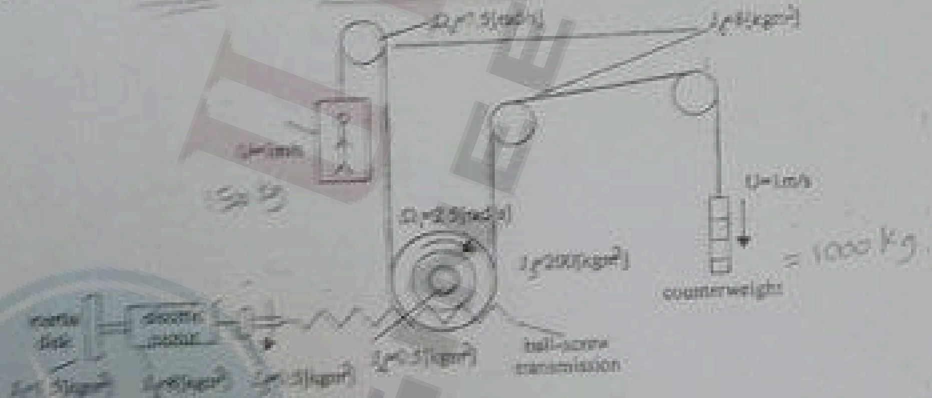
$\alpha = \cos^{-1}\left(\frac{241.06}{270.1}\right) = 26.81^\circ$

∴ range of α

$(26.81^\circ - 88.93^\circ)$

2. The figure bellow shows an elevator drive with multiple mechanical transmission and counterweight. The motor is a 4 pole motor operating at a slip of 0.05 and an efficiency of 85% from a 3-phase supply of 400V, 50 Hz. The counterweight = 1000Kg and the elevator load is 1500kg. **5marks**

Calculate the torque and the electromagnetic power without counterweight



5

$\omega_s = \frac{120 \times 50}{4} = 1500 \text{ rpm} = 157.1 \text{ rad/sec}$

$\omega_m = (1-0.05) \times 1500 = 1425 \text{ rpm} = 149.2 \text{ rad/sec}$

$J_c = (m_c + m_{cw}) \cdot \frac{u^2}{\omega_m^2} = (1000 + 1500) \times \frac{1}{(149.2)^2}$

$J_c = 0.1123 \text{ kgm}^2$

$J_t = J_n + J_c = 10.05 + 0.1123 = 10.1623 \text{ kgm}^2$

$\Sigma T = \alpha \Sigma J$

$T_{em} \cdot \omega_m \cdot \eta = m_c \cdot g \cdot u$

$T_{em} = \frac{1500 \times 9.81 \times 1}{149.2 \times 0.85} = 116.03 \text{ N.m}$

$P_{em} = T_{em} \cdot \omega_m = 116.03 \times 149.2 =$

$P_{em} = 17311.876 \text{ W}$

$4475 - 128V_i' + .092V_i'^2 + 863 V_i' - .125 V_i'^2$

$= .033 V_i'^2 - 4.17 V_i' + 443.5$

$-63.18 - j89.2$

Torque

5. A 3-phase, 400V, 50Hz, 6-poles, induction motor is driving a constant load of 80Nm. The parameters of the motor are:

$R_{TH} = R_1 = 0.5\Omega$ $R_2 = 0.3\ \Omega$ $X_{TH} = 2\ \Omega$ $X_2 = 2\ \Omega$ $N_1/N_2 = 2$

7marks

(i) Calculate the magnitude of the injected voltage that will reduce the motor speed to 700 rpm

$\frac{120 f_s}{P} = \frac{120(50)}{6} = 1000$ rpm

new speed.

$\frac{n_s - n}{n_s} = \frac{1000-700}{1000}$

$= .3$

$= (2) * 2^2 = 8\ \Omega$

$(.3) * (2)^2 = 1.2\ \Omega$

$8 + 2 = 10\ \Omega$

$Td = \frac{3}{S\omega_s}\left[(I_2')^2 * R_2' + V_i' I_2' \cos\theta\right.$

$80 = \frac{3}{.3 * \left(\frac{2\pi * 1000}{60}\right)}\left[(I_2')^2 . (1.2) + V_i' I_2' c\right.$

$I_2' = \frac{\left(230.94 - \frac{V_i'}{.3}\right) * .3}{(10.97) * .3}$

$I_2' = \left[\frac{69.28 - V_i'}{3.29}\right]$

$80 = \frac{3}{10\pi}\left(\left(\frac{69.29 - V_i'}{3.29}\right)^2 * 1.2 + V_i'\left[6\right.\right.$

$= \frac{3}{}\left[4801.1 - 138.58 V_i' + V_i'^2\right. + \left[\frac{69.}{3.2}\right.$

A 300 V dc shunt motor drives a certain load at a speed of 1000 rpm. The arm
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load at 1200rpm. What is the value of the armature current then?

6marks

I_{f_1}

$82 - 2 = 80A$

A.

$= K\phi_1 I_{a_1}$

$= K\phi_1 (80)$

$K\phi_1 I_{a_2}$

$\longrightarrow (1000 rpm)^2$

$\longrightarrow (1200)^2$

$$\frac{\phi_1}{\phi_2} \frac{n_1}{n_2} = \frac{V - I_{a_1}}{V - I_{a_2}}$$

$$\frac{\phi_1}{\phi_2} = \frac{n_2}{n_1} \left[\frac{300 -}{300} \right.$$

$$\frac{\phi_1}{\phi_2} = \frac{1200}{1000} \left[\frac{30}{3} \right.$$

$$\frac{\phi_1}{\phi_2} = \cancel{1.2} \quad \frac{31}{300}$$

see table 10.1

10.3

a. @ operating point 1 → $T = 40 = \frac{V^2 s_1}{\omega_s R_2'}$

→ $n_s = \frac{120 f}{P} = \frac{120 \times 60}{4} = 1800$ rpm → $\omega_s = \frac{2\pi n_s}{60} = 188.5$ rad/s

→ $40 = \frac{(480)^2 s_1}{188.5 \times 0.3}$ → $s_1 \approx 0.01$ (0.0098) → $I = \frac{V s_1}{\sqrt{3} R_2'} = \frac{480 \times 0.01}{\sqrt{3} \times 0.3} = 9.237$ A

b. @ operating point 2 → $I = \frac{V}{\sqrt{3} X_{eq}} = \frac{480}{\sqrt{3} \times 12} = 23.09$ A

c. @ operating point 3 → $I = \frac{V}{\sqrt{3} X_{eq}} = 23.09$ A

d. @ operating point 4 → $T = \frac{V^2 R_2'}{s_3(-\omega_s) X_{eq}^2} = \frac{(480)^2 \times 0.3}{(1)(-188.5)(12)^2} = -2.546$ Nm

e. @ operating point 6 → $T_6 = T_1 = 40 = \frac{V^2 s_6}{(-\omega_s) R_2'}$ → $s_6 = \frac{40(-\omega_s)(R_2')}{V^2} \approx -0.01$ (-0.0098)

f. $T_6 = T_1 = 40$ Nm

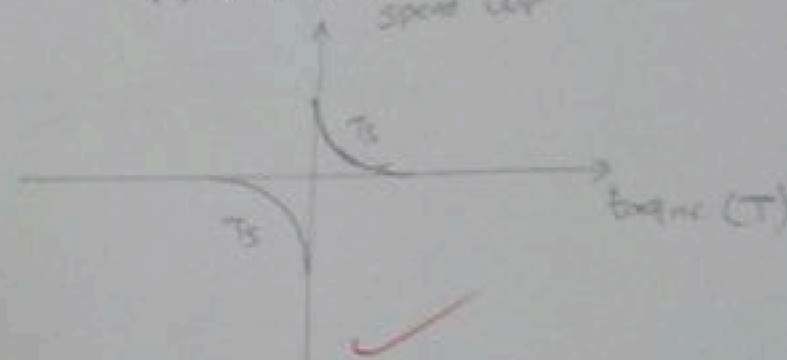
g. $n_6 = n_s(1 - s_6) = 1800(1 + 0.01) = 1818$ rpm

6. Sketch the relationship of torque speed for **2marks**

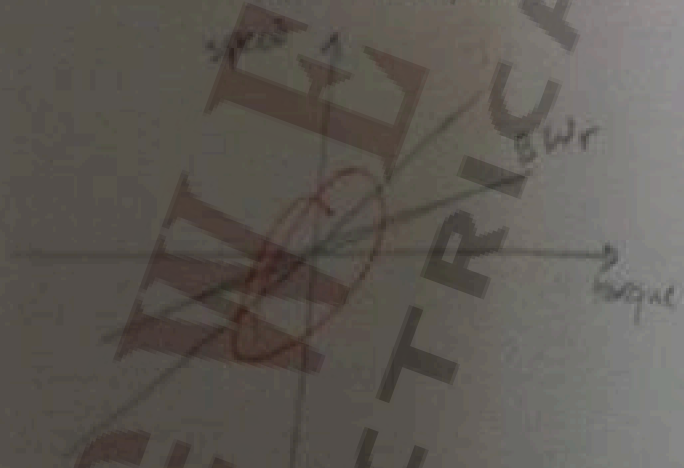
2

(i) Coulomb friction

(ii) Static friction



(iii) Viscous friction



(iv) Windage friction