



**UNIVERSITI TUN HUSSEIN ONN MALAYSIA**

**FINAL EXAMINATION  
SEMESTER II  
SESSION 2016/2017**

COURSE NAME : ELECTRICAL CONTROL SYSTEM  
COURSE CODE : BEF 33003  
PROGRAMME CODE : BEV  
EXAMINATION DATE : JUNE 2017  
DURATION : 3 HOURS  
INSTRUCTION : ANSWER **ALL** QUESTIONS

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THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

- Q1** (a) List **one (1)** advantage of closed loop control system. (2 marks)
- (b) Describe each of the control system component listed below:
- (i) Input. (2 marks)
- (ii) Output. (2 marks)
- (c) Amira was assigned by his lecturer to obtain the transfer function,  $\frac{C(s)}{R(s)}$  for steam distillation system as shown in **Figure Q1(c)**. The resulted transfer function obtained by Amira is shown below:

$$\frac{C(s)}{R(s)} = \frac{G1G2G3^2}{G3 + G1H4[G3 + H3(G2G3)(H1 + G3H2 + 1)] + G1G2G3H5}$$

By using block diagram algebra approach, investigate either the transfer function,  $\frac{C(s)}{R(s)}$  obtained by Amira is correct or not.

(14 marks)

- Q2** (a) List **two (2)** physical law of science and engineering uses in developing mathematical modeling in practice. (4 marks)
- (b) Describe the definition of translational mechanical system. (2 marks)
- (c) Determine the transfer function,  $G(s) = \frac{X(s)}{F(s)}$  for the translational mechanical system as shown in **Figure Q2(c)**. Given the parameters of the system are as below:

$$\begin{aligned} M_1 &= M_2 = M_3 = 1 \text{ Kg} \\ D_1 &= D_2 = D_3 = 2 \text{ N-s/m} \\ K_1 &= K_2 = K_3 = 1 \text{ N/m} \end{aligned}$$

(14 marks)

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- Q3** (a) Differentiate between over damped, critically damped and underdamped response. (6 marks)
- (b) Based on the block diagram of a positioning system as shown in **Figure Q3(b)**:
- (i) Determine the closed loop transfer function of the system. (1 marks)
- (ii) Calculate the peak time,  $T_p$ , rise time,  $T_r$  and percentage of overshoot,  $\% \mu_s$  of the system. (6 marks)
- (c) A feedback control system is given in **Figure Q3(c)**. The system will be stable if the  $K_c$  values are positive. Using Routh Hurwitz stability Criterion, investigate the range of  $K_c$  for stable system. (7 marks)

- Q4** (a) Distinguish clearly the meaning of offset and neutral zone. (6 marks)
- (b) The temperature of heating process is controlled by an on-off controller. When the heater is *on*, the temperature rises at  $0.5^\circ$  celcius per minute. When the heater is *off*, the temperature drop at  $0.2^\circ$  celcius per minute. The setpoint or the input is  $80^\circ$  celcius and the neutral zone is  $\pm 5\%$  of the setpoint. There is a 2 min lag at the *on* and *off* switch points. With proper calculation and sketching, prove that the period of oscillation of the system is equal to 65.8 minutes. (14 marks)

- Q5** (a) The schematic diagram of a Direct Current (DC) motor is shown in **Figure Q5(a)**. The DC motor is controlled by armature voltage. Assume that the DC motor is in 'no-load' condition. Given that,

$$x_1(t) = i_a(t)$$

$$x_2(t) = \theta_m(t)$$

$$x_3(t) = \omega_m(t)$$

$$y(t) = \theta_m(t) = x_2(t)$$

$$u(t) = v_a(t)$$

Construct the state equation and the output equation in matrix form for the DC motor.

(10 marks)



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- (b) A single input single output control system can be represented by the state equation and output equation respectively as  $\dot{\underline{x}}(t) = A\underline{x}(t) + B\underline{u}(t)$  and  $y(t) = C\underline{x}(t)$ , where the matrices  $A$ ,  $B$  and  $C$  are given respectively by:

$$A = \begin{bmatrix} -2 & -5 \\ 1 & 0 \end{bmatrix}, \quad B = \begin{bmatrix} 2 \\ 0 \end{bmatrix} \quad \text{and} \quad C = [1 \quad 0]$$

The system is subjected to a unit step input,  $\frac{1}{s}$  and the initial states are given by  $\underline{x}(0) = [0 \quad 0]^T$ . Produce the output equation,  $y(t)$  for the system.

(10 marks)

- END OF QUESTIONS -

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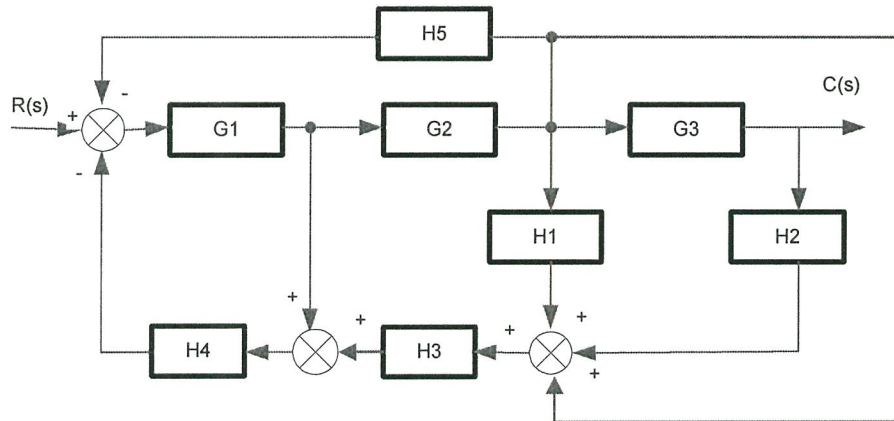


Figure Q1(c)

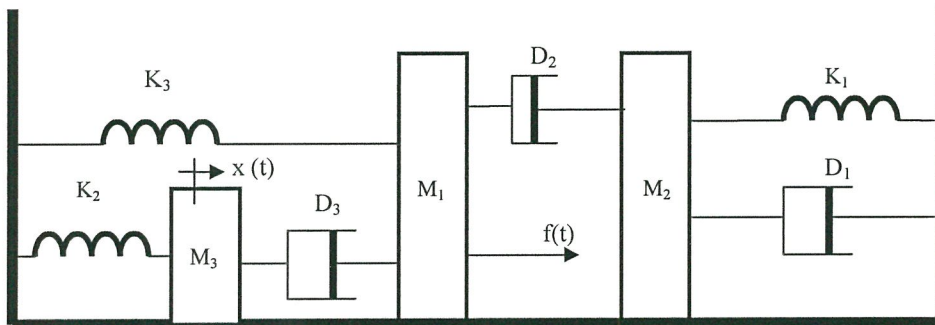


Figure Q2(c)

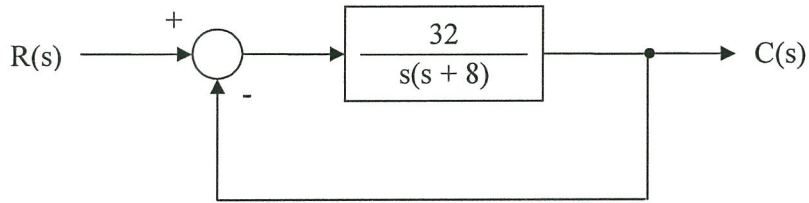
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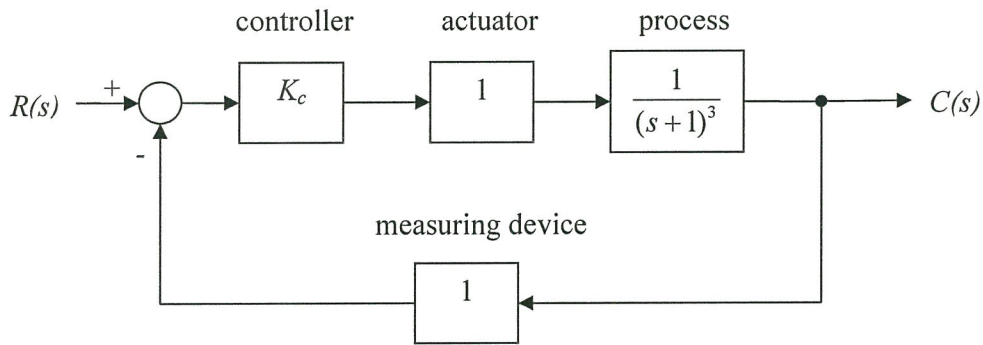
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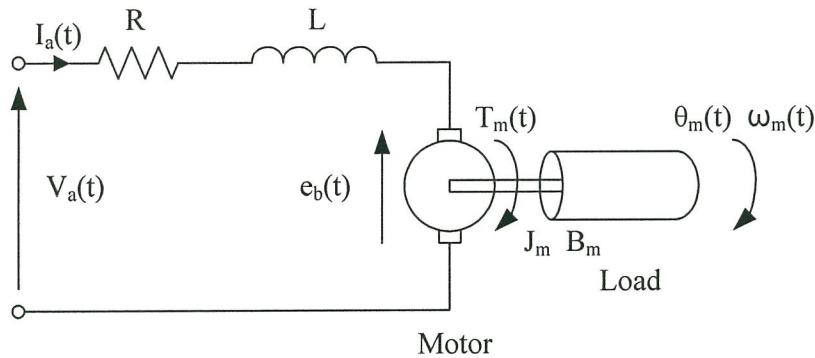
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**Figure Q3(b)**



**Figure Q3(c)**



**Figure Q5(a)**

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**FORMULAE**

**Table A**  
 Laplace transform table

$f(t)$	$F(s)$
$\delta(t)$	1
$u(t)$	$\frac{1}{s}$
$tu(t)$	$\frac{1}{s^2}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$
$e^{-at} u(t)$	$\frac{1}{s+a}$
$\sin \omega t u(t)$	$\frac{\omega}{s^2 + \omega^2}$
$\cos \omega t u(t)$	$\frac{s}{s^2 + \omega^2}$
$e^{-at} \sin \omega t u(t)$	$\frac{\omega}{(s+a)^2 + \omega^2}$
$e^{-at} \cos \omega t u(t)$	$\frac{(s+a)}{(s+a)^2 + \omega^2}$

**Table B**  
 Laplace transform theorems

Name	Theorem
Frequency shift	$\mathcal{L}[e^{-at} f(t)] = F(s+a)$
Time shift	$\mathcal{L}[f(t-T)] = e^{-sT} F(s)$
Differentiation	$\mathcal{L}\left[\frac{d^n f}{dt^n}\right] = s^n F(s) - \sum_{k=1}^n s^{n-k} f^{(k-1)}(0^-)$
Integration	$\mathcal{L}\left[\int_0^t f(\tau) d\tau\right] = \frac{F(s)}{s}$
Initial value	$\lim_{t \rightarrow 0} f(t) = \lim_{s \rightarrow \infty} sF(s)$
Final value	$\lim_{t \rightarrow \infty} f(t) = \lim_{s \rightarrow 0} sF(s)$

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**Table C**

2<sup>nd</sup> Order prototype system equations

$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$	$T_r = \frac{\pi - \cos^{-1} \zeta}{\omega_n \sqrt{1 - \zeta^2}}$
$\mu_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$	$T_p = \frac{\pi}{\omega_n \sqrt{1 - \zeta^2}}$
$T_s = \frac{4}{\zeta\omega_n} \text{ (2\% criterion)}$	$T_s = \frac{3}{\zeta\omega_n} \text{ (5\% criterion)}$

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