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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

COURSE NAME	:	CONTROL SYSTEM THEORY
COURSE CODE	:	BEH 30603
PROGRAMME CODE	:	BEJ/BEV
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

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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:

$M_1 = M_2 = M_3 = 1$ Kg
$D_1 = D_2 = D_3 = 2$ N-s/m
$K_1 = K_2 = K_3 = 1$ N/m

(14 marks)

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 steam distillation system is controlled by an on-off controller. When the heater is *on,* the temperature rises at 0.5° celcius per minute. When the heater is *off,* the temperature drop at 0.2° celcius per minute. The setpoint or the input, is 80° celcius and the neutral zone is ±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 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)

(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:

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

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 –

TERBUKA

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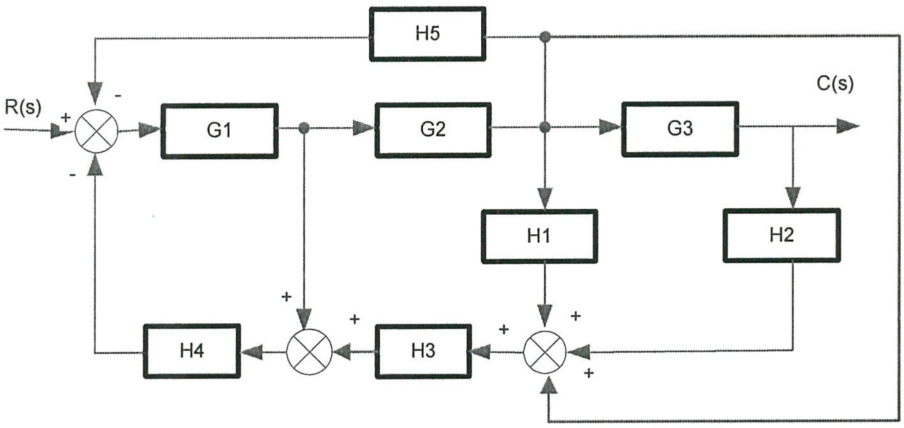

Figure Q1(c)

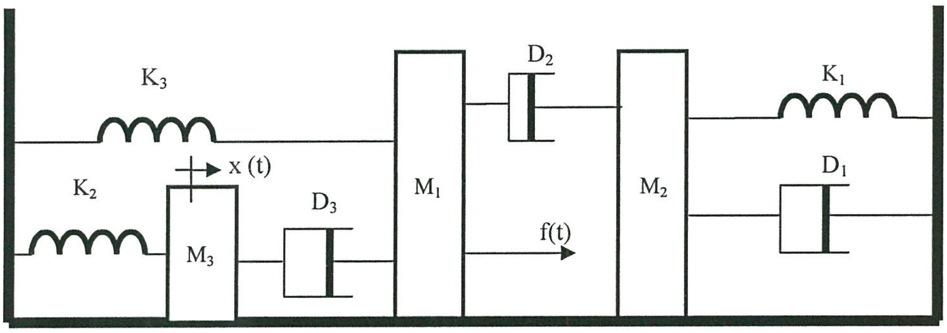

Figure Q2(c)

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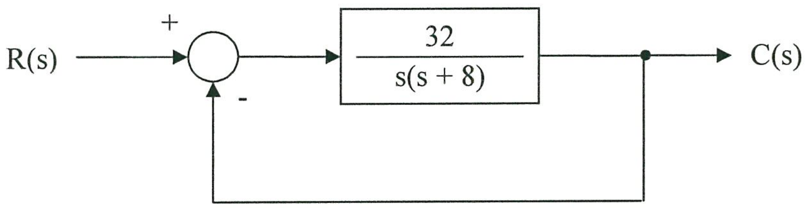

Figure Q3(b)

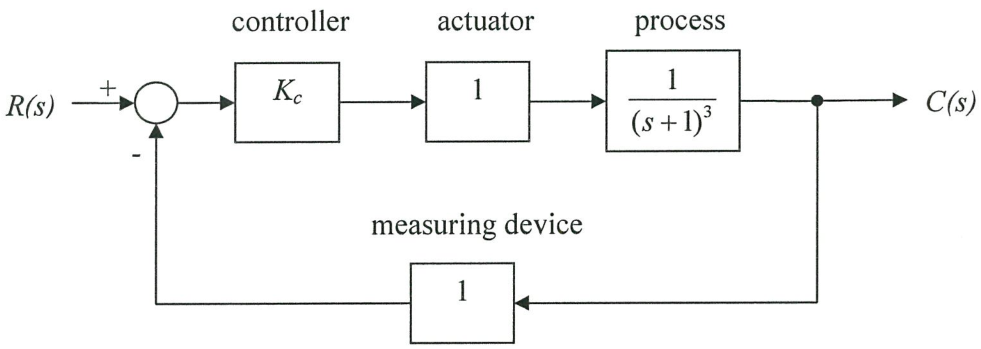

Figure Q3(c)

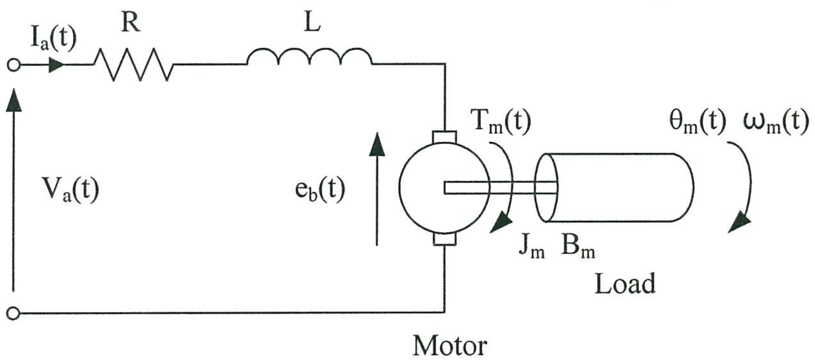

Figure Q5(a)

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

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Table C

2^{nd} Order prototype system equations

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