Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	CONTROL SYSTEM
COURSE CODE	:	BNR 37502
PROGRAMME CODE	:	BND/BNE/BNF
EXAMINATION DATE	:	JULY/AUGUST 2023
DURATION	:	2 HOURS
INSTRUCTIONS	1.	ANSWER **ALL** QUESTIONS
	2.	THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.**
	3.	STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

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

Q1 (a) **Figure Q1 (a)** shows step responses of different variations of PID controllers (P, PI, PD, PID).

(i) State number of step response that belongs to the PD-controller.

(2 marks)

(ii) Discuss the difference between PD and PI controller effect.

(4 marks)

(iii) Name **THREE (3)** PID components that affect the time response.

(3 marks)

(b) **Figure Q1 (b)** depicts a block diagram for a control system.

(i) Define stability concept in control engineering.

(2 marks)

(ii) Find the closed-loop transfer function.

(3 marks)

(iii) Analyse the stability of system using Routh table method.

(11 marks)

Q2 (a) Block diagram of a feedback control system is shown in **Figure Q2 (a)**.

(i) Draw the Signal Flow Graph (SFG).

(4 marks)

(ii) Find the transfer function, $G(s) = \frac{C(s)}{R(s)}$ using Mason's Rule.

(8 marks)

(b) An autonomous ground vehicle uses a servomotor as an actuator for navigation control. The block diagram of the control system is given in **Figure Q2 (b)**.

(i) Explain the use of block diagram.

(3 marks)

(ii) Determine the transfer function of C(s)/R(s) using block diagram reduction.

(10 marks)

Q3 (a) The electrical system in time domain is shown in **Figure Q3 (a)** with the applied voltage $v_i(t)$ as the input and $v_o(t)$ as the output.

(i) Draw electrical system in Laplace domain.

(2 marks)

(ii) Find the transfer function, $G(s) = \frac{V_0(s)}{V_i(s)}$ using mesh analysis.

(8 marks)

(b) Obtain the transfer function $G(s) = \frac{X(s)}{F(s)}$ of the translational mechanical system as shown in **Figure Q3 (b)** with a free body diagram.

(5 marks)

(c) Determine the ramp response in time domain for below transfer function of a system.

$$G(s) = \frac{5s}{(s-2)(s+3)^2}$$

(10 marks)

Q4 (a) **Figure Q4 (a)** shows a time response of a system.

(i) State the order of the system.

(2 marks)

(ii) Briefly explain **TWO (2)** main components in the time response.

(4 marks)

(b) A rotational mechanical system as shown in **Figure Q4 (b)** can be modelled using Laplace transform.
Let $K = 5\ N - m/rad$, $J = 0.26\ kg - m^2$ and $D = 1.04\ N - \mathrm{m} - \mathrm{s/rad}$.

(i) Draw an equivalent diagram.

(4 marks)

(ii) Generate a transfer function of $G(s) = \frac{\theta(s)}{T(s)}$.

(5 marks)

(iii) Find ζ , ω_n, T_p, T_s, and % OS.

(10 marks)

– END OF QUESTIONS –

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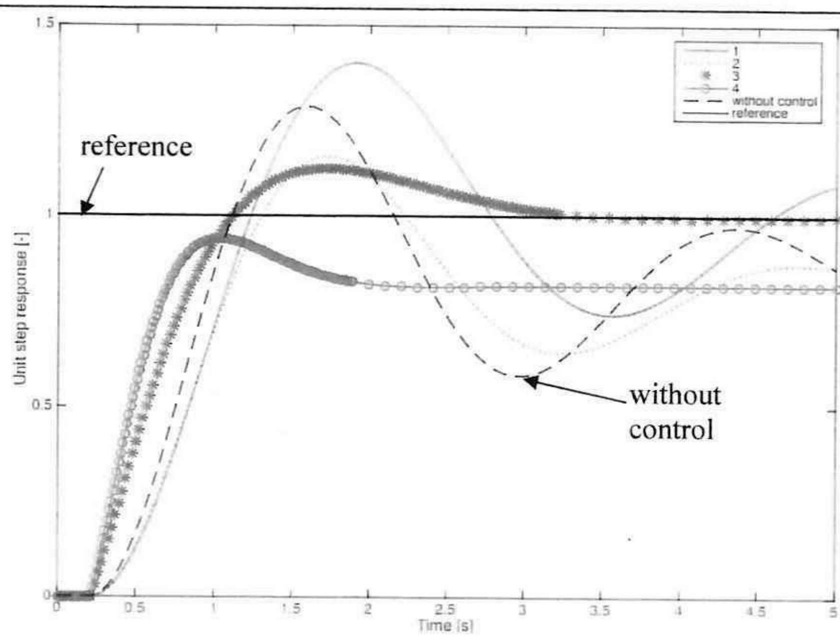

Figure Q1 (a)

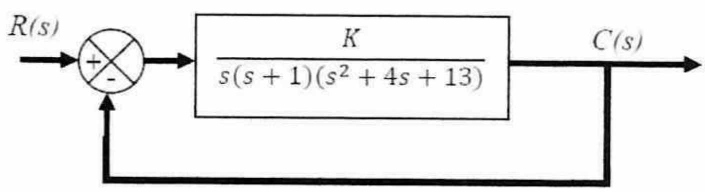

Figure Q1 (b)

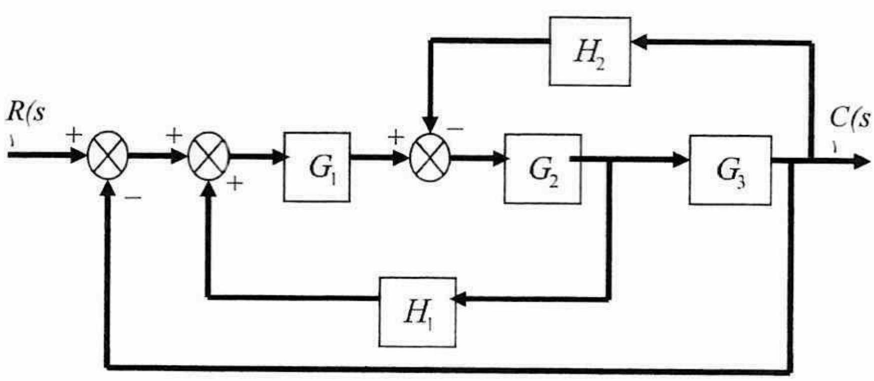

Figure Q2 (a)

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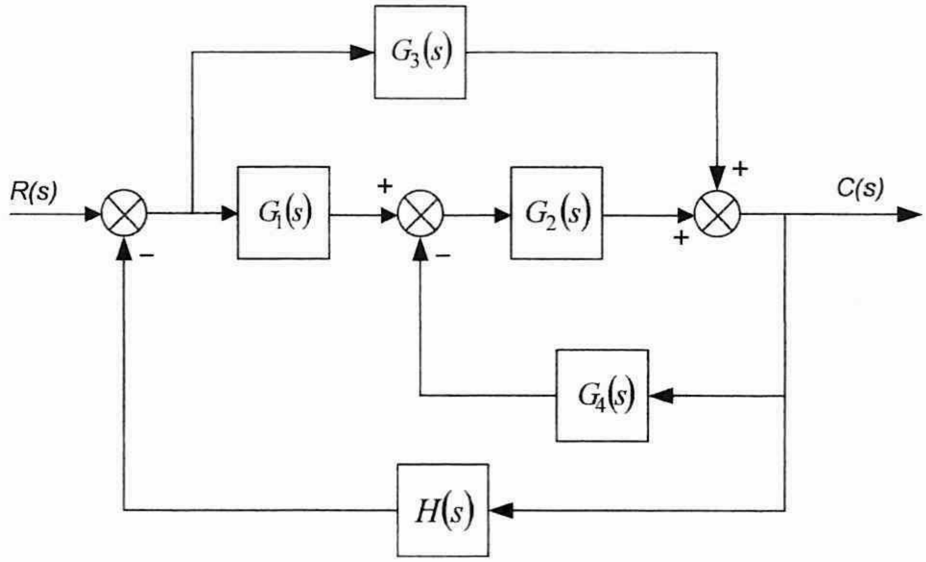

Figure Q2 (b)

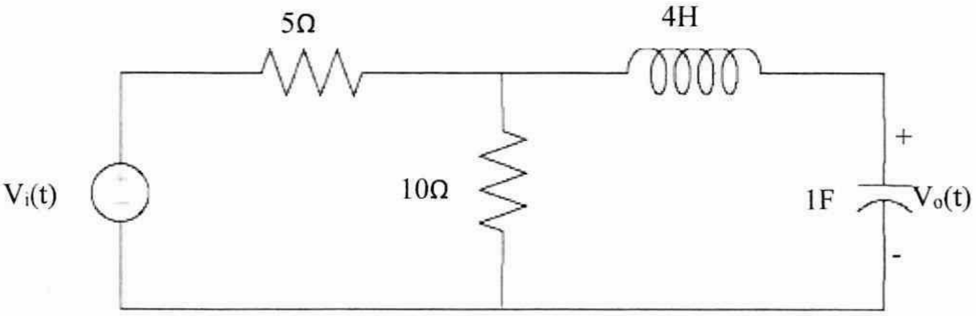

Figure Q3 (a)

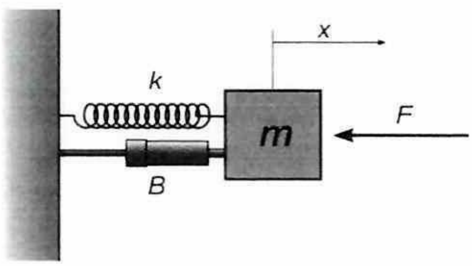

Figure Q3 (b)

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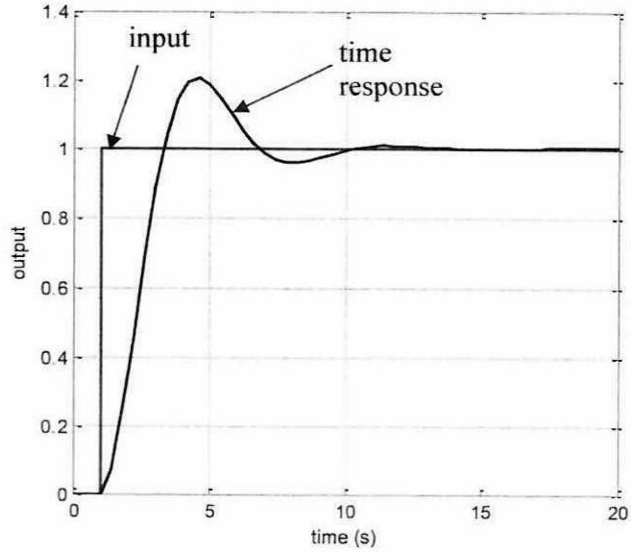

Figure Q4 (a)

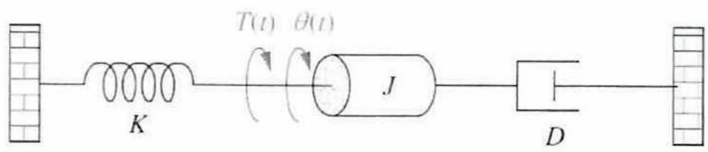

Figure Q4 (b)

APPENDIX

I. TIME RESPONSE TABLE

$\xi = \dfrac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}}$	$T_p = \dfrac{\pi}{\omega_n\sqrt{1-\xi^2}}$ (sec)	$T_s = 4\tau = \dfrac{4}{\zeta\omega_n}$ (sec)
$T_r = \dfrac{2.16\zeta + 0.60}{\omega_n}$ (sec)	$OS = 100e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$ (%)	$M_{pt} = 1 + e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$

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II. LAPLACE TRANSFORM TABLE

No.	*f(t)*	*F(s)*	
1.	$\delta(t)$	1	Unit Impulse Function
2.	$u(t)$	$\frac{1}{s}$	Unit Step Function
3.	$tu(t)$	$\frac{1}{s^2}$	Unit Ramp Function
4.	$t^n u(t)$	$\frac{n!}{s^{n+1}}$	
5.	$e^{-at}u(t)$	$\frac{1}{s+a}$	
6.	$te^{-at}u(t)$	$\frac{1}{(s+a)^2}$	
7.	$t^n e^{-at}u(t)$	$\frac{n!}{(s+a)^{n+1}}$	
8.	$(1-at)e^{-at}u(t)$	$\frac{s}{(s+a)^2}$	
9.	$\frac{1}{a}[1-e^{-at}u(t)]$	$\frac{1}{s(s+a)}$	
10.	$sin\,\omega t\,u(t)$	$\frac{\omega}{s^2+\omega^2}$	
11.	$cos\,\omega t\,u(t)$	$\frac{s}{s^2+\omega^2}$	
12.	$e^{-at}\,sin\,\omega t\,u(t)$	$\frac{\omega}{(s+a)^2+\omega^2}$	
13.	$e^{-at}\,cos\,\omega t\,u(t)$	$\frac{s+a}{(s+a)^2+\omega^2}$	

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III. LAPLACE TRANSFORM THEOREMS

No.	*Theorem*	*Name*
1.	$\mathcal{L}[f(t)] = F(s) = \int_0^\infty f(t)e^{-st}dt$	*Laplace definition*
2.	$\mathcal{L}[kf(t)] = kF(s)$	*Linearity Theorem*
3.	$\mathcal{L}[f_1(t) + f_2(t)] = F_1(s) + F_2(s)$	*Linearity Theorem*
4.	$\mathcal{L}[e^{-at}f(t)] = F(s+a)$	*Frequency Shift Theorem*
5.	$\mathcal{L}[f(t-T)] = e^{-sT}F(s)$	*Time Shift* (T) *Theorem*
6.	$\mathcal{L}[f(at)] = \frac{1}{a}F\left(\frac{s}{a}\right)$	*Scaling Theorem*
7.	$\mathcal{L}\left[\frac{df(t)}{dt}\right] = sF(s) - f(0^-)$	*Differentiation Theorem*
8.	$\mathcal{L}\left[\frac{d^2f(t)}{dt^2}\right] = s^2F(s) - sf(0^-) - f'(0^-)$	*Differentiation Theorem*
9.	$\mathcal{L}\left[\frac{d^nf(t)}{dt^n}\right] = s^nF(s) - \sum_{k=1}^{n} s^{n-k} f^{k-1}(0^-)$	*Differentiation Theorem (in general)*
10.	$\mathcal{L}\left[\int_0^t f(\tau)d\tau\right] = \frac{F(s)}{s}$	*Integration Theorem*
11.	$f(\infty) = \lim_{s\to 0} sF(s)$	*Final Value Theorem*
12.	$f(0^+) = \lim_{s\to\infty} sF(s)$	*Initial Value Theorem*