UNIVERSITI TUN HUSSEIN ONN MALAYSIA
FINAL EXAMINATION
SEMESTER II
SESI 2021/2022

COURSE NAME	: CONTROL SYSTEM DESIGN
COURSE CODE	: BDC 40103
PROGRAM ME CODE	: BDD
EXAMINATION DATE	: JULY 2022
DURATION	: 3 HOURS
INSTRUCTION	: 1) **PART A** : ANSWER **ALL** QUESTIONS **PART B** : ANSWER **TWO (2)** QUESTIONS ONLY 2) THIS FINAL EXAMINATION IS CONDUCTED VIA CLOSED BOOK. 3) STUDENTS ARE PROHIBITED TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RECOURSES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

PART A: ANSWER ALL QUESTIONS

Q1 **Figure Q1** shows a spring-mass-damper system with two mass, m, k_1 and k_2 are the spring coefficient, and b is damping coefficient of the system. $f_a(t)$ is the force acting on mass m. The system is given with input f_a; and the desired output is z

(a) Define all equations related to this system. (8 marks)

(b) Obtain the state variable differential matrix equation using state space methods. (11 marks)

(c) Determine the transfer function of the system. (6 marks)

Q2 (a) State **FOUR (4)** steps to design lag-lead compensator with Bode diagram plots.

(6 marks)

(b) The control system of robot manipulator has open loop transfer function as follows:

$G_p(s)=280(s+0.5)/s(s+0.2)(s+5)(s+70)$

(i) Plot the Bode diagram on a semi-log graph paper. (8 marks)

(ii) Design a **lag-lead compensator** with the specifications:

- Phase Margin, $PM_{specified} \geq 55°$;
- Steady State Error, $ess_{\_specified} = 0.02$ for ramp input;
- Gain crossover frequency $\omega_{x\_specified} = 5$ rad/s.

(7 marks)

(iii) Compare your results of the system's stability with and without controller in **Table Q2**. (4 marks)

PART B: ANSWER TWO (2) QUESTIONS ONLY

Q3 (a) Ziegler and Nichols proposed rules for determining values of the K_p, T_i and T_d based on the transient response characteristics of a given plant. Explain **TWO (2)** methods of Ziegler–Nichols tuning rules.

(8 marks)

(b) Consider the control system shown in **Figure Q3**. Apply a Ziegler–Nichols tuning rule for the determination of the values of parameters K_p, T_i and T_d. (Given **Table Q3** as references.)

(17 marks)

Q4 (a) (i) Describe the integrated full-state feedback and observer block diagram. (3 marks)

(ii) From diagram obtained in part **Q4 (a) (i)**, prove that the equation of feedback law and observer for the compensator system is given by:

$$\hat{\dot{x}} = (\mathbf{A}\text{-}\mathbf{BK}\text{-}\mathbf{LC})\hat{x} + \mathbf{L}y$$

$$u = -\mathbf{K}$$

(5 marks)

(b) Consider the system represented in state variable form:

$$\dot{x} = \begin{bmatrix} -10 & 0 \\ 1 & 0 \end{bmatrix} x + \begin{pmatrix} 1 \\ 0 \end{pmatrix} u$$

$$y = [0 \ \ 1]x + [0]u$$

(i) Verify that the system is observable and controllable. (3 marks)

(ii) Determine the state variable feedback gains to achieve a settling time (with a 2% criterion) of one second and an overshoot of about 10%. (7 marks)

(iii) Sketch the block diagram of the resulting system. (4 marks)

(iv) Examine an observer by placing the closed loop system poles at $s_{1,2} = -3 \pm j5$. (3 marks)

Q5 (a) Describe **THREE (3)** common circumstances under which adaptive control can be preferred over classical PID controllers.

(3 marks)

(b) The block diagram shown in **Figure 5(b)** shows a gain scheduling adaptive control strategy.

(i) Explain why such an approach is called gain scheduling (3 marks)

(ii) The system can be viewed as having two loops. Explain these two loops, and justify the advantages and drawbacks of such an approach.

(7 marks)

(c) (i) Define the system sensitivity? (2 marks)

(ii) In robust control system, explain the principal of sensitivity to the variation of parameter which refer to changes in the feedback element H(s). (3 marks)

(d) **Figure 5 (d)** shows robust Control of Temperature Using PID Controller which employing ITAE performance for a step input and a settling time of less than 0.5 seconds. Examine $G_p(s)$ if $G_c(s)$ is PID controller and $G(s)=1/(s+1)^2$. Select the optimum coefficients of the characteristic equation for ITAE is $s^3 + 1.7s^2 + 2.15{w_n}^2 s + {w_n}^3$, where w_n=10 and ζ=0.8.

(7 marks)

- END OF QUESTION –

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SEMESTER/SESSION :II/2021/2022 PROGRAMME: BDD

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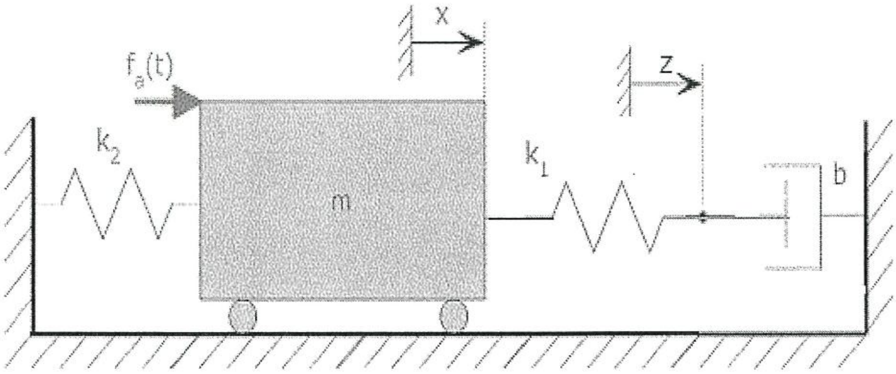

Figure Q1

Table Q2

	Gain Margin GM, (dB)	Phase Margin, PM (°)
Without compensator		
With Lag-lead compensator		

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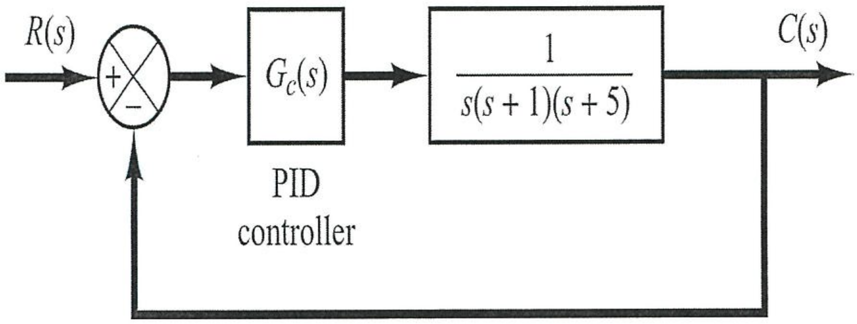

Figure Q3

Table Q3

Type of Controller	K_p	T_i	T_d
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$\frac{1}{1.2}P_{cr}$	0
PID	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

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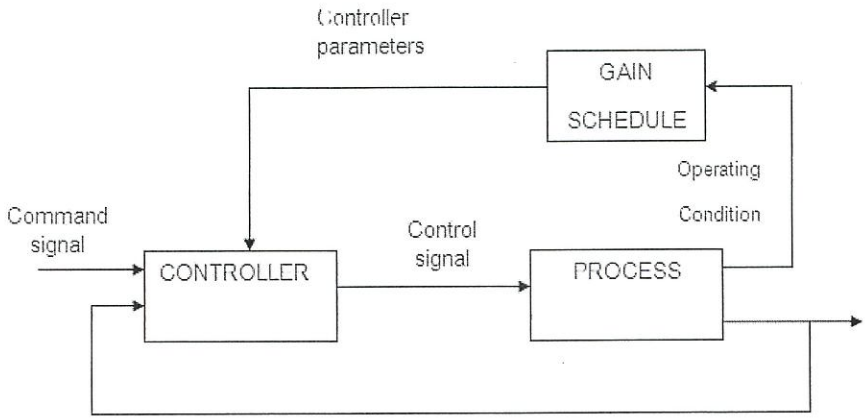

Figure 5(b)

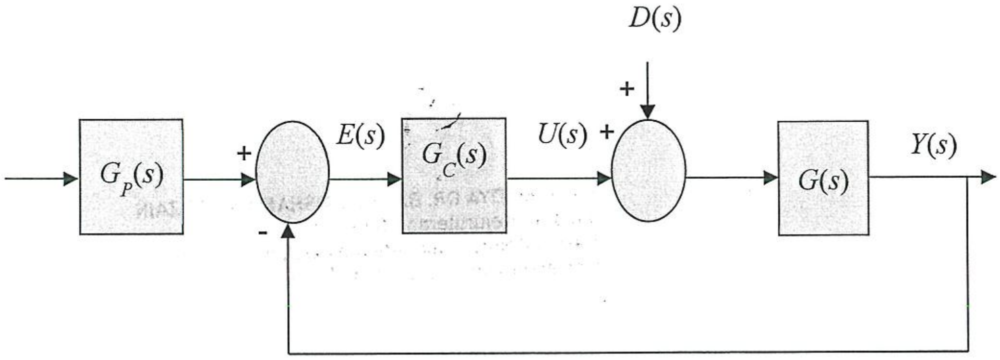

Figure 5(d)