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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	CONTROL SYSTEM DESIGN
COURSE CODE	:	BDC 40103
PROGRAMME CODE	:	BDD
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. PART A: ANSWER ALL QUESTIONS 2. PART B: ANSWER **TWO (2)** QUESTIONS FROM THREE (3) QUESTIONS 3. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 4. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES

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

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PART A:

Instructions: ANSWER ALL QUESTIONS

Q1 (a) As the state equation in the following form

$$\dot{\vec{x}} = A\vec{x} + B\vec{u}$$
$$\vec{y} = C\vec{x} + D\vec{u}$$

Adapt state equations to a transfer function, $\frac{y(s)}{u(s)}$ by using Laplace Transform.

(4 marks)

(b) **Figure Q1.1** 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 actingon mass m. The system is given with input f_a; and the desired output is z.

(i) Define all equations related to this system.

(8 marks)

(ii) Obtain the state variable differential matrix equation using state space methods.

(7 marks)

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

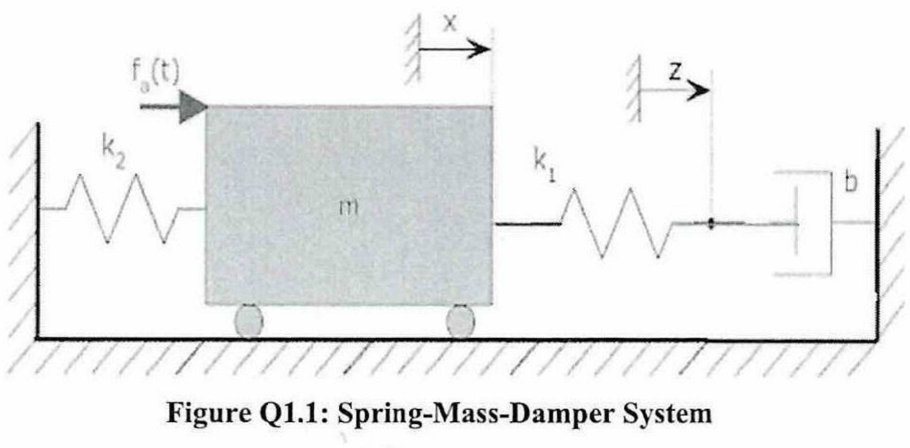

Figure Q1.1: Spring-Mass-Damper System

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

(6 marks)

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

$$Gp(s) = \frac{260}{s(s+1)(s+0.5)(s+10)(s+50)}$$

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

(8 marks)

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

- Phase Margin, $PM_{specified} \geq 45^{\circ}$;
- Steady State Error, $ess\_{specified} = 0.05$ for ramp input;
- Gain crossover frequency $\omega_{x\_specified} = 7$ rad/s.

(7 marks)

(iii) Evaluate your results of the system's stability with and without controller.

(4 marks)

PART B:

Instructions: ANSWER TWO (2) QUESTIONS FROM THREE (3) QUESTIONS

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 one **(1)** method of Ziegler–Nichols tuning rules.

(8 marks)

(b) Consider the control system shown in **Figure Q3.1**. Apply a Ziegler–Nichols tuning rule for the determination of the values of parameters Kp, Ti and Td.

(17 marks)

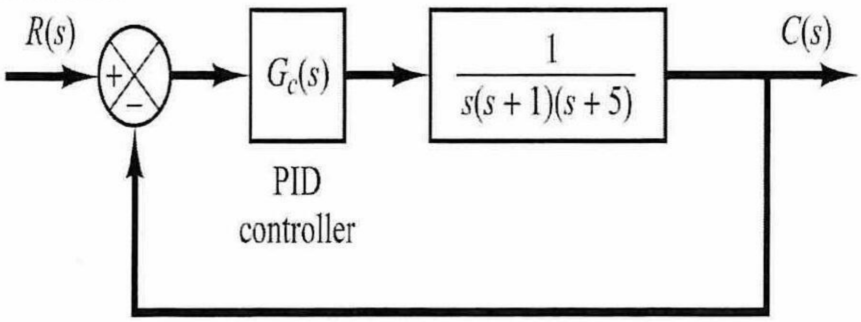

Figure Q3.1: Control System

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:

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

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

(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 $s_{1,2} = -1 \pm j5$.

(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 Q5.1** shows a model reference adaptive systems (MRAS) in scheduling adaptive control strategy.

(i) Explain why such an approach is called model reference adaptive systems (MRAS).

(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)

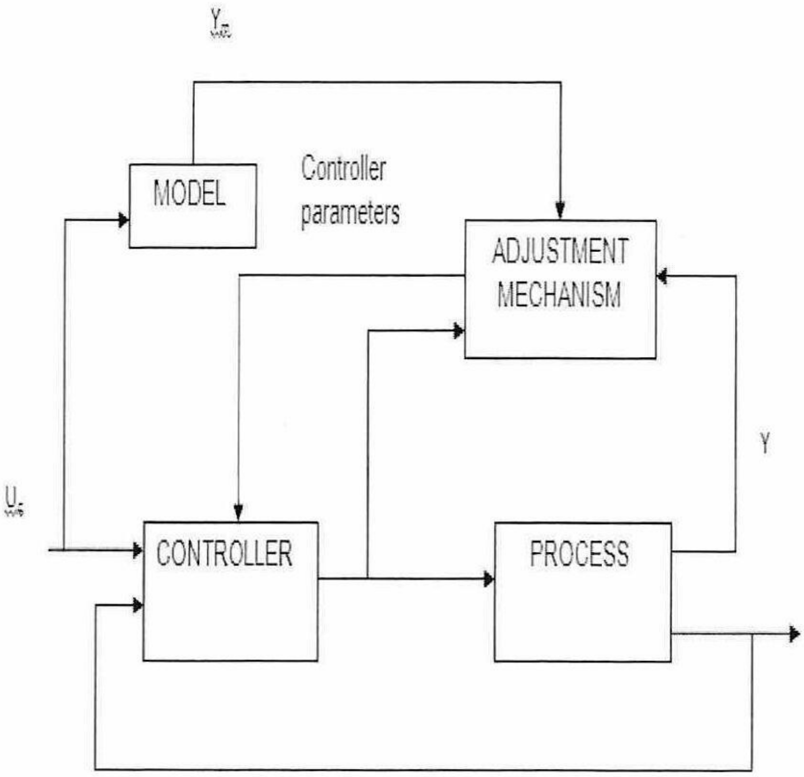

Figure Q5.1: Model Reference Adaptive System (MRAS) control strategy

(c) In robust control system, explain the principal of sensitivity to the variation of parameter which refer to changes in the feedback element H(s). (5 marks)

Q5 (d) **Figure Q5.2** shows robust Control of Pressure Using PID Controller which employing ITAE performance for a step input and a settling time of less than 0.3 seconds. Examine $G_p(s)$ if $G_c(s)$ is PID controller and $G(s) = \frac{2}{(s+1)}$. Select the optimum coefficients of the characteristic equation for ITAE is $s^3 + 1.7w_n s^2 + 2.15w_n^2 s + w_n^3$, where w_n=10 and ζ=0.8.

(10 marks)

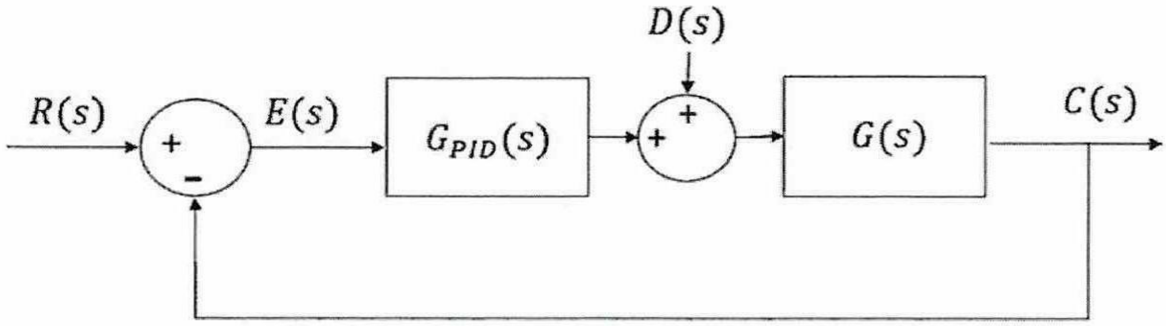

Figure Q5.2

- END OF QUESTIONS -

APPENDIX A

$$G_c(s) = K_c \alpha \frac{Ts + 1}{\alpha Ts + 1} = K_c \frac{s + \frac{1}{T}}{s + \frac{1}{\alpha T}}, \qquad (0 < \alpha < 1)$$

Figure APPENDIX A.1

APPENDIX B

Table APPENDIX B.1

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	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$