UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESI 2018/2019

COURSE	: CONTROL SYSTEM DESIGN
CODE	: BDC 40103
PROGRAM ME	: BDD
EXAMINATION DATE	: JUNE/JULY 2019
DURATION	: 3 HOURS
INSTRUCTION	: **PART A** : ANSWER **ALL** QUESTIONS **PART B** : ANSWER **TWO (2)** QUESTIONS ONLY

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

PART A: ANSWER ALL QUESTIONS

Q1 **Figure Q1** shows a spring-mass-damper and pulley system with two masses, M_1 and M_2 where K_s is the spring coefficient, and K_d is damping coefficient of the system. The system is given with input x_1; and the desired output is x_2. In this system the upper mass, M_1, is between a spring and a cable and there is viscous damping, B between the mass and the floor. The suspended mass, M_2, is between the cable and a damper. The cable runs over a massless, frictionless pulley.

(a) Define all equations related to this system. (10 marks)

(b) Obtain the state variable differential matrix equation using state space methods. (10 marks)

(c) Determine the transfer function of the system. (5 marks)

Q2 (a) Explain how to define stability with root locus plot in control system design. (5 marks)

(b) Consider the control system of machine to wind copper wire onto the rotors of small motors. It is important that the windings be consistent and the DC motor is used to achieve accurate rapid windings as shown in **Figure Q2 (a)**. **Figure Q2 (b)** shows the block diagram of the controller and the system.

(i) If $G_c(s)$ is the **Lead** controller, examine the compensator with root locus if dominant poles damping ratio $\zeta = 0.6$ and dominant poles time constant $\tau = 0.5$ seconds. This system has zero steady-state error (e_{ss}) for a step input and the steady-state error for a ramp input is $e_{ss} = 1/Kv$, where $k_v = \lim_{s-0} G_c(s)/50$.

(8 marks)

(ii) **Lead** controller, $G_c(s)$ is replaced with **lag** controller with the same specification. Examine the Lag controller transfer function.

(6 marks)

(ii) Evaluate the performance of the controller if it is use the **Lead-lag** compensator. (6 marks)

PART B: ANSWER TWO (2) QUESTIONS ONLY

Q3 (a) (i) Describe the integrated full-state feedback and observer block diagram. (3 marks)

(ii) From diagram obtained in part **Q3 (a) (i)**, prove that the equation of feedback law and observer for the compensator system is given by:

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

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

(5 marks)

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

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

$$\mathrm{y} = [0 \quad 1]\mathrm{x} + [0]\mathrm{u}$$

(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)

Q4 (a) Sketch the Bode diagram to explain the stability of the system. (5 marks)

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

$$KGH(s) = \frac{60}{(s+1)(s+2)(s+3)}$$

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

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

- Phase Margin, $PM_{specified} \geq 50^{\circ}$;
- Steady State Error, $ess_{\_specified} = 0.02$ for ramp input. (8 marks)

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

Q5 (a) Give **FOUR (4)** advantages of Digital controllers.

(4 marks)

(b) Given the system shown in **Figure Q5**, with $G(z) = Z[Go(s)Gp(s)]$ and $Go(s)=\frac{1-e^{-sT}}{s}$ and $Gp(s)=\frac{5}{s(s+20)}$. Given sampling time period is typically 100 μs to 1 ms. Determine the digital controller, D(z) of the system.

(9 marks)

(c) Differentiate the stability of the following characteristic equation using Jury Stability test.

$$1+G(z)=z^4-1.2z^3+0.07z^2+0.3z-0.08$$

(12 marks)

- END OF QUESTION –

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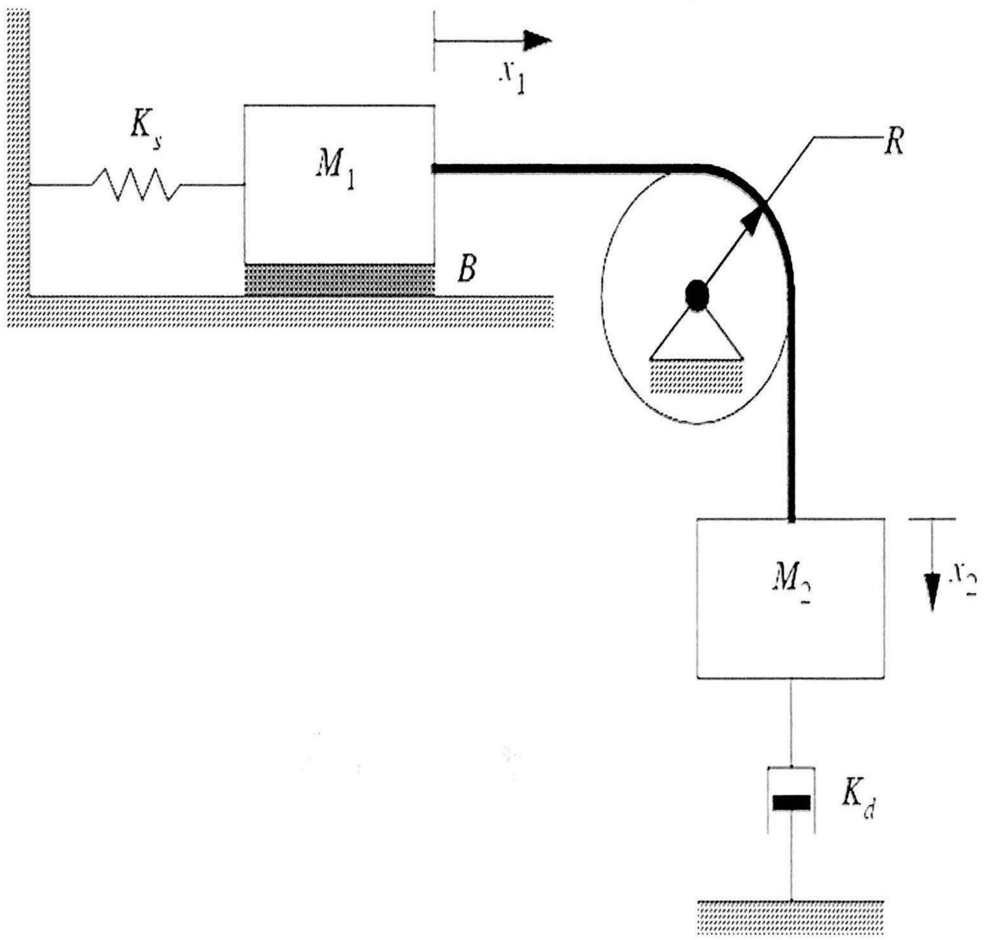

Figure Q1

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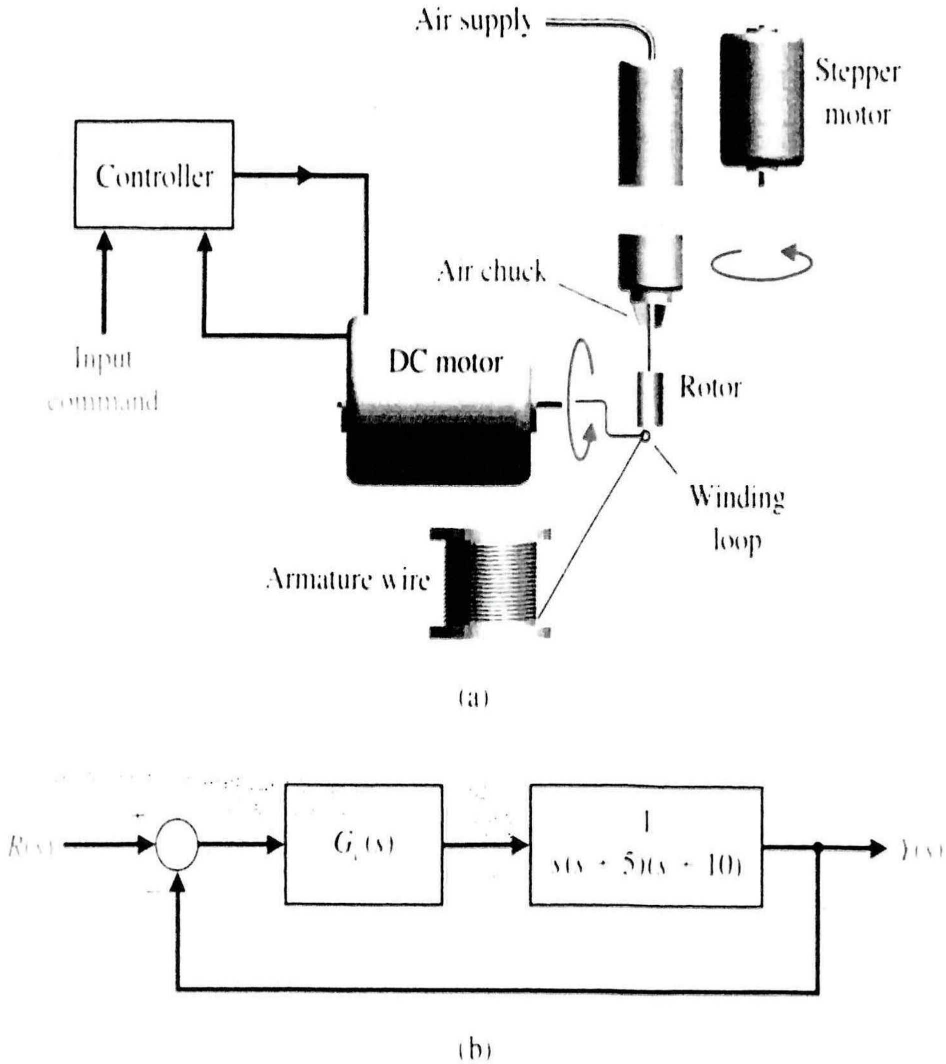

Figure Q2

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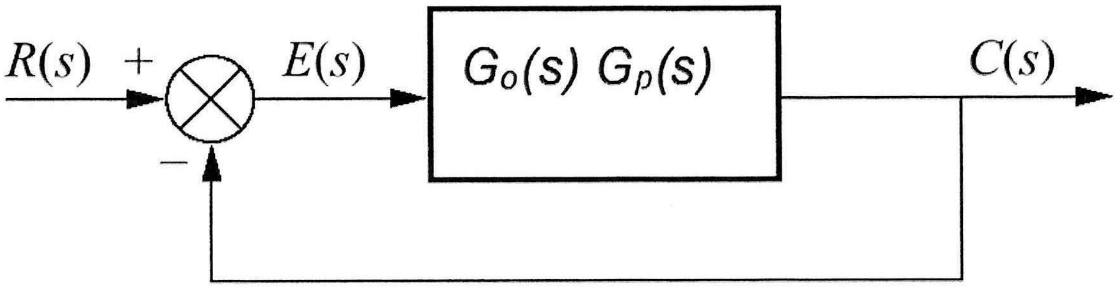

Figure Q5