

MASTER OF ENGINEERING ELECTRICAL ENGINEERING

1ST YEAR 1ST SEMESTER EXAMINATION, 2024

Subject: CONTROL SYSTEM ENGINEERING(CS)

Time: Three Hours

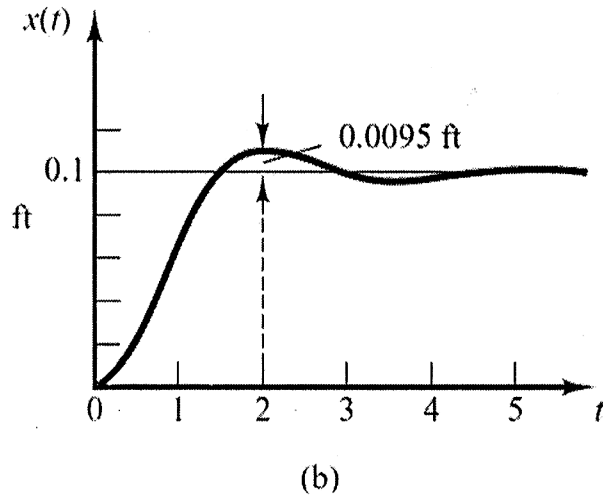
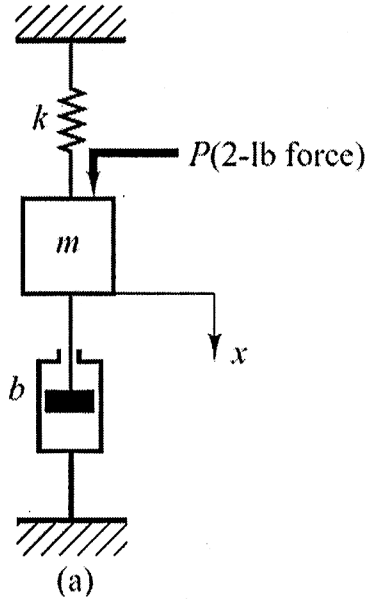
Full Marks: 100

Part I (50 marks)Use a separate answer-script for each partQuestion
No.Question 1 is compulsoryAnswer Any Two questions from the rest (2×20)

Marks

Q1 Answer *Any One* : (a) or (b)

- (a) A mechanical system, as shown in Figure Q1-(a), is subjected to 2 lb of force (step-input) at time $t=0$. The resulting response (displacement x in ft) exhibits a peak overshoot of 9.5% at time $t=2$ sec and finally settles down to a value of 0.1 ft as shown in Figure Q1-(b).



10

Figure Q1Determine m , b , and k of the system.The displacement x is measured from the point where spring and mass are at static equilibrium.

OR

[Turn over

Q1 (b) The block diagram of a control system is shown in Figure Q1(b) with

$$G(s) = \frac{100}{(1 + 0.1s)(1 + 0.5s)}$$

6+4

- (i) Find the step-, ramp-, and parabolic-error constants. Assume the system to be stable.
- (ii) Determine the minimum steady-state error that can be achieved with a unit-ramp input by varying the values of K and K_t .

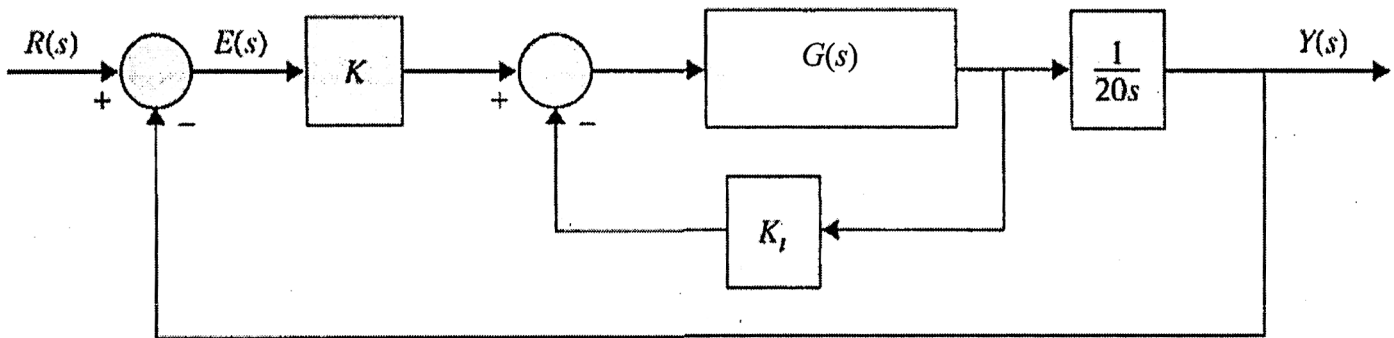


Figure Q1(b)

Q2 (a) Consider the system shown in Figure Q2(a), which involves velocity feedback. Determine the values of the amplifier gain K and the velocity feedback gain K_h so that the following specifications are satisfied:

14

- (i) Damping ratio of the closed-loop poles is 0.5.
- (ii) Settling time ≤ 2 sec.
- (iii) Static velocity error constant $K_v \geq 50 \text{ sec}^{-1}$.
- (iv) $0 < K_h < 1$.

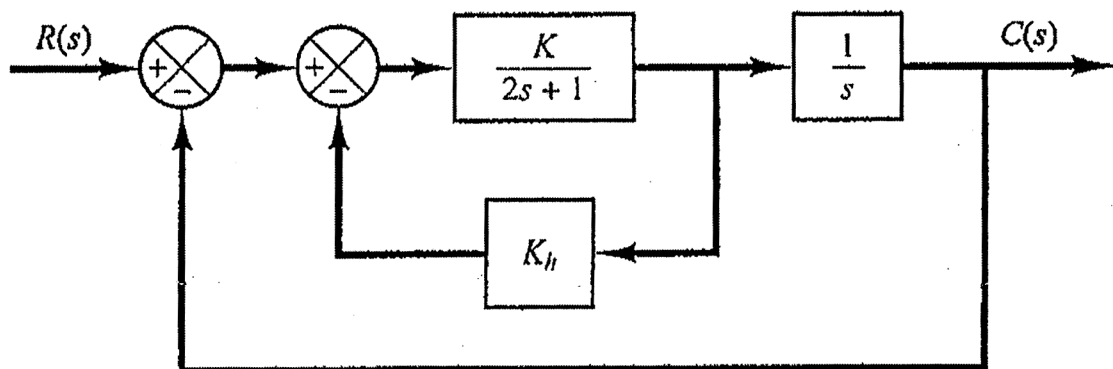


Figure Q2(a)

(b) Show that the root loci for a unity negative feedback system with

$$G(s) = \frac{K(s^2 + 6s + 10)}{s^2 + 2s + 10}$$

6

will be the arcs of a circle centered at the origin with radius $\sqrt{10}$.

- Q3 (a) Consider the system shown in Figure Q3(a). Plot the root loci as the value of k varies from 0 to ∞ .

8

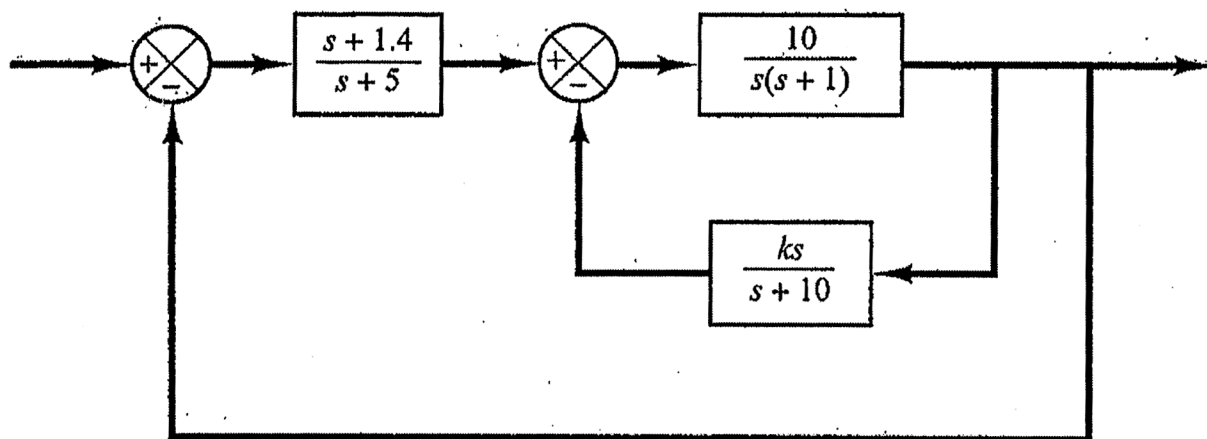


Figure Q3(a)

- (b) Consider the servo system with tachometer feedback shown in Figure Q3(b). Determine the ranges of stability for K and K_h . (K_h must be positive.)

6

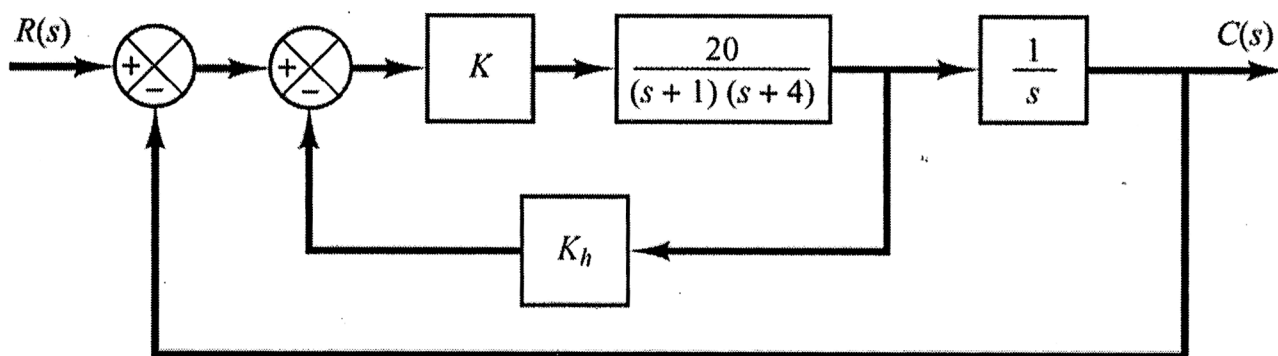


Figure Q3(b)

- (c) Show how the following aspects of a control system can be improved by feedback:
(i) speed of response, (ii) sensitivity to parameter variations.

3+3

- Q4 (a) Define "Type" of a system? For a unity feedback system define the following terms and find the expressions for steady-state error in response to Step, Ramp and Parabolic inputs in terms of these constants:

- Static position error constant
- Static velocity error constant
- Static acceleration error constant

2+6

- Q4 (b) A control system with a PD controller is shown in Figure Q4(b). Find (analytically) the values of K_P and K_D so that the ramp-error constant K_v is 1000 and the damping ratio is 0.5. 6

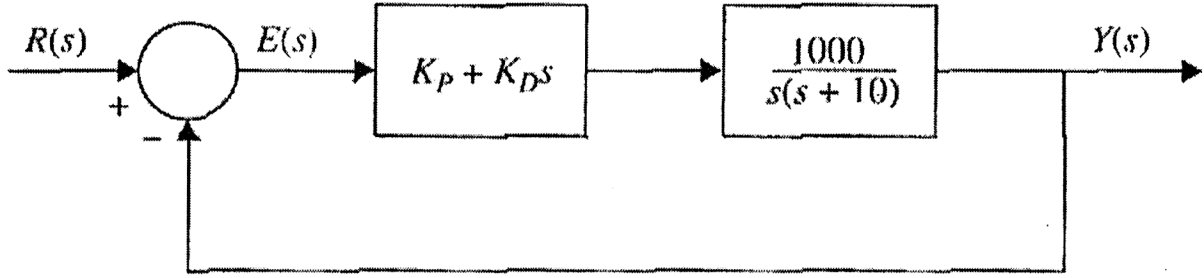


Figure Q4(b)

- (c) Obtain the transfer function of the electrical network shown in Figure Q4(c). Determine whether this is an electrical *lead network* or *lag network*? 4+2

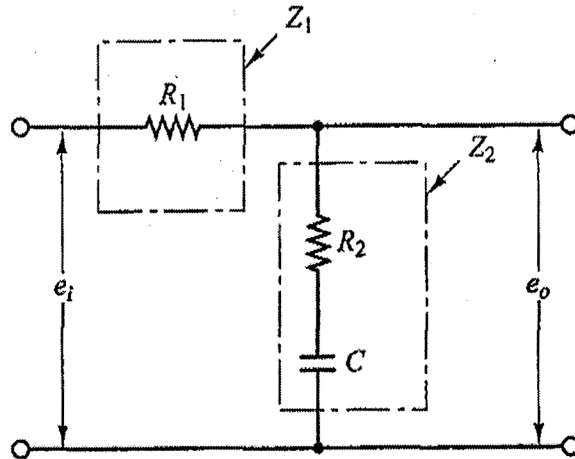


Figure Q4(c)

- Q5 (a) What is *Set Point Kick* phenomenon associated with PID Controllers? What are the components responsible for such behavior? 2+2
Show, with the help of block diagrams, how the PID control configuration needs to be modified to eliminate such phenomena. 6
- (b) Describe, stating the assumption, the Ziegler Nichols method of PID controller tuning based on unit step test. 4
- (c) Consider a control system in which a PID controller is used to control the plant 6

$$G(s) = \frac{1}{s(s+2)(s+4)}$$
Determine the parameters of PID controller by Ziegler-Nichols tuning rule.

MASTER OF ENGINEERING ELECTRICAL ENGINEERING**1ST YEAR 1ST SEMESTER EXAMINATION, 2024****Subject: CONTROL SYSTEM ENGINEERING(CS)****Time: Three Hours****Full Marks: 100****Part II** (50 marks)Question
No.Answer Any FIVE questions (5×10)

Marks

- Q1 (a) Comment, by inspection, on linearity and time-invariance property of the following system:

2

$$\ddot{y} + 5 \cos y + 2\dot{y} + y^2 = -u$$

- (b) For the following Matrix A:

$$\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

4+4

- (i) Find the eigenvalues
- $\lambda_1, \lambda_2, \lambda_3$
- and
- λ_4
- of the matrix A.

- (ii) Obtain a transformation matrix
- P
- , such that

$$P^{-1}AP = \text{diag}(\lambda_1, \lambda_2, \lambda_3, \lambda_4)$$

- Q2 (a) Consider the system defined by

$$\dot{x} = Ax + Bu, \quad y = Cx$$

where,

$$A = \begin{bmatrix} -2 & 0 & 1 \\ 1 & 2 & 0 \\ -1 & 0 & -4 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, \quad C = [1 \ 1 \ 0]$$

5+1

Derive the transfer function $Y(s)/U(s)$. Comment on the stability of the system.

- (b) Find
- $x_1(t)$
- and
- $x_2(t)$
- of the system described by

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -5 & -6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

where the initial conditions are

$$\begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix} = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

4

- Q3 (a) What is detectability?

1

- (b) Discuss Popov-Belevich-Hautus (PBH) test for observability.

2

- (c) Given a system in state equation form as

$$\dot{x} = Ax + Bu,$$

$$\text{with, } A = \begin{bmatrix} 3 & 1 \\ 0 & -2 \end{bmatrix} \text{ and } B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

7

Determine, with the help of Popov-Belevich-Hautus test the controllability of the system.

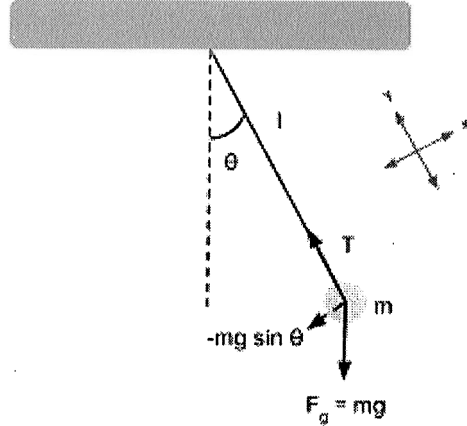
Q4 (a) State the difference between a Forced Equilibrium and a Natural Equilibrium. 2

- (b) Consider a simple pendulum system, as shown in the figure, with bob of mass m , string of length l .

Let the tension in the string be T at an angle θ .

(i) Derive the dynamical equation of the system.

(ii) Find out the equilibrium points and discuss their characteristics in terms of stability.



4+4

Q5 (a) A system is described by the following equation

$$\ddot{y} + 6\dot{y} + 11y + 6y = 6u$$

Obtain a state space representation of this system. Comment on controllability of the system.

3+2

(b) Consider a system defined by state equation

$$\dot{x} = Ax + Bu, \quad \text{with } A = \begin{bmatrix} 1 & -1 \\ 3 & 2 \end{bmatrix} \text{ and } B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

5

Design, using Ackermann's formula, a state feedback controller to place the closed-loop poles at $s = -2 \pm j0$.

Q6 (a) Draw the block diagram for full-order observer-based state feedback control scheme. 5

(b) Derive the equation to describe the error dynamics of a full-order observer. 5

Q7 A system is given by the following state and output equations

$$\dot{x} = Ax + Bu, \quad y = Cx,$$

$$\text{with } A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 2 \end{bmatrix} \text{ and } C = [1 \quad 0]$$

The system is compensated using a full-order observer based state-feedback control with the following desired criterion:

10

i. Location of closed-loop poles at $s = -3, -5$.

ii. Location of observer poles at $s = -10 \pm j2$,

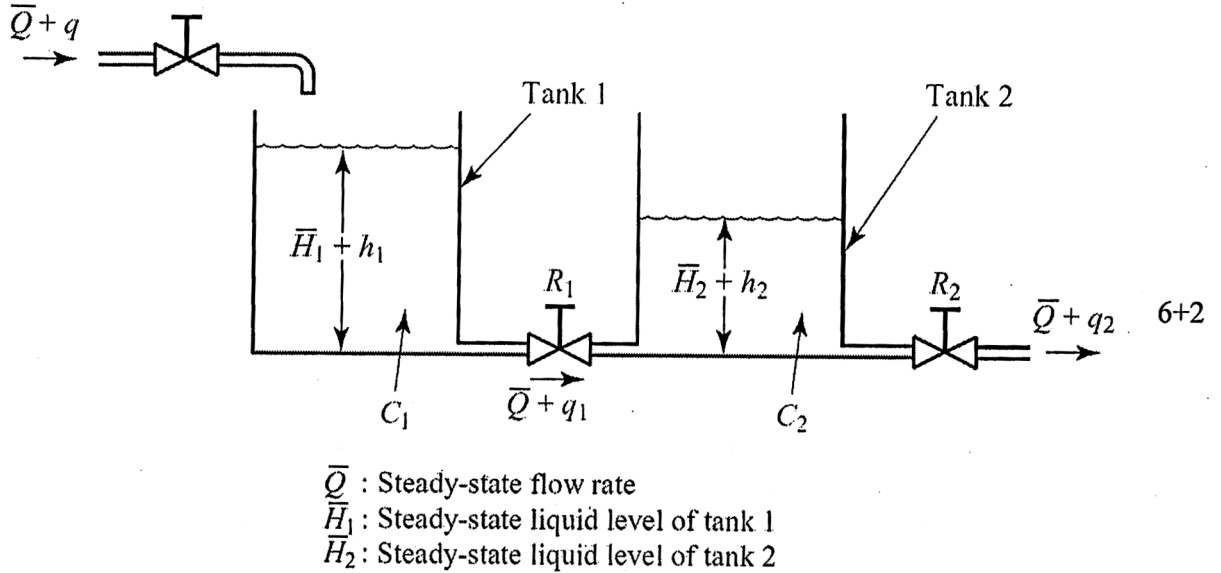
Design the observer. Determine the necessary state-feedback gain matrix K .

With necessary block diagram represent the compensated system.

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Q8 (a) Consider the system as shown in Figure, where the two tanks interact with each other.



- Derive the nonlinear state-space equations for the system.
- Briefly discuss the control problem involved herein.

(b) What is *Controllability Gramian*? Explain its significance over Kalman controllability