Ref. No.: Ex/EE/PC/B/T/313/2024

B.E. ELECTRICAL ENGINEERING
THIRD YEAR FIRST SEMESTER EXAM 2024

LINEAR CONTROL SYSTEM

Time: Three Hours | Full Marks: 100

Use Separate Answer script for each part

Part-I

(50 Marks)

Question nos. 1, 4 and 5 are compulsory
Answer any *ONE* question from Question nos. 2 and 3

1.	a)	Explain the difference between a time invariant system and a time varying system with appropriate examples.	4	CO1
	b)	Correct or Justify the following statement, providing proper explanation in support of your answer: *Use of feedback makes the closed loop control system response relatively sensitive to internal variations in system parameters.*	5	CO2
	c)	State *four* limitations of rotary potentiometers.	4	CO1
	d)	Compare the characteristics of D.C. servomotor when used in armature controlled mode and in field controlled mode.	2	CO2

2. a) Find the position, velocity and acceleration error constants and corresponding steady-state errors for the unity feedback control system having the open-loop transfer function — 6 — CO3

$$G(s) = \frac{10}{(s+1)(s+2)}$$

b) For the system shown in Fig. 1, determine the values of gain K and velocity feedback constant K_h so that the maximum overshoot in the unit step response is 0.2 and the peak time is 1 sec. With these values of K and K_h, obtain the rise time and settling time. — 9 — CO4

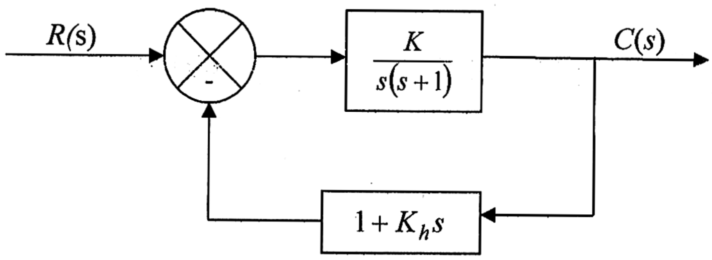

Fig.1

OR

[Turn over

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3 a) Given a unity feedback system with forward path transfer function $G(s)=\frac{10}{s(s+1)^2}$. Find the position, velocity and acceleration error constants. 6 CO3

b) The unity feedback system with a forward path transfer function $G(s)=\frac{K(s+\alpha)}{(s+\beta)^2}$ is to be designed to meet the following specifications: $e_{ss}|_{position}=0.1\,rad$; Damping ratio = 0.5 and Natural frequency of oscillation = $\sqrt{10}$. Find the values of K, α and β. 9 CO4

4. A system is given by the following closed loop transfer function 10 CO4

$$M(s)=\frac{1}{s^2+2s+1}$$

(a) Sketch the response of the above system to a unit step input. (`Sketch on plain paper. Graph paper is not required.`)

(b) Analyze the effect of addition of the following to the closed loop transfer function of the system.
(i) a non-minimum phase zero
(ii) a zero in the left-half of the s-plane.

5 The transfer function of a plant is given by 10 CO5

$$G(s)=\frac{K}{s(s+2)(s+5)}.$$

Design a suitable compensator to meet the following specifications:

a) Velocity constant $K_v \geq 10\ \text{sec}^{-1}$.

b) Phase margin $\phi_m \geq 35°$.

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Linear Control System

Part-II

Use a separate Answer-script for each part

Time: Three Hours **Full Marks: 100/50√**

Answer all the Questions.

Q1a. Explain the phenomenon of instability due to resonance. (CO1) **04**

Q1b. By means of Hurwitz Criterion determine the stability of the system represented by the following characteristic equation. (CO2) **08**

$$q(s) = s^4 + 8s^3 + 18s^2 + 16s + 5 = 0$$

OR

Q1b. The characteristic equation for a certain feedback control system is given below. Determine the range of gain K for which the system will be stable. (CO2) **08**

$$q(s) = s^3 + (K + 0.5)s^2 + 4Ks + 50 = 0$$

Q2a. In the context of signal flow graph define source, path and loop. (CO3) **06**

Q2b. Construct the Signal Flow Graph for the system shown in Fig. P-2. Find out the closed loop transfer function of the system using Mason's Gain Formula. (CO3) **06**

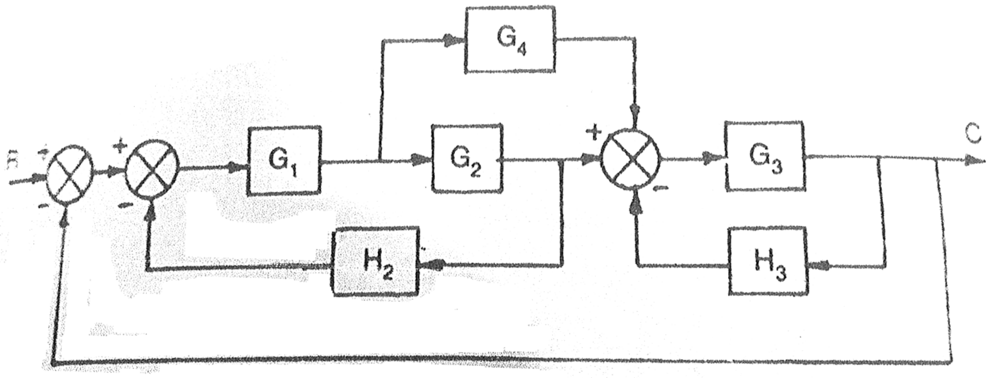

Fig. P-2

Q3. By use of Nyquist criterion, determine whether the closed-loop system having the following open-loop transfer function is stable or not. If, not how many closed-loop poles lie in the right half s-plane? (CO4) **12**

$$G(s)H(s) = \frac{(1+4s)}{s^2(1+s)(1+2s)}$$

OR

Q3.Plot the Root-Locus for a unity feedback system whose open-loop transfer function is as follows

$$G(s)H(s) = \frac{K(s+1)}{s^2(s+3)(s+5)}$$

Also determine and indicate on the sketch i) number and angles of asymptotes, ii) the centroid, iii) the breakaway point/ points, if any, iv) intersection of the root locus and the asymptotes with the imaginary axis, if any v) the range of gain K for which the closed loop system remains stable, vi) any other value that has relevance to the plotting of root locus. (CO4) **12**

Q4a. Explain how a state model developed using physical variables where the system matrix is not a diagonal one can be converted into a state model having a diagonal system matrix. Assume that the closed loop poles are all real and distinct. Derive all the steps. (CO5) **07**

Q4b. A linear time invariant system is described by the following state equation. Obtain eigenvalues, eigenvectors and the state model in canonical form. (CO5) **07**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 3 & 0 & 2 \\ -12 & -7 & -6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1y \\ 0 \\ 2 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

OR

Q4a. Prove that an LTI system can be represented by infinite number of state models. (CO5) **04**

Q4b. A system is described by **06**

$$T(s) = \frac{Y(s)}{U(s)} = \frac{2}{s^4 + 3s^3 + 3s^2 + 3s + 2}$$

Define Phase Variables. Find the State Model of the system in Bush Form.

Derive all the steps. (CO5)

Q4c. What is a Vander Monde Matrix? **04**