SREENIVASA INSTITUTE OF TECHNOLOGY AND MANAGEMENT STUDIES (AUTONOMOUS)

QUESTION BANK

Year / Semester: II B.Tech IV Semester **Regulation: R23**

Subject and Code: Linear Control Systems &23ECE243T

SYLLABUS

UNIT –1: CONTROL SYSTEMS CONCEPTS:
Open loop and closed loop control systems and their differences- Examples of control systems- Classification of control systems, Feedback characteristics, Effects of positive and negative feedback, Mathematical models – Differential equations of translational and rotational mechanical systems and electrical systems, Analogous Systems, Block diagram reduction methods – Signal flow graphs - Reduction using Mason's gain formula. Controller components, DC Servomotor and AC Servomotor- their transfer functions, Synchros.

UNIT –2: TIME RESPONSE ANALYSIS: (9)
Step Response - Impulse Response - Time response of first order systems – Characteristic Equation of Feedback control systems, Transient response of second order systems - Time domain specifications – Steady state response - Steady state errors and error constants, Study of effects and Design of P, PI, PD and PID Controllers on second order system.

UNIT –3: STABILITY ANALYSIS IN TIME DOMAIN: (9)
The concept of stability – Routh's stability criterion – Stability and conditional stability - limitations of Routh's stability. The Root locus concept - construction of root loci-effects of adding poles and zeros to G(s) H(s) on the root loci.

UNIT –4: FREQUENCY RESPONSE ANALYSIS: (9)
Introduction, Frequency domain specifications-Bode diagrams-Determination of Frequency domain specifications and transfer function from the Bode Diagram - Stability Analysis from Bode Plots. Polar Plots- Nyquist Plots- Phase margin and Gain margin-Stability Analysis.
Compensation techniques – Study of Effects and Design of Lag, Lead, Lag-Lead Compensator design in frequency Domain on a second order system.

UNIT –5: STATE SPACE ANALYSIS OF CONTINUOUS SYSTEMS: (9)
Concepts of state, state variables and state model - differential equations & Transfer function models - Block diagrams. Diagonalization, Transfer function from state model, solving the Time invariant state Equations- State Transition Matrix and it's Properties. System response through State Space models. The concepts of controllability and observability, Duality between controllability and observability.

DIGITAL CONTROL SYSTEMS:
Introduction to Digital control systems, Design of Digital Control Systems, Applications.

COURSE OUTCOMES:

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On successful completion of the course, students will be able to		Pos
CO1	Summarize the basic principles and applications of control systems.	**PO1, PO2, P03, PO4**
CO2	Understand the time response and steady state response of the systems.	**PO1, PO2, P03, PO4**
CO3	Understand the concept of state space, controllability and observability.	**PO1, PO2, P03, PO4**
CO4	Apply time domain analysis to find solutions to time invariant systems.	**PO1, PO2, P03, PO4**
CO5	Analyze different aspects of stability analysis of systems in frequency domain.	**PO1, PO2, P03, PO4**

Max Marks: 10

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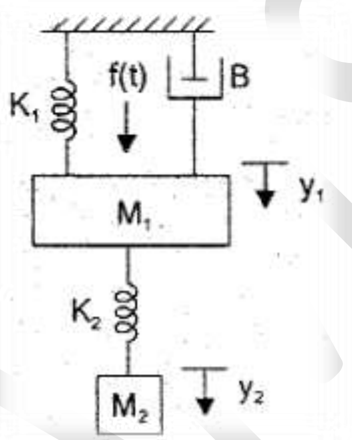
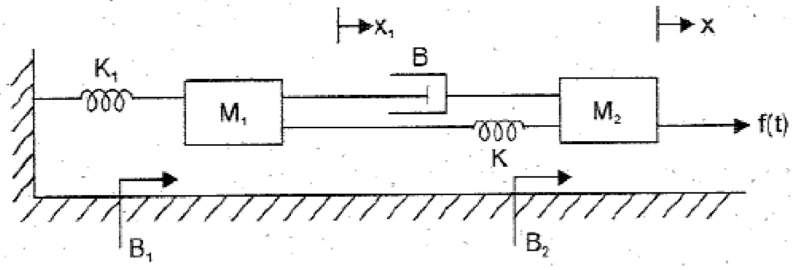
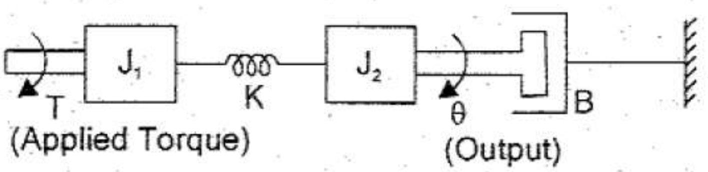
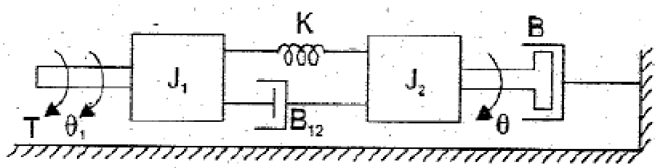
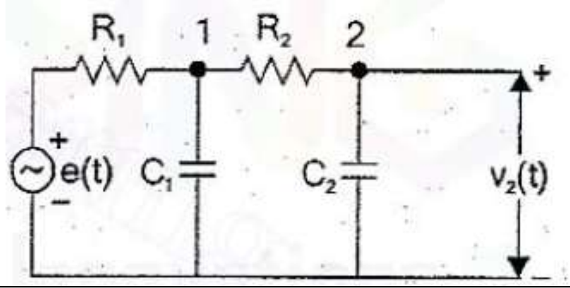
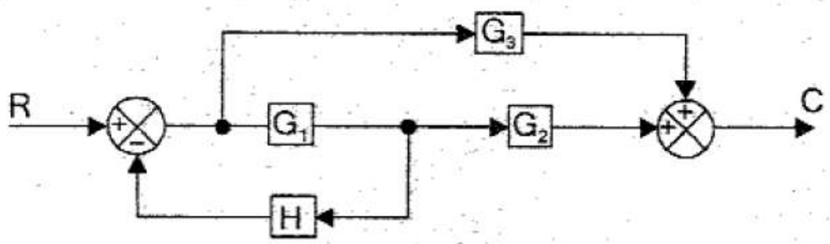
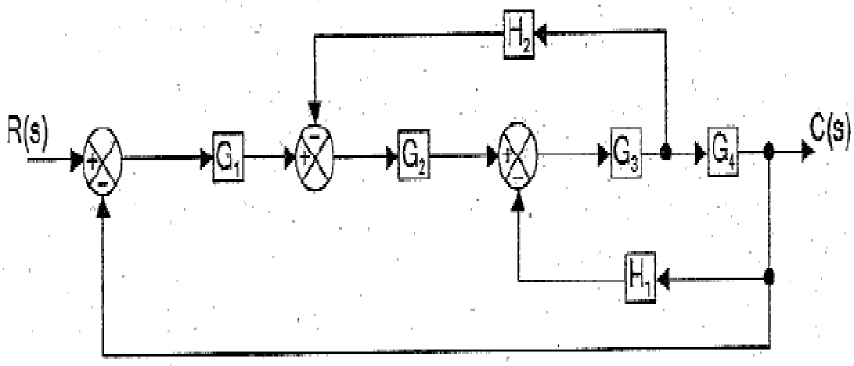
S.No.	CO	Questions	BT
		Unit I: (Control Systems Concepts)	
1	1	**a. Compare open loop and closed loop control systems** **b. Analyze the effect of negative feedback on gain, bandwidth, stability, and sensitivity**	L4
2	1	**Write the differential equations governing the mechanical translational system as shown in figure and determine its transfer function.** 	L4
3	1	**Sketch the free body diagram, determine the transfer function of the mechanical translation system as shown in figure.** 	L3
4	1	**Solve the differential equations for following rotational system and derive the transfer function** $\frac{\theta(s)}{T(s)}$ 	L3

5	**1**	**Write the differential equations governing the mechanical rotational system shown in the figure and find transfer function**  	L5
6	**1**	**For the electrical system shown in Fig, find the transfer function**  	L3
7	**1**	**Evaluate the transfer function of the system shown in below figure using block diagram reduction technique**  	L3
8	**1**	**Apply the block diagram reduction rules for solving the transfer function of the following system.**  	L3

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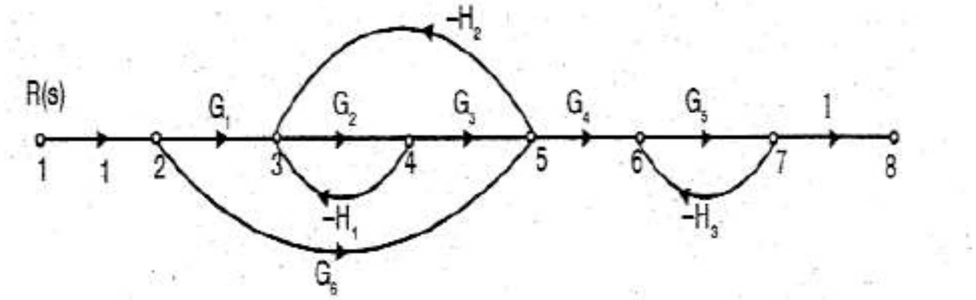
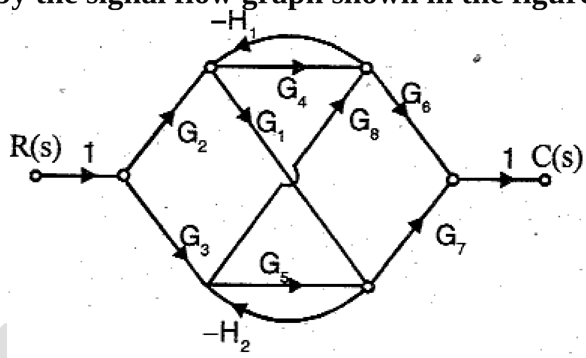
9	**1**	**Compute the gain of each forward path and loop in the given signal flow graph.** 	**L4**
10	**1**	**Using Mason's gain formula, obtain the overall gain of the system represented by the signal flow graph shown in the figure** 	**L3**

S.No.	**CO**	**Questions**	**BT**
		Unit II: (Time Response Analysis)	
1	**2**	**Explain the time response of a first-order system for a unit step input**	**L2**
2	**2**	**List out the time domain specifications and derive the expressions for Delay time and Rise time.**	**L1**
3	**2**	**Obtain the time response of under-damped second order system for unit step input.**	**L4**
4	**2**	**A unity feedback control system has an open loop transfer function, $(s) = \frac{10}{S(S+2)}$. Find the rise time, percentage overshoot, peak time and settling time for a step input.**	**L4**

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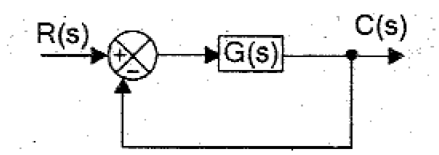
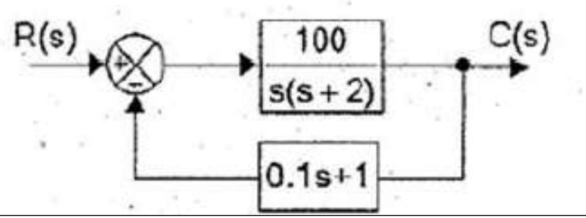
5	**2**	**Obtain the response of a unity feedback system whose open-loop transfer function is $G(s) = \frac{4}{s(s+5)}$ when the input is unit step** 	**L3**
6	**2**	**A positional control system with velocity feedback shown in fig. What is the response c(t) of the system for unit step input?** 	**L5**
7	**2**	**Measurements conducted on a Servomechanism show the system response to be $c(t) = 1 + 0.2e^{-60t} - 1.2e^{-10t}$ when subjected to a unit step. Obtain an expression for closed loop transfer function and also determine the undamped natural frequency**	**L4**
8	**2**	**For a unity feedback control system, the open loop transfer function** $G(s) = \frac{10(s+2)}{s^2(s+2)}$ **(a) Determine the position, velocity, and acceleration error constants.** **(b) Find the steady-state error when the input is $R(s) = \frac{3}{s} - \frac{2}{s^2} + \frac{1}{3s^2}$**	**L3**
9	**2**	**For servomechanisms with the open-loop transfer function $G(s) = \frac{20(s+2)}{s(s+1)(s+3)}$ Compute steady-state error constants**	**L4**
10	**2**	**Discuss the effect of a PI controller on steady-state error and transient response of a second-order system**	**L2**
S.No.	**CO**	**Questions**	**BT**
		Unit III: (Stability Analysis In Time Domain)	
1	**3**	**Discuss the procedure for constructing Routh Array and determine the roots on the S-plane for the Characteristic polynomial $S^4+8S^3+18S^2+16S+5=0$ Using RH criteria.**	**L2**

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2	3	Determine the stability of the system $S^5+4S^4+8S^3+8S^2+7S+4=0$ using Routh Array and Comment location of roots on the S-Plane.	L3
3	3	Using Routh criterion determine the stability of the system whose characteristic equation is $S^6+2S^5+8S^4+12S^3+20S^2+16S+16=0$. Find the number of roots falling in the RHS Plane and LHS Plane.	L4
4	3	A Unity feedback control system is characterized by the open loop transfer function $G(S) = \frac{K(S+13)}{S(S+3)(S+7)}$. Using Routh criterion, Calculate the range of K for the system to be stable	L3
5	3	Construct routh array and determine the stability of the system represented by characteristic polynomial represented by $S^5+S^4+2S^3+2S^2+3S+5=0$, Comment on the location of the roots.	L4
6	3	Construct the Routh array for the given Characteristic polynomial $S^7+9S^5+24S^5+24S^4+24S^3+24S^2+23S+15=0$. Determine the location of roots on S-plane and stability of the system	L4
7	3	By applying Routh criterion, determine the range of K for stability of unity feedback system whose open loop transfer function is $G(S) = \frac{K}{s(s+1)(s+2)}$.	L3
8	3	The Open loop transfer function of a unity negative feedback control system is given as $G(S) = \frac{K}{S(S+2)(S+4)}$. Sketch the root locus and find the Value of K corresponding to crossing point on imaginary axis	L4
9	3	A Unity feedback control system has an open loop transfer function $G(S) = \frac{K}{S(S^2+4S+13)}$. Sketch the root locus and obtain the limiting value of K for stability.	L4
10	3	Explain in detail the procedure for constructing the Root Locus of a control system	L2

S.No.	CO	Questions	BT
Unit IV: (Frequency Response Analysis)			
1	4	List out the frequency domain specifications and derive the expressions for resonant peak.	L2

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2	**4**	**Develop the Bode plot for the following transfer function and determine the system gain K for the gain cross over frequency to be 5 rad/sec.** $$G(s) = \frac{Ks^2}{s(1+0.2s)(1+0.02s)}$$	**L4**
3	**4**	**Plot the Bode diagram for the given transfer function and obtain the gain crossover frequency and phase crossover frequency. Also analyze the stability of the system** $$G(s) = \frac{10}{s(1+0.4s)(1+0.1s)}$$	**L4**
4	**4**	**Sketch the Bode plot for the given transfer function and determine the phase margin and gain margin.** $$G(s) = \frac{75(1+0.2s)}{s(s^2+16s+100)}$$	**L4**
5	**4**	**Sketch the polar plot and determine the gain margin and phase margin for the open loop transfer function given by,** $$G(s) = \frac{1}{s(1+s)(1+2s)}$$	**L3**
6	**4**	**a.Define and derive the expression for resonant frequency** **b. Given $\xi = 0.7$ and $\omega_n = 10$ rad/sec. Find resonant peak, resonant frequency and bandwidth.**	**L5**
7	**4**	**The open-loop transfer function of a unity feedback system is given by** $G(s) = \frac{1}{s^2(1+s)(1+2s)}$ **Sketch the polar plot and determine the gain margin and phase margin.**	**L4**
8	**4**	**A unity feed-back system with open loop transfer function** $G(s) = \frac{1}{s(s+1)(s+2)}$ **Draw the Nyquist plot and comment on closed loop stability.**	**L3**
9	**4**	**Consider a unity feedback system having an open-loop transfer function** $\frac{K}{s(1+0.2s)(1+0.05s)}$ **Sketch the polar plot and determine the value of K such that:** **(i) Gain margin is 18 dB** **(ii) Phase margin is 60°**	**L4**
10	**4**	**a. Determine the transfer function of Lag Compensator and draw pole-zero plot.** **b. Determine the transfer function of Lead Compensator and draw pole-zero plot.**	**L3**

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S.No.	CO	Questions	BT
Unit V: (State Space Analysis Of Continuous Systems)			
1	5	Construct a state model for a system characterized by the differential equation $\frac{d^3y}{dt^3}+\frac{d^2y}{dt^2}+\frac{dy}{dt}+6y+u=0$	L4
2	5	Obtain the state model of the system whose transfer function is given by $\frac{Y(S)}{U(S)}=\frac{10}{S^3+4S^2+2S+1}$	L3
3	5	Obtain the state space model of a system described by the differential equation is given by $\dddot{Y}+4\ddot{Y}+7\dot{Y}+2Y=5U$	L4
4	5	Determine the state transition matrix for the system $\dot{X}$ =AX + BU with A = $\begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix}$	L3
5	5	A Linear time-invariant system is characterized by the homogeneous state equation $\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\end{bmatrix}=\begin{bmatrix}1 & 0\\ 1 & 1\end{bmatrix}\begin{bmatrix}X_1\\ X_2\end{bmatrix}$ Compute the state solution of state equation when subjected to unit step input. Assume the following initial conditions X(0) = $\begin{bmatrix}0\\ 1\end{bmatrix}$	L5
6	5	Consider a unity feedback system with the plant $\dot{X}$ = AX +BU, Y=CX where A = $\begin{bmatrix}2 & 1\\ -1 & 2\end{bmatrix}$, B= $\begin{bmatrix}1\\ 1\end{bmatrix}$, C= $\begin{bmatrix}1 & 1\end{bmatrix}$ Test the controllability and Observability of the system given state space representation.	L4
7	5	Discuss the concept of controllability. Evaluate the controllability of the system with state equation $\dot{X}$ = AX +BU, Y=CX where A = $\begin{bmatrix}0 & 1\\ -1 & -3\end{bmatrix}$, B= $\begin{bmatrix}1\\ 2\end{bmatrix}$, C= $\begin{bmatrix}1 & 1\end{bmatrix}$	L3

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8	**5**	**Discuss the concept of obervability. Evaluate the obervability of the system with state equation** $\dot{X} = AX + BU$, $Y=CX$ **where** $A=\begin{bmatrix} 0 & 1 \\ -1 & -3 \end{bmatrix}$, $B=\begin{bmatrix} 1 \\ 2 \end{bmatrix}$, $C=\begin{bmatrix} 1 & 1 \end{bmatrix}$	**L5**
9	**5**	**Test the controllability and obervability of the system described by** $\begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ -3 & -2 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U$ **and** $Y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$	**L4**
10	**5**	**Draw the block diagram of a basic digital control system and explain the function of each block**	**L3**

Note: L1-Remembering, L2-Understanding, L3-Applying, L4-Analyzing, L5-Evaluating, and L6-Creating

TEXT BOOKS:

1. Modern Control Engineering by Katsuhiko Ogata, Prentice Hall of India Pvt. Ltd., 5thedition, 2010.
2. Control Systems Engineering by I. J. Nagrath and M. Gopal, New Age International (P) Limited Publishers, 5th edition, 2007.

REFERENCE BOOKS:

1. Control Systems Principles & Design by M.Gopal, 4th Edition, McGraw Hill Education,2012.
2. Automatic Control Systems by B. C. Kuo and Farid Golnaraghi, John wiley and sons, 8th edition,2003.
3. Feedback and Control Systems, Joseph J Distefano III, Allen R Stubberud & Ivan J Williams, 2nd Edition, Schaum's outlines, McGraw Hill Education,2013.
4. Control System Design by Graham C. Goodwin, Stefan F. Graebe and Mario E. Salgado, Pearson, 2000.
5. Feedback Control of Dynamic Systems by Gene F. Franklin, J.D. Powell and Abbas Emami-Naeini, 6th Edition, Pearson,2010.

Instruction to Faculty Members:

The Six Levels of Bloom's Taxonomy:

1. **Remembering:** Retrieving, recognizing, and recalling relevant knowledge from long-term memory (e.g., list, define, name, locate).

2. **Understanding:** Constructing meaning, explaining ideas, or concepts (e.g., summarize, interpret, classify, compare).
3. **Applying:** Using information in new situations or implementing procedures to solve problems (e.g., solve, use, demonstrate, implement).
4. **Analyzing:** Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure (e.g., contrast, categorize, distinguish, diagram).
5. **Evaluating:** Making judgments based on criteria and standards through checking and critiquing (e.g., judge, critique, justify, defend, argue).
6. **Creating:** Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure (e.g., design, construct, develop, formulate).