SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)

Approved by AICTE, Affiliated to Anna University, Chennai, Accredited by NBA,
'A' Grade Accreditation by NAAC & ISO 9001:2015 Certified Institution

SRM Nagar, Kattankulathur – 603 203

QUESTION BANK

IV SEMESTER

EI3464 – Control Systems

Regulation - 2023

Academic Year 2024 - 2025 (Even Sem)

Common to

Department of Electronics and Instrumentation Engineering
Department of Electrical and Electronics Engineering
Department of Electronics and Communication Engineering

Prepared by

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QUESTION BANK

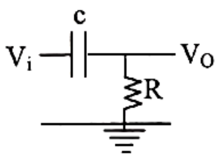
SUBJECT: EI3464 – Control Systems

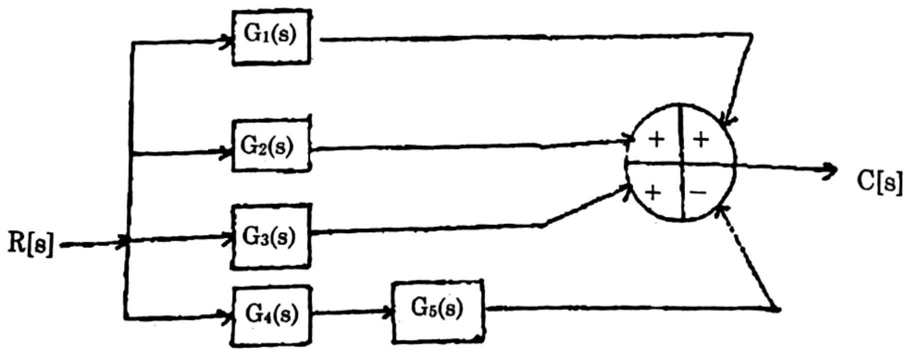
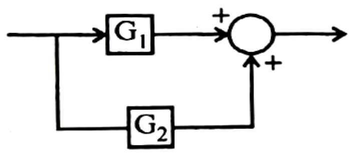
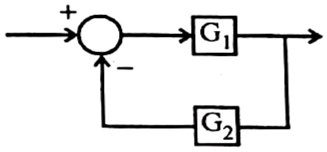
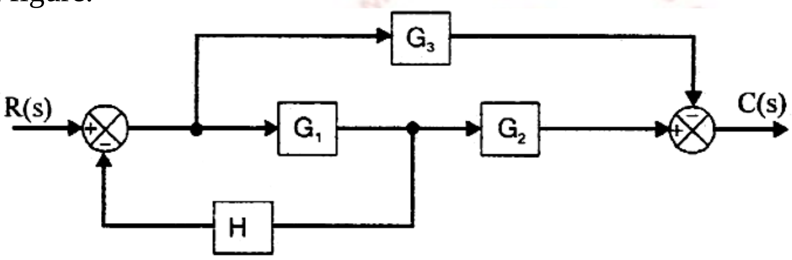
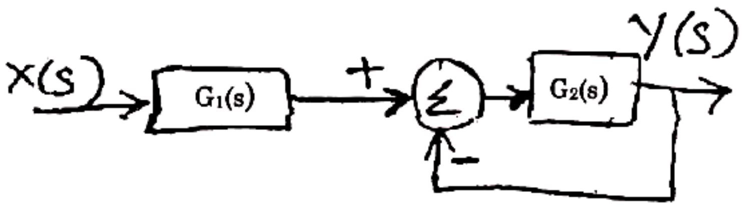
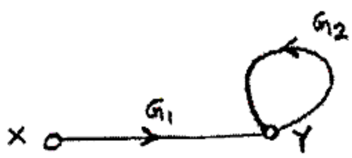
BRANCH / YEAR / SEM: EIE, EEE & ECE / II / IV

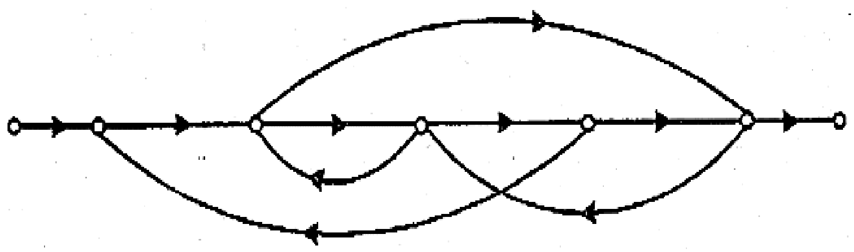
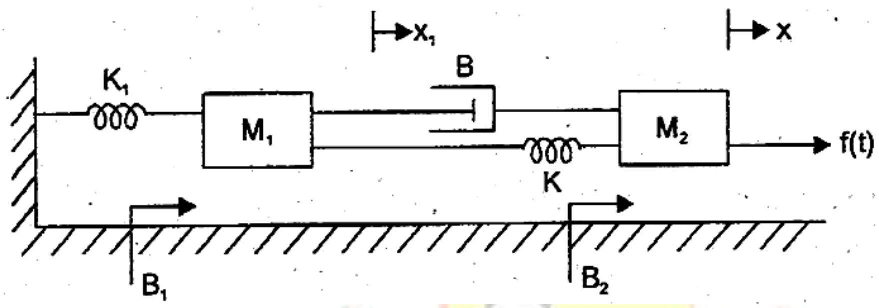
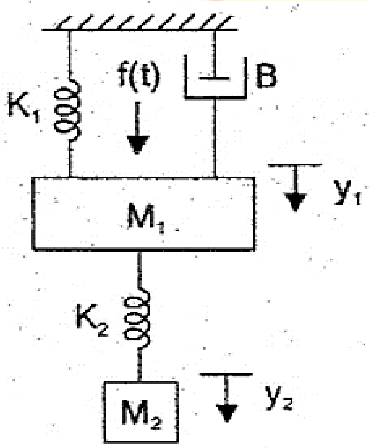
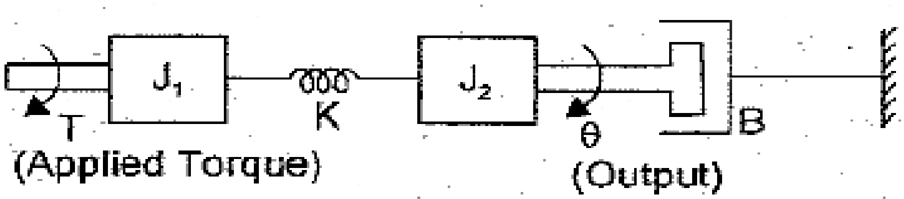
UNIT I - SYSTEMS AND REPRESENTATION

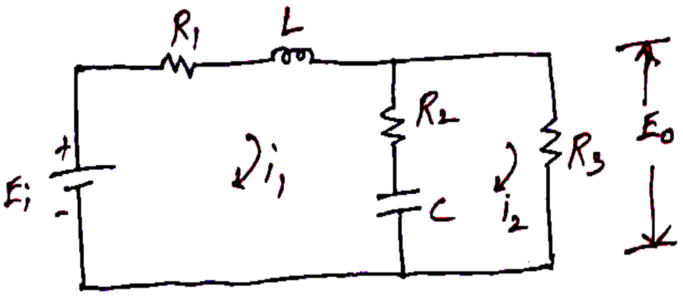
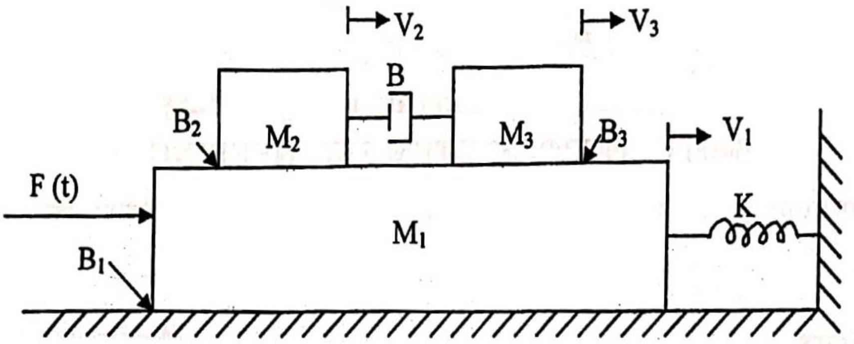
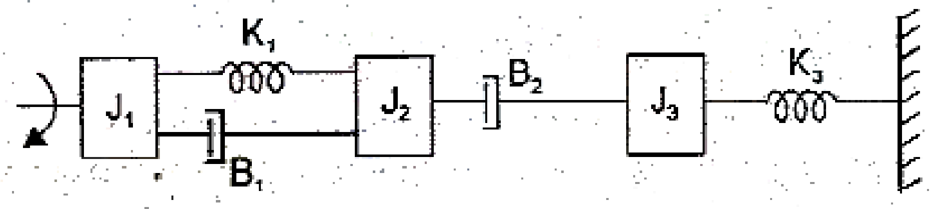
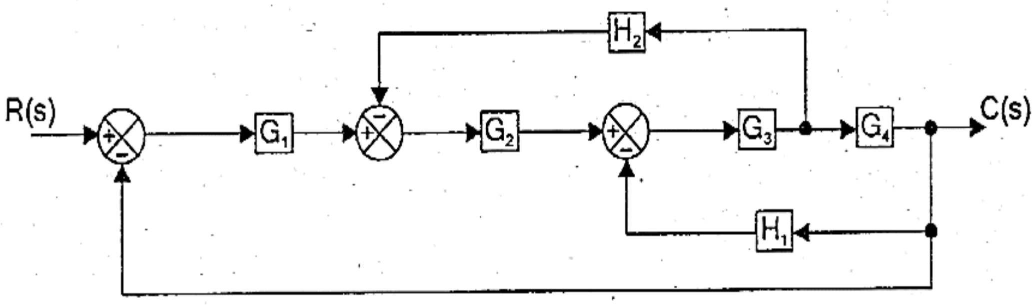
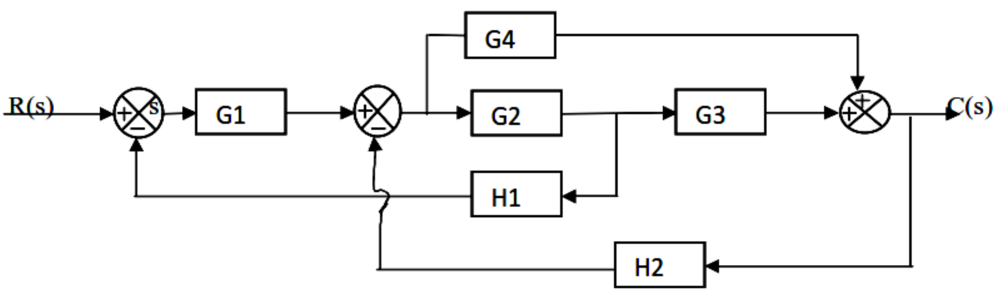
Basic elements in control systems: – Open and closed loop systems – Electrical analogy of mechanical system– Transfer function – AC and DC servomotors - Synchro – Block diagram reduction techniques – Signal flow graphs.

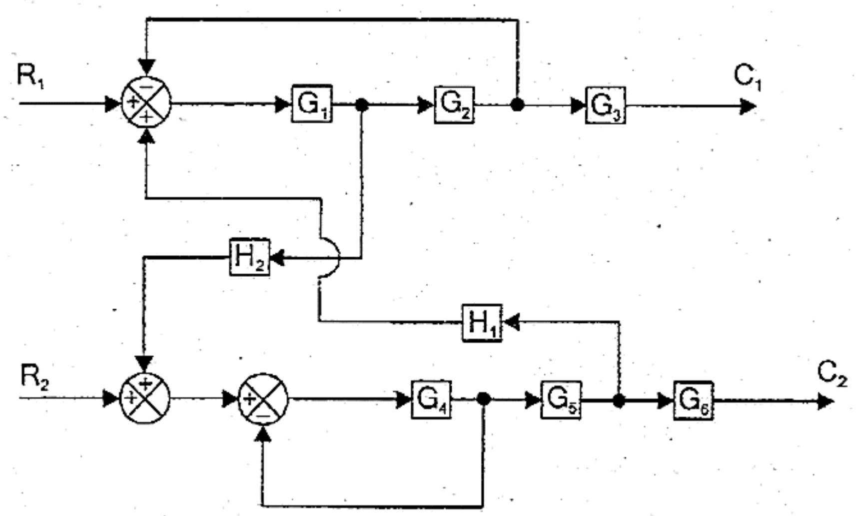
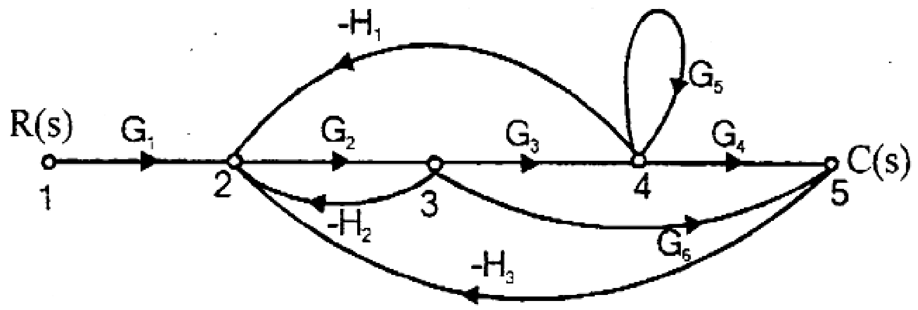
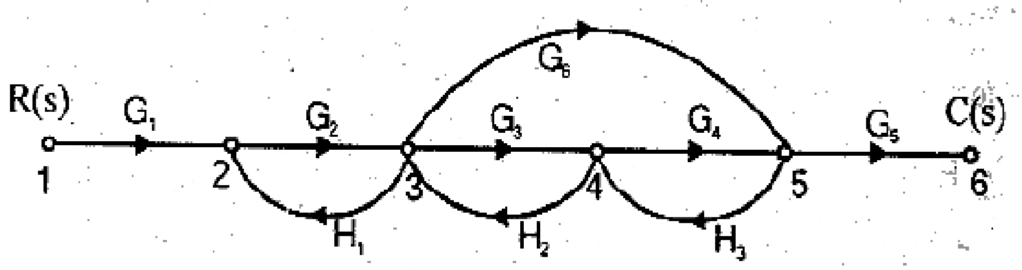
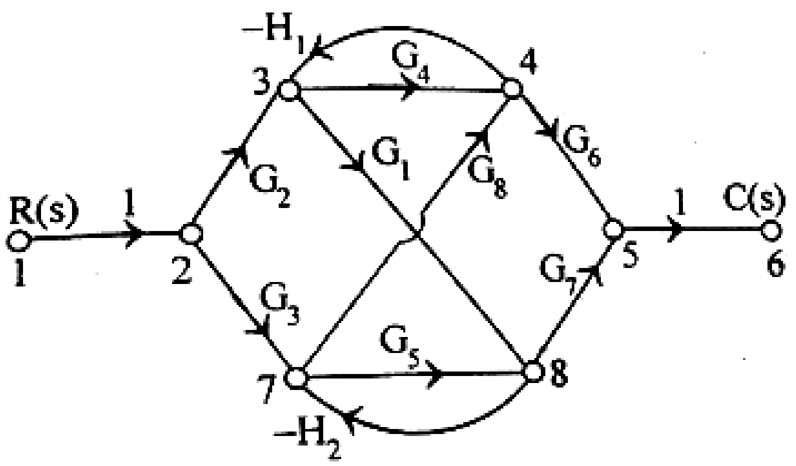
PART – A

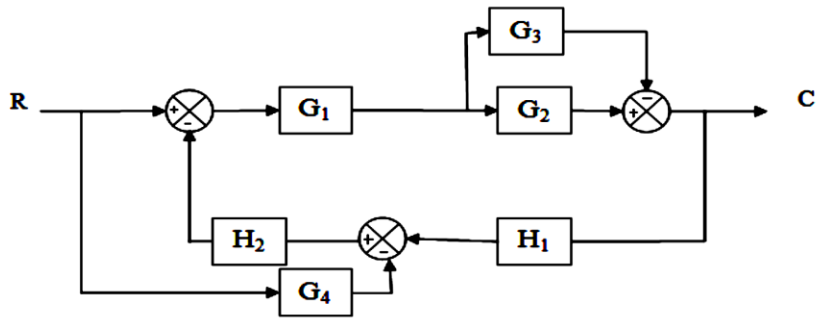
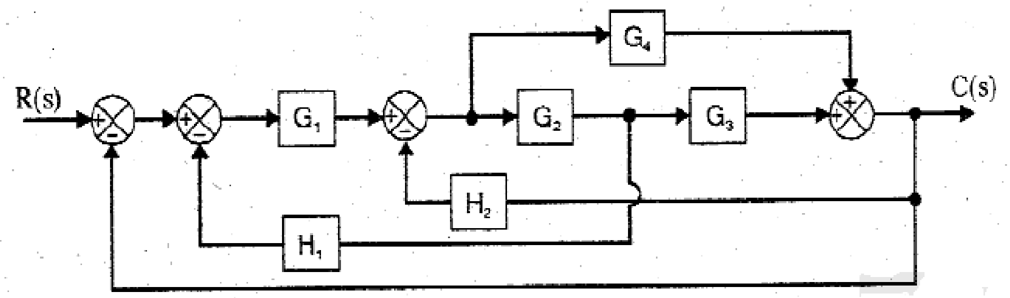
Q.No.	Questions	BT Level	Competence	Course Outcome
1.	What is system?	BTL 1	Remember	CO 1
2.	Define control system.	BTL 1	Remember	CO 1
3.	Distinguish between open loop and closed loop system.	BTL 2	Understand	CO 1
4.	Narrate components of feedback control system.	BTL 2	Understand	CO 1
5.	Express the transfer function of a control system.	BTL 2	Understand	CO 1
6.	Write the torque balance equation of a of an ideal rotational mass element.	BTL 2	Understand	CO 1
7.	Find the transfer function of the network given in figure below. 	BTL 2	Understand	CO 1
8.	Mention the basic elements of the translational mechanical system.	BTL 2	Understand	CO 1
9.	Name the two types of electrical analogous for mechanical system.	BTL 1	Remember	CO 1
10.	Write down the transfer function of the system whose block diagram is shown in below.	BTL 2	Understand	CO 1

				
11.	Draw the equivalent block diagram for the figures 1 and 2 given below: (i)  (ii)  **Figure-1** **Figure-2**	BTL 2	Understand	CO 1
12.	Observe the ideal spring in a control system and write the force balance equation.	BTL 2	Understand	CO 1
13.	How will you reduce two blocks in parallel using block diagram reduction technique?	BTL 2	Understand	CO 1
14.	Draw the equivalent signal flow graph for the system whose block diagram is as shown in figure. 	BTL 2	Understand	CO 1
15.	Evaluate the closed loop transfer function Y(s)/X(s) for the given system. 	BTL 1	Remember	CO 1
16.	Write the Mason's Gain formula.	BTL 1	Remember	CO 1
17.	Obtain the gain $\frac{Y}{X}$ for the signal flow graph shown below: 	BTL 2	Understand	CO 1
18.	Interpret how the signal flow graph is used to represent a control system.	BTL 2	Understand	CO 1
19.	Interpret non-touching loop.	BTL 2	Understand	CO 1
20.	For the given signal flow graph, identify the number of forward paths and individual loops.	BTL 2	Understand	CO 1

				
21.	Enumerate the features of a servo motor.	BTL 2	Understand	CO 1
22.	Differentiate AC and DC servo motor.	BTL 2	Understand	CO 1
23.	Analyze the need of electrical zero position in synchro transmitter.	BTL 2	Understand	CO 1
24.	Quote the differential equation for series and parallel RLC circuit.	BTL 1	Remember	CO 1
	PART-B			
1.	Write the differential equations governing the mechanical system, and determine the transfer function for the system. **(16)** 	BTL 3	Apply	CO 1
2.	Formulate the differential equation defining the mechanical translational system given below. And also derive the transfer function for the system. **(16)** 	BTL 3	Apply	CO 1
3.	Exhibit the mechanical rotational system with an appropriate differential equation and obtain the transfer function of the system. **(16)** 	BTL 3	Apply	CO 1
4.	Examine the given electrical network and deduce the transfer function. **(16)**	BTL 4	Analyze	CO 1

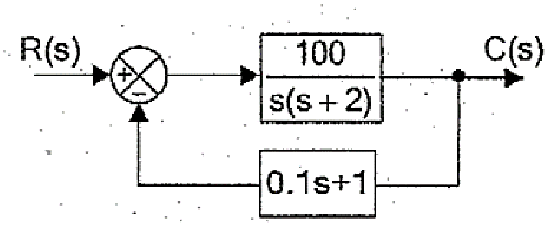
				
5.	Demonstrate the given mechanical rotational system with force-voltage and force-current electrical analogous circuits. **(16)** 	BTL 4	Analyze	CO 1
6.	Devise a torque-voltage, torque-current analogous circuit and verify it by writing mesh and node equations. **(16)** 			
7.	Evaluate the transfer function C(s)/R(s) for the given system. **(16)** 	BTL 3	Apply	CO 1
8.	Obtain the transfer function C(s)/R(s) for the block diagram shown in figure using block diagram reduction technique. **(16)** 	BTL 4	Analyze	CO 1
9.	For the system represented by the block diagram shown in figure, determine C_1/R_1 or C_2/R_2. **(16)**	BTL 3	Apply	CO 1

				
10.	Apply Masons gain formula to determine the transfer function of the given signal flow graph. **(16)** 	BTL 3	Apply	CO 1
11.	For the signal flow graph of the closed loop feedback system shown below, Determine the closed loop transfer function. **(16)** 	BTL 4	Analyze	CO 1
12.	Using the mason's gain formula formulate the gain of the following system: **(16)** 	BTL 3	Apply	CO 1
13.	Develop the transfer function for the block diagram shown in fig. using (i) Block diagram reduction technique. **(8)**	BTL 4	Analyze	CO 1

	(ii) Mason's Gain Formula. **(8)** 			
14.	Interpret the transfer function by converting the block diagram into signal flow graph. **(16)** 	BTL 4	Analyze	CO 1
15.	Derive the transfer function of field Controlled DC servomotor with relevant diagram. **(16)**	BTL 4	Analyze	CO 1
16.	Derive the transfer function of armature Controlled DC servomotor with relevant diagram. **(16)**	BTL 4	Analyze	CO 1
17.	Explain the working principle of AC servomotor with relevant diagram. **(16)**	BTL 4	Analyze	CO 1

UNIT II - TIME RESPONSE ANALYSIS				
Time response: – Time domain specifications – Types of test input – I and II order system response – Error coefficients – Generalized error series – Steady state error – Effects of P, PI, PID modes of feedback control – Time response analysis.				
Q.No.	**Questions**	**BT Level**	**Competence**	**Course Outcome**
1.	What is time response?	BTL 1	Remember	CO 2
2.	Name the test signals used in control system.	BTL 1	Remember	CO 2
3.	Illustrate the mathematical expressions for step input and impulse input.	BTL 2	Understand	CO 2
4.	Point out the different time domain specifications.	BTL 2	Understand	CO 2
5.	Illustrate peak overshoot.	BTL 2	Understand	CO 2
6.	Express the type and order of the following system $$\frac{G(s)}{H(s)} = \frac{10}{s^3(s^2+2s+1)}$$	BTL 2	Understand	CO 2
7.	Distinguish between the order and type of system.	BTL 2	Understand	CO 2
8.	For a system described by $$\frac{C(S)}{R(S)} = \frac{16}{S^2+8S+16}.$$ Find the nature of the time response and justify.	BTL 2	Understand	CO 2
9.	Define pole and zero of a function F(s).	BTL 2	Understand	CO 2
10.	Assess the significance of rise time.	BTL 2	Understand	CO 2
11.	Estimate the damped frequency of oscillation for a second order system which has a damping ratio of 0.6 and natural frequency of oscillation is 10 rad/sec.	BTL 2	Understand	CO 2
12.	The closed loop transfer function of a second order system is given by $$\frac{C(s)}{R(s)} = \frac{400}{(S^2+2S+400)}$$ Determine the damping ratio and natural frequency of oscillation.	BTL 2	Understand	CO 2
13.	A unity feedback system has an open loop transfer function of $$G(s) = \frac{10}{(s+1)(s+2)}$$ Formulate the steady state error for unit step input.	BTL 2	Understand	CO 2
14.	Exhibit the damped frequency of oscillation in a control system.	BTL 2	Understand	CO 2
15.	Solve for the type and order of the system $$G(s)H(s) = \frac{(s+4)}{(s-2)(s+0.25)}$$	BTL 2	Understand	CO 2
16.	Analyze the response of first-order system with unit step input.	BTL 2	Understand	CO 2
17.	How did the type number of a system is identified? Mention its significance.	BTL 2	Understand	CO 2
18.	Give the steady state errors to a various standard input for type-2 system.	BTL 2	Understand	CO 2
19.	The open loop transfer function of a unity feedback control system is given by	BTL 2	Understand	CO 2

	$$G(s) = \frac{10(S+2)}{S^2(S+5)}$$ Calculate the acceleration error constant.			
20.	Find the unit impulse of system given with zero initial conditions. $$H(s) = \frac{5S}{(S+2)}$$	BTL 2	Understand	CO 2
21.	Express the transfer functions of PI and PID controllers.	BTL 2	Understand	CO 2
22.	Why derivative controller is not used separately in control applications?	BTL 2	Understand	CO 2
23.	For servo mechanisms with open loop transfer function is given by $$G(s) = \frac{1}{S^2 + 2S + 3}$$ Calculate position error and steady state error for a unit step input.	BTL 2	Understand	CO 2
24.	Write the relation between generalized and static error coefficients.	BTL 2	Understand	CO 2
	PART-B			
1.	Name the various standard test signals? Draw the characteristics diagram and obtain the mathematical representation of the test signals. **(16)**	BTL 3	Apply	CO 2
2.	Analyze the response of first order system for a unit step input. Plot the response of the system. **(16)**	BTL 4	Analyze	CO 2
3.	Summarize the response of undamped second order system for unit step input. **(16)**	BTL 3	Apply	CO 2
4.	Derive the expression for second order system for under damped case and when the input is unit step. **(16)**	BTL 3	Apply	CO 2
5.	Derive the expression for second order system for critically damped case and when the input is unit step. **(16)**	BTL 3	Apply	CO 2
6.	Obtain the response of unity feedback system whose open loop transfer function is $$G(s) = \frac{4}{s(s+5)}$$ and when the input is unit step. **(16)**	BTL 3	Apply	CO 2
7.	Derive Expressions for the following time domain specifications of second order under damped system due to unit step input. **(i)** Rise time. **(4)** **(ii)** Peak time. **(4)** **(iii)** Delay time. **(4)** **(iv)** Peak over shoot. **(4)**	BTL 4	Analyze	CO 2
8.	The unity feedback system is characterized by an open loop transfer function $$G(s) = \frac{K}{s(s+10)}$$	BTL 3	Apply	CO 2
	(i) Examine the gain K, so that the system will have a damping ratio of 0.5 for this value of K. **(8)**			
	(ii) Examine peak overshoot for a unit step input. **(8)**			

9.	A Unity feedback control system is characterized by open loop transfer function $$G(s) = \frac{10}{s(s+2)}$$ Find the rise time, percentage overshoot, peak time and settling time for a step input of 12 units. **(16)**	BTL 4	Analyze	CO 2
10.	A closed loop servo is represented by the differential equation $$\frac{d^2c}{dt^2} + 8\frac{dc}{dt} = 64e$$ where c is the displacement of the output shaft, r is the displacement of the input shaft and $e = r - c$. Determine undamped natural frequency, damping ratio and percentage maximum overshoot for unit step input. **(16)**	BTL 3	Apply	CO 2
11.	For a unity feedback control system, the open loop transfer function is $$G(s) = \frac{10(s+2)}{s^2(s+1)}$$	BTL 3	Apply	CO 2
	(i) Find the position, velocity, acceleration error constants. **(8)**			
	(ii) Compute the steady state error when the input is R(s) where **(8)** $$R(s) = \frac{3}{s} - \frac{2}{s^2} + \frac{1}{3s^3}$$			
12.	For the given open loop transfer function G(s) for servomechanism, interpret what type of input signal give rise to a constant steady state error and calculate the value. **(16)** $$G(s) = \frac{10}{s^2(s+1)(s+2)}$$	BTL 3	Apply	CO 2
13.	Measurements conducted on a servo mechanism show that the system response to be $c(t) = 1 + 0.2e^{-60t} - 1.2e^{-10t}$ when subjected to a unit step input. **(16)**	BTL 3	Apply	CO 2
	(i) Obtain an expression for closed loop transfer function. **(8)**			
	(ii) Compute the undamped natural frequency and damping ratio. **(8)**			
14.	A positional control system with velocity feedback is shown. Compute the response of the system for unit step input. **(16)**  	BTL 4	Analyze	CO 2
15.	A unity feedback system has the forward transfer function $$G(s) = \frac{K(2s+1)}{s(5s+1)(1+s)^2}$$ When the input is $r(t) = 1 + 6t$. Evaluate the minimum value of K so that the steady state error is less than 0.1 **(16)**	BTL 4	Analyze	CO 2

16.	Calculate the static error coefficients for a system whose transfer function is $G(s)H(s) = \frac{10}{s(1+s)(1+2s)}$. And also Calculate the steady state error for $r(t) = 1 + t + \frac{t^2}{2}$. **(16)**	BTL 4	Analyze	CO 2
17.	Examine the Effects of P, PI, PID modes of feedback control. **(16)**	BTL 4	Analyze	CO 2

UNIT III - FREQUENCY RESPONSE ANALYSIS				
Frequency response: – Bode plot – Polar plot – Determination of closed loop response from open loop response - Correlation between frequency domain and time domain specifications.				
PART - A				
Q.No.	Questions	BT Level	Competence	Course Outcome
1.	Define Phase margin.	BTL 1	Remember	CO 4
2.	Define gain margin.	BTL 1	Remember	CO 4
3.	The damping ratio and natural frequency of oscillations of a second order system is 0.3 and 3 rad/sec respectively. Calculate resonant frequency and resonant peak.	BTL 2	Understand	CO 4
4.	Evaluate the shape of polar plot for the open loop transfer function $$G(s)H(s) = \frac{1}{s(1+Ts)}$$	BTL 2	Understand	CO 4
5.	Show the shape of polar plot for the transfer function $$G(s) = \frac{K}{s(1+sT_1)(1+sT_2)}$$	BTL 2	Understand	CO 4
6.	Why frequency domain analysis is needed?	BTL 2	Understand	CO 4
7.	List the advantages of Frequency Response Analysis.	BTL 1	Remember	CO 4
8.	Define phase cross over frequency.	BTL 1	Remember	CO 4
9.	Define gain cross over frequency.	BTL 1	Remember	CO 4
10.	State the significance of Nichol's plot.	BTL 1	Remember	CO 4
11.	Demonstrate the correlation between time and frequency response.	BTL 2	Understand	CO 4
12.	Differentiate non-minimum phase and minimum phase systems.	BTL 2	Understand	CO 4
13.	Discuss about the corner frequency in frequency response analysis?	BTL 2	Understand	CO 4
14.	Determine the phase angle of the given transfer function $$G(s) = \frac{10}{s(1+0.4s)(1+0.1s)}$$	BTL 2	Understand	CO 4
15.	A second order system has peak over shoot = 50% and period of oscillations 0.2 seconds. Tell the resonant frequency.	BTL 2	Understand	CO 4
16.	What does, a gain margin close to unity or phase margin close to zero indicate?	BTL 2	Understand	CO 4
17.	Describe the approximate polar plot for a Type 0 second order system.	BTL 2	Understand	CO 4
18.	Define the terms: resonant peak and resonant frequency.	BTL 1	Remember	CO 4
19.	What is meant by cut-off frequency?	BTL 2	Understand	CO 4
20.	Quote how will you get the closed loop frequency response from open loop response?	BTL 1	Remember	CO 4
21.	List the uses of Nichol's Chart.	BTL 1	Remember	CO 4

22.	Draw the polar plot of $G(s)=\frac{1}{1+sT}$.	BTL 2	Understand	CO 4
23.	Quote the corner frequency of $G(s)=\frac{10}{s(1+0.5s)}$.	BTL 2	Understand	CO 4
24.	List frequency domain specifications.	BTL 1	Remember	CO 4
	PART – B			
1.	Plot the bode diagram for the given transfer function and estimate the gain and phase cross over frequencies. **(16)** $$G(s) = \frac{10}{s(1+0.4s)(1+0.1s)}$$	BTL 3	Apply	CO 4
2.	Sketch the bode plot for the transfer function $$G(s) = \frac{75(1+0.2s)}{s(s^2+16s+100)}$$ and determine phase margin and gain margin. **(16)**	BTL 3	Apply	CO 4
3.	Calculate the system gain K by sketching the Bode plot for the transfer function $$G(s) = \frac{Ks^2}{(1+0.2s)(1+0.02s)}$$ with gain cross over frequency of 5rad/sec. **(16)**	BTL 4	Analyze	CO 4
4.	Analyze the bode plot for the function given by **(16)** $$G(s) = \frac{5(1+2s)}{(1+4s)(1+0.25s)}$$	BTL 3	Apply	CO 4
5.	Given $$G(s) = \frac{Ke^{-0.2s}}{s(s+2)(s+8)}$$ Draw the Bode plot and Calculate K for the following two cases: **(16)** **(i)** Gain margin equal to 6db. **(ii)** Phase margin equal to 45°.	BTL 3	Apply	CO 4
6.	Sketch the Bode plot and hence evaluate Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin for the function **(16)** $$G(s) = \frac{10(s+3)}{s(s+2)(s^2+4s+100)}$$	BTL 4	Analyze	CO 4
7.	Demonstrate the bode plot for the system whose open loop transfer function is given below and Find (i) Gain margin (ii) Phase margin and (iii) closed loop stability. **(16)** $$G(s)=\frac{100}{s(s+1)(s+2)}.$$	BTL 4	Analyze	CO 4
8.	Evaluate open loop transfer function of a unity feedback system given by $$G(s) = \frac{1}{s(1+s)(1+2s)}$$ Sketch the polar plot. Evaluate the gain and phase margin for the above system. **(16)**	BTL 4	Analyze	CO 4
9.	Report on the polar plot of an open loop transfer function of a unity feedback system given by $$G(s) = \frac{1}{s^2(1+s)(1+2s)}$$	BTL 4	Analyze	CO 4

	Sketch the polar plot. Evaluate the gain and phase margin for the above system. **(16)**			
10.	Construct the polar plot and determine the gain margin and phase margin of a unity feedback control system whose open loop transfer function is, **(16)** $$G(s) = \frac{(1 + 0.2s)(1 + 0.025s)}{s^3(1 + 0.005s)(1 + 0.001s)}$$	BTL 4	Analyze	CO 4
11.	Consider a unity feedback system with open loop transfer function $$G(s) = \frac{1}{s(1 + s^2)}$$ From the polar plot and determine the gain and phase margin. **(16)**	BTL 3	Apply	CO 4
12.	Describe the procedure for obtaining the polar plot for a system whose open loop transfer function is **(16)** $$G(s) = \frac{4}{(s + 2)(s + 4)}$$	BTL 3	Apply	CO 4
13.	Consider a unity feedback system having an open loop transfer function $$G(s) = \frac{K}{s(1 + 0.2s)(1 + 0.05s)}$$ Sketch the polar plot and determine the value of K so that **(16)** **(i)** gain margin is 18 dB. **(ii)** phase margin is 60^0.	BTL 4	Analyze	CO 4
14.	Sketch the polar plot of a unity feedback system with open loop transfer function given by, $$G(s) = \frac{50}{s(s + 1)(s + 5)(s + 10)}$$ and calculate the gain and phase margins of the closed loop system. **(16)**	BTL 3	Apply	CO 4
15.	Using polar plot, calculate gain cross over frequency, phase cross over frequency, gain margin and phase margin of feedback system with open loop transfer function. **(16)** $$G(s) = \frac{10}{s(1 + 0.2s)(1 + 0.002s)}$$	BTL 4	Analyze	CO 4
16.	Solve using Nichol's chart to obtain closed loop frequency response from open loop frequency response of a unity feedback system. Explain how the gain adjustment is carried out on this chart. **(16)**	BTL 4	Analyze	CO 4
17.	Draw the polar plot for the following transfer function and evaluate Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin for the transfer function $G(s) = \frac{400}{s(s+2)(s+10)}$. **(16)**	BTL 3	Apply	CO 4

UNIT IV – STABILITY ANALYSIS

Characteristics equation – Location of roots in S plane for stability – Routh Hurwitz criterion – Root locus construction – Effect of pole, zero addition – Gain margin and phase margin – Nyquist stability criterion. Design of Compensators using Bode plots.

PART – A

Q.No.	Questions	BT Level	Competence	Course Outcome
1.	What is characteristic equation?	BTL 1	Remember	CO 4
2.	Quote BIBO stability criterion.	BTL 1	Remember	CO 4
3.	State Routh's criterion for stability.	BTL 1	Remember	CO 4
4.	Write the necessary and sufficient condition for stability.	BTL 1	Remember	CO 4
5.	What conclusion can be provided when there is a row of all zeros in Routh array?	BTL 2	Understand	CO 4
6.	List the advantages of Routh Hurwitz stability criterion?	BTL 1	Remember	CO 4
7.	Give any two limitations of Routh stability criterion.	BTL 1	Remember	CO 4
8.	Find the range of K for stability of a closed loop system with characteristic equations $s^4 + 8s^3 + 36s^2 + 80s + K = 0$ using Routh stability criterion.	BTL 2	Understand	CO 4
9.	Point out the main objective of root locus analysis technique.	BTL 2	Understand	CO 4
10.	Interpret the relationship between roots of characteristic equation and stability.	BTL 2	Understand	CO 4
11.	Identify the meaning of relative stability.	BTL 1	Remember	CO 4
12.	Identify dominant pole location in s-plane and its significance.	BTL 1	Remember	CO 4
13.	Evaluate the effects of adding a zero to a system?	BTL 2	Understand	CO 4
14.	How centroid of the asymptotes found in root locus technique?	BTL 2	Understand	CO 4
15.	How will you find root locus on real axis?	BTL 2	Understand	CO 4
16.	Illustrate the effects of adding open loop poles and zeros on the nature of the root locus and on system?	BTL 1	Remember	CO 4
17.	Point out the regions of root locations for stable, unstable and limitedly stable systems.	BTL 1	Remember	CO 4
18.	Predict about the stability of the system when the roots of the characteristic equation are lying on imaginary axis?	BTL 2	Understand	CO 4
19.	State Nyquist stability criteria	BTL 1	Remember	CO 4
20.	Write the necessary and sufficient condition for stability.	BTL 1	Remember	CO 4
21.	Illustrate the need for compensation.	BTL 2	Understand	CO 4
22.	Summarize the lag-lead compensator using R and C network components.	BTL 2	Understand	CO 4
23.	Examine the circuit for lead compensator along with pole zero diagram.	BTL 2	Understand	CO 4
24.	Draw the circuit of lag compensator and draw its pole-zero diagram.	BTL 2	Understand	CO 4

PART – B				
1.	Using Routh criterion, determine the stability of the system represented by the characteristics equation, $s^4 + 8s^3 + 18s^2 + 16s + 5 = 0$. Comment on the location of the roots of characteristic equation. **(16)**	BTL 3	Apply	CO 4
2.	Consider the sixth order system with the characteristic equation $s^6 + 2s^5 + 8s^4 + 12s^3 + 20s^2 + 16s + 16 = 0$ Use Routh-Hurwitz criterion to examine the stability of the system and comment on location of the roots of the characteristics equation. **(16)**	BTL 4	Analyze	CO 4
3.	Apply Routh array and determine the stability of the system represented by the characteristic equation, $s^5 + s^4 + 2s^3 + 2s^2 + 3s + 5 = 0$ Comment on the location of characteristic equation. **(16)**	BTL 3	Apply	CO 4
4.	The characteristic equation of a feedback control system is given by $F(s) = s^6 + 4s^5 + 8s^4 + 24s^3 + 20s^2 + 32s + 16 = 0$ .Analyze the stability analysis of the system using Routh's array and also find the frequency of oscillation. **(16)**	BTL 3	Apply	CO 4
5.	Evaluate the stability of the system by using Routh stability criterion for the equation $9s^5 - 20s^4 + 10s^3 - s^2 - 9s - 10 = 0$ **(16)** Identify the location of the roots and comment.	BTL 3	Apply	CO 4
6.	Determine the location of roots on S- Plane and stability for the polynomial $s^7 + 9s^6 + 24s^5 + 24s^4 + 24s^3 + 24s^2 + 23s + 15 = 0$ **(16)**	BTL 3	Apply	CO 4
7.	Identify the root locus of a unity feedback system having transfer function $G(s) = \frac{K}{s(s^2 + 4s + 13)}$ Find the range of K for which the system is stable. **(16)**	BTL 3	Apply	CO 4
8.	Sketch the root locus of the system whose open loop transfer function is $G(s) = \frac{K}{s(s+2)(s+4)}$ Find the value of K so that damping ratio of the closed loop system is 0.5. **(16)**	BTL 4	Analyze	CO 4
9.	The open loop transfer function of a unity feedback system $G(s) = \frac{K(s+9)}{s(s^2 + 4s + 11)}$ Sketch the root locus of the system. **(16)**	BTL 3	Apply	CO 4
10.	Sketch the root locus for the unity feedback system whose open loop transfer function is **(16)** $G(s)H(s) = \frac{K}{s(s+4)(s^2 + 4s + 20)}$	BTL 3	Apply	CO 4
11.	Sketch root locus for the unity feedback system whose open loop transfer function is, **(16)** $G(s)H(s) = \frac{K(s+1.5)}{s(s+1)(s+5)}$	BTL 3	Apply	CO 4
12.	Determine the range of K for which closed loop system is stable for the open loop transfer function $G(s)H(s) = \frac{K}{s(s+2)(s+10)}$ by drawing the Nyquist plot. **(16)**	BTL 3	Apply	CO 4

13.	Construct the Nyquist plot for a system whose open loop transfer function is given by **(16)** $$G(s)H(s) = \frac{K(1+s)^2}{s^3}$$ Find the range of K for stability.	BTL 3	Apply	CO 4
14.	Write down the procedure for designing lead compensator using bode plot. **(16)**	BTL 4	Analyze	CO 4
15.	Write down the procedure for designing lag-lead compensator using bode plot. **(16)**	BTL 3	Apply	CO 4
16.	Construct a phase lag series compensator for an open loop transfer function of certain unity feedback control system given by $$G(s) = \frac{K}{s(s+4)(s+80)}$$ It is desired to have phase margin to be at least 33^o and the velocity error constant $K_V = 30\ Sec^{-1}$. **(16)**	BTL 4	Analyze	CO 4
17.	Design a lead compensator for a unity feedback system with open loop transfer function, $$G(s) = \frac{K}{s(s+1)(s+5)}$$ to satisfy velocity error constant ≥ 50 and phase margin $\geq 20^o$. **(16)**	BTL 4	Analyze	CO 4

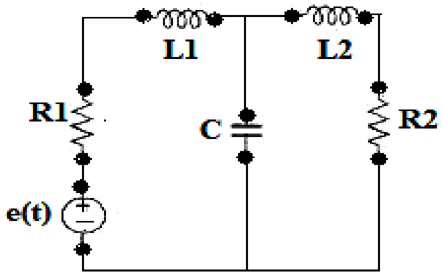
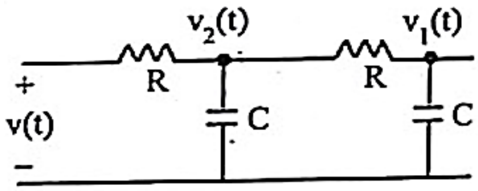
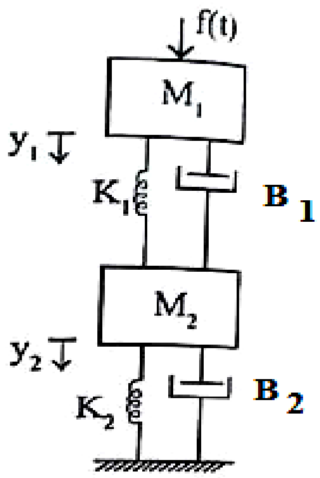
UNIT V – STATE VARIABLE ANALYSIS

Concept of state variables – State models for linear and time invariant Systems – Solution of state and output equation in controllable canonical form – Concepts of controllability and observability.

PART – A

Q.No.	Questions	BT Level	Competence	Course Outcome
1.	Write the state model of n^{th} order system	BTL 1	Remember	CO 5
2.	Analyze the basic elements used to construct the state diagram?	BTL 2	Understand	CO 5
3.	Draw the block diagram representation of state model.	BTL 2	Understand	CO 5
4.	Mention the advantages of state space analysis?	BTL 2	Understand	CO 5
5.	List down the draw backs in transfer function model analysis?	BTL 1	Remember	CO 5
6.	Point out the limitations of physical system modelled by transfer function approach.	BTL 2	Understand	CO 5
7.	Illustrate the state model using the signal flow graph?	BTL 1	Remember	CO 5
8.	Define state and state variable	BTL 1	Remember	CO 5
9.	Discuss about state vector?	BTL 2	Understand	CO 5
10.	How will you analyze the controllability and observability of a system using Kalman's Test?	BTL 2	Understand	CO 5
11.	Give the condition for controllability by Kalman's method.	BTL 1	Remember	CO 5
12.	State the condition for observability by Gilberts method.	BTL 1	Remember	CO 5
13.	Describe about state space?	BTL 2	Understand	CO 5
14.	Summarize the disadvantages in choosing phase variable for state space modeling?	BTL 2	Understand	CO 5
15.	Outline the properties of state transition matrix?	BTL 2	Understand	CO 5
16.	State the solution of homogenous state equation	BTL 1	Remember	CO 5
17.	What do you mean by controllability?	BTL 1	Remember	CO 5
18.	Identify the difference between transfer function and state space system	BTL 1	Remember	CO 5
19.	Point out the state equation and output equation of the state model.	BTL 2	Understand	CO 5
20.	Develop the advantages and disadvantages in canonical form of state model	BTL 1	Remember	CO 5
21.	Formulate the block diagram of the state model of a discrete time system	BTL 2	Understand	CO 5
22.	Deduce the state model of n^{th} order discrete time system	BTL 1	Remember	CO 5
23.	Evaluate the state model of a discrete time system using signal flow graph	BTL 2	Understand	CO 5
24.	Formulate the necessary condition to be satisfied for designing state feedback.	BTL 2	Understand	CO 5

PART – B

1.	Obtain the state model of the given electrical network by choosing minimal number of state variables. **(16)** 	BTL 3	Apply	CO 5
2.	Obtain the state model of the given electrical network by choosing $v_1(t)$ and $v_2(t)$ as state variables. **(16)** 	BTL 4	Analyze	CO 5
3.	For the given mechanical system, write the differential equations governing the system. 	BTL 3	Apply	CO 5
	Construct the state model of the given mechanical system. **(16)**			
4.	Construct a state model for the system characterized by the differential equation. $\frac{d^3y}{dt^3} + 6\frac{d^2y}{dt^2} + 11\frac{dy}{dt} + 6y + u = 0$	BTL 3	Apply	CO 5
	Give the block diagram representation of the state model. **(16)**			
5.	Obtain the state model of the system whose transfer function is given as, **(16)** $\frac{Y(s)}{U(s)} = \frac{10}{s^3 + 4s^2 + 2s + 1}$	BTL 3	Apply	CO 5
6.	For $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$ Compute the state transition matrix e^{At} using Cayley-Hamilton theorem. **(16)**	BTL 3	Apply	CO 5
7.	A linear time invariant system is described by the following state model. $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix} u$ $y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$	BTL 4	Analyze	CO 5

	Transform this state model in to a canonical state model. **(16)**			
8.	Deduce the canonical state model for the given transfer function. **(16)** $\frac{Y(s)}{U(s)} = \frac{10(s+4)}{s(s+1)(s+3)}$	BTL 3	Apply	CO 5
9.	Obtain the transfer function of the system defined by the following state space model. **(16)** $\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -3 & 1 \\ -3 & -4 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$ $y = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$	BTL 3	Apply	CO 5
10.	A LTI system is characterized by homogenous state equation **(16)** $\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$ Compute the solution of the homogenous equation, assuming initial state vector $X_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$	BTL 3	Apply	CO 5
11.	Examine the controllability and observability of a system having following coefficient matrices. **(16)** $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}; C^T = \begin{bmatrix} 10 \\ 5 \\ 1 \end{bmatrix}$	BTL 3	Apply	CO 5
12.	Consider the following plant of the state space representation: $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}; B = \begin{bmatrix} -2 \\ 2 \end{bmatrix}; \; C = \begin{bmatrix} -2 & 0 \end{bmatrix}$ Examine the controllability and observability of a state space formed by the system. **(16)**	BTL 3	Apply	CO 5
13.	Examine the controllability and observability of the system with state equation. **(16)** $\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$ $y = \begin{bmatrix} 3 & 4 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$	BTL 3	Apply	CO 5
14.	Elaborate whether the given system is completely Controllable and Observable **(16)** $\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} u$ $y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$	BTL 4	Analyze	CO 5
15.	Given that $A_1 = \begin{bmatrix} \sigma & 0 \\ 0 & \sigma \end{bmatrix}; A_2 = \begin{bmatrix} 0 & \omega \\ -\omega & 0 \end{bmatrix}; A = \begin{bmatrix} \sigma & \omega \\ -\omega & \sigma \end{bmatrix}$. Compute e^{At}. **(16)**	BTL 3	Apply	CO 5
16.	For the given digital transfer function $\frac{Y(z)}{U(z)} = \frac{4z^3 - 12z^2 + 13z - 7}{(z-1)^2(z-2)}$ Develop the state model in Jordan Canonical Form. **(16)**	BTL 4	Analyze	CO 5
17.	The state model of a discrete time system is given by	BTL 4	Analyze	CO 5

	$$X(k+1) = A\,X(k) + B\,U(k)$$ $$Y(k) = C\,X(k) + D\,U(k)$$ Determine its transfer function. **(16)**			