SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)

SRM Nagar, Kattankulathur – 603 203.

DEPARTMENT OF

ELECTRICAL AND ELECTRONICS ENGINEERING

QUESTION BANK

ME-Power Systems Engineering

I SEMESTER

1916104- SYSTEM THEORY

Regulation–2019

Academic Year 2021–22

Prepared by

Ms.R.V.Preetha, Assistant Professor-O.G/EEE

1916104 **SYSTEM THEORY** **L T P C**

3 2 0 4

UNIT I STATE VARIABLE REPRESENTATION 9

Introduction-Concept of State-State equations for Dynamic Systems -Time invariance and linearity- Non uniqueness of state model- Physical Systems and State Assignment - free and forced responses- State Diagrams.

UNIT II SOLUTION OF STATE EQUATIONS 9

Existence and uniqueness of solutions to Continuous-time state equations - Solution of Nonlinear and Linear Time Varying State equations - State transition matrix and its properties – Evaluation of matrix exponential- System modes- Role of Eigen values and Eigen vectors- Cayley Hamilton’s Theorem – Canonical form.

UNIT III STABILITY ANALYSIS OF LINEAR SYSTEMS 9

Controllability and Observability definitions and Kalman rank conditions -Stabilizability and Detectability-Test for Continuous time Systems- Time varying and Time invariant case-Output Controllability-Reducibility- System Realizations.

UNIT IV STATE FEEDBACK CONTROL AND STATE ESTIMATOR 9

Introduction-Controllable and Observable Companion Forms-SISO and MIMO Systems- The Effect of State Feedback on Controllability and Observability-Pole Placement by State Feedback for both SISO and MIMO Systems-Full Order and Reduced Order Observers.

UNIT V LYAPUNOV STABILTY ANALYSIS 9

Introduction-Equilibrium Points- BIBO Stability-Stability of LTI Systems- Stability in the sense of Lyapunov - Equilibrium Stability of Nonlinear Continuous-Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous-Time Autonomous Systems– Krasovskil’s and Variable-Gradiant Method.

TOTAL : 45+30 = 75 PERIODS

TEXT BOOKS:

1 M. Gopal, “Modern Control System Theory”, New Age International, 2005.

2 K. Ogatta, “Modern Control Engineering”, PHI, 2002.

3 John S. Bay, “Fundamentals of Linear State Space Systems”, McGraw-Hill, 1999.

4 D. Roy Choudhury, “Modern Control Systems”, New Age International, 2005.

5 John J. D’Azzo, C. H. Houpis and S. N. Sheldon, “Linear Control System Analysis and Design with MATLAB”, Taylor Francis, 2003.

6 Z. Bubnicki, ”Modern Control Theory”, Springer, 2005.

7 C.T. Chen, “Linear Systems Theory and Design’’ Oxford University Press, 3rd Edition, 1999.

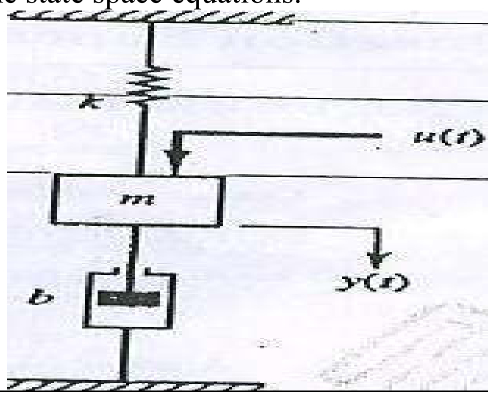
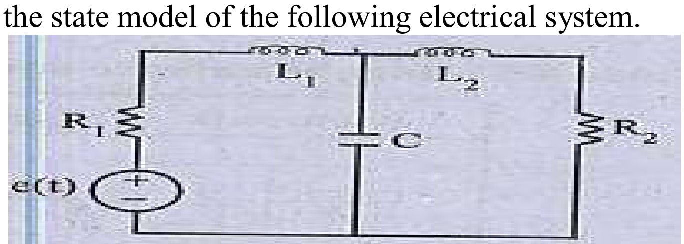
8 M. Vidyasagar,“Nonlinear Systems Analysis’, 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey.

UNIT I: STATE VARIABLE REPRESENTATION

Introduction-Concept of State-State equations for Dynamic Systems -Time invariance and linearity- Non uniqueness of state model- Physical Systems and State Assignment - free and forced responses- State Diagrams.

PART A (2 Marks)

Q.No.	Questions	Course Outcome	BT Level	Competence
1.	Examine the general form of the state space model for continuous system. And also write the state diagram.	CO 1	BTL 1	Remember
2.	Define the following terms such as (i) State (ii) State Variable (iii) State Vector (iv) State Space Model.	CO 1	BTL 1	Remember
3.	Give any two approach to convert the transfer function approach to the state space model.	CO 1	BTL 1	Remember
4.	List the drawbacks in transfer function model analysis?	CO 1	BTL 1	Remember
5.	Define the terms (i) Linearity (ii) Time invariance.	CO 1	BTL 1	Remember
6.	Define the term (i) Non-uniqueness of the state space model.	CO 1	BTL 1	Remember
7.	Express the state space model for a simple (i) Mass–Spring–Damper System (ii) Mechanical Rotational System.	CO 1	BTL 2	Understand
8.	Express the Formula in which the general form of state space model into transfer functional approach.	CO 1	BTL 2	Understand
9.	How the Diagonal canonical form is distinguished with Jordon Canonical form.	CO 1	BTL 2	Understand
10.	Distinguish the difference between (i) Physical variable model (ii) Phase Variable model.	CO 1	BTL 2	Understand
11.	Obtain the state space model for the given differential equation $\frac{d^3Y}{dt^2} + 6\frac{d^2Y}{dt^2} + 11\frac{dY}{dt} + 6Y = U(t)$	CO 1	BTL 3	Apply
12.	Consider a system whose transfer function is given by Y(S)/U(S) = $10(S+1)/S^3+6s^2+5s+10$. Calculate state model for this system.	CO 1	BTL 3	Apply
13.	A discrete time system is described by the difference equation Y(K+2)+5Y(K+1)+6Y(K) =U(K).Solve and find the transfer function of the system.	CO 1	BTL 3	Apply
14.	Compare the merits and demerits of realizing a given system in state variable and transfer function form.	CO 1	BTL 4	Analyze
15.	Derive and explain the transfer function model of a LTI system whose state equation is given by $X = \begin{pmatrix} 1 & 2 \\ 1 & 1 \end{pmatrix} X + \begin{pmatrix} 1 \\ -1 \end{pmatrix} U$ $Y = \begin{pmatrix} 1 & 1 \end{pmatrix} X$	CO 1	BTL 4	Analyze
16.	Explain the applications of state space model for the different system.	CO 1	BTL 4	Analyze

17.	Summarize the draw backs of transfer function model compare with state space model.	CO 1	BTL 5	Evaluate
18.	Judge any 2-methods for the conversion of transfer functional model into state space model.	CO 1	BTL 5	Evaluate
19.	Formulate state space model with state diagram for observable canonical form.	CO 1	BTL 6	Create
20.	Develop state space model with state diagram for controllable canonical form.	CO 1	BTL 6	Create
PART B (13 Marks)				
1.	Evaluate the state space model for the mechanical system as shown in Fig. Where u(t) is input and y(t) is output. Also derive the transfer function from the state space equations. 	CO 1	BTL 5	Evaluate
2.	Design & explain (i) Armature control of DC Motor (ii) Field Control of DC Motor.	CO 1	BTL 6	Create
3.	Analyze the state model of the following electrical system.  Fig 4.1.1.	CO 1	BTL 4	Analyze
4.	Calculate the state space model for Series RLC Circuit.	CO 1	BTL 3	Apply
5.	Illustrate the expression for the state space model for the continuous system and also draw the state diagram for it.	CO 1	BTL3	Apply
6.	Formulate the expression for the Controllable canonical form.	CO 1	BTL 6	Create
7.	Solve the state space model for the given system $Y(S)/U(S)=10/S^3+4S^2+2S+1$ by the method of (i) Laplace Transform (ii) Signal Flow Graph Method.	CO 1	BTL 3	Apply
8.	Evaluate the state space model for the given differential equation $\frac{d^3Y}{dt^2} + 6\frac{d^2Y}{dt^2} + 11\frac{dY}{dt} + 6Y = U(t)$ by Canonical form and also draw the state diagram for it.	CO 1	BTL 5	Evaluate
9.	A discrete time system is represented by the differential equation $y(n+2)+6y(n+1)+8y(n)=u(n)$ in which the initial condition y(0)=y(1)=0 with T=1Second (i) Estimate the controllable Canonical discrete state space model.	CO 1	BTL 2	Understand
10.	Define the terms (i) Linearity (ii) Non uniqueness (iii) Time invariance for state space model.	CO 1	BTL 1	Remember

11.	Illustrate the expression for the state space model for continuous system.	CO 1	BTL 3	Apply
12.	Evaluate the method for converting the transfer function into state space model (i) Bush Form (or) Companion form (ii) Signal Flow Graph Method (iii) Canonical Form Method.	CO 1	BTL 5	Evaluate
13.	Solve the state space model for the given system Y(S)/U(S)=8/(S+1)(S+2)(S+3) by the method of (i) Laplace Transform (ii) Signal Flow Graph Method.	CO 1	BTL 3	Apply
14.	Create the state space model by using signal flow graph for the given problem $Y(S)/U(S)=10/(S^3+5S^2+4S+10)$.	CO 1	BTL 6	Create
PART C (15 Marks)				
1.	Derive the expression for state space model for the system (i) Armature control of DC Motor (ii) Field Control of DC Motor. And also draw the diagrammatic representation for (i) Block diagram (ii) State diagram and State space model of the system.	CO 1	BTL 6	Create
2.	Illustrate the expression for the state space model for the continuous system and also draw the state diagram for it.	CO 1	BTL 6	Create
3.	Evaluate the state space model for the given differential equation $\frac{d^3Y}{dt^2} + 6\frac{d^2Y}{dt^2} + 11\frac{dY}{dt} + 6Y = U(t)$ by companion form method and also draw the state diagram for it.	CO 1	BTL 5	Evaluate
4.	Obtain the general expression for (i) Controllable canonical form (ii) Observable canonical form.	CO 1	BTL 5	Evaluate

UNIT II: SOLUTION OF STATE EQUATIONS

Existence and uniqueness of solutions to Continuous-time state equations - Solution of Nonlinear and Linear Time Varying State equations - State transition matrix and its properties – Evaluation of matrix exponential- System modes- Role of Eigen values and Eigen vectors- Cayley Hamilton’s Theorem – Canonical form.

PART A (2 Marks)

Q.No.	Questions	Course Outcome	BT Level	Competence
1.	What is the state transition matrix? List any two methods for finding state transition matrix.	CO 2	BTL 1	Remember
2.	Quote the formula for the solution of the state equation in time domain?	CO 2	BTL 1	Remember
3.	What is eigen values and eigen vectors? Examine how the eigen values can be calculated?	CO 2	BTL 1	Remember
4.	What is state transition matrix and identify how it is related to state of a system?	CO 2	BTL 1	Remember
5.	Describe the formula for Matrix exponential method.	CO 2	BTL 1	Remember
6.	Quote the different methods available for computing e^{At}?	CO 2	BTL 1	Remember
7.	Summarize the term Jordan canonical form.	CO 2	BTL 2	Understand
8.	Predict the transformation used to diagonalize a system matrix?	CO 2	BTL 2	Understand
9.	Estimate the transformed canonical state model of a system?	CO 2	BTL 2	Understand
10.	Express the term Model Matrix and explain with suitable formulae..	CO 2	BTL 2	Understand
11.	Demonstrate how the modal matrix can be determined?	CO 2	BTL 3	Apply

12.	Illustrate Cayley-Hamilton theorem.	CO 2	BTL 3	Apply
13.	Examine How the state transition matrix e^{At} is computed by canonical transformation.	CO 2	BTL 3	Apply
14.	Analyze how the state transition matrix e^{At} is computed using Cayley-Hamilton theorem?	CO 2	BTL 4	Analyze
15.	Point out how the state transition matrix and how it is related to state of a system?	CO 2	BTL 4	Analyze
16.	Explain the solution of homogeneous state equations.	CO 2	BTL 4	Analyze
17.	Write the solution of non-homogeneous state equations.	CO 2	BTL 5	Evaluate
18.	Judge the term resolvant matrix.	CO 2	BTL 5	Evaluate
19.	Formulate the state transition matrix by Laplace Transform method $A = \begin{bmatrix} 0 & 5 \\ -1 & -2 \end{bmatrix}$	CO 2	BTL 6	Create
20.	Formulate the state transition matrix by Matrix Exponential method $A = \begin{bmatrix} -1 & 1 \\ 0 & -1 \end{bmatrix}$	CO 2	BTL 6	Create
PART B (13 Marks)				
1.	Illustrate the expression by (i) Matrix Exponential Method (ii) Laplace Transform Method for state transistion of matrix.	CO 2	BTL 3	Apply
2.	Obtain the state space Model. $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 4 \\ 5 \end{bmatrix} U$; $y=[1\ 0\ 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Convert the state space model into canonical form. Also calculate the value of state transition matrix.	CO 2	BTL 3	Apply
3.	State Cayley-Hamilton's Theorem. Derive and explain the expression of state transition matrix using Cayley- Hamilton's theorem for continuous system.	CO 2	BTL 4	Analyze
4.	Evaluate the state transition matrix for the given discrete system matrix $A = \begin{bmatrix} 0 & 1 \\ -12 & 7 \end{bmatrix}$ by (i) Z-transform technique (ii) Cayley-Hamilton's theorem.	CO 2	BTL 5	Evaluate
5.	The given state space model $A = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix}$; Calculate the (i) Eigen values and Eigen vectors (ii) Rank of the matrix.	CO 2	BTL 3	Apply
6.	Evaluate the value of e^{At} by (i) Trial and Error Method (ii) Cayley Hamilton's Theorem. $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$	CO 2	BTL 5	Evaluate
7.	Analyze the value of state transition matrix or e^{At} by using (a) Laplace Transform Method in which $A = \begin{bmatrix} 0 & 1 \\ -12 & 7 \end{bmatrix}$	CO 2	BTL 4	Analyze

8.	The given matrix $A = \begin{bmatrix} -1 & 1 & 1 \\ 0 & -1 & 1 \\ 0 & 0 & --1 \end{bmatrix}$; Calculate the state transistion matrix by using Laplace transform method.	CO 2	BTL 3	Apply
9.	The given matrix $A = \begin{bmatrix} 2 & 1 & 4 \\ 0 & 2 & 0 \\ 0 & 3 & 1 \end{bmatrix}$; Estimate the value of state transition matrix by using Cayley Hamilton's Theorem.	CO 2	BTL 2	Understand
10.	Convert the transfer function for the state space model and calculate $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -3 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \end{bmatrix} U$ y=[1 0] $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$ $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -5 & -1 \\ 3 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 2 \\ 5 \end{bmatrix} U$; y=[1 2] $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$ $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -0.4 & -1.3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U$; y=[0.8 1] $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$	CO 2	BTL 3	Apply
11.	Solve and Calculate the value of state transition matrix or e^{At} by using (a)Cayley Hamilton's Theorem (b)A^{10} in which $A = \begin{bmatrix} 0 & 1 \\ -12 & 7 \end{bmatrix}$	CO 2	BTL 3	Apply
12.	Find and point out the value of e^{At} by (i) Trial and Error Method (ii) Cayley Hamilton's Theorem. $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$	CO 2	BTL 4	Analyze
13.	Consider a system whose transfer function is given by Y(S)/U(S) = $10(S+1)/S^3+6S^2+5S+10$ Evaluate the state model for the system by (i) Block diagram reduction (ii) Signal flow graph Method.	CO 2	BTL 5	Evaluate
14.	Create the expression for the following Methods for State Transition Matrix (i) Trial and Error Method (iii) Laplace Transform Method (iv) Canonical Form.	CO 2	BTL 6	Create
PART C (15 Marks)				
1.	Find and point out the value of State Transistion Matrix e^{At} by (i) Trial and Error Method (ii) Laplace Transform Method (iii) Cayley Hamilton's Theorem. $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$	CO 2	BTL 5	Evaluate
2.	Derive the general expression for the state transition matrix by (i) Trial and Error Method (ii) Laplace Transform (iii) Cayley Hamilton's Theorem.	CO 2	BTL 6	Create

3.	The given matrix $A = \begin{bmatrix} 2 & 1 & 4 \\ 0 & 2 & 0 \\ 0 & 3 & 1 \end{bmatrix}$; Estimate the value of state transistion matrix by using (i) Cayley Hamilton's Theorem (ii) Laplace Transform Method.	CO 2	BTL 5	Evaluate
4.	Explain the terms (i) Role of Eigen values and Eigen vectors (ii) Cayley Hamilton's Theorem.	CO 2	BTL 6	Create

UNIT III: STABILITY ANALYSIS OF LINEAR SYSTEMS

Controllability and Observability definitions and Kalman rank conditions-Stabilizability and Detectability-Test for Continuous time Systems-Time varying and Time invariant case- Output Controllability-Reducibility- System Realizations.

PART A (2 Marks)

Q.No.	Questions	Course Outcome	BT Level	Competence
1.	Quote what is meant by the rank of the matrix?	CO 3	BTL 1	Remember
2.	Define the duality of the system between controllability and observability concept?	CO 3	BTL 1	Remember
3.	The given state space model $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 4 \\ 5 \end{bmatrix} U$; y=[1 0 0] $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Tell whether the given is controllable.	CO 3	BTL 1	Remember
4.	Examine the need for observability test?	CO 3	BTL 1	Remember
5.	Describe the condition for observability by Gilbert's method.	CO 3	BTL 1	Remember
6.	When the Controllability test is normally applicable?	CO 3	BTL 1	Remember
7.	Summarize the condition for controllability by Gilbert's method.	CO 3	BTL 2	Understand
8.	Describe the condition for controllability by Kalman's method.	CO 3	BTL 2	Understand
9.	What is meant by minimal realization? Give the expression for it.	CO 3	BTL 2	Understand
10.	Discuss the effect of pole zero cancellation in transfer function approach.	CO 3	BTL 2	Understand
11.	Illustrate the concept of stabilizability.	CO 3	BTL 3	Apply
12.	Illustrate the concept of detectability.	CO 3	BTL 3	Apply
13.	Discover the advantage and disadvantage in Kalman's test for observability?	CO 3	BTL 3	Analyze
14.	The given state space model $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 4 \\ 5 \end{bmatrix} U$; y=[1 0 0] $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Solve whether the given is observable.	CO 3	BTL 3	Apply
15.	Analyze the condition for O/P controllability by Kalman;s method.	CO 3	BTL 4	Analyze

16.	Analyze the condition for observability by Kalman's method.	CO 3	BTL 4	Analyze
17.	Given two equivalent mathematical expressions which state that a given pair of matrices (A, B) is controllable. Evaluate the expression.	CO 3	BTL 5	Evaluate
18.	Write the Ackerman's formula for state feed back gain and explain it.	CO 3	BTL 5	Evaluate
19.	Create the formula for Observability of the system.	CO 3	BTL 6	Create
20.	What is meant by duality of the system. Develop the expression by Kalman's Method.	CO 3	BTL 6	Create
PART – B (13 Marks)				
1.	What is meant by rank of the matrix? Tell Whether the rank of the matrix depends on controllability or not explain it.	CO 3	BTL 1	Remember
2.	Define the concept of Controllability and observability of the system.Write the expression for the controllability and observability in (i) Kalman's Method (ii) Gilbert's Method.	CO 3	BTL 1	Remember
3.	Derive and Examine the expression for the (i) Controllable canonical form (ii) Observable Canonical Form.	CO 3	BTL 1	Remember
4.	The given state space model $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} U$; $y=[1\ 0\ 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Check whether the given is controllable and observable or not by Kalman's approach and Gilbert's method.	CO 3	BTL 1	Remember
5.	The given state space model $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 1 \\ 0 & 0 & 1 \\ -1 & -5 & -6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} U$; $y=[1\ 0\ 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Check and discuss whether the given is controllable and observable or not. And also check the duality by Kalman's approach and Gilbert's method.	CO 3	BTL 2	Understand
6.	The transfer function of the system $Y(S)/U(S)=3/S^3+6S^2+11S+6$. Check and express whether the given system is controllable as well as observable. And also check the duality by Kalman's approach and Gilbert's method.	CO 3	BTL 2	Understand
7.	Estimate the controllable canonical realization of the following systems. Hence, obtain the state space model in controllable canonical form (i) $H(S)=(S+2)/(S+5)$ (ii) $H(S)=(S+2)/(S^2+2S+5)$ (iii) $H(S)=(2S+9)/(S^3+8S^2+12S+1)$ (iv) $H(S)=(S^2+2S+3)/(S^4+3S^3+12S^2+9S+10)$.	CO 3	BTL 2	Understand
8.	Illustrate the expression for the Controllability and Observability in Kalman's Method.	CO 3	BTL 3	Apply
9.	Explain and demonstrate the (i) Reduciability (ii) System Realization. Explain with an example for each for solving a problem.	CO 3	BTL 3	Apply

10.	Explain with an example explain (i) Output Controllability and Observability (ii) Controllable and Observability concept applicable for time varying and invariant system.	CO 3	BTL 4	Analyze
11.	Consider a system with state space model is given below. $\begin{bmatrix}\dot{x}_1\\\dot{x}_2\\\dot{x}_3\end{bmatrix}=\begin{bmatrix}0&1&2\\0&0&1\\-1&-2&-3\end{bmatrix}\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}+\begin{bmatrix}0\\0\\4\end{bmatrix}U$; y=[2 -4 0] $\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}$ Point out that the system is observable and controllable.	CO 3	BTL 4	Analyze
12.	The given state space model $\begin{bmatrix}\dot{x}_1\\\dot{x}_2\\\dot{x}_3\end{bmatrix}=\begin{bmatrix}0&1&0\\0&0&1\\-6&-11&-6\end{bmatrix}\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}+\begin{bmatrix}0\\0\\3\end{bmatrix}U$;y=[1 0 0] $\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}$ Check whether the given is controllable and observable or not. And also Point out the duality by Kalman's approach and Gilbert's method.	CO 3	BTL 4	Analyze
13.	With the case study Summarize (i) Armature control of DC Motor (ii) Field Control of DC Motor. And also draw the (i) Block diagram (ii) State diagram and state space model for the system.	CO 3	BTL 5	Evaluate
14.	(i) Consider a system whose transfer function is given by Y(S)/U(S) = $10(S+1)/S^3+6s^2+5s+10$. Solve and explain state model for this system.	CO 3	BTL 4	Analyze
PART – C (15 Marks)				
1.	Illustrate the expression for the Controllability and Observability in (i) Kalman's Method (ii) Gilbert's Method.	CO 3	BTL 6	Create
2.	Consider a system with state space model is given below. $\begin{bmatrix}\dot{x}_1\\\dot{x}_2\\\dot{x}_3\end{bmatrix}=\begin{bmatrix}0&1&2\\0&0&1\\-1&-2&-3\end{bmatrix}\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}+\begin{bmatrix}0\\0\\4\end{bmatrix}U$; y=[2 -4 0] $\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}$ whether the given is controllable and observable or not. And also Point out the duality by Kalman's approach and Gilbert's method.	CO 3	BTL 5	Evaluate
3.	(i) Consider a system whose transfer function is given by Y(S)/U(S) = $20(S+1)/S^3+6s^2+5s+30$.Solve and explain state model for this system. (ii) The given state space model $\begin{bmatrix}\dot{x}_1\\\dot{x}_2\\\dot{x}_3\end{bmatrix}=\begin{bmatrix}-5&1&1\\-1&0&1\\0&0&1\end{bmatrix}\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}+\begin{bmatrix}0\\4\\5\end{bmatrix}U$; y=[1 0 0] $\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}$ Point out whether the given is controllable or observable or not. And also check the duality principle.	CO 3	BTL 5	Create
4.	Define the terms (i) Controllability (ii) Observability (iii) Stabilizability (iv) Detectability (v) Reducibility (vi) System Realizations.	CO 3	BTL 6	Evaluate

UNIT IV: STATE FEEDBACK CONTROL AND STATE ESTIMATOR

Introduction-Controllable and Observable Companion Forms-SISO and MIMO Systems- The Effect of State Feedback on Controllability and Observability-Pole Placement by State Feedback for both SISO and MIMO Systems-Full Order and Reduced Order Observers.

PART A (2 Marks)

Q.No.	Questions	Course Outcome	BT Level	Competence
1.	What is the state observer? Draw the diagram for State Observer and point out main features.	CO 4	BTL 4	Analyze
2.	Analyze the need for state observer for the system?	CO 4	BTL 4	Analyze
3.	Summarize the following terms (i) Full-order observer (ii) Reduced-order observer (iii) Minimum-order state observer?	CO 4	BTL 2	Understand
4.	What is the necessary condition to be satisfied for the design of state observer? Also Write the Ackermann's formula to identify the state observer gain matrix, G.	CO 4	BTL 1	Remember
5.	Define the term Pole Placement of controller.	CO 4	BTL 1	Remember
6.	Formulate the Ackermann's formula to find the state feedback gain matrix, K.	CO 4	BTL 6	Create
7.	Illustrate the general form of observable phase variable form of state model.	CO 4	BTL 3	Apply
8.	Summarize the pole placement controller by state feedback?	CO 4	BTL 5	Evaluate
9.	How will you evaluate the transformation matrix, P_O to the state model to observable phase variable form?	CO 4	BTL 5	Evaluate
10.	How control system design is carried in state space and discuss with an suitable example.	CO 4	BTL 2	Understand
11.	Quote the necessary condition to be satisfied for design using state feedback?	CO 4	BTL 1	Remember
12.	Illustrate the block diagram of a system with state feedback concept for controller.	CO 4	BTL 3	Apply
13.	Express the general form of controllable phase variable form of state model approach.	CO 4	BTL 2	Understand
14.	What is meant by Control law? And also write the gain formulae and analyze the Ackermann's Method.	CO 4	BTL 4	Analyze
15.	Illustrate how will you find the transformation matrix, Pc to transform the state model to controllable phase variable form using the characteristic equation?	CO 4	BTL 3	Apply
16.	How will you examine the transformation matrix, Pc to transform the state model to controllable phase variable form using the characteristic equation?	CO 4	BTL 1	Remember
17.	A system exhibits critically damped response for a step input and has a natural frequency of oscillation of 10rad/sec. Quote the equivalent pole locations.	CO 4	BTL 1	Remember
18.	Discuss observability of the system and explain with a diagram.	CO 4	BTL 2	Understand

19.	Formulate the state space model with state diagram for controllable canonical form	CO 4	BTL 6	Create
20.	Formulate the state space model with state diagram for observable canonical form.	CO 4	BTL 6	Create
PART – B (13 Marks)				
1.	Examine the design of pole placement concept for SISO and MIMO System with suitable diagram and expression.	CO 4	BTL 1	Remember
2.	Consider the state space model described by $\dot{X}(t) = AX(t)$, $Y(t) = CX(t)$; $A = \begin{bmatrix} -1 & 1 \\ -1 & -2 \end{bmatrix}$; C=[1 0]. Design and examine a full-order state observer. The desired Eigen values for the observer matrix $\mu_1 = -5; \mu_2 = -5$.	CO 4	BTL 1	Remember
3.	Explain the controllable canonical form and observable canonical form for an example.	CO 4	BTL 4	Analyze
4.	Obtain and analyze the expression for (i) Full order observer (ii) Reduced Order Observer (iii) Pole Placement of Controller.	CO 4	BTL 4	Analyze
5.	Describe the effect of feedback on the concept of Controllability and Observability of the system.	CO 4	BTL 2	Understand
6.	Describe in detail the concept of state space model for full order observer and reduced order observer.	CO 4	BTL 1	Remember
7.	Discuss briefly about the controllable and observable forms of SISO systems.	CO 4	BTL 2	Understand
8.	(i) Illustrate the Controllable Canonical Form and Observable Canonical forms for MIMO system. (ii) Illustrate the effect of state feedback on Controllability and Observability.	CO 4	BTL 3	Apply
9.	What is meant by state observer? Draw and analyze the state diagram and explain with an example for state space with feedback (i) Full Order (ii) Reduced Order Observer.	CO 4	BTL 4	Analyze
10.	The given state space model as follows $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} U$; y=[1 0 0] $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Convert the state model into observable phase variable format and evaluate it.	CO 4	BTL 5	Evaluate
11.	Illustrate the effect of state feedback gain by pole placement (i) Open loop state space without feedback gain (ii) Closed loop state feedback gain with control law for obtaining gain K by any one of the method with necessary condition.	CO 4	BTL 3	Apply
12.	Consider the state space model described by $\dot{X}(t) = AX(t)$, $Y(t) = CX(t)$; $A = \begin{bmatrix} -1 & 1 \\ -1 & -2 \end{bmatrix}$; C=[1 0]. Design and express a full-order state observer. The desired Eigen values for the observer matrix $\mu_1 = -5; \mu_2 = -5$.	CO 4	BTL 6	Create
13.	What is meant by observer? How the observer concept related with Observability. Examine the following types of observer (i) Full Order Observer (ii) Reduced Order Observer.	CO 4	BTL 1	Remember

14.	Estimate the following types of Canonical form with expression for (i) Controllable Canonical Form (ii) Observable Canonical Form.	CO 4	BTL 2	Understand
PART C (15 Marks)				
1.	Explain with expression for the terms (i) SISO System (ii) MIMO System.	CO 4	BTL 5	Evaluate
2.	Consider the state space model described by $\dot{X}(t) = AX(t)$, $Y(t) = CX(t)$ $A = \begin{bmatrix} -1 & 2 \\ -1 & -2 \end{bmatrix}$; C=[1 0]. Design and express a full-order state observer. The desired Eigen values for the observer matrix μ_1=-3; μ_2=-3.	CO 4	BTL 6	Create
3.	Explain the following terms with (i) Full Order Observer (ii) Reduced Order Observer (iii) Pole Placement of the controller (iv) Observability of the System.	CO 4	BTL 5	Evaluate
4.	Consider the state space model described by $\dot{X}(t) = AX(t)$, $Y(t) = CX(t)$ $A = \begin{bmatrix} -1 & 2 \\ -1 & -2 \end{bmatrix}$; C=[1 0]. Design and express a full-order state observer. The desired Eigen values for the observer matrix $\mu_1 = -7; \mu_2 = -7$.	CO 4	BTL 6	Create
UNIT V LYAPUNOV STABILTY ANALYSIS				
Introduction-Equilibrium Points- BIBO Stability-Stability of LTI Systems- Stability in the sense of Lyapunov - Equilibrium Stability of Nonlinear Continuous-Time Autonomous Systems-The Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems-Finding Lyapunov Functions for Nonlinear Continuous-Time Autonomous Systems – Krasovskil's and Variable-Gradiant Method.				
PART A (2 Marks)				
Q.No.	**Questions**	**Course Outcome**	**BTL Level**	**Competence**
1.	Define (i) Conditionally Stable (ii) Limitedly Stable (iii) Marginally Stable (iv) Unstable.	CO 5	BTL 1	Remember
2.	Explain BIBO stability.	CO 5	BTL 2	Understand
3.	Define positive definiteness of scalar functions. Give an example?	CO 5	BTL 1	Remember
4.	Point out Lyapunov's asymptotic stability.	CO 5	BTL 5	Evaluate
5.	Define the term stability.	CO 5	BTL 1	Remember
6.	Evaluate the concept of equilibrium points?	CO 5	BTL 5	Evaluate
7.	Examine what is meant by autonomous system?	CO 5	BTL 3	Apply
8.	Summarize the negative definiteness of scalar functions. Give an example?	CO 5	BTL 2	Understand
9.	Illustrate the Lyapunov's instability theorem.	CO 5	BTL 3	Apply
10.	Define positive semi definiteness of scalar functions. Give an example?	CO 5	BTL 1	Remember

11.	Draw and quote graphical representation of stable, asymptotic stable and unstable equilibrium states with their trajectory.	CO 5	BTL 1	Remember
12.	Show that the following quadratic form is + ve definite. $V(X)=10x_1^2+4x_2^2+x_3^2+2x_1x_2-2x_2x_3-4x_1x_3$	CO 5	BTL 3	Apply
13.	Determine whether the following quadratic form is – ve definite. $V(X) = -x_1^2-3x_2^2-11x_3^2+2x_1x_2-4x_2x_3-2x_1x_3$	CO 5	BTL 2	Understand
14.	In routh array Analyze the conclusions you can make when there is arrow of all zeros?	CO 5	BTL 4	Analyze
15.	Analyze the concept of limitedly stable system?	CO 5	BTL 4	Analyze
16.	Invent the necessary and sufficient condition for stability?	CO 5	BTL 6	Create
17.	A system has repeated Eigen values on imaginary axis. What can you create about the asymptotic stability of the system?	CO 5	BTL 6	Create
18.	List out various methods for stability analysis of non linear system.	CO 5	BTL 1	Remember
19.	Define Lyapunov's sufficient condition for asymptotic stability.	CO 5	BTL 1	Remember
20.	Mention the advantages of Lyapunov's stability criteria.	CO 5	BTL 1	Remember
	PART B (13 Marks)			
1.	Describe the modeling energy system in terms of quadratic function.	CO 5	BTL 1	Remember
2.	Explain the Lyapunov's stability criteria with diagrammatic representation (i) Asymptotically stable (ii) Stable (iii) Unstable.	CO 5	BTL 4	Analyze
3.	Examine the Lyapunov's stability analysis for (i) Linear time invariant system (ii) Nonlinear Continuous system.	CO 5	BTL 3	Apply
4.	Explain the Lyapunov's criterion stability analysis for (i) Continuous system (ii) Discrete time systems.	CO 5	BTL 5	Evaluate
5.	Summarize Krasovskii method and how it can be applicable for stability analysis. Explain with an example for it.	CO 5	BTL 2	Understand
6.	Summarize direct method of Lyapunov's function how it can be applicable for nonlinear continuous time system.	CO 5	BTL 2	Understand
7.	Examine Lyapunov's direct method of Lyapunov for Continuous time autonomous system.	CO 5	BTL 1	Remember
8.	Examine the following terminology: Stability in the sense of Lyapunov.	CO 5	BTL 1	Remember
9.	Design and determine if the following matrix is positive definite. $V(X)=10x_1^2+4x_2^2+x_3^2+2x_1x_2-2x_2x_3-4x_1x_3$.	CO 5	BTL 6	Create
10.	Estimate the direct method of Lyapunov's function how it can be applicable for nonlinear continuous time system.	CO 5	BTL 2	Understand
11.	Illustrate Variable-Gradiant Method for stability analysis with suitable example.	CO 5	BTL 3	Apply
12.	Describe Lyapunov's Method Stability analysis for (i) Linear System (ii) Non-Linear System with suitable example.	CO 5	BTL 1	Remember
13.	What is meant by autonomous of the system? Analyze how the Lyapunov's Method applicable for Linear and Nonlinear autonomous system.	CO 5	BTL 4	Analyze

14.	Explain following stability concepts (i) Lyapunov's Method stability at orgin (ii) Lyapunov's Method stability in stable boundary (iii) Lyapunov's Method for unstable condition.	CO 5	BTL 4	Analyze
PART C (15 Marks)				
1.	Illustrate the following methods for stability analysis with suitable example (i) Krasovskii Method (ii) Variable-Gradiant Method.	CO 5	BTL 5	Evaluate
2.	Explain the Lyapunov's stability criteria with diagrammatic representation (i) Asymptotically stable (ii) Stable (iii) Unstable (iv) Linear time invariant system (v) Nonlinear Continuous system.	CO 5	BTL 5	Evaluate
3.	Examine Lyapunov's direct method of Lyapunov for Continuous time autonomous system & non linear continuous time system.	CO 5	BTL 6	Create
4.	Examine the following terminology: BIBO Stability for Linear Time Invarient System.	CO 5	BTL 6	Create

COURSE OUTCOMES:

1. Ability to acquire the knowledge on Physical systems representation in the State Variable form.
2. Ability to acquire the knowledge on the solution of state transition matrix by different techniques.
3. Ability to represent the time-invariant systems in state space form as well as analyze whether the system is stabilizable, controllable, observable and detectable.
4. Ability to assess the stability of certain class of non-linear system.
5. Ability to apply the techniques such as describing function, Lyapunov Stability, Popov's Stability Criterion and Circle Criterion to assess the stability of certain class of non-linear system. Ability to design state feedback controller and state observers.