Course Code: 18EE0223 **R18**

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QUESTION BANK (DESCRIPTIVE)

Subject with Code: Modern Control Theory (18EE0223) **Course & Branch**: B.Tech - EEE

Year & Sem: III-B.Tech & II-Sem **Regulation:** R18

UNIT –I

STATE VARIABLE DESCRIPTION AND SOLUTION OF STATE EQUATION

1	**a)**	Define state variable.	[L1][CO1]	**[2M]**
	b)	Write any two properties of state transition matrix.	[L1][CO1]	**[2M]**
	c)	What are the advantages of state space representation? Compare with transfer function representation.	[L1][CO1]	**[2M]**
	d)	What is state diagram?	[L1][CO1]	**[2M]**
	e)	Define state model.	[L1][CO1]	**[2M]**
2		Consider the following transfer function of a system $\frac{y(s)}{U(s)} = \frac{s+6}{s^2+6s+6}$. Obtain state space representation of the system.	[L1][CO1]	**[10M]**
3	a)	Explain state model and prove state model representation is not unique with example.	[L2][CO1]	**[5M]**
	b)	Construct a state model for a system characterized by the differential equation $\frac{d^3y}{dt^3} + 6\frac{d^2y}{dt^2} + 11\frac{dy}{dt} + 6y = \frac{d^3u}{dt^3} + 8\frac{d^2u}{dt^2} + 17\frac{du}{dt} + 8u$.	[L6][CO1]	**[5M]**
4	a)	Derive a solution of homogeneous state equation.	[L3][CO1]	**[5M]**
	b)	Obtain the state transition matrix of $A = \begin{bmatrix} -6 & 1 & 0 \\ -11 & 0 & 1 \\ -6 & 0 & 0 \end{bmatrix}$.	[L1][CO1]	**[5M]**
5	a)	State and prove the various properties of state transition matrix.	[L5][CO1]	**[5M]**
	b)	Computer the solution of state equation $X = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} X + \begin{bmatrix} 1 \\ 1 \end{bmatrix} U$; $X_0 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$		**[5M]**
6		Obtain state space representation for following systems (a) $\frac{Y(s)}{U(s)} = \frac{10(s+4)}{s(s+1)(s+3)}$ (b) $\frac{Y(s)}{U(s)} = \frac{10}{s^3+4s^2+2s+1}$	[L1][CO1]	**[10M]**
7		Obtain a state space equation and output equation for the system defined by $\frac{Y(s)}{U(s)} = \frac{2s^3+s^2+s+2}{s^3+4s^2+5s+2}$	[L1][CO1]	**[10M]**
8		For a system represented by state equation $\dot{x}(t) = Ax(t)$. The response is $x(t) = \begin{bmatrix} e^{-2t} \\ -2e^{-2t} \end{bmatrix}$ when $x(0) = \begin{bmatrix} 1 \\ -2 \end{bmatrix}$ & $x(t) = \begin{bmatrix} e^{-t} \\ -e^{-t} \end{bmatrix}$ where $x(0) = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$. Determine the system matrix A and the state transition matrix.	[L5][CO1]	**[10M]**
9		$X = \begin{bmatrix} -1 & -4 & -1 \\ -1 & -6 & -2 \\ -1 & -2 & -3 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} U; Y = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix} X.$ Find the transfer function of the system.	[L1][CO1]	**[10M]**
10		Explain state model and derive the solutions of state equation.	[L2][CO1]	**[10M]**

UNIT –II
CONTROLLABILITY, OBSERVABILITY

1	**a)**	Define controllability.	[L1][CO2]	**[2M]**
	b)	What is need for observability test?	[L1][CO2]	**[2M]**
	c)	State the reality between controllability and observability.	[L2][CO2]	**[2M]**
	d)	State the condition for observability by Kalman's method.	[L2][CO2]	**[2M]**
	e)	What canonical form of state model?	[L1][CO2]	**[2M]**
2	a)	Define Controllability. What are the tests to find the controllability of a system?	[L1][CO2]	**[5M]**
	b)	The state equation is given by $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} U$. Test for controllability.	[L4][CO2]	**[5M]**
3	a)	Define Observability. What are the tests to find the observability of a given system?	[L1][CO2]	**[5M]**
	b)	Test observability for $\dot{x_1} = -2x_1 + x_2 + U,\ \dot{x_2} = -x_2 + U$ and y= $x_1 + x_2$.	[L4][CO2]	**[5M]**
4		A System is represented by the state model: $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 1 & 3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} U;\ y(t) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Check whether system is (a) Completely Controllable (b) Completely Observable.	[L1][CO2]	**[10M]**
5		A System is represented by the state model: $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -2 & -1 & -3 \\ 0 & -2 & 1 \\ -7 & -8 & -9 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 2 \\ 1 \\ 2 \end{bmatrix} U(t);\quad y(t) = \begin{bmatrix} 4 & 6 & 8 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$. Test whether the system is (a) Completely Controllable (b) Completely Observable	[L4][CO2]	**[10M]**
6		Consider the system $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 3 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ the output is given by $Y = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$. (a) Show that the system is not completely observable (b) Show that the system is completely observable if the output is given by $\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$.	[L1][CO2]	**[10M]**
7		State and prove the principle of duality between controllability and observability.	[L2][CO2]	**[10M]**
8		The state model of a system is given by $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} [u];\ Y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Convert the state model to canonical form	[L2][CO2]	**[10M]**
9		The state model of a system is given by	[L1][CO2]	**[10M]**

$\dot{x} = \begin{bmatrix} 2 & -2 & 3 \\ 1 & 1 & 1 \\ 1 & 3 & -1 \end{bmatrix} x + \begin{bmatrix} 11 \\ 1 \\ -14 \end{bmatrix} u;\ Y = \begin{bmatrix} -3 & -5 & -2 \end{bmatrix} x$. Find the canonical format representation.

10 Write the effect of state feedback on controllability and observability. [L1][CO2] **[10M]**

UNIT –III

STATE FEEDBACK CONTROLLERS AND OBSERVERS

1 **a)** What is pole placement by state feedback? [L1][CO3] **[2M]**

b) Define state observer? [L1][CO3] **[2M]**

c) What is the need for state observer? [L1][CO3] **[2M]**

d) Define full order & reduced order observer. [L1][CO3] **[2M]**

e) What is the necessary condition to be satisfied for design of state observer? [L1][CO3] **[2M]**

2 Explain the design of pole placement controller using state feedback. [L1][CO3] **[10M]**

3 Consider a linear system described by the transfer function $\frac{Y(s)}{U(s)} = \frac{10}{s(s+1)(s+2)}$. Design a feedback controller with a state feedback, so that the closed loop poles are placed at -2, -1± j1. [L1][CO3] **[10M]**

4 A single input system is described by the following state equation [L1][CO3] **[10M]**

$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 1 & -2 & 0 \\ 2 & 1 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 10 \\ 1 \\ 0 \end{bmatrix} U$. Design a state feedback controller which will give closed loop poles at -1±j2, 6.

5 Explain the full order and reduced order observer. [L1][CO3] **[10M]**

6 As $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} U;\ Y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$. Convert the state model to observable phase variable form. [L2][CO3] **[10M]**

7 The state model is given by [L2][CO3] **[10M]**

$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} U;\ Y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$. Convert the state model to controllable phase variable form.

8 Consider the system described by the state model x=Ax; y=Cx; Where A=$\begin{bmatrix} -1 & 1 \\ 1 & -2 \end{bmatrix}$; C=$\begin{bmatrix} 1 & 0 \end{bmatrix}$. Design a full order state observer. The desired eigen values for the observer matrix are $\mu_1 = -5$; $\mu_2 = -5$. [L1][CO3] **[10M]**

9 What is state observer? Explain about state observer. [L1][CO3] **[10M]**

10 Consider the system defined by [L1][CO3] **[10M]**

$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -5 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u(t);\ y(t) = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$. Design a full order state observer assuming the desired poles for the observer are located at -10,-10,-15.

UNIT –IV
ANALYSIS OF NON LINEAR SYSTEMS

1	**a)**	How nonlinearities are introduced in the system.	[L1][CO4]	**[2M]**
	b)	What are the methods available for the analysis of nonlinear system?	[L1][CO4]	**[2M]**
	c)	What is dead zone?	[L1][CO4]	**[2M]**
	d)	What is phase trajectory?	[L1][CO4]	**[2M]**
	e)	How limit cycles are determined from phase portrait.	[L1][CO4]	**[2M]**
2		Derive the describing function of back lash nonlinearities.	[L6][CO4]	**[10M]**
3		Derive the describing function of saturation nonlinearities.	[L6][CO4]	**[10M]**
4		Derive the describing function of relay with dead zone.	[L6][CO4]	**[10M]**
5		Explain the classification of non-linear systems.	[L2][CO4]	**[10M]**
6		With the help of graphical representations, explain about various common physical nonlinearities.	[L2][CO4]	**[10M]**
7		Explain the method of isoclines for the construction of phase trajectories.	[L2][CO4]	**[10M]**
8		What is singular point? Explain various types of singular points.	[L1][CO4]	**[10M]**
9		A linear second order servo is described by the equation $\ddot{e}+2\zeta\omega_n\dot{e}+\omega_n^2 e=0$, Where, $\zeta = 0.15$, $\omega_n = 1$ rad/sec, $e(0) = 1.5$ and $\dot{e}(0) = 0$. Determine the singular point construct the phase trajectory using method of isoclines.	[L5][CO4]	**[10M]**
10	a)	Explain in detail about various characteristics of non-linear systems.	[L2][CO4]	**[5M]**
	b)	Describe various types of singular points and their corresponding phase portraits with rough sketches	[L1][CO4]	**[5M]**

UNIT –V
STABILITY ANALYSIS

1	**a)**	State Lyapunov instability theorem.	[L5][CO5]	**[2M]**
	b)	State Lyapunov stability theorem.	[L5][CO5]	**[2M]**
	c)	What is the condition for stability in Lyapunov direct method?	[L1][CO5]	**[2M]**
	d)	What are the linear autonomous system?	[L1][CO5]	**[2M]**
	e)	Define positive definiteness of a system.	[L1][CO5]	**[2M]**
2		State and prove Lyapunov stability theorem	[L5][CO5]	**[10M]**
3		Show that the asymptotically stable condition of a linear system $\dot{x} = Ax$ at origin is: $A^T P + PA = -Q$. Where P&Q are the symmetric positive definite matrices.	[L2][CO5]	**[10M]**
4		Consider the non-linear system: $\dot{x}_1 = x_2,\ \dot{x}_2 = -x_1 - x_1^2 x_2$ investigate the stability of this non-linear system around its equilibrium point at origin.	[L4][CO5]	**[10M]**
5		Use Krasovskii's theorem to show that the equilibrium state x=0 of the system described by $\dot{x}_1 = -3x_1 + x_2,\ \ \dot{x}_2 = x_1 - x_2 - x_2^3$ is asymptotically stable in the large.	[L2][CO5]	**[10M]**
6	a)	State and prove Lyapunov instability theorem.	[L5][CO5]	**[5M]**
	b)	Show that the following quadratic form is positive definite V(x) = $8x_1^2 + x_2^2 + 4x_3^2 + 2x_1x_2 - 4x_1x_3 - 2x_2x_3$	[L1][CO5]	**[5M]**

7	a)	Show the graphical representation of stability, asymptotic stability and instability	[L1][CO5]	**[5M]**
	b)	Define quadratic form and Hermitian form.	[L1][CO5]	**[5M]**
8		Using Lyapunov analysis, determine the stability of the equilibrium state of the system $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -1 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$.	[L5][CO5]	**[10M]**
9		Examine the stability of the system described by the following equation by Krasovskii's theorem $\dot{x}_1 = -x_1 \;\; \dot{x}_2 = x_1 - x_2 - x_2^3$	[L4][CO5]	**[10M]**
10		State and explain about Lyapunov stability for non-linear system.	[L2][CO5]	**[10M]**

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