# WEST BENGAL UNIVERSITY OF TECHNOLOGY

## EE-601

## CONTROL SYSTEM -II

Time Allotted: 3 Hours | Full Marks: 70

*The questions are of equal value.*
*The figures in the margin indicate full marks.*
*Candidates are required to give their answers in their own words as far as practicable.*
*All symbols are of usual significance.*

### GROUP A
### (Multiple Choice Type Questions)

1. Answer any *ten* questions. $10\times1 = 10$

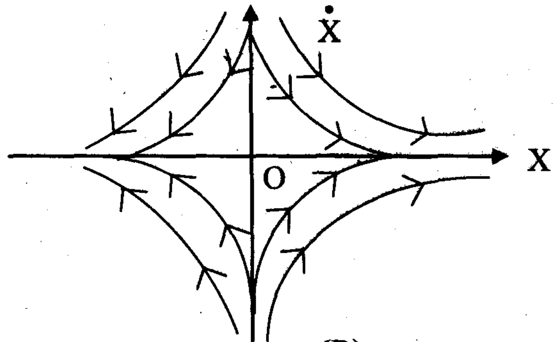
(i) When the roots of the characteristic equation of a second order system are complex conjugate with negative real part, then the equilibrium point is termed as

(A) stable node (B) saddle node
(C) unstable node (D) focus

(ii) To compute the describing function of a nonlinear element for a sinusoidal input.

(A) the fundamental harmonic component of the output is required
(B) the dead zone and saturation are to be avoided
(C) the nonlinear system is to be assumed linear
(D) the fundamental and higher harmonics are required

(iii) The phase portrait of a nonlinear system is shown in the following figure. Here the origin is a




(A) stable focus (B) vortex

(C) stable node (D) saddle point

(iv) Consider the following state equations for a discrete system

$$\begin{bmatrix} X_1(k+1) \\ X_2(k+1) \end{bmatrix} = \begin{bmatrix} -\frac{1}{2} & 0 \\ -\frac{1}{4} & -\frac{1}{4} \end{bmatrix} \begin{bmatrix} X_1(k) \\ X_2(k) \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} U(k)$$

$$Y(k) = \begin{bmatrix} 1 & -1 \end{bmatrix} \begin{bmatrix} X_1(k) \\ X_2(k) \end{bmatrix} - 4U(k)$$

The system given above is

(A) controllable and observable

(B) uncontrollable and observable

(C) uncontrollable and unobservable

(D) controllable and unobservable

(v) The transfer function of a multi-input multi-output system, with the state space representation of

$\dot{X} = AX + BU$

$Y = CX + DU$

where $X$ represents the state, $Y$ the output and U the input vector, will be given by

(A) $C(SI - A)^{-1}B$ (B) $C(SI - A)^{-1}B + D$

(C) $(SI - A)^{-1}B + D$ (D) $(SI - A)^{-1}B$

(vi) If the eigen values are on the imaginary axis, the phase portrait has

(A) closed path trajectories
(B) spiral trajectories focusing at the origin
(C) trajectories converging to the origin
(D) unstable focus

(vii) The variable gradient method is used to find

(A) Lyapunov function
(B) Describing function
(C) State transition matrix
(D) Eigen vectors

(viii) If the z-transform of a function is $\frac{z \sin wt}{z^2 - 2z\cos wt + 1}$, its corresponding Laplace transform will be

(A) $\frac{s}{s^2 + w^2}$
(B) $\frac{w}{s^2 + w^2}$
(C) $\sin wt$
(D) $\frac{w}{s + w}$

(ix) $V = X_1^2 + X_2^2$ is positive definite

(A) in the three dimensional state space
(B) in the two dimensional state space
(C) in any dimensional state space
(D) in the four dimensional state space

(x) If the state equation of a dynamic system is given by $\dot{X}(t) = AX(t)$

$$A = \begin{bmatrix} -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & -3 & 4 \\ 0 & 0 & 0 & -4 & -3 \end{bmatrix}$$

the eigen values of the system would be.

(A) real non repeated
(B) real non repeated and complex
(C) real repeated
(D) real repeated and complex

(xi) The necessary and sufficient condition for pole placement approach is

(A) completely controllable

(B) completely observable

(C) completely controllable and observable

(D) neither controllable and non observable

(xii) An anti-aliasing filter is a

(A) low pass filter (B) high pass filter

(C) band pass filter (D) band stop filter

## GROUP B
### (Short Answer Type Questions)

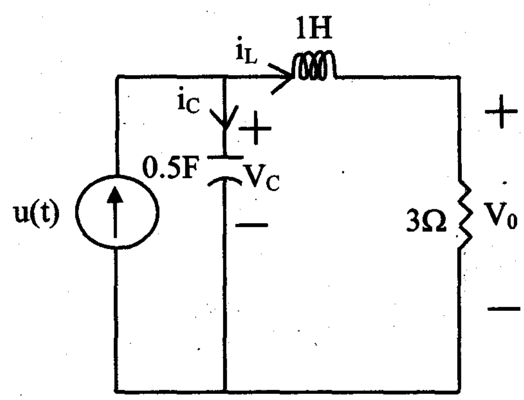
Answer any *three* questions. $3\times5 = 15$

2. Predict the controllability and observability for the system

$$\dot{X}(t)=AX(t)+BU(t) \text{ and } Y(t)=CX(t)$$

$$\text{Where } A=\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix},\ B=\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \text{ and } C=\begin{bmatrix} 4 & 5 & 1 \end{bmatrix}$$

3. Find the state space model of the electrical systems shown below in terms of physical variable. Take $V_C$ and $i_L$ as state variables and $V_0$ as output variable.



4. For the discrete time system

$$x(k+2)+5x(k+1)+6x(k)=u(k)$$
$$x(0)=x(1)=0$$

Find the state transition matrix.

5. Compute the Z transform of a unit parabolic function $P(k)$ where

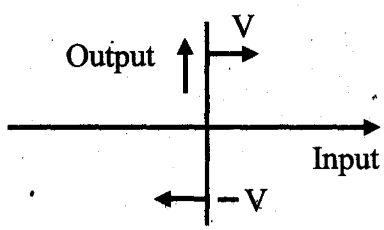
$$P(k)=\begin{cases} k^2, & \text{for } k \geq 0 \\ 0, & \text{for } k < 0 \end{cases}$$

6. A system is represented by $\dot{x} = -4x + x^3$

(a) Find the singular points

(b) Draw the phase portrait

7. Find out the describing function of a relay at ideal condition.




## GROUP C
## (Long Answer Type Questions)

Answer any *three* questions. $3 \times 15 = 45$

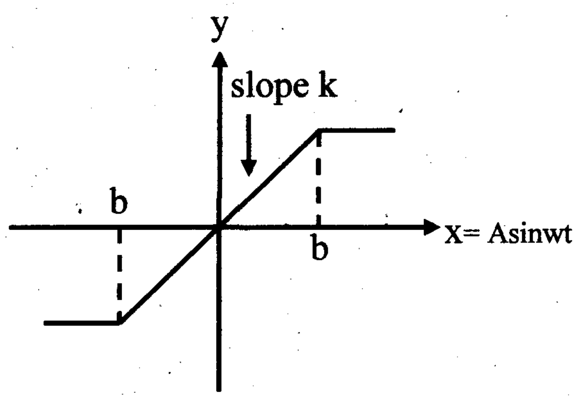
8. (a) Consider a system defined by 8

$$\dot{X} = AX + BU, \text{ where } A=\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -6 \end{bmatrix} \;\&\; B=\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Using state feedback control U = – KX, it is desired to have closed loop poles at $s = 2 \pm j4$, $s = -10$. Determine the state feedback gain matrix K.

(b) A system is described by the state equation $\dot{X}=\begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}X+\begin{bmatrix} 0 \\ 1 \end{bmatrix}U$ & $Y=[1 \quad 0]X$, where $x(0)=[0 \quad 0]^T$, the input to the system is unit step. Find out the state solution of the above system. 7

9. (a) Find the describing function for the following non linearity. 10



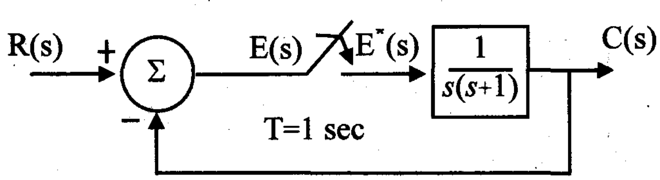

(b) Explain how prediction of limit cycles using describing function technique is made. 5

10.(a) Define the system's stability in the light of Lypunov criterion. 3

(b) Find the equilibrium point of the nonlinear system described by the following differential equation 5

$$\frac{d^2x}{dt^2}+x^2+\left(\frac{dx}{dt}\right)^2-2x+\frac{dx}{dt}=0$$

(c) Find the pulse transfer function of the error sampled system shown in figure given below. 7



11.(a) Solve the following difference equation using z-transform method. 6

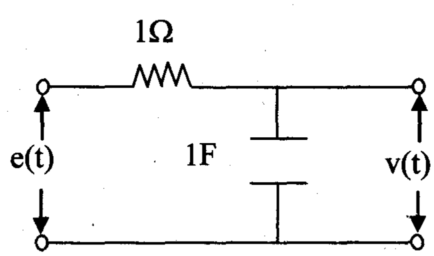
$$x(k+2)+3x(k+1)+2x(k)=0$$
$$x(0)=0,\ x(1)=1$$

(b) In continuous time, a system is given by the transfer function $G(s)=\dfrac{k}{s+a}$ 3

Find the z-transfer function $G(z)$.

(c) Find the output voltage in discrete form of the RC circuit shown in figure given below when the input voltage is applied as follows 6

$$e(t)=e(nT) \text{ where } nT \le t \le (n+1)T \text{ and } T=1S$$




12. A system is characterized is the following state equation 4+3+4+4

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}u$$

$$x(0)=\begin{bmatrix}1\\ 1\end{bmatrix},\ y=\begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

(i) Find the transfer function of the system;
(ii) Draw the block diagram of the above transfer function;
(iii) Compute the state transition matrix;
(iv) Determine the output response of the system to unit step input.

13.(a) Explain the term Asymptotic stability and Global stability. 4+6+5
(b) Explain the second method of Lyapunov to analyze nonlinear systems.

(c) For the dynamic system given by the state space equation, investigate the stability of the system using Lyapunov method

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -3 & -4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

14. Write short note on any *three* of the following : 3×5

(a) Harmonic linearization

(b) Digital compensator design using frequency response.

(c) Limit cycles in nonlinear system

(d) Characteristic of common nonlinearities.