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Paper Code : EE-601

CONTROL SYSTEM - II

Time Allotted : 3 Hours | *Full Marks* : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) To compute the describing function of a non-linear element for a sinusoidal input

   a) the fundamental harmonic component of the output is required

   b) the dead zone & saturation are to be avoided

   c) the non-linear system is to be assumed linear

   d) the fundamental & higher harmonic are required.

ii) The variable gradient method is used to find

a) Lyapunov function

b) Describing function

c) State transition matrix

d) Exgen vectors.

iii) In a parallel R-L-C circuit, the number of state variables required to describe the system is

a) 1 b) 2

c) 3 d) 4.

iv) The state equation of a linear system is given by $\dot{X}(t)=\begin{bmatrix}-2 & 0\\ 0 & -3\end{bmatrix}X(t)+\begin{bmatrix}1\\1\end{bmatrix}U(t)$, then the system is

a) controllable

b) observable

c) both controllable & observable

d) unstable.

v) Consider the following state equation :

$$\begin{bmatrix}X_1(k+1)\\X_2(k+1)\end{bmatrix}=\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\begin{bmatrix}X_1(k)\\X_2(k)\end{bmatrix}+\begin{bmatrix}1\\1\end{bmatrix}u(k)$$

$$Y(k)=\begin{bmatrix}1 & 2\end{bmatrix}\begin{bmatrix}X_1(k)\\X_2(k)\end{bmatrix}.$$

The system given above is

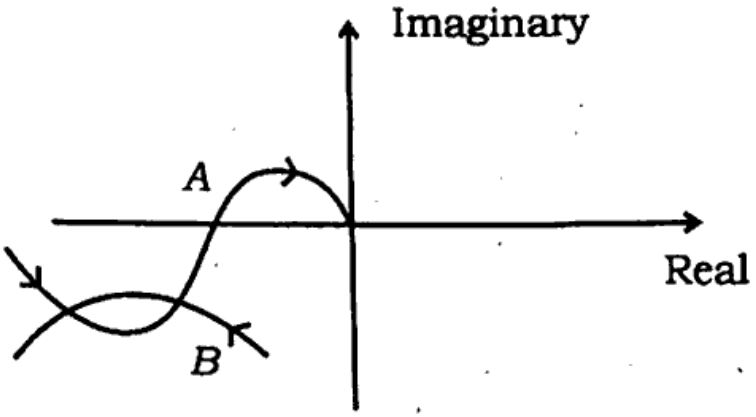
a) uncontrollable & observable

b) controllable & unobservable

c) uncontrollable & unobservable

d) controllable & observable.

vi) In the figure shone



a) *A* has unstable limit cycle & *B* has stable limit cycle

b) *A* has stable limit cycle & *B* has unstable limit cycle

c) both *A* & *B* have unstable limit cycle

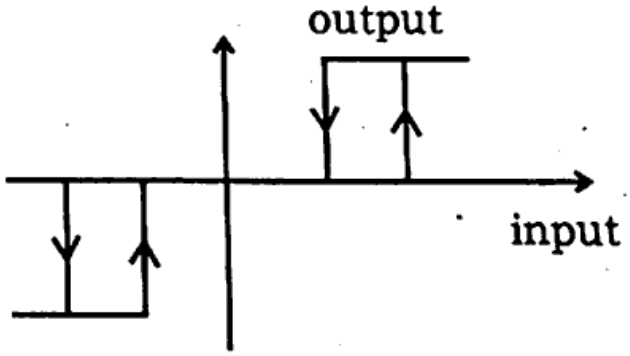
d) both *A* & *B* have stable limit cycle.

vii) The inverse *z*-transform of the function $\frac{Tz}{(z-1)^2}$ is

a) kT b) k^2T

c) kT^2 d) k.

viii) The input-output characteristics of the control system is shown below. The non-linearity is



a) Relay with dead zone

b) Relay with dead zone & hysteresis

c) Relay with hysteresis

d) Relay.

ix) The phase plane analysis method is restricted to

a) second order systems

b) 4th order systems

c) n th order system

d) 3rd order systems.

x) Jump resonance characteristic can be found in

a) chaotic system

b) second order non-linear system

c) higher order non-linear system

d) linear time varying system.

xi) The matrix A is given by $\begin{bmatrix} 4 & -4 & 2 \\ -4 & 5 & -2 \\ 2 & -2 & 1 \end{bmatrix}$.

The matrix A is

a) positive semi-definite

b) negative semi-definite.

c) positive definite

d) negative definite.

xii) The state equation of a system is given by $\dot{X} = AX + BU$ & $Y = CX + DU$. The transfer function is

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

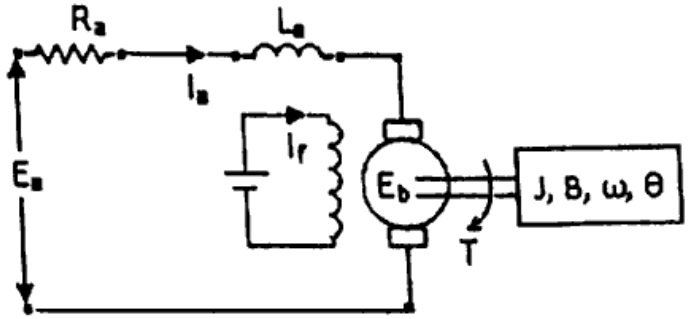
c) $B(SI - A)^{-1}B + C$ d) $B(SI - A)^{-1}D + B$.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. Obtain the state model for an armature controlled DC motor shown in the figure below. Symbols have their usual meaning.



3. Determine the describing function of a 'saturation' non-linearity.

4. A system is described by

$$\dot{X}_1 = -X_1 + X_2 + X_1(X_1^2 + X_2^2)$$

$$\dot{X}_2 = -X_1 - X_2 + X_1(X_1^2 + X_2^2)$$

Determine the asymptotic stability of the system using Lyapunov's second method.

5. Draw the phase plane portrait of the system described by $\ddot{x} + 0 \cdot 5\dot{x} + 2x + x^2 = 0$.

6. Determine the stability of a discrete data system described by the following characteristic equation :

$$Q(z) = z^3 + 3 \cdot 3z^2 + 42 + 0 \cdot 8 = 0.$$

GROUP – C

(Long Answer Type Questions)

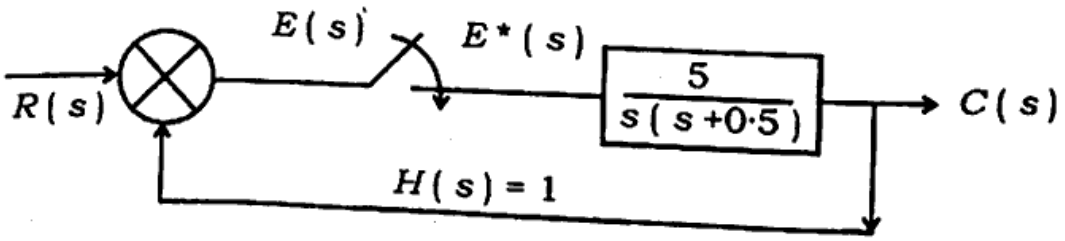
Answer any *three* of the following. $3 \times 15 = 45$

7. a) Find the state transition matrix using Cayley-Hamilton theorem of the system having $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$.

b) The dynamic equation of a non-homogeneous system is given as $\dot{X}(t) = \begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix} X(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U(t)$ & output $Y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} X(t)$. The initial condition is $X(0) = \begin{bmatrix} 1 & 0 \end{bmatrix}^T$, where $U(t)$ is unit step input. Determine the output of $Y(t)$ at $t = 1$ sec.

c) A system is characterised by $\dot{X} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U$, $X(0) = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$, $Y = \begin{bmatrix} 1 & 0 \end{bmatrix} X$. Find the transfer function of the system. $5 + 7 + 3$

8. a) Determine the pulse transfer function and stability of the sampled data control system shown in figure below. The sampling time is 1 sec.



b) Comment on the controllability & observability of the given discrete time system shown.

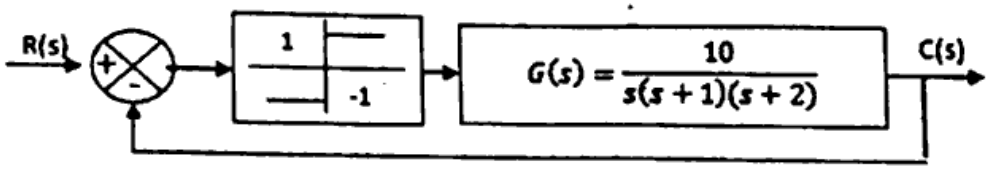
$$X(k+1)=\begin{bmatrix}0 & 1\\ -6 & -5\end{bmatrix}X(k)+\begin{bmatrix}0\\1\end{bmatrix}U(k)$$

$$Y(k)=\begin{bmatrix}2 & 2\end{bmatrix}X(k).$$

8 + 7

9. a) Explain the phenomenon of jump resonance in nonlinear control system.

b) Determine the amplitude and frequency of the limit cycle of the nonlinear system shown in the figure below :



5 + 10

10. a) Discuss the concept of Lyapunov's first & second stability analysis.

b) Investigate stability of the system shown using Lyapunov's second method $\dot{X}=\begin{bmatrix}0 & 1\\ -1 & -1\end{bmatrix}X$.

c) Explain the term asymptotic stability & global stability.

5 + 5 + 5

11. a) Consider a system having the plant represented by

$$\dot{X}(t)=\begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}X(t)+\begin{bmatrix}0\\1\end{bmatrix}U(t)$$

$$Y(t)=\begin{bmatrix}0 & 1\end{bmatrix}X(t).$$

Using the state feedback control $U=-kX$, it is desired to have the closed loop poles at $S=-10,-5$. Determine the state feedback gain matrix.

b) A system is represented by

$$\dot{X}(t)=\begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix}X(t)+\begin{bmatrix}0\\1\end{bmatrix}U(t)$$

$$Y(t)=\begin{bmatrix}1 & 0\end{bmatrix}X(t).$$

Comment on controllability & observability of the system. 10 + 5

12. Write short notes on any *three* of the following : 3 × 5

a) Properties of state transition matrix.

b) Zero order hold device.

c) Digital compensator design.

d) Harmonic linearization.