Reg. No. :

Question Paper Code : X10605

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2021
Sixth Semester
Instrumentation and Control Engineering
IC 8651 – ADVANCED CONTROL SYSTEM
(Common to Electrical and Electronics Engineering)
(Regulations 2017)

Time : Three Hours   Maximum : 100 Marks

Answer ALL questions

PART – A   **(10×2=20 Marks)**

1. A system is characterized by differential equation $\frac{d^2y}{dt^2}+10\frac{dy}{dt}+7y-u=0$. Determine its state space model.

2. The state-space model of a system is given by
$\dot{X}(t) = AX(t) + bu(t)$
$y(t) = CX(t)$
where $A=\begin{bmatrix}0 & 1 & 0\\ 0 & -1 & 1\\ 0 & -1 & 10\end{bmatrix}$, $b=\begin{bmatrix}0\\ 0\\ 10\end{bmatrix}$, $c=\begin{bmatrix}1 & 0 & 0\end{bmatrix}$
Find the transfer function.

3. Write the state space equations in the controller canonical forms for the following systems described by the transfer functions $G_1(s)=\frac{s+1}{s^2+5s+5}$, $G_2=\frac{s+1}{4s^2+4s+1}$.

4. Write the state space equations in the observer canonical forms for the following systems described by the transfer functions $G_1(s)=\frac{s+1}{s^2+5s+5}$, $G_2=\frac{s+1}{4s^2+4s+1}$.

5. Calculate the z-transform for the unit impulse sequence.

6. Determine the inverse z-transform $F(z)=\frac{1}{1-1.5z^{-1}+0.5z^{-2}}$.

7. Draw the phase trajectory of a 1st order nonlinear system represented by a differential equation $\dot{y} + 2y - 2y^3 = 0$.

8. For a nonlinear autonomous system the state equations are
$\dot{x}_1 = x_2$
$\dot{x}_2 = -x_1 - x_1^2 - x_2$
Determine its equilibrium states.

9. What are the performance indices for minimum-time optimal control, minimum energy optimal control problem, state regulator optimal control problem and output regulator problem ?

10. What is meant by quadratic optimal control problem ? Give its performance index.

PART – B **(5×13=65 Marks)**

11. a) Find the states $x_1(t)$, $x_2(t)$ and $x_3(t)$ of the system described by

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

where the initial conditions are :

$$\begin{bmatrix} x_1(0) \\ x_2(0) \\ x_3(0) \end{bmatrix} = \begin{bmatrix} 1 \\ -1 \\ 0 \end{bmatrix}$$

Compute the state transition matrix using any two approaches. Compute the eigenvalues of the system.

(OR)

b) Obtain the response y(t) of the following system

$$\dot{x}(t) = \begin{bmatrix} -1 & 0.5 \\ 1 & 0 \end{bmatrix} x(t) + \begin{bmatrix} 0.5 \\ 0 \end{bmatrix} u(t) \; x(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$y(t) = [1 \;\; 0] \, x(t)$ where u(t) is the unit-step input. Write the MATLAB command to plot the unit-step response.

12. a) A regulator system has the plant $\dot{x} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u; \; y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} x$.

Design a state-feedback controller which will place the closed-loop poles at $-2 \pm j3.464, -5$ using

i) Direct comparison of coefficients

ii) Ackermann's formulae. Give a block diagram of the control configuration.

(OR)

b) Consider the second-order system $\dot{X}(t) = \begin{bmatrix} 2 & 3 \\ -1 & 4 \end{bmatrix} X(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$ and $Y(t) = [0 \;\; 1]\, X(t)$.

The desired characteristic equation of the observer is given by $\phi(s) = s^2 + 2\xi\omega_n s + \omega_n^2$ where $\xi = 0.8$ and $\omega_n = 10$. Design a full-state observer such that the desired performance specifications for the observer are satisfied using

i) Comparison of coefficients methods

ii) Ackermann's formula

13. a) Consider a discrete time system $y(k+1) = \frac{1}{4} y(k+1) - \frac{1}{8} y(k) = 3r(k+1) - r(k)$ with input $r(k) = (-1)^k u(k)$ and initial conditions $y(-1) = 5$, $y(-2) = 6$. Find the output, $y(k)$, for $k \geq 0$.

(OR)

b) A plant is described by the transfer function $\frac{Y(s)}{U(s)} = \frac{5}{s(s+5)}$ and the systems input and output are sampled with a sampling interval $T = 0.1$ second.

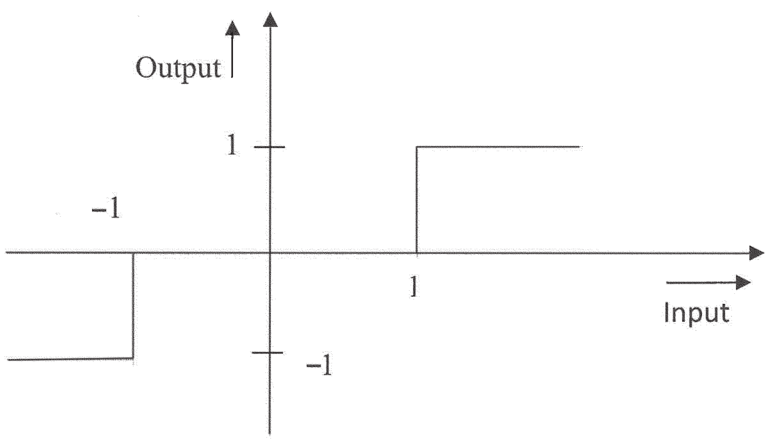
1) Obtain the z transfer function between the input and the output.

2) Obtain the difference equation relating $y(k)$ and $u(k)$.

14. a) Derive the describing function for a nonlinear element with dead-zone in its input-output characteristics.

(OR)

b) Obtain the describing function of the following ON-OFF nonlinearity.



15. a) Consider the system described by the state model :

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix} x + \begin{bmatrix} 0 \\ 20 \end{bmatrix} u; \; y = \begin{bmatrix} 1 & 0 \end{bmatrix} x.$$

Find the optimal control law that minimizes $J = \frac{1}{2}\int_0^\infty \left[(y(t)-1)^2 + u^2\right] dt.$

(OR)

b) Consider a first order dynamic system $\dot{x} = x + u$. The control input is designed as u = – kx such that the system is stable. Evaluate the performance index $J = \int_0^\infty x^2 dt$ with x(0) = 2 and hence obtain an optimal value of k such that J is minimum.

PART – C **(1×15=15 Marks)**

16. a) Given a continuous time plant as $G(s) = \frac{1}{s(s+1)}$

i) Use a Zero Order Hold device prior to this plant and obtain a discretized plant transfer function considering sampling time 1 sec. **(3)**

ii) Consider a step input (discrete-time) obtain step response of the closed-loop system. **(4)**

iii) Apply final-value theorem to obtain the steady-state error. **(4)**

iv) Obtain the velocity error constants of the continuous-time and discrete-time plants. **(4)**

(OR)

b) Investigate the stability of a system with ON-OFF controller shown in below figure using describing function analysis.