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## ADVANCE CONTROL SYSTEM

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) Both the eigenvalues of a second order system are real and negative, then it is termed as
    - the saddle point
- b) the nodal point
- the focus point
- d) the unstable focus point.
- For a system  $\dot{X} = AX$ , the state transition matrix can be ii) expressed as

b) 
$$\sum_{r} \frac{A^r t^r}{r!}$$

a)  $\sum_{\substack{r=0\\ \infty}} \frac{A^{r}t}{r!}$  b)  $\sum_{\substack{r=0\\ \infty}} \frac{A^{r}t^{r}}{r!}$  c)  $\sum_{\substack{r=0\\ r=0}} \frac{(At)^{r-1}}{r!}$  d)  $\sum_{\substack{r=0\\ r=0}} (At)^{r}$ .

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- iii) For analysis of non-linear system by describing function, it is assumed that linear part of the system act as
  - a) Low-pass filter
  - b) High-pass filter
  - c) Band-pass filter
  - d) Band elimination filter.
- iv) X(k+1) = AX(k) + Bu(K) is a
  - a) Non-linear equation
    - b) Linear time invariant difference equation
    - c) Dynamic non-linear equation
    - d) None of these.
- v) Phase plane analysis generally restricted to
  - a) third order system
  - b) first order system
  - c) second order system
  - d) any order system.
- vi) Which of the following properties are associated with the state transition matrix  $\phi$  ( t )?
  - a)  $\phi(-t) = \phi^{-1}(t)$
  - b)  $\phi$  (  $t_1$  / $t_2$  ) =  $\phi$  (  $t_1$  ) .  $\phi$   $^{-1}$  (  $t_2$  )
  - c)  $\phi(t_1 t_2) = \phi(-t_2) \phi(t_1)$
  - d) None of these.

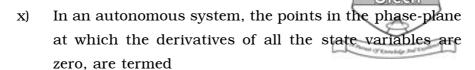
vii) The input-output characteristics of the control system relay shown in *figure* below is

## Fig.

- a) with pure hysteresis
- b) with dead zone and hysteresis
- c) with dead zone
- d) with none of these.
- viii) X = f(X) is called
  - a) a servo system
  - b) non-linear system
  - c) a linear system
  - d) an autonomous system.
- ix) The phase portrait of a second order system shown below in the  $\boldsymbol{y}_1$  ,  $\boldsymbol{y}_2$  plane as

## Fig

- a) stable focus b) unstable focus
- c) stable nodal point d) none of these.



- a) non-singular points b) singular points
- c) non-equilibrium points d) none of these.

xi) Hysterisis in a mechanical transmission is termed as

- a) damping
- b) backlash
- c) dead zone
- d) drift.

xii) If the time varying behaviour of all the states and input are known, the transient response of output can be determined with the help of

- a) D and C matrix
- b) D and B matrix
- c) A and B matrix
- d) A and C matrix.

#### GROUP - B

## (Short Answer Type Questions)

Answer any three of the following.

 $3 \times 5 = 15$ 

2. a) Examine the sign definiteness of the following quadratic form :

$$2{x_{1}}^{2} \; + 3{x_{2}}^{2} \; + 3{x_{3}}^{2} \; + 2{x_{1}}\,{x_{2}} \; + 4{x_{2}}\,{x_{3}}$$

b) For a given state equation X = AX + Bu, where  $B = \begin{pmatrix} 0 \\ 2 \end{pmatrix}$ , find damped natural frequency, peak overshooting % and settling time (5% tolerance) for a step input.

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# 3. Consider the dynamics of the system represented by

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

Formulate the Lyapunov function to test asymptototic stability of the system. 5

4. A system is described by the following differential equation.

Represent the system in state space.

$$\frac{d^{3}x}{dt^{3}} + 3\frac{d^{2}x}{dt^{2}} + 4\frac{dx}{dt} + 4x = u_{1}(t) + 4u_{3}(t)$$

and outputs are

$$y_1 = 4 \frac{dx}{dt} + 3u_1$$

$$y_2 = \frac{d^2x}{dt^2} + 4u_2 + u_3$$

- 5. a) Define Sate transition matrix.
  - b) Find the STM of the following state equation :

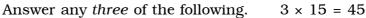
$$X = \begin{pmatrix} 1 & 0 \\ 1 & 1 \end{pmatrix} \quad X + \begin{pmatrix} 1 \\ 1 \end{pmatrix} \quad u.$$
 1 + 4

6. Find the inversre Z transform of the following siscrete system:

$$F(z) = \frac{4x^2 - 2z}{z^3 - 5z^2 + 8z - 4} .$$



## (Long Answer Type Questions)



- 7. a) What do you mean in the sense of Lyapunov asymptotic stability, global stability and local stability?
  - b) Consider the system

$$\dot{x}_1 = -x_2 + ax_1 x_2^2$$

$$\dot{x}_1 = x_1 - bx_1^2 x_2$$

where  $a \neq b$ .

Find the condition of the stability of this system using Lyapunov's theorem assuming that the Lyapunov function  $V(x) = \frac{1}{2} x_1^2 + \frac{1}{2} x_2^2$ . 5 + 10

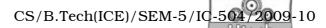
8. The block diagram of a linear time invariant system is given in *figure*.

Fig.

- a) Write down the state variable equations for the system in matrix form assuming state vector to be  $[x_1(t) x_2(t)]^T$ .
- b) Find out the state transition matrix.
- c) Determine y ( t ),  $t \ge 0$ , when the initial values of the state at time t = 0 are  $x_1$  ( 0 ) = 1 and  $x_2$  ( 0 ) = 1 for step input. 4 + 5 + 6

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- 9. a) What do you understand by
  - i) controllability
  - ii) observability of a linear continuous system?
  - b) Determine the following system is completely controllable or not :

#### Math

c) Obtain the eigenvalue & eigenvectors for a system described by the state matrices : 4 + 6 + 5

#### Math

- 10. a) What is limit cycle?
  - b) Prove the final value theorem of *Z* transform.
  - c) A regulator system has a plant

$$\frac{Y(s)}{U(s)} = \frac{10}{(s+1)(s+2)(s+3)}.$$

by using the state feedback control u = -kx, it is desire to place the closed loop poles at  $-2 \pm j \sqrt{3}$  and -10. Determine the necessary state feedback gain matrix K. 3 + 6 + 6

11. Answer any three of the following:

 $3 \times 5$ 

- a) Reduced order observer
- b) Zero order hold
- c) Sampling theorem of digital control system
- d) Bilinear transformation.