Code :R7420202 **1**

IV B.Tech II Semester(R07) Regular Examinations, April 2011
ADVANCED CONTROL SYSTEMS
(Electrical & Electronics Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE questions
All questions carry equal marks
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1. (a) State the basic theorem to transform a linear time invariant system to transform into observable canonical form.
   (b) Explain the same with proof.

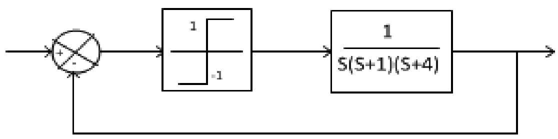
2. (a) Obtain the condition for complete state controllability of time continuous system.
   (b) Consider the system given by

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 3 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

   Is the system completely state controllable and completely observable?

3. (a) Explain the popular nonlinearities.
   (b) For the system shown in figure, determine the amplitude and frequency of the limit cycle.



4. Draw a phase plane portrait of the following system.
   $\ddot{\theta} + \dot{\theta} + \sin\theta = 0$.

5. For the system $\dot{x} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} x$.
   Find a suitable lyapunov function v(x). Find an upper bound on time that it takes the system to get from the initial condition $x(0) = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ to within the area defined by $x_1^2 + x_2^2 = 0.1$.

6. (a) Consider the system with
      i. Consider the system with
      $A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$ $B = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 1 \end{bmatrix}$ *and* $C = \begin{bmatrix} 1 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
      Obtain equivalent system in controllable companion form.
      ii. Obtain equivalent system observable companion form for the system given in (a). Obtain equivalent system in controllable companion form.
   (b) Obtain equivalent system observable companion form for the given in (a).

7. (a) Find the Euler lagrange equations and the boundary conditions for the extremal of the functional
   $J(x) = \int_0^{\frac{\pi}{2}} (\dot{x}_1^2 + 2x_1x_2 + \dot{x}_2^2)dt$
   $x_1(0) = 0, x_1\left(\frac{\pi}{2}\right)$ is tree $x_1\left(\frac{\pi}{2}\right) = -1$.
   (b) What is Hamiltonian formulate the optimal control problem in terms of Hamiltonian.

8. A plant described by the equations.

$x = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u.x_1(0) = 1.x_2(0) = choose$

The feedback law $u = -k \begin{bmatrix} x_1+ & x_1 \end{bmatrix}$. Find the value of k. So that $J = \frac{1}{2} \int\limits_0^\infty (x_1^2 + x_2^2 + \lambda . u^2) dt$

is minimized. When $\begin{matrix} a)\lambda = 0 \\ b)\lambda = 1 \end{matrix}$

Also determine the values of minimum J in two cases.

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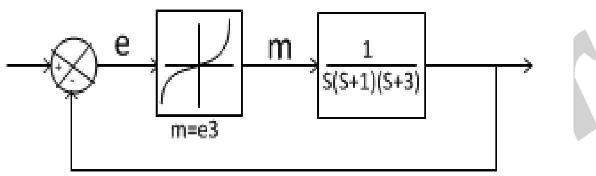
1. Consider $\frac{y(s)}{u(s)} = \frac{b_0.s^n+b_1s^{n-1}+---+b_{n-1}s+b_n}{s^n+a_1.s^{n-1}+---+a_{n-1}s+a_n}$.
Derive the controllable canonical form of the state space representation.

2. (a) Consider a single-i/p/single-o/p system.
$\dot{x} = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$ Check for controllability & observability.
$y = \begin{bmatrix} 1 & 2 \end{bmatrix} x$
(b) Now introducing a feedback signal u=x+(2-1)x in (a) comment on controllability and observability.

3. Obtain the describing function analysis for the system shown in figure.



4. (a) Explain the delta method for construction of trajectories of second order dynamical systems.
(b) Consider the system described by the following equation. $\ddot{x} + x + x^3 = 0$. Given the initial conditions $x(0) = 1, \dot{x}(0) = 0$, construct the trajectory starting at the initial point.

5. (a) Define lyapunov's is stability and instability theorem.
(b) Suppose you are given a linear continuous time autonomous system, how do you decide whether a system is globally asymptotically stable?

6. (a) Consider the system with
i. $A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$ $B = \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 1 & 1 \end{bmatrix}$ *and* $C = \begin{bmatrix} 1 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
Obtain equivalent system in controllable companion form.
ii. Obtain equivalent observable companion form for the system given in (a). Obtain equivalent system in controllable companion form.
(b) Obtain equivalent observable companion form for the system given in (a).

7. (a) Explain minimum-time problem?
(b) Explain state regulator problem in brief?

8. (a) Derive the transversality condition in extermination of functions.
(b) prove that for the functional
$J(x) = \int_{t_0}^{t_1} A(x,t)\sqrt{1+\dot{x}^2}.dt$
The transversality condition reduces to orthogonlity is $\dot{x}\,\dot{y} = -1$. where y(t) is the curve on which the movable right points lies.

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Code :R7420202 **3**

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1. (a) What is state transition matrix & write its properties.
   (b) Consider $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$, computer SIM e^{At} by using any two methods.

2. Consider a system described by state equation.
   $\dot{x} = A(t)X(t) + b.u(t)$
   Where,
   $A(t) = \begin{bmatrix} 1 & e^{-t} \\ 0 & -1 \end{bmatrix}; b = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$
   Is this system controllable at t=? If yes, find the min-energy control to drive it from x(0)=0 to $x^1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ at t=1.

3. (a) Explain the effect of inherent non linearities on static accuracy.
   (b) Derive the describe function for an on-off non linearity with hysteresis.

4. Draw a phase-plane portrait of the following system.
   $\ddot{\theta} + \dot{\theta} + \sin\theta = 0.$

5. (a) Define:
      i. positive definite
      ii. negative definite.
      Give examples for the above.
   (b) Consider the linear autonomous system
      $x(k+1) = \begin{bmatrix} 0.5 & 1 \\ -1 & -1 \end{bmatrix}.x(k).$
      Using direct method of lyapunov, determine stability of the equilibrium state.

6. (a) Given the system X-AX+Bu. Where
      $A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix} B = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 1 \end{bmatrix}$
      Design a linear state variable feedback such that the closed-loop poles are located at -1, -2 and -3.
   (b) Explain the concept of stabilizability.

7. (a) Find the Euler lagrange equations and the boundary conditions for the extremal of the functional
      $J(x) = \int_0^{\frac{\pi}{2}} (\dot{x}_1^2 + 2x_1x_2 + \dot{x}_2^2)dt$
      $x_1(0) = 0, x_1\left(\frac{\pi}{2}\right)$ is tree $x_1\left(\frac{\pi}{2}\right) = -1.$
   (b) What is a Hamiltonian. Formulate the optimal control problem in terms of Hamiltonian.

8. (a) Explain the minimum-time problem?
   (b) Explain state regulator problem in brief?

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Code :R7420202 **4**

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Time: 3 hours **Max Marks: 80**

Answer any FIVE questions
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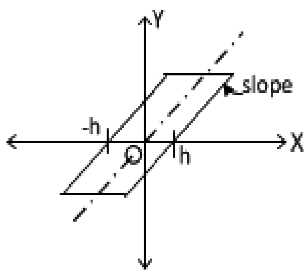
1. Consider $\frac{y(s)}{u(s)} = \frac{b_0.s^n+b_1s^{n-1}+---+b_{n-1}s+b_n}{s^n+a_1.s^{n-1}+---+a_{n-1}s+a_n}$.
   Derive the controllable canonical form of the state space representation.

2. (a) Obtain the condition for complete state observability of time continuous system.
   (b) Is the following system is completely observable and complete state controllable?
   $$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$
   $$y = \begin{bmatrix} 20 & 9 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}.$$

3. (a) Explain the concept of limit cycle and jump response.
   (b) Derive the equation for the describing formation 'N' for the hysteresis non linearity show in fig.



4. (a) Explain the delta method for construction of trajectories of second order dynamical systems.
   (b) Consider the system described by the following equation. $\ddot{x} + \dot{x} + x^2 = 0$. Given the initial conditions $x(0) = 1, \dot{x}(0) = 0$, construct the trajectory starting at the initial point.

5. (a) Define:
      i. Positive define
      ii. Negative define
   (b) Suppose you are given a linear continuous time autonomous system, how do you decide whether a system is globally asymptotically stable?

6. (a) Explain the design of fall order state observer?
   (b) Consider the system with
   $$A = \begin{bmatrix} 0 & 20.6 \\ 1 & 0 \end{bmatrix}; B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}; C = \begin{bmatrix} 0 & 1 \end{bmatrix}$$
   Design a fall-order state observer. Assume that the desired eigen values of the observer matrix are $\mu_1 = -1.8 + j2.4; \mu_2 = -1.8 - j2.4$.

7. (a) Derive the transversality condition in extermination of functions.
   (b) Prove that for the function
   $J(x) = \int_{t_0}^{t_1} A(x,t)\sqrt{1 + \dot{x}^2}.dt$
   The transversality condition reduces to orthogonlity is $\dot{x}\dot{y} = -1$. where y(t) is the curve on which the movable right points lies.

8. For the discrete time system given
$G_p(s) = \frac{1}{s}.G_0(s) = \frac{1-e^{-ST}}{s}; r(t) = unit$ step; T=1 sec. Find optimal transfer function $T^*(Z)$ so that output C(t) follows input r(t) minimizing $J_e = \sum_{k=0}^{\infty} [r(kt) - c(kt)]^2$ with $J_u = \sum_{k=0}^{\infty} u^2(kt) = 0.5$

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