Ref. No: *Ex/EE/T/422A/2018*

Bachelor of Electrical Engineering 4th Year, 2nd Semester Examination, 2018

ELECTIVE – II ADVANCED CONTROL THEORY

Time: Three Hours

Full Marks: 100

Answer both parts on the same answer script

Part-I

Answer *any three* questions from this part (all questions carry equal marks)
Two marks for neat and well-organized answers

1. a) Define equilibrium point of a nonlinear dynamic system. **4+6+6**

   b) Obtain the equilibrium points for the following nonlinear system

$$\dot{x}_1 = -x_1 + x_2$$
$$\dot{x}_2 = 0.5x_1 - 1.5x_2 - 2x_1^2 - x_1^3$$

   c) Obtain the linearized equations about the equilibrium point at the origin for the system given in part (b) above.

2. a) State the advantages and disadvantages of on-off control. **3+5+8**

   b) Describe the functioning of an on-off type temperature controller for an electric oven with the help of a schematic diagram. Sketch and explain the necessary controller characteristics.

   c) Assuming that the above on-off temperature control system has a first order plant with a finite delay, obtain approximate expressions for on-time, off-time and duty cycle of the system. Sketch the time response.

3. a) (i) Derive the equations for the isoclines for a unity feedback system where the controller is a linear amplifier with gain *5* and the plant transfer function is $G_p(s) = \dfrac{0.5}{s(1+0.5s)}$. (ii) Sketch isoclines covering all the four quadrants and indicate the slopes of trajectories. **8+8**

   b) A satellite attitude control system has forward-reverse type of thrusters and a controller with proportional plus derivative control with dead zone. With the help of a phase plane plot investigate the stability of the system.

[Turn over

4 a) Discuss the common sources and types of nonlinearity in plants and controllers. **6+4+4+2**

b) What is static non-linearity? Explain with an example.

c) (i) What is dead-zone type of nonlinear characteristics? (ii) Why is it called a nonlinearity without memory?

d) Give two examples of nonlinearity with memory.

5. a) Define (i) Asymptotic Stability (ii) Global Asymptotic Stability. **4+6+6**

b) A nonlinear system is given by

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} x_2 \\ x_2 + \left(x_1^2 + 1\right)x_1 + x_1 \cos x_2 \end{bmatrix}.$$

Investigate whether the system is asymptotically stable at x=0 using Lyapunov's first theorem or any other suitable method.

c) State Lyapunov's <u>2nd</u> theorem. Briefly describe how this theorem may be used to determine the stability of a nonlinear dynamic system. What are its limitations?

Part II

Answer *<u>any three</u>* questions from this part (all questions carry equal marks)
Two marks for neat and well-organized answers

6. a) Distinguish between structured and unstructured uncertainty. With the help of suitable diagrams, explain the terms additive and multiplicative unstructured uncertainty. **6+10**

b) In the system shown in Fig 1, the nominal parameters are a=3; T=0.2; K=5. Investigate the stability of the closed-loop system by assuming $\pm$10% uncertainty in each parameter.

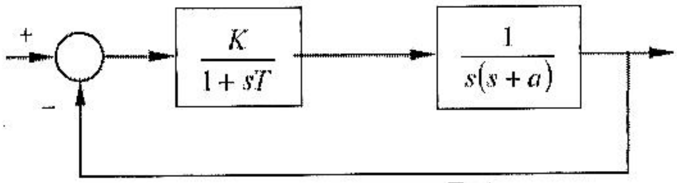

Fig 1

7. a) A process plant given by $G_1(s) = \dfrac{10}{(s+1)(0.005s+1)}$ is modeled by using the transfer function $G_2(s) = \dfrac{10}{s+1}$. **4+6+6**

For the above plant and its model, compare

(i) the open loop unit step responses,

(ii) the closed loop unit step responses,

(iii) the frequency responses (Bode plot).

8. a) Given a transfer function $G(s) = \dfrac{10}{(s+1)^2(s+2)(s+5)}$. Find $\|G\|_2$. **4+6+6**

b) For the system with transfer function $G(s) = \dfrac{0.5s+1}{0.2s+1}$, find $\|G\|_\infty$.

c) Given a system with transfer function $G(s) = \dfrac{625}{s^2+50s+625}$. Briefly describe the methods which may be used to find $\|G\|_\infty$ for the above system.

9. A ship roll stabilization system has a forward path transfer function **3+3+6+4**

$$\frac{\phi_a(s)}{\delta_d(s)} = \frac{K}{(s+1)(s^2+0.7s+2)}.$$

a) For the condition K=1, find the state and output equations when

$$x_1 = \phi_a(t), x_2 = \dot{x}_1, x_3 = \dot{x}_2 \text{ and } u = \delta_d(t)$$

b) Demonstrate that the system is fully observable.

c) Design a full order state observer such that the closed-loop poles are at $-16; -16.15 \pm j16.5$.

d) If the output $x_1 = \phi_a(t)$ is measured, design a reduced order state observer with desired closed-loop poles at $-16.15 \pm j16.5$.

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10. A regulator contains a plant described by **6+6+4**

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

and has the performance index

$$J = \int_0^{\infty} \left[x^T \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} x + 0.2u^2 \right] dt .$$

For the above plant,

a) Determine the Riccati matrix P in the steady state

b) Design an optimum controller

c) Find the closed loop eigenvalues of the controlled system with the controller designed in 10 (b).