EX/ME/T/424B/2018

B.E. Mechanical Engineering Fourth Year 2nd Semester Examination – 2018

Subject: **Introduction to Modern Control Theory**

Time : Three hours **Full Marks: 100**

Different parts of the same question should be answered together.
Use of Gaussian Error Function Tables permitted.

CO1 [10]

Answer any **one(1)** from **(a) and (b)** *in this block:*

[1] (a) For the 2 tank system shown in Fig.1, q_1 and q_2 are liquid volume flow rates, h_1 and h_2 are liquid levels, where h_1 is the system output, R_1 and R_2 are the hydraulic resistances of the inter-connecting pipe and outlet pipe respectively and A_1 and A_2 are the tank cross-sectional areas. w_1 and w_2 are the flows through the inter-connecting pipe and outlet pipe respectively. Let A_1=12, A_2=6, R_1=6 and R_2=4. Derive a state model selecting meaningful and measurable state variables.

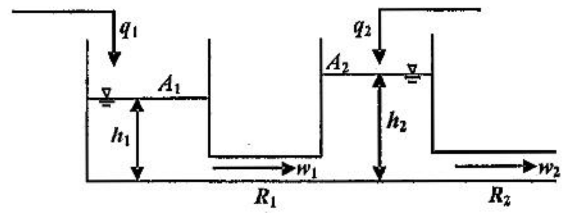

Figure: 1

[10]

(b) Determine the state model for the system shown in Fig. 2.

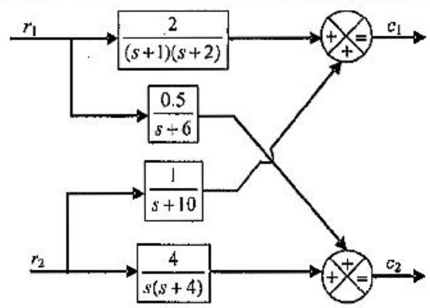

Figure: 2

[10]

CO2 [10]

Answer any **one(1)** from **(a) and (b)** *in this block:*

[2](a) For a system with plant transfer function $G(s) = 2/(s^2 + 4s + 5)$, design a state feedback control $u = -\mathbf{k}'\mathbf{x}$, to place the closed-loop eigenvalues at $-3\pm2j$. [10]

(b) (i) For a state space model , explain how a dynamic observer can be designed. What is the difference between a *full-order observer* and a *reduced-order observer*?

(ii)Design the observer matrix **L** to estimate the states of the system from the output y. Place the observer eigenvalues at $-10\pm10j$. [(5+2)+3=10]

CO3 [25]

Answer any **one(1)** from **(a) and (b)** *in this block:*

[3] (a) (i) Describe 4 typical characteristics of nonlinear behaviours of dynamic systems.

(ii) For a second order nonlinear dynamic system, explain what is meant by the *phase-plane equation* and the *isocline equation*.

(iii) For an under-damped second order system obtain the *phase-plane equation* and the *isocline equation*. Sketch the isoclines.

(iv) Explain the terms *focus* and *node* in a phase-plane. [6+8+(3+4)+4=25]

(b)(i) For a dynamic system with **x** as the *state vector*, what can be a possible *Liapunov* function $V(\mathbf{x})$?

(ii)Explain the terms *globally asymptotically stable*, *locally asymptotically stable* and *stable* for a dynamic system with **x** as the *state vector*.

(iii) State *Sylvester's Theorem* for a general quadratic form. For , check whether Q is positive definite.

(iv) State *Liapunov's Stability Theorem*.

(v) The differential equation for a nonlinear system is given by. Check for the stability of the system using *Liapunov's Stability Theorem*. [3+6+(2+4)+3+7=25]

CO4 [30]	*Answer any* **one(1) from (a) and (b)** *in this block:* [4] (a)(i)What is the unique property of sliding mode control as compared to other nonlinear control strategies? (ii) What is meant by sliding mode and reaching mode – explain with a sketch? (iii) What is meant by matching conditions and lumped uncertainty of a dynamic system – explain. (iv) What is meant by the boundedness of the lumped uncertainties? (v) What is meant by the sliding condition? [5×6=30]
	(b) (i) For a simple spool valve driving a symmetric linear actuator connected to a spring and a dashpot, construct a suitable state space model with appropriate linearization technique. Assume constant pump and tank pressures, incompressible flow, zero leakage and zero transmission loss. Choose appropriate symbols wherever necessary. (ii) Design a suitable sliding mode controller for the above system. [15+15=30]
CO5 [25]	*Answer any* **one(1) from (a) and (b)** *from this block:* [5] (a) For a 3-layer feedforward neural network with 2 inputs and one output, 3 hidden neurons, linear activation function in the output layer and tan-hyperbolic activation function in the hidden layer – show how learning by back-propagation can be carried out. Assume suitable symbols wherever necessary [25]
	(b)(i) The fuzzy logic controller for an electrohydraulic actuation system consists of two inputs – the position error and the velocity error of the actuator. The controller output is the control voltage. If the range of the position error is ±0.2m, that of the velocity error is ±0.6m/s and that of the control voltage is ±10V – construct fuzzy membership functions for the inputs and the outputs. Suggest suitable rules for the fuzzy system. (ii) Explain Mamdani's inference methodology. (iii) What are the limitations in the application of fuzzy logic theory? [12+8+5=25]