Ref. No: Ex/PG/CTS/PE/T/113A/2025
Ex/PG/EE/T/111B/2025

M.E. ELECTRICAL ENGINEERING FIRST YEAR FIRST SEMESTER – 2025
&
M.E. CONTROL SYSTEM ENGG FIRST YEAR FIRST SEMESTER – 2025

MODELING & SIMULATION OF DYNAMIC SYSTEMS

Time: Three Hours; Full Marks: 100

Answer any five questions

1. a) Describe the modelling life-cycle with the help of a flow-chart. 4+6+10

   b) Briefly state the different forms of abstract models that are used to represent dynamic systems. Discuss the advantages and limitations of each form.

   c) For the nonlinear two-tank system shown in Fig 1, given that $Q_2 = C_f\sqrt{(H_1 - H_2)}$. A_1 and A_2 are the cross-sectional areas of the two cylindrical tanks as shown. (i) Obtain the nonlinear state space representation of the system. (ii) Linearize the model about $H_1 = \tilde{H}_1, H_2 = \tilde{H}_2, Q_1 = \tilde{Q}_1, Q_3 = \tilde{Q}_3$.

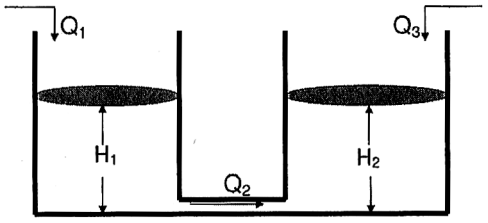

Fig. 1

2. In an inverted pendulum, the control force acting on the cart is F and the angular deviation of the pendulum from the vertical is θ. 5+5+10

   a) Draw a free body diagram of (i) the cart and (ii) the pendulum. Clearly define all symbols used and state any assumptions made.

   b) Write the nonlinear differential equations for the above system.

   c) Obtain the linearized state model for the above system.

[Turn over

3. a) Obtain the equivalent state space representation for two models that are connected in cascade form. (Assume that the individual models representing the systems are known in state variable form.) 8+12

b) Derive the state space model for the following electrical circuit. The voltage drop across the capacitor should be considered as the output.

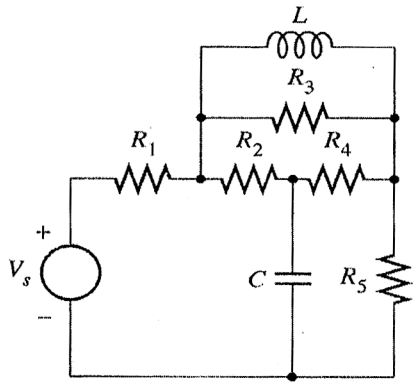

Fig. 2

4. a) State the advantages of simulation. 4+10+6

b) Given $\frac{dy}{dx} = 1 + x^2 + y^3;\ y(1) = -2,\ h = 0.1.$

Obtain a solution of the above differential equation by using the Euler's method for 2 steps.

c) What do you mean by (i) *variable step size method*, (ii) *variable order method* and (iii) *stiff ODE solver*.

5. a) Distinguish between real-time simulation and non-real-time simulation. 5+3 +12

b) State three reasons why non real-time simulation would be necessary.

c) Given $\frac{d^2y}{dx^2} + \left(1 - y^2\right)\frac{dy}{dx} + y = 0;\quad y(0) = 1;\quad \left.\frac{dy}{dx}\right|_{x=0} = 0;\quad h = 0.1.$

Obtain a solution of the above differential equation for 2 consecutive steps by using the fourth-order Runge-Kutta method.

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6. a) What are pseudo random numbers? 3+5
   b) Enumerate the possible defects of pseudo random number generators. +6+6
   c) Perform the Kolmogorov - Smirnov Test to check the uniformity of the following sequence of random numbers with a level of significance $\alpha = 0.01$.
   0.28, 0.43, 0.77, 0.05, 0.97, 0.64, 0.83, 0.91, 0.95, 0.39.
   Given that at $\alpha = 0.01$, critical value is 0.490.
   d) With a seed of 11, m=19, a=2, b=13, generate a sequence of 10 random numbers by using the mixed congruential random number generation method.

7. 10+10
   a) Find the value of $5\int_{1}^{3} x^4 dx$ by generating 50 random numbers with your calculator.
   b) The following is a sequence of 73 random numbers:
   47, 27, 56, 52, 01, 18, 08, 90, 27, 54,
   25, 02, 52, 63, 52, 64, 91, 15, 68, 97,
   88, 48, 67, 76, 96, 18, 98, 80, 57, 05,
   92, 75, 96, 84, 47, 38, 56, 78, 17, 09,
   39, 35, 11, 46, 58, 59, 44, 72, 43, 84,
   22, 98, 60, 29, 99, 16, 49, 08, 64, 67,
   64, 23, 47, 80, 64, 37, 36, 84, 85, 43,
   66, 55, 27.
   By assuming that the number of classes is 9, perform the Chi-square test for auto-correlation to check whether the sequence is acceptable at 95% confidence level. Given that for 7 degrees of freedom, at 95% confidence level, the acceptable value of chi-square is 14.067.