Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/M.Tech (CHE)/SEM-2/CHE-902/2010

2010

PROCESS MODELLING AND SIMULATION

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

Answer Question No. 1 and any *three* from the rest.

4 × 10 = 40

1. a) Explain with proper example the term 'Mathematical Consistency of a Model'. 3

   b) Compare between Deterministic Process and Stochastic Process. Give examples. 3

   c) Differentiate between Physical modelling and Mathematical modelling. 4

2. A fluid of constant density ρ is pumped into a cone shaped tank of total length H. The flow out of the bottom of the tank is proportional to the square root of the height h of the liquid in the tank. Derive the model equations describing the system. List the assumptions required. Show the mathematical consistency of the model equations, where, R is the total radius of the tank. F_0 and F are the volumetric flow rates at inlet and outlet respectively.

3. Present a method of partitioning and sequencing for the following algebraic equations in order to solve for variables.

$$f_1 : x_1\, x_2 + \frac{x_6^2}{x_4} - 4 = 0$$

$$f_2 : x_2\, x_5 - 3x_6 = 0$$

$$f_3 : \frac{x_1}{x_2} + ln\left(\frac{x_3}{x_4}\right) - 2 = 0$$

$$f_4 : x_3^2 + 2x_3^3 - 2x_3 + 1 = 0$$

$$f_5 : x_4 + x_2 - 7 = 0$$

$$f_6 : x_3\,(x_3 + x_6) - 10 = 0$$

4. Develop the steady state model for an ideal double pipe heat exchanger as is shown in the figure below :

i) List all the assumptions that you make while modelling the system.

ii) Identify the relevant balance and rate equations.

iii) If you have to account for the variations of the overall heat transfer coefficient, what will be the necessary change in the final state equation ?

iv) Write the algorithm or flowchart to calculate numerically the total heat transfer area of length of the heat exchanger using the developed model equations.

5. A perfectly mixed, isothermal CSTR has an outlet weir. The flow rate over the weir is proportional to the height of liquid over the weir, h_{ow} to the 1·5 powers. the weir height is h_w. The cross-sectional area of the tank is A. Assume density is constant. A first order reaction takes place in the tank : $A \xrightarrow{k} B$.

Derive the model equations describing the system. List the assumptions required, where, F_0 and F are the flow rates of feed and product respectively. Present an Algorithm or Flowchart to evaluate product composition.

GROUP - B

Answer any *two* of the following questions. $2 \times 15 = 30$

6. F moles per hour of an n-component natural gas stream is introduced as feed to the flash vaporization tank shown in figure below. The resulting vapour and liquid streams are withdrawn at the rate of V and L moles/hour respectively. The mole fractions of the components in the feed, vapour and liquid streams are designated by z_i, y_i and x_i respectively.

   ($i = 1, 2, 3, \ldots\ldots n$).

   Assume vapour and liquid are in equilibrium. Derive the model equations describing the system under steady and unsteady operations. List the assumptions required. Show the mathematical consistency of the model equations. Also write the Algorithm or Flowchart to solve those equations. Write separate Algorithm or Flowchart for steady and unsteady operations.

7. A vessel with a steam jacket has an inlet flow rate and outlet flow rate of a liquid F_1 and F_2 (volume/time) respectively. The hold-up volume in vessel is V. The steam in the jacket is considered as saturated. The temperature and pressure of steam inside the jacket are T_s and P_s respectively. Derive the model equations describing the system. List the assumptions required. Show the mathematical consistency of the model equations. Also write the Algorithm or Flowchart to solve those equations.

8. An exothermic reaction $A \xrightarrow{k} B$ is taking place in a CSTR. The reaction is nth order in the reactant A and has a heat of reaction λ (kJ/mole of A reacted). Neglect heat losses through the atmosphere and assume constant densities. The heat from the reactor is removed by a jacket surrounding the reactor vessel.

Data :

Feed rate = $40\ m^3$/hr of pure A

Volume of reactor = $48\ m^3$

Inlet coolant and feed temperature = 33° C

Coolant flow rate = $50\ m^3$/hr

Activation energy of reaction = 30000 kcal/mole

Heat transfer coefficient of jacket reactor surface =

150 kcal/hrm² °F, λ = – 30000 kJ/mole

Specific heat (average) of reactants/mixture =

0·75 kcal/kmol°C

Specific heat (average) of coolant = 1·0 kcal/kmol °C

Density of feed and product = $50\ kg/m^3$

Density of coolant = $1000\ kg/m^3$

Assume steady state operation and CSTR is well agitated. Present an Algorithm or Flowchart to evaluate product composition and temperature. Also evaluate the exit temperature of coolant. Use any trial and error method. Perform at least three iterations.