Total Pages—6

(Set-K)

B.Tech -7(Chem Engg)

Process Simulation and Modeling

Full Marks : 70

Time : 3 hours

Answer any **six** questions including **Q.No.1** which is compulsory.

The figures in the right-hand margin indicate marks.

Symbols carry usual meaning.

1. Answer *all* questions : 2 × 10

(*a*) What do you mean by simulation ? Explain.

(*b*) Write the total continuity and component continuity equation of a system.

(*c*) Discuss why modelling assumptions are important in the building of a model.

(*d*) Explain in detail the use of mathematical models.

(*e*) Derive the energy equation applicable for a batch reactor. State the assumptions clearly.

(*Turn Over*)

(*f*) What do you mean by computer aided design ?

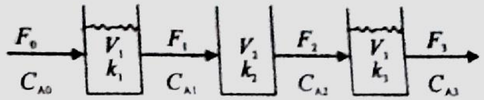
(*g*) Write down the steps involved in digital simulation.

(*h*) Write a short note on information flow diagram.

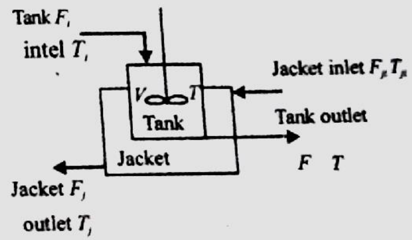
(*i*) What are the necessity and sufficiency conditions for the optimization ?

(*j*) What is linear programming problem ? State the linear programming problem in standard form.

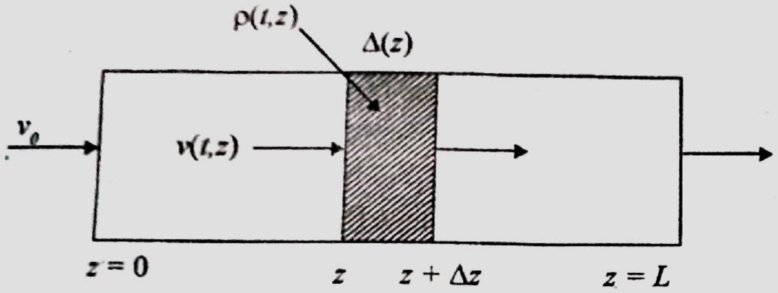
2. (*a*) Product B is produced and reactant A is consumed in each of the three perfectly mixed reactors by a first-order reaction occurring in the liquid. For the moment let us assume that the temperatures and holdups (volumes) of the three tanks can be different, but both temperatures and the liquid volumes are assumed to be constant (isothermal and constant holdup). Density is assumed constant throughout the system, which is a binary mixture of A and B. With these assumptions, develop a mathematical model. 5



(*b*) Consider a stirred tank heater as shown in Figure, where the tank inlet stream is received from another process unit. The objective is to raise the temperature of the inlet stream to a desired value. A heat transfer fluid is circulated through a jacket to heat the fluid in the tank. Develop a dynamic model for the stirred tank heater (Hint: Balance around tank and heater). Make some valid assumptions. Find the state space model where tank temperature is output and jacket flowrate is manipulated variable. 5



3. (*a*) Consider a fluid flowing inside a pipe of constant cross-sectional area (A) as shown in Figure. Let v be the velocity of the fluid. Develop a mathematical model for the change in the fluid mass inside the pipe. State all the assumptions. 5



(*b*) Define Lumped parameter model and distributed parameter models with examples. 5

4. (*a*) Differentiate between steady state and dynamic simulation. List the various chemical engineering simulation packages. 5

(*b*) Explain the fundamental laws of physics and chemistry with their applications to simple chemical systems. 5

5. (*a*) Write a note on the transport equations used for modelling. 5

(*b*) Develop a mathematical model for the batch distillation with holdup. 5

6. (*a*) Explain the problem solving procedure of (*i*) flow sheeting problem, (*ii*) Specific (design) problem and, (*iii*) optimization problem. 5

(*b*) Develop mathematical model equations for the continuous distillation column which contains *n*th number of trays. Also write down the procedure for simulating the whole distillation unit. (Hint: Mass, Component and energy balance equations) 5

7. (*a*) Discuss essential features of optimization problem. 5

(*b*) Define Hessian matrix. Write down its applications in optimization. 5

8. (*a*) The two frictionless rigid bodies (carts) *A* and *B* connected by three linear elastic springs having spring constants k_1, k_2, and k_3. The springs are at their natural positions when the applied force *P* is zero. Find the displacements x_1 and x_2 under the force *P* by using the principle of minimum potential energy. The potential energy is a minimum. The potential energy of the system is given by potential energy (*U*) 5

$$U=\left[\frac{1}{2}k_2x_1^2+\frac{1}{2}k_3(x_2-x_1)^2+\frac{1}{2}k_1x_2^2\right]-Px_2$$

(*b*) Air is to be compressed from 1 to 10 atm. pressure in a two stage compressor. To increase the compression efficiency, the compressed air from the first stage of compression is cooled (it is passed through a heat exchanger) before entering the second stage of compression. For isentropic compression of air the total work input to a compressor (W) can be represented by

$$W=c_pT_1\left[\left(\frac{p_2}{p_1}\right)^{(k-1)/k}+\left(\frac{p_3}{p_2}\right)^{(k-1)/k}-2\right]$$

where the specific heat of air at constant pressure is c_p = 1.006 kJ/(kg.K), k = 1.4 is the ratio of specific heat at constant pressure to specific heat at constant volume of air, and the entering gas temperature $T_1 = 300$K. Find the intermediate p_2 at which cooling is required to operate the compressor. Also, calculate the minimum work requird to operate the compressor. Solve the problem by golden section method using $n = 6$. 5
