MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

II SEMESTER M.TECH GRADE IMPRPVEMENT EXAMINATIONS AUG 2021

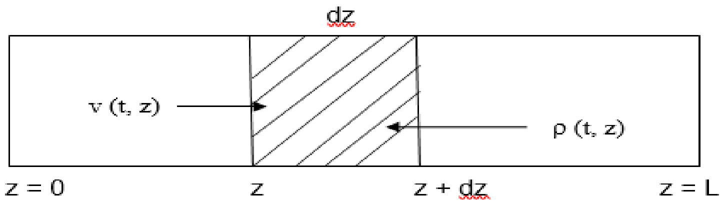
SUBJECT: BIOPROCESS MODELLING ANALYSIS AND SIMULATION

[BIO 5222]

Date of Exam: **17/08/2021** Time of Exam: **2:30 PM – 4:30 PM** Max. Marks: **40**

Instructions to Candidates:

- Answer any FOUR questions & missing data may be suitable assumed

1A.	Define Mathematical Model. Discuss uses and limitation of modeling and simulation.	**5**
1B.	Water is flowing into a well-stirred tank at 150 kg/hr and methanol (MeOH) is being added at 30 kg/hr. The resulting solution is leaving the tank at 120 kg/hr. Because of effective stirring, the concentration of the outlet solution is the same as that within the tank. There are 100 kg of fresh water in the tank at the start of the operation, and the rates of input and output remain constant thereafter. Calculate the outlet concentration (mass fraction of methanol) after 1 hr.	**5**
2A.	Fluid is flowing through a constant-diameter cylindrical pipe as sketched below**.** The flows are turbulent and therefore assume plug flow conditions, i.e., each slice of liquid flows down the pipe as a unit. There are no radial gradients in velocity or any other properties. However axial gradients can exist. Density and velocity can change as the fluid flows along the axial or z direction. Density and velocities are functions of both time t and position z, apply the total continuity equation to a system that consists of a small slice. The differential element is located at an arbitrary spot z down the pipe. It is dz thick and has an area equal to the cross-sectional area of the pipe A. Develop a model equation which describes the system.  	**5**
2B.	A tank initially contains 1000 kg of salt solution of 10% salt by mass. An inlet stream containing 20% salt by mass flows at a rate of 20 kg/min. The mixture is well stirred and removed from the tank outlet at a rate of 10 kg/min. Find the amount of salt in the tank at any time ‘t’ and the elapsed time when amount of salt in the tank is 200 kg. Derive the dynamic model equations.	**5**
3A.	Baker’s yeast is produced in a 50,000 L fermenter under aerobic conditions. The carbon substrate is sucrose; ammonia is provided as nitrogen source. The average biomass composition is $CH_{1.83}O_{0.55}N_{0.17}$ with 5 % ash. Under efficient growth conditions, biomass is the only major product; the biomass yield from sucrose is 0.5 g/g. if the specific growth rate is 0.45 h^{-1}, estimate the rate of heat removal required to maintain constant temperature in the fermenter when the yeast concentration is 10 g/L. $C_{12}H_{22}O_{11} + aO_2 + bNH_3$ ------→ $cCH_{1.83}O_{0.55}N_{0.17} + dCO_2 + eH_2O$	**5**

3B.	A 5 m^3 fermenter is operated continuously with feed substrate concentration 20 kg/m^3. The microorganism cultivated in the reactor has the following characteristics: μ_{max} = 0.45 h^{-1}, K_s = 0.8 kg/m^3, Y_{xs} = 0.55 kg/kg. a. What feed flowrate is required to achieve 90 % substrate conversion? b. How does the biomass productivity at 90 % substrate conversion with the maximum possible?	**5**
4A.	A steam coil is immersed in a stirred tank. Saturated steam at 890°C condenses within the coil. Condensate emerges out at saturation temperature. A solvent with specific heat is 4.6 kJ/kg°C is fed at a rate of 24 kg/min at T = 50°C. Heated solvent is discharged at the same rate. Tank is initially filled with 1520 kg of solvent at T=50°C. At which point flows of both steam and solvent are connected? The rate at which the heat is transferred from the coil to the solvent is given by Q = UA (T_s-T), T_s is steam saturation temperature, U is overall heat transfer coefficient, UA= 23.0 kJ/min°C. Develop the model equations, and calculate the temperature after 80 min.	**5**
4B.	A dilute solution is added to a well stirred tank at a rate of 360 kg/h at 40°C. A heating coil having an area 1.8 m^2 is located in the tank and contains steam at 300°C. The heated liquid leaves the tank at 240 kg/h, at 'T' temperature. There is 1000 kg of solution at 80°C in the tank at the start of the operation. Overall heat transfer coefficient = 682 kcal/h $m^{2o}C$. Cp of solution = 2 kcal/kg°C. i. Derive the general model to describe the system. ii. Calculate the outlet temperature after 2 h operation.	**5**
5A.	The heat capacity of CO_2 is given as a function of temperature as follows: $C_p = 1.716 - 4.25 \times 10^{-6}T - 15.04/\sqrt{T}$. Determine the temperature which yields a value of heat capacity of 1 kJ/kg K. Use Regular falsi method. Tolerance level: 2 x 10^{-4}. Initial condition: T_1 = 400 K and T_2 = 600 K.	**5**
5B.	A component material balance around a biochemical reactor yields the following steady-state equation: $0 = (F/V)\,C_{in} - (F/V)\,C - K\,C^3$ Where (F/V) = 0.1 min^{-1}, C_{in} = 1.0 lbmol/ft^3 and K = 0.05 ft^3/ (lb.mol^2 .min). Calculate the steady state concentration using Newton Raphson method with initial guess 1.	**5**
6A.	*Pseudomonas methylotrophus* is used to produce single-cell protein from methanol in a l000 m^3 pressure-cycle airlift fermenter. The biomass yield from substrate is 0.41 g/g, Ks is 0.7 mg/L, and the maximum specific growth rate is 0.44 h^{-1}. The medium contains 4% (w/v) methanol. A substrate conversion of 98% is desirable. The reactor may be operated either in batch or continuous mode. If operated continuously, a downtime between batches of 25 d is expected per year. Neglecting maintenance requirements, calculate the annual biomass production from continuous reactor.	**5**
6B.	Consider the growth of a microorganism in batch culture. When the substrate concentration is high, the cell density doubles every 0.75 h, the observed substrate yield coefficient is 0.3 gDCW/g, and substrate consumption is allocated towards biosynthesis (60%), maintenance (10%), as well as product formation (30%). The product formation is strictly growth-associated. The batch reactor is inoculated with 0.01 gDCW/L and 10 g/L substrate. a. Estimate the maximum cell density (after lag phase). b. Refer to part(a) and, Estimate the time (after lag phase) required achieving it. Refer to part (a) and part (b), and determine the value of the maintenance coefficient (g substrate/gDCW/h).	**5**