MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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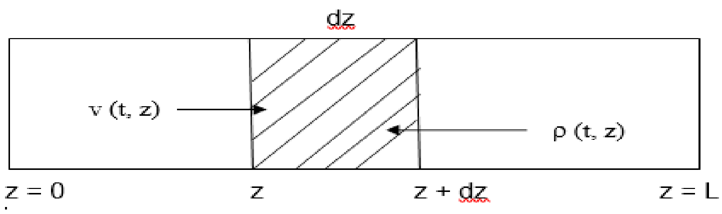
II SEMESTER M.TECH. EXTERNAL EXAMINATIONS APRIL 2019

SUBJECT: BIOPROCESS MODELLING ANALYSIS AND SIMULATION [BIO 5222]

Date of Exam: **26/04/2019** Time of Exam: **9.00 PM – 12.00 PM** Max. Marks: **50**

Instructions to Candidates:

❖ Answer ALL the questions & missing data may be suitable assumed

1A.	Define Mathematical Model. Discuss uses and limitation of modeling and simulation.	**3**
1B.	Differentiate between lumped parameter and distributed parameter models with an example.	**2**
1C.	A crude fermenter is set up in a shed in the backyard of a suburban house. Under anaerobic conditions with ammonia as the nitrogen source, about 0.45 g ethanol are formed per g glucose consumed. At steady state, the ethanol production rate averages 0.4 kg/h. The owner of this enterprise decides to reduce her electricity bill by using the heat released during the fermentation to warm water as an adjunct to the household hot water system. Cold water at 10°C is fed into a jacket surrounding the fermenter at a rate of 2.5 l/h. To what temperature is the water heated? Heat losses from the system are negligible. Use a biomass composition of $CH_{1.75}O_{0.58}N_{0.18}$ plus 8% ash. $C_6H_{12}O_6 + bNH_3 \dashrightarrow cCH_{1.75}O_{0.58}N_{0.18} + d\,CO_2 + e\,H_2O + f\,C_2H_6O$ Cp of water = 75.4 $J.gmol^{-1}.{}^{o}C^{-1}$. The heat of combustion of yeast = -21.2 kJ/g The heat of combustion of glucose = -2805 kJ/gmol The heat of combustion of NH_3 = -382.6 kJ/gmol The heat of combustion of ethanol = -1366.8 kJ/gmol.	**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. $C_{12}H_{22}O_{11} + aO_2 + bNH_3 \text{------}\rightarrow cCH_{1.83}O_{0.55}N_{0.17} + dCO_2 + eH_2O$	**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.	Differentiate between structured and unstructured model. Elucidate an age distribution model for the production of an antibiotic	**5**
4B.	Consider a chemostat you wish to know the no. of cells in the reactor and the fraction of the cells that are viable (i.e. alive as determined by ability to divide). a. Write an equation for viable cell number (n_v). Assume that $$\mu_{net,rep} = \left\{\frac{\mu_{m,rep}\, S}{K_{s,rep} + S}\right\} - k_d$$ Where $\mu_{net,rep}$ = net specific replication rate $\mu_{m,rep}$ = maximum specific replication rate and k_d = death rate and $K_{s,rep}$ is the saturation parameter. b. Derive an expression for the value of S at steady state. c. Write the number balance in the chemostat on dead cells (n_d). d. Derive an expression for the fraction of the total population which are dead cells.	**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: 2×10^{-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**