MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
A Constituent Institution of Manipal University

VII SEMESTER B.TECH. (BIOTECHNOLOGY)

END SEMESTER EXAMINATIONS, NOV/DEC 2016

SUBJECT: MODELLING AND SIMULATION IN BIOPROCESS ENGINEERING [BIO 405]

REVISED CREDIT SYSTEM
(28/11/2016)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ANY FIVE FULL** questions.
- Missing data may be suitable assumed.

1A.	Define briefly the need and significance of modelling and simulation in bioprocess industries.	**3M**
1B.	Differentiate between linear and non-linear models with an example.	**2M**
1C.	Consider the CSTR process, both a liquid product stream F and a vapor product stream F_v (volumetric flow) are withdrawn from the vessel. The pressure in the reactor is P. Vapor and liquid volumes are V_v and V. The density and temperature of the vapor phase are ρ_v and T_v. The mole fraction of A in the vapor is y. If the phases are in phase equilibrium, the liquid and vapor compositions are related by Raoult's law, a relative volatility relationship or some other vapor-liquid equilibrium relationship. The enthalpies of the vapor phase H is a function of composition y, temperature T_v, pressure P. Apply energy equation and develop a model which describes a system by stating if any assumptions made.	**5M**
2A.	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^{o}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	**5M**

	The heat of combustion of ethanol = -1366.8 kJ/gmol.	
2B	Two species A and B are present in both inlets. In reactor, A + B --------→ P. Feed 1 and Feed 2 contains concentrated and dilute feed respectively. The flow rate of concentrated feed is F_1 (m^3/min), dilute feed is F_2 (m^3/min) and for Outlet is F (m^3/min). Concentration C_{A1}, C_{B1} are in concentrated feed (inlet 1) and C_{A2}, C_{B2} are in dilute feed (inlet 2). In reactor and outlet, the concentrations are C_A, C_B and C_P. Assume perfect mixing. Reaction rate equation given; $r = k_1C_B/(1+k_2C_B^2)$; So rate depend on B only, as A is the excess reactant. Develop model for the rate of change of concentration of B in the tank and rate of change of height of liquid in the tank.	**5M**
3A	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.	**5M**
3B	Steam is used to heat nutrient medium in a continuous-flow process. Saturated stream at 150°C enters a coil on the outside of the heating vessel and is completely condensed. Liquid medium enters the vessel at 15°C and leaves at 44°C. Heat losses from the one jacket to the surroundings are estimated as 0.22kW. If the flow rate of medium is 3250 kg/hr and its heat capacity is 0.9 cal/g/°C, how much steam is required? [h_v of water at 150°C = 2113.1 kJ/kg]	**5M**
4A	Develop a general expression for mass balance of biomass and substrate in continuous stirred tank reactor operation.	**5M**
4B	Consider a culture of bacteria that secrete a product in a chemostat operated at steady state. The specific growth rate of biomass is adequately described by the Monod equation, and the rate of product formation is given by the Leudeking and Piret equation: $r_P = (\alpha\mu + \beta)x$ This system is well characterized, such that the following constants are known: $Y_{X/S}$ = 0.4 g/g μ_{max} = 0.7 h^{-1}, K_S = 0.2 g/L, α = 0.2 g/g, β = 0.3 g/g-h. The liquid feed to the chemostat is sterile and contains 10 g/L of the limiting growth substrate. a. What dilution rate will optimize the productivity of the chemostat (g product/h)? b. Consider that a high product concentration (g/L) is also desirable. With this in mind, how might you adjust the dilution rate from the value given in part a? Choose a new dilution rate and give the reasoning behind your answer.	**5 M**
5A	Explain why compartmental model is classified under structured-segregated model. With an appropriate example discuss mechanism of compartmental model listing all the assumptions made.	**5M**

5B	Under substrate-limited conditions, a microorganism exhibits the following net specific growth rate, μ_{net}, and yield coefficient, $Y_{X/S}$: μ_{net} (h^{-1}) = 0.70 $S/(0.1 + S)$, with S in g/L; $Y_{X/S}$ (g DCW/g) = 0.40. The available growth medium contains 10 g/L substrate. a. When a batch bioreactor containing 100 L of the growth medium is inoculated with 1.0 g DCW of biomass, estimate the maximum cell density achieved, and the approximate time required to achieve it, after exponential growth is initiated. b. You decide instead to culture the microorganism in a chemostat, using the same growth medium as the (sterile) feed. Estimate the dilution rate (h^{-1}) at which the chemostat will achieve maximum steady-state productivity of biomass. c. Calculate and compare the overall biomass productivities (g DCW/L/h) of the two scenarios in parts a and b. What other consideration will make the batch process even less productive compared to the chemostat?	**5M**
6A	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. Initial condition: T_1 = 400 K and T_2 = 600 K. Solve by using successive substitution method.	**5M**
6B	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 lb. mol/ft^3 and K = 0.05 ft^6/ (lb.mol^2 .min). Calculate the steady state concentration using bisection method with initial guess 0.1 and 1.	**5M**