Reg. No.										

Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

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VII SEMESTER B.TECH (BIOTECHNOLOGY)

END SEMESTER EXAMINATIONS, NOV/DEC 2015

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

REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A.	Define Mathematical Model. Discuss uses and limitation of modeling and simulation.	**3M**
1B.	Differentiate between lumped parameter and distributed parameter models with an example.	**2M**
1C.	A tank contains 10 L of salt solution at concentration 2 g/l. Another salt solution enters the tank at rate of 1.5 l/min, at salt concentration of 1 g/l. The contents are mixed well, and the mixture leaves the tank at a rate of 1 l/min. Estimate (i) Time at which the concentration in the tank will be 1.6 g/l. (ii) time at which the contents in the tank will be 18 L.	**5M**
2A.	Fluid is flowing through a constant-diameter cylindrical pipe as sketched in **fig.1.** 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.	**5M**

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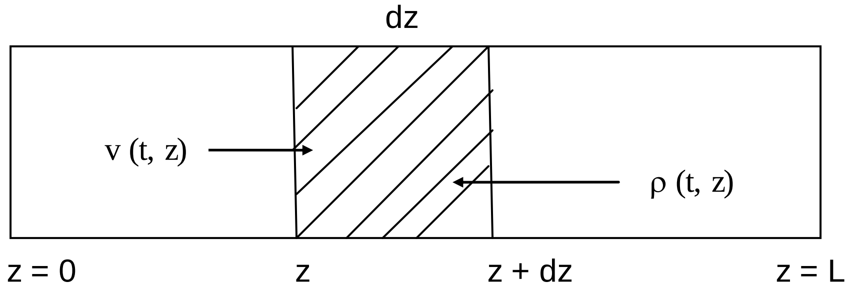
	Fig 1 	
2B	A steam coil is immersed in a stirred tank. Saturated steam at 890°C condenses within the coil. Condensate emerges out at saturation temperature. A solvent with specific heat is 4.6 kJ/kg°C is fed at a rate of 24 kg/min at T = 50°C. Heated solvent is discharged at the same rate. Tank is initially 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.	**5M**
3A.	An equilibrium distillation is charged with 20 kmol of bio-ethanol and its composition is same as feed stream. The composition of feed entering is 0.32 mole fraction of ethanol with a flow rate of 10 kmol/hr. Stream leaving at the same rate. α = relative velocity of ethanol and water mixture (2.48), Y_D = mole fraction of ethanol in vapor phase, X_W = mole fraction of ethanol in liquid phase. $Y_D = \alpha X_W/(1+ (\alpha-1) X_W)$. Estimate time required for composition of overall product to fall to 0.4 mole fraction.	**5M**
3B.	A dilute solution is added to a well stirred tank at a rate of 360 kg/hr 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/hr, 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/hr m^{2o}C. Cp of solution = 2 kcal/kg°C. a. Derive the general model to describe the system. b. Calculate the outlet temperature after 2 hr operation.	**5M**
4A.	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).	**5M**

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	a. Write an equation for viable cell number (n_v). Assume that $\mu_{net.rep} = (\mu_{m,rep} S)/(K_{s,rep} + S) - k_d$ 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.	
4B.	Develop a general expression for mass balance of substrate in batch and fed-batch reactor operation.	**5M**
5A.	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}, KS = 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)? *An approximate answer is sufficient.* 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.	**5M**
5B.	Develop an unstructured non-segregated model with a suitable example and also list an assumptions made.	**5M**
6A.	Consider a stirred tank with fluid flowing in at a known volumetric flow rate (Note that there is a change in rate F_1, F_2, rates can be a function of time, and need not be constant). Consider the height of liquid in tank, z. Develop a dynamic model and calculate the height of the tank after 1 min and 2 min using following data: $F_1 = B \sin\alpha t + C$; $F_2 = 0.27\ m^3/min$, $A = 0.9\ m^2$, z = 30 m, B = 0.27 m^3/min, C = 0.27 m^3/min and α = 0.1 m^3/min. Assume that density changes are constant. Use RK 4^{th} Order.	**5M**

6B.	The following data have been obtained for an enzyme catalysed reaction.	**5M**

$V([E_o]= 0.015g/l)$ g/l min	[S] g/l	([S]/V) min
1.14	20	17.5
0.87	10	11.5
0.7	6.7	9.6

The rate expression for an enzyme catalyzed reaction is given as $K_m/V_m + [S]/V_m = [S]/V$.

a. Calculate K_m/V_m and $1/V_m$ using Gauss Siedel method for six iterations with an initial guess $K_m/V_m = 4$ and $1/V_m = 0.1$

b. Calculate K_m and V_m.