MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
A Constituent Institution of Manipal University

II SEMESTER M.TECH. (INDUSTRIAL BIOTECHNOLOGY)

END SEMESTER EXAMINATIONS, APRIL/MAY 2017

SUBJECT: BIOPROCESS MODELLING ANALYSIS AND SIMULATION

[BIO 5222]

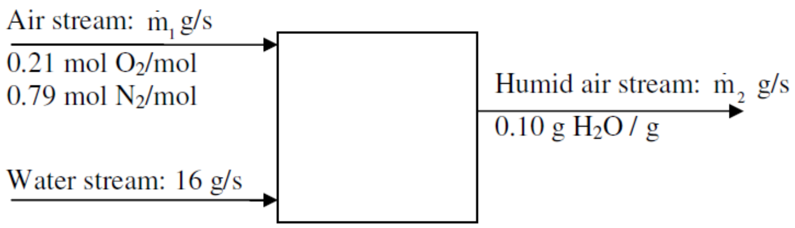
REVISED CREDIT SYSTEM
(22/04/2017)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** questions.
- Missing data may be suitable assumed.

1A.	Define Mathematical Model. Discuss uses and limitation of modeling and simulation.	**3M**
1B.	Differentiate between steady state and un steady state 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	Consider the CSTR process**,** both a liquid product stream F and a vapor product stream F_v (volumetric flow) are withdrawn from the vessel.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 ventilation system has been designed for a large laboratory with volume of 1100 m^3. The volumetric flow rate of ventilation is 700 m^3/min at 22°C and 1 atm pressure. The later values may also be taken as that of room air. A reactor in the laboratory is capable of emitting as much as 1.5 moles of SO_2 into the room. If a seal ruptures and SO_2 mole fraction in the room air > 1 ppm constitutes health hazard. Suppose the reactor seal ruptures at time t=0 and maximum amount of SO_2 is emitted almost instantaneously assuming that air flow is sufficient to make the room air composition spatially uniform. Calculate the concentration of SO_2 (moles/l) in the room, 2 minutes after the rupture occurs and also the time required for the SO_2 concentrate in the room to reach level of safety.	**5M**

2B	Consider a CSTR with constant volume and with a single first order chemical reaction taking place. The feed contains the reactant in an inert fluid. Let us assume that the tank is adiabatic such that the wall is perfectly insulated from the surroundings. Develop a process model and dynamic prediction and control purposes following a seven step modeling procedure with all its ingredients by listing if any assumptions made.	**5M**
3A	A tank has an area of 1 m^2 and normal depth h =4 m and a normal discharge of 20 m^3/hr. a) how does the depth of liquid change with time if the inlet flow rate is fed at 25 m^3/hr. b) Derive the dynamic model of the system if outlet flowrate F_2 is related to depth of liquid as follows F_2 = 10 sqrt(h) m^3/hr. c) Calculate new steady state height and time required to reach it?	**5M**
3B	Fuel cell membranes need to be humidified in order to conduct protons, and therefore lead to electrical current flow. This is often done by adding water in with the incoming air flow. Suppose you have a water flow of 16 g/s being added to an air stream. The humid air stream is to contain 10 wt% water. Determine the air and effluent flows in g/s and the component mole fractions in the humid air stream. Consider the schematic below.  	**5M**
4A	Develop a general expression for mass balance of biomass and substrate in continuous stirred tank reactor operation.	**5M**
4B	*Pseudomonas methylotrophus* is used to produce single-cell protein from methanol in 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 in batch an inoculum of 0.01% (w/v) is used and the downtime between batches is 20 h. If operated continuously, a downtime of 25 d is expected per year. Neglecting maintenance requirements, compare the annual biomass production from batch and continuous reactors.	**5 M**
5A	The virial equation-of-state for a real gas is expressed as : $Pv = RT \left[1 + \frac{B}{v} + \frac{C}{v^2} + \ldots\right]$ Where B and C are known as second and third virial coefficients, respectively. Often this equation is truncated after the second virial coefficient. The virial equation then simplifies to $Pv = RT + \frac{BRT}{v}$ This is a second order polynomial equation for molar volume *v*. Obtain the molar volume of a gas at temperature at T = 298 K and P = 1 atm. pressure using the Newton-Raphson method. The second virial coefficient for the gas	**5M**

	is B = 12 lit. mol^{-1}. Take R = 0.082 (lit.atm) mol^{-1} K^{-1}. Compare your result with the exact solution (which can be obtained by the quadratic formula). A good guess can be estimated from the ideal gas law: v = RT/P.	
5B	A battery of cylindrical membranes is used for an extractive bioconversion. Extractive bioconversion means that fermentation and extraction of product occur at the same time. Yeast cells are immobilized within the membrane walls. A 10% glucose in water solution is passed through the annular space at a rate of 40 kg/h. An organic solvent, such as 2-ethyl-1,3-hexanediol, enters the inner tube at a rate of 40 kg/h. Because the membrane is constructed of a polymer that repels organic solvents, the hexanediol cannot penetrate the membrane and the yeast is relatively unaffected by its toxicity. On the other hand, because glucose and water are virtually insoluble in 2-ethyl-1,3-hexanediol, these compounds do not enter the inner tube to an appreciable extent. Once immobilized in the membrane, the yeast cells cannot reproduce but convert glucose to ethanol according to the equation: $C_6H_{12}O_6 \longrightarrow 2\ C_2H_6O + 2\ CO_2$ Ethanol is soluble in 2-ethyl-1,3-hexanediol; it diffuses into the inner tube and is carried out of the system. CO2 gas exits from the membrane unit through an escape valve. In the aqueous stream leaving the annular space, the concentration of unconverted glucose is 0.2% and the concentration of ethanol is 0.5%. If the system operates at steady state: (a) What is the concentration of ethanol in the hexanediol stream leaving the reactor? (b) What is the mass flow rate of CO_2?	**5M**