Reg. No.										

Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

VI SEMESTER B.TECH (BIOTECHNOLOGY)

END SEMESTER EXAMINATIONS, MAY 2016

SUBJECT: **BIOPROCESS EQUIPMENT DESIGN** [BIO 306]

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.	Estimate the thickness required for the component parts of a cylindrical vessel (1.5 m diameter and 2 m length). The vessel is to be operated at a pressure of 13 bar (abs) and temperature of 300°C. The material of construction will be plain carbon steel. Welds will be fully radiographed. A corrosion allowance of 2 mm should be used. The allowable design stress value = 85 N/mm^2. **Type of closures:** Torispherical (100-6), Ellipsoidal (2:1) and bolted cover with C=0.4 and De=1.7m. Comment on the results:	**5**
1B.	You have been given responsibility to design a jacket for a 5 m^3 cylindrical fermentor over 85% of the straight section. Steam at 10.27 x 10^5 Pa should be circulated through the jacket in order to sterilize the media in the fermentor which is operated at atmospheric pressure. The spacing between the vessel and jacket should be 80mm. Material of construction is carbon steel and the allowable design stress value at the design temperature of 250°C as 50 N/mm^2. One of your team mates says that "Just give 20mm thickness each for both vessel and jacket". Is the thickness enough? If not, calculate the thickness of both by assuming the length of the straight portion to inner diameter of the vessel is equal to 1.	**5**
2	A pilot-scale fermenter of diameter and liquid height 0.5 m is fitted with four baffles of width one-tenth the tank diameter. Stirring is provided using a Scaba 6SRGT curved-blade disc turbine with diameter one-third the tank diameter. The density of the culture broth is 1000 kg/m^3 and the viscosity is 5 cP. Optimum culture conditions are provided in the pilot-scale fermenter when the stirrer speed is 185 rpm. Following completion of the pilot studies, a larger production-scale fermenter is constructed. The large fermenter has a capacity of 6 m^3, is geometrically similar to the pilot-scale vessel, and is also equipped with a Scaba 6SRGT impeller of diameter one-third the tank diameter.	**10**

Type of flow	Power number correlation
Laminar	$N_P = 75 / Re_i$
Transition	$N_P = 600 / Re_i$
Turbulent	$N_P = 6 + (1/Re_i)$

	i. What is the power consumption in the pilot-scale fermenter? ii. If the production-scale fermenter is operated so that the power consumed per unit volume is the same as in the pilot-scale vessel, what is the stirrer speed after scale-up? iii. For the conditions in (ii), what is the power requirement after scale-up? iv. If, instead of (ii) and (iii), the impeller tip speed ($\pi N_i D_i$) is kept the same in the pilot and production-scale fermenters, what is the stirrer speed after scale-up? v. For the conditions in (iv), what power is required after scale-up?	
3	A 5000L (working volume) bioreactor is used to be designed to generate 40 g/L of actinomycete cells that are producing a highly viscous extracellular polysaccharide. The cells have a specific oxygen uptake rate of 4.6 mmol O_2/g-hr and critical oxygen concentration of 0.022 mM and grow optimally at 40°C. During the fermentation the density and viscosity of the fermentation fluid reach 1040 kg/m^3 and 160 cP respectively. Assume C_{AL}^*(mg/L) = 468 / (31.6 + T°C). Design the bioreactor based on k_La method, accounting for hold up and head space. You can choose the following design parameters: N=250 RPM, D_T = 1.6 m, D_i = 0.65 m, v_g=107 m/h; Flooding: $Q_g < 0.6\ (D_i^5 N^2/D_T^{1.5})$; Gas hold-up $\varphi = 1.8\ P_m^{0.14} v_g^{0.75}$; $N_P = 6.2 + 1/Re_i$; $P_g/P = 2.99\text{x}10^3\ N_A^4 - 1\text{x}10^3\ N_A^3 + 1.25\text{x}10^2\ N_A^2 - 10.2N_A+1.012$; $k_La = (0.0333/D_T^4)(P_g/V)^{0.541} Q_g^{(0.541/\sqrt{D_T})}$	**10**
4	A decision has been made to use a STHE with one shell and two tube passes in a biochemical industry for the purpose of cooling ethyl acetate from 65°C to 35°C at a rate of 8.3 kg/s using river water available at 20°C and leaving at 30°C. Find the value of heat transfer coefficient (h_o) assuming ethyl acetate as the shell side fluid and using the following data. Overall heat transfer coefficient = 800 W/m^{2}K, correction factor F_T=0.9, ¾ inch on 1 inch triangular pitch 16 BWG (OD=1.905cms, ID=1.5748 cms) with length 5m. The shell diameter = 305mm. Properties of ethyl acetate at 50°C: ρ=880kg/m^3, Cp=2.051kJ/kgK, μ=0.45cP, k= 0.573 W/mK ; $Nu= 0.36(N_{Re})^{0.55}(N_{Pr})^{1/3}$; $De=4\{[(0.43P_T^2)-(\pi d_o/8)^2]/[1/2\ \pi d_o]\}$	**10**
5	A triple effect evaporator system is to be used for concentrating 6% (wt) NaOH solution to 60% (wt) entering at 18°C. Overall HTUs (W/m^{2}K) of 3500, 2500, 1300 are expected in three effects in the given order. Steam is available at 8.5 atm (abs) and 0.07atm (abs) will be maintained in the third effect. Cooling water is available at 19°C. Take BPE (°C) = $21.2x+100x^2$ where x is the weight fraction of solids in the solution. The heat capacities of the solution can be estimated using the equation: Cp=4.19-2.35x in kJ/kg K. The heating areas are to be large enough to produce 25000kg/hr of concentrated product. If each effect has the same surface area, Calculate (a) the area (b) the steam rate used.	**10**
6A	Explain the strategies that can be applied for increasing the values of shell side and tube side convective heat transfer coefficients.	**5**
6B	A single effect evaporator is to be used to concentrate a food solution containing 10% (by mass) dissolved solids to 30% solids. The feed stream (7800 kg/hr) enters the evaporator at 26°C. Steam is available at 2.4 bar and 0.05 bar (abs) is maintained in the evaporator. Assuming that the properties of the solution are the same as those of water, and taking the overall HTU to be 2700 W m^{-2}K^{-1}, calculate the rate of steam consumption and the heat transfer surface area.	**5**