Reg. No.										

Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

IV SEMESTER B.TECH (BIOTECHNOLOGY)

END SEMESTER EXAMINATIONS, May 2017

SUBJECT: HEAT AND MASS TRANSFER OPERATIONS IN BIOPROCESSING

[BIO 2205]

REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A	State and explain Kirchoff's law of radiation.	**2M**
1B	An aluminum pipe carries steam at 110°C. The pipe (k=85W/mK) has an inner diameter of 10cm and an outer diameter of 12cm. The pipe is located in a room where the ambient temperature is 30°Cand the convective heat transfer coefficient is 15W/m^{2}K. Determine the heat transfer rate per unit length of the pipe. To reduce the heat loss from the pipe, it is covered with a 5cm thick layer of insulation (k=0.2W/mK). Determine the rate of heat loss per unit length and the of the percentage reduction in heat loss by the insulation. Neglect the convective resistance of the steam.	**4M**
1C	A pipe made of steel (k=50W/mK) of inner diameter 100mm and outer diameter 110mm is to be covered with two layers of insulation each having a thickness of 50mm. The thermal conductivity of the first insulation material is 0.06W/mK and that of the second is 0.12W/mK. Calculate the loss of heat per meter length of the pipe and the interface temperature between two layers of insulation when the temperature of the inside tube surface is 250°C and that of the outside surface of the insulation is 50°C.	**4M**
2A	Perform a dimensional analysis to find the dimensionless groups involved in the process of free convection by identifying the variables affecting the phenomenon.	**3M**
2B	In a long annulus (3.125 cm inner diameter and 5 cm outer diameter), the air is heated by maintaining the temperature of the outer surface of inner tube at 50°C. The air enters at 16°C and leaves at 32°C and its flow rate is 30m/s. Estimate the heat transfer coefficient between the air and the inner tube. The properties of air are: ρ=1.614kg/m^3, ν=15.9*10^{-6}m^2/s, c_p=1.007kJ/kgK, Pr=0.707, k=0.0263W/mK. Given: Nu=0.023Re$_{Dh}^{0.8}$Pr$^{0.4}$	**3M**
2C	Sodium potassium alloy (25:75) flowing at a rate of 3kg/s is heated in a tube of 5cm inner diameter from 200°C to 400°C. Tube surface is maintained at constant heat flux and the temperature difference between the tube surface and the mean bulk temperature of the fluid is 40°C. Determine the heat transfer coefficient, heat flux at the surface and length of the tube required. Properties of the alloy are ρ=799kg/m^3, ν=0.366*10^{-6}m^2/s, c_p=1038.8J/kgC, k=22.68W/mC, Pr=0.0134: Nu=6.3+(0.0167(Re$^{0.85}$Pr$^{0.93}$))	**4M**

3A	In a double pipe heat exchanger hot oil flows with a capacity rate of 2500W/K. It enters at a temperature of 360°C and leaves ta 300°C. Cold fluid enters at 30°C and leaves at 200°C. If the overall heat transfer coefficient is 800W/m2K, determine the heat exchanger area required for parallel and counter flow.	**3M**
3B	Explain the different regimes of flow boiling.	**3M**
3C	A single-effect evaporator is used to concentrate 7 kg/s of a solution from 10 to 50 percent solids. Steam is available at 205 kN/m^2 and evaporation takes place at 13.5 kN/m^2. If the overall coefficient of heat transfer is 3 kW/m^2K, estimate the heating surface required and the amount of steam used if the feed to the evaporator is at 294 K and the condensate leaves the heating space at 352.7 K. The specific heats of 10 and 50 per cent solutions are 3.76 and 3.14 kJ/kgK respectively. Assuming that the steam is dry and saturated at 205 kN/m^2, then from the Steam Tables, the steam temperature = 394 K at which the enthalpy of steam = 2530 kJ/kg and the enthalpy of condensate is 333.2kJ/kg. At 13.5 kN/m^2, water boils at 325 K .The total enthalpy of vapour at 325 K is 2594 kJ/kg.	**4M**
4A	Explain the analogy between heat and mass transfer.	**4M**
4B.	State the physical significance of Sherwood and Schmidt number	**3M**
4C.	A packed bed distillation column is used to separate a mixture of methanol and water at a total pressure of 1 atm. Methanol diffuses from the liquid phase towards the vapor phase while water diffuses in the opposite direction. The process is modelled as equimolar counter diffusion. At a point in the column the mass transfer coefficient is estimated as $1.62*10^{-5}kmol/m^2s\text{-}kPa$. The gas phase methanol mole fraction at the interphase is 0.707 while at the bulk of the gas it is 0.656. Estimate the methanol flux at that point.	**3M**
5A.	In an experimental study of the absorption of ammonia by water in a wetted column, the value of K_G was found to be $2.75*10^{-6}kmol/m^2s\text{-}kPa$. At one point in the column, the composition of the gas and liquid phases were 8.0 and 0.115 mole% NH_3 respectively. The temperature was 300K, and the total pressure was 1 atm. Eighty five percent of the total resistance to mass transfer was found to be in the gas phase. At 300K, ammonia-water solutions follow Henry's law upto 5 mole% ammonia in the liquid, with m=1.64 when the total pressure is 1 atm. Calculate the individual film coefficients and the interfacial concentrations.	**4M**
5B.	A packed tower uses an organic amine to absorb CO_2. The entering gas contains 1.26 mole % CO_2 is to leave with only 0.4 mole% CO_2. If the amine left is in equilibrium with the entering gas, it would contain 0.80 mole% CO_2. The gas flow is 2.3gmol/sec, the liquid flow is 4.8gmol/s, the tower diameter is 40cm and the overall mass transfer coefficient times the area per unit volume is $5*10^{-5}gmol/cm^{3}\text{-}s$. How tall should the tower be?	**4M**
5C.	What is the physical significance of HTU and NTU.	**2M**