Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent institution of MAHE, Manipal)

IV SEMESTER B.TECH BIOTECHNOLOGY

END SEMESTER EXAMINATIONS, APRIL/MAY 2018

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	A container is insulated with two layers of insulation which is of 60mm thickness and had a conductivity of 0.05W/mK and 0.15W/mK. The inner diameter of the stainless steel container is 300mm and thickness is 20mm.The inside surface temperature is -194°C and the outside is exposed to air at 30°C with convection coefficient of 34W/m^{2}K. There is a contact resistance of 1*10^{-3}m^2°C/W between the two insulations. Determine the heat gain and the overall heat transfer coefficient based on inside surface area of the container.	**4**
1B	A thin metal plate is insulated at the back and exposed to solar radiation at the front surface. The exposed surface of the plate has an absorptivity of 0.6 for solar radiation. If solar radiation is incident on the plate at the rate of 700W/m^2 and the surrounding air temperature is 25°C determine the surface temperature of the plate when the heat loss by convection and radiation equals the solar energy absorbed by the plate. Assume the combined convection and radiation heat transfer coefficient to be 50W/m^{2}K.	**3**
1C	Heat is generated uniformly in a stainless steel plate having K=20W/mK. Thickness of the plate is 1cm and heat generation rate is 500MW/m3. If the temperature on either side of the plate are maintained at 100 and 200°C calculate the (a) Temperature at the centreline and temperature at one quarter of the thickness from the surface	**3**

2A	Explain the typical boiling curve of water at 1 atm pressure with the sketch indicating the various boiling regimes.	**3**
2B	A vertical cylinder 2m high and 20cm in diameter is maintained at a temperature of 100℃ in an atmospheric environment of 20℃. Calculate the heat lost by free convection for this cylinder. [$Nu=0.12\ (Gr.Pr)^{1/3}$]. Given properties at mean temperature: $\rho=1.06 kg/m^3$; $Cp=0.24$ kcal/kgK; $K=0.0249$ kcal/m.hr.K; $\mu=2.05*10^{-5}$ kgf-sec/m^2; $\nu=18.97*10^{-6} m^2/sec$; State the physical significance of Grashof number.	**4**
2C	Using dimensional analysis, obtain an expression for heat transfer coefficient in forced convection in terms of the following groups: $\pi1$= h, ρ, D, V,μ; $\pi2$= h, ρ, D, V, cp ; $\pi3$= h, ρ, D, V, k	**3**
3A	In a power plant steam is to be condensed at a temperature of 30°C with cooling water from a nearby lake which enters the tubes of the condenser at 14°C and leaves at 22°C. The surface area of the tube is $45 m^2$ and the overall heat transfer coefficient is $2100 W/m^2K$. Calculate the mass flow rate of cooling water and rate of condensation of steam in the condenser. Given λ=2430kJ/kg.	**3**
3B	Explain the backward feed system in an evaporator with a neat sketch	**3**
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 area 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.	**4**
4A	Describe the following theories of mass transfer, i. Penetration theory ii. Combination of film-surface renewal theory	**2**
4B	Define HETP and on what factors does HETP depend? Give reasons	**2**
4C	While selecting a plastic material for packaging food items, what factors need to be considered? Provide reasons	**2**
4D	A gas mixture has components A and B in it. The concentration of gas A, 4 mm apart are 10% and 2% by volume. The total pressure is 1 atm and the temperature is 20^0C.	**4**

	The diffusivity of the two gases under these conditions is 0.15 cm^2/s. Determine the rate of diffusion in kmol/s if diffusion occurs under 1. Equimolal counter diffusion 2. Gas A diffusing with non-diffusing gas B	
5A	Define a stage and its efficiency in mass transfer.	**2**
5B	Ammonia from an aqueous ammonia solution is being desorbed into air stream in a column. At one point in the column, the concentration of ammonia in liquid is 0.3 $kmol/m^3$ and partial pressure of ammonia in the gas is 0.06 atm. The equilibrium relationship under operating condition is $P_A = 0.25\ C_A$, where P_A is the partial pressure of ammonia in the atmosphere and C_A is the concentration in the liquid in $kmol/m^3$. The overall mass transfer coefficient K_x is 0.0875 kmol/[$h.m^2$.($kmol/m^3$)]. If the gas phase resistance is 70% of the total resistance, (i) Plot P_A vs. C_A (ii) Calculate individual mass transfer coefficient- gas phase in kmol/[$h.m^2$.atm] and liquid phase kmol / [$h.m^2$($kmol/m^3$)] (iii) Compute overall gas phase mass transfer coefficient K_y kmol/[$h.m^2$.atm] (iv) Determine interfacial concentrations of ammonia in gas phase (as partial pressure, atm) and in liquid side in $kmol/m^3$, use graphical method (v) Calculate Overall mass flux in kmol/[$h.m^2$]	**5**
5C	A spherical drop of water 0.5mm in diameter is falling at a velocity of 2.15 m/s through dry and stagnant air at 1 atm with no internal circulation. Calculate, 1. The mean mass transfer coefficient (in m/s) 2. The instantaneous rate of evaporation from the drop (in mol/s) The drop surface is at 21^0C, air far from the surface is totally dry. Vapour pressure of water at 21^0C is 0.0247 atm. Assume that at the interface, partial pressure of water is vapor pressure. Use the relationship, $$\mathbf{Sh=2.0+0.6\ Re^{0.5}Sc^{0.33}}$$ Diffusivity of moisture through air is 0.282 cm^2/s, density of air is 1.1769 kg/m^3 and viscosity of air 18.53×10^{-6} Ns/m^2.	**3**