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# Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

## IV SEMESTER B.TECH (BIOTECHNOLOGY)

## END SEMESTER EXAMINATIONS, May 2016

## SUBJECT: HEAT AND MASS TRANSFER 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.

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| **1A** | Consider a plane wall of thickness L whose thermal conductivity varies linearly in a specified temperature range as k(T)=ko (1+ßT) where ko and ß are constants. The wall surface at x=0 is maintained at a constant temperature of T1 while the surface at x=L is maintained at a temperature of T2. Assuming steady one dimensional heat transfer , obtain a relation for (a) the heat transfer rate through the wall (b) the temperature distribution T(x) in the wall. | **3M** |
| **1B** | 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 surface temperatures, heat gain and the overall heat transfer coefficient based on inside surface area of the container. | **4M** |
| **1C** | 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. | **3M** |
| **2A** | Calculate the convective heat loss from a radiator of 0.5m wide and 1m high maintained at a temperature f 84°C in a room at 20°C. Treat the radiator as a vertical plate. Properties of the air: $k=28.15*10^{-3}$W/mK,$\nu$=18.41*10-6$m^2$/s,Pr=0.7, $Nu=\{0.825+[(0.387Ra^{1/6})/(1+(0.492/Pr)^{9/16})^{8/27}\}^2$ | **3M** |
| **2B** | Identify the variables affecting the free convection phenomena and perform a dimensional analysis to find the dimensionless groups involved in the process. | **3M** |

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| **2C** | Steam in a condenser of a steam power plant is to be condensed at a temperature of 40°C with cooling water from a nearby lake which enters the tubes of a condenser at 19°C and leaves at 28°C. The surface area of the tubes is $45m^2$ and the overall heat transfer coefficient is $2300W/m^2K$. Calculate the mass flow rate of the cooling water and the rate of heat condensation in the condenser. Given that latent heat of condensation = 2430.5kJ/kg. Explain the temperature distribution of a fluid in a condenser. | **4M** |
| **3A** | A concentric tube heat exchanger must be designed to cool oil.The flow rate of the cooling water in 0.2kg/s. The inner tube has a ID=25mm. Oil is made to flow through the annulus at a flow rate of 0.1kg/s. The outer annulus through which the oil flows has a OD of 45mm. The oil and water enter at temperatures of 100°C and 30°C respectively. If the exit temperature of the oil is 60°C what should be the length of the tube? State the assumptions. Properties of oil: Cp= 2.131kJ/kg.K, $\mu=3.25*10^{-2}Ns/m^2$, K=0.138W/mK: Properties of water: Cp= 4.178kJ/kg.K, $\mu=728*10^{-6}Ns/m^2$, K=0.625W/mK; Given: $Nu=0.023(Re)^{4/5}(Pr)^{0.4}$ | **4M** |
| **3B** | Explain the different regimes of pool boiling and flow boiling. | **3M** |
| **3C** | Consider a person standing in a breezy room at 20°C. Determine the total rate of heat transfer from this person if the exposed surface area and the average outer surface temperature of the person are $1.6m^2$ and 29°C respectively and the convection heat transfer coefficient is $6W/m^2K$ . State the assumptions. | **3M** |
| **4A** | An open circular tank 8m in diameter contains n-Propanol at $25^0C$ exposed to the atmosphere in such a manner that the liquid is covered with a stagnant air film estimated to be 5mm thick. The concentration of propanol beyond stagnant film is negligible. The vapor pressure of propanol at $25^0C$ is 20mmHg. If propanol is worth Rs 120 per litre, what is the value of loss of propanol in Rs per day? The specific gravity of n- Propanol is 0.8. Diffusivity of propanol in air is 0.1329 $cm^2/s$. Assume non diffusion of air through the film. Mol. wt. of n-Propanol is 60. | **5M** |
| **4B** | Explain the following Mass Transfer Dimensionless numbers and their significance<br>(i) Peclet Number (Pe)<br>(ii) Stanton Number (St) | **2M** |
| **4C.** | The equilibrium relationship between mole fractions (of two component A and B) x and y is<br>$y=0.85*x^{1.4}$<br>Tabulate and plot y, Y with the corresponding x, X, where X and Y are the mole ratios i.e., mole-A/mole-B. Minimum 10 data points are required. Range of data for x is 0 to 1.0. | **3M** |
| **5A.** | Explain the Surface Renewal Theory of Mass Transfer | **2M** |
| **5B.** | What is HETP? On what factors HETP depend? Explain | **2M** |
| **5C.** | In a laboratory experiment, the solute A is being absorbed from a mixture with an insoluble gas in a falling film of water at $30^0C$ and a total pressure of 1.45 bar. The gas phase mass transfer coefficient at the given velocity is estimated to be $k_y=5.196$ kmol/h.$m^2$. It is known that 13.6% of the total mass transfer resistance lies in the gas phase. At a particular section of the apparatus, the mole fraction of the solute in the bulk gas is 0.065 and the interfacial concentration of the solute in the liquid is known to be $x_i=0.00201$. The equilibrium solubility relationship of the gas in water at the given temperature is<br>$p=3.318*10^4*x$<br>where p is the partial pressure of A in the gas in mmHg and x is the solubility of A in water in mole fraction.<br>Calculate,<br>(i) Absorption flux of the gas at the given section of the apparatus in kmol/h.$m^2$<br>(ii) Bulk liquid concentration at that section of the apparatus, in mole fraction<br>(iii) Overall liquid phase mass transfer in kmol/h.$m^2$<br>(iv) Individual and overall gas phase driving force in terms of $\Delta p$ and $\Delta y$ | **6M** |