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

DEPARTMENT OF BIOTECHNOLOGY

IV SEMESTER B.TECH. (BIOTECHNOLOGY)

END SEMESTER EXAMINATIONS, JUNE 2024

SUBJECT: PRINCIPLES OF HEAT AND MASS TRANSFER [BIO2224]

Time: 3 Hours **MAX. MARKS: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- Any data not provided may be suitably assumed.

Q. No	Question	M	CO	PO	BL
1A	The wall of a boiler is made up of 250mm of the brick, K_{FB} = 1.05 W/m K; 120 mm of insulation brick K_{IB} = 0.15 W/m K, and 200 mm of red brick, K_{RB} = 0.85 W/m K. The inner and outer surface temperatures of the wall are 850^0 C and 65^0C respectively. Calculate the temperatures at the contact surfaces	4	1	1,2,3,4, 5,6,11, 12	3
1B	Water flows at 60^0C inside a 2 cm inside diameter, length =1 meter, tube such that h_i=500 W/m^2 ^{0}C. The tube has a wall thickness of 2 mm with a thermal conductivity of 25 W/m ^{0}C. The outside of the tube loses heat by free convection with h_0= 30W/m^2 ^{0}C. Calculate the overall heat transfer coefficient based on the inner area. $$\text{Resistance for radial heat flow} = \frac{\ln(\frac{r_o}{r_i})}{2\pi kL}$$	3	1	1,2,3,4, 5,6,11, 12	3
1C	. A material has thermal conductivity k= 30(1 + 0.02T) W/m ^{0}C, T=temperature in ^{0}C. Two faces of the slab of the material are maintained at 20^0C and 100^0C. Calculate the heat flux W/m^2. Thickness of the slab is 10 cm.	3	1	1,2,3,4, 5,6,11, 12	3

2A	Water is heated while flowing through a tube, Re=2000, pipe diameter = 2.54 cm, Compute (i) velocity of water, m/s (ii) mass flow rate of water, m', kg/s (iii) heat transfer coefficient W/m^2C. **Data:** L=1 meter, Cp=4.19kJ/kg.K, ρ=995 kg/m^3, μ=0.0005471 Pas.s ,k=0.6 W/m ^0C, **Nu=2(m' C_p /k L)$^{0.333}$**	**3**	**2**	1,2,3,4, 5,6,11, 12	**3**
2B	Water is heated while flowing through a 4 cm diameter tube at a velocity of 1m/s. Entering water is at a temperature of 30^0C and tube wall is at constant temperature of 70^0C. It is required to raise the temperature of water by 30^0C. Determine, (i) LMTD (ii) mass flow rate, kg/s (iii) heat transfer coefficient, W/m^2 C (iv) the length of the tube required, m. **Data:** Properties of water ρ=985kg/m^3, μ=0.000509 Pas.s, Pr=3.2, k=0.653 W/mK, C_P=4.18kJ/Kg.K, **Nu=0.023Re$^{0.8}$Pr$^{0.3}$**	**4**	**2**	1,2,3,4, 5,6,11, 12	**3**
2C	Oxygen dissolves in the surface and diffuses through water. Oxygen concentration at the depth of 10 m is almost zero due to an oxidation reaction at the bottom. Solubility of oxygen is 8 ppm (by weight), diffusivity of oxygen is 3.24×10^{-5} cm^2/s. Mol wt of Fe = 55. **Reaction :** $4Fe+3O_2 = 2Fe_2O_3$. Compute the amount of Fe getting oxidized kg/month/m^2.	**3**	**2**	1,2,3,4, 5,6,11, 12	**3**
3A	Steam at 100^0 C is being condensed on the inside surface of a horizontal tube of 10 m length and 25 mm ID and tube surface is maintained at 90 ^{0} C. The tube is cooled from outside by flowing cold water. Determine the flow rate of cooling water in m^3/h, entering at 20^0 C and leaving at 60^0 C. **Data:** Average properties of water (condensate) at 100^0C are ρ=962 kg/m^3, k=0.677 W/mK, Cp=4179J/kgK, $\mu=3.0 \times 10^{-4}$kg/ms, $\lambda=2.27 \times 10^6$J/kg. $\bar{h} = 0.555\left(\frac{\rho^2 k^3 g\lambda}{\mu D\Delta T}\right)^{0.25}$	**4**	**3**	1,2,3,4, 5,6,11, 12	**3**

3B	In a plant location near a furnace, radiant energy flux is incident on a vertical metal surface 3.5 m high and 2 m wide. The metal is insulated on the back side and painted black so that all the incoming radiation is lost by free convection to the surrounding air at 30^0C, average metal temperature is 185^0C. What is the net radiant energy flux falling on the metal surface? **Data:** Properties of air at mean temperature Pr=0.695, k=0.0320W/mK, $\mu/\rho=2.354\times10^{-5} m^2/s$; $Nu=0.17(GrPr)^{1/4}$, $Gr= H^3\rho^2 g\beta\,(\Delta T)/\mu^2$	**3**	**3**	1,2,3,4, 5,6,11, 12	**3**
3C	The equilibrium relationship between mole fraction of an active component in liquid (x) and in gas (y), at total pressure of 1 atm, is given by y= 0.85 x. If k_x=3 and k_y= 5.5, compute K_x and K_y, percentage of resistance offered by the liquid phase and vapor phase. $$\frac{1}{K_x}=\frac{1}{k_x}+\frac{1}{mk_y};\ \frac{1}{K_y}=\frac{1}{k_y}+\frac{m}{k_x}$$	**3**	**3**	1,2,3,4, 5,6,11, 12	**3**
4A	A spherical drop of Camphor, 4 mm in diameter, is falling at a velocity of 0.5 m/s through dry and stagnant air at 1 atm with no internal circulation in the film. Calculate, a. The mean mass transfer coefficient (in m/s) b. The instantaneous rate of evaporation from the drop (in mol/m^2 s) The drop surface is at 25^0C, air far from the surface is totally free from camphor. Vapour pressure of Camphor at 25^0C is 27Pa. Assume that at the interface, partial pressure of Camphor is vapor pressure. **Data:** Use the relationship, $$Sh=2.0+0.514\,Re^{0.5}\,Sc^{0.33}$$ Diffusivity of camphor through air, D, is $5.64\times10^{-6} m^2/s$, density of air is 1.1769 kg/m^3 and viscosity of air $18.53\times10^{-6} Ns/m^2$, R=8.314 J/mol.K, Sh= Sherwood number = kd/D; Sc = Schmidt number = $\mu/D\rho$, d is the diameter and D is the diffusivity	**5**	**4**	1,2,3,4, 5,6,11, 12	**3**
4B	Water evaporating from a pond does so as if it were diffusing across an air film of 0.15cm thick. The mass transfer Coefficient of water in 20°C air is 1.66 cm/s due to blowing air across the stagnant water surface. If the air out of the film is 50% saturated, how fast the level drop in a day, in m/d? V.P of water (20°C) = 17.5 mm Hg, R=8.314 J/mol.K , Density of mercury =13.5×10^3 kg/m^3.	**3**	**4**	1,2,3,4, 5,6,11, 12	**3**

<table>
<tr><td>4C</td><td>Briefly describe Kirchoff's law of radiation (2)</td><td>2</td><td>5</td><td>1,2,3,4,
5,6,11,
12</td><td>3</td></tr>
<tr><td>5A</td><td>The equilibrium adsorption of benzene vapor in N_2 gas on a certain activated charcoal at 33.3°C and 1 atm is reported as
<table><tr><td>Benzene vapor adsorbed cm^3 (at STP) /g charcoal</td><td>0</td><td>15</td><td>25</td><td>40</td><td>50</td><td>65</td><td>80</td><td>90</td><td>100</td></tr><tr><td>Partial pressure of benzene, mm Hg</td><td>0</td><td>0.001</td><td>0.0045</td><td>0.0251</td><td>0.115</td><td>0.251</td><td>1</td><td>2.81</td><td>7.82</td></tr></table>
Convert this equilibrium data into X (milli-moles Benzene/g Charcoal) vs. Y(milli-moles Benzene/moles N_2) and plot. Mol wt of Benzene is 78.</td><td>4</td><td>5</td><td>1,2,3,4,
5,6,11,
12</td><td>3</td></tr>
<tr><td>5B</td><td>How can film boiling be prevented?</td><td>2</td><td>5</td><td>1,2,3,4,
5,6,11,
12</td><td>3</td></tr>
<tr><td>5C</td><td>Acetone in an air acetone mixture is to be reduced from initial mole ratio of 0.05 mol/mol air, by contacting with fresh wash oil in a three equilibrium stage countercurrent gas absorber. The inlet flow rate of air-acetone mixture is 10 mol/s while acetone free wash oil enters at 9.5 mol/s. If the equilibrium curve is given by Y=X, where Y and X are equilibrium mole ratios of acetone in air and acetone in oil respectively, compute the concentration of acetone in outlet air and concentration (mole fraction) of acetone in outgoing wash oil. Solve the problem graphically, by trial and error method.</td><td>4</td><td>5</td><td>1,2,3,4,
5,6,11,
12</td><td>3</td></tr>
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