Question Paper

Exam Date & Time: 24-Apr-2019 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

TRANSPORT PROCESS-II - HEAT-MASS TRANSFER [IBT 241]

Marks: 100 **Duration: 180 mins.**

C

Answer 5 out of 8 questions.

1) A) A brick wall (k=0.7 W/mK) is 0.30m thick. If the temperatures of the inner and the outer surfaces are maintained at 50°C and 30°C respectively , calculate the heat loss through one square meter area. Find also the temperature at the interior of the wall 24cm distant from the outer wall. List the assumptions and explain the Fourier's law of heat conduction (8)

B) A wall made of a certain material is 20cm thick has its two surfaces maintained at 1000°C and 200°C. The thermal conductivity of the fireclay varies with temperature in °C as k (W/mK)=0.813+0.000582T. Calculate the rate of heat flow. (4)

C) A vessel spherical in nature having inner diameter 0.3m and thickness of 20mm is made of a metal with thermal conductivity 40W/mK. The vessel is insulated with two layers of 60mm thickness of conductivity 0.05 and 0.15W/mK. The inside temperature is -196 °C. The outside is exposed to ambient at 30°C with convection coefficient of 35W/m^{2}K. There is a contact resistance of 1.5*10^{-3} °C/W between the two insulations. Determine the heat gain and the overall heat transfer coefficient based on the inside and the outside area and also represent the resistances in terms of electrical circuit. (8)

2) A) Determine the overall heat transfer coefficient based on the inner and the outer area between water and oil if the water flows through the copper pipe 1.8 cm inner diameter and 2.1 cm outer diameter while the oil flows through the annulus between the pipe and the steel pipe. The water and the oil side film coefficients are respectively 4000 and 1100 kcal/hr m^2 °C. The fouling factors on the water side and oil side may be taken as 0.0004 and 0.001 °C hr m^2/kcal respectively. The thermal conductivity of the tube wall is 300 kcal/hr m °C . What are fouling factors. (10)

B) Consider a steam pipe of length L = 20 m, inner radius r_1 = 6 cm, outer radius r_2=8cm, and thermal conductivity k =20 W/m°C. The inner and outer surfaces of the pipe are maintained at average temperatures of T1 = 150°C and T2 =60°C, respectively.Obtain a general relation for the temperature distribution inside the pipe under steady conditions, and determine the rate of heat loss from the steam through the pipe. List the assumptions. (6)

C) Explain the development of a thermal boundary layer in an external flow (4)

3) (8)

A) Using dimensional analysis derive an expression for heat transfer coefficient in forced convection.

B) Air at 27°C is flowing across a tube with velocity of 25m/s. The tube could be a square with a side of 5cm or a circular cylinder of diameter 5cm. Compare the heat transfer coefficient in each case if the tube surface temperature is 124°C.Given (8)

for circular tube : $Nu=0.027(Re_D)^{0.805}Pr^{1/3}$,

for square tube : $Nu=0.102(Re_D)^{0.675}Pr^{1/3}$,

$\nu=20.92*10^{-6}m^2/s$, $k=3*10^{-2}W/mK$, Pr=0.7

C) Explain the following (i) contact resistance (ii) film condensation (4)

4) A) Explain the natural convection and film boiling regimes of pool boiling with a graphical representation. (8)

B) In a food industry brine (Cp=3.18 kJ/kgK) is heated from 8 to 14 °C in a double pipe heat exchanger with water at 55°C leaving at 40°C a rate of 0.18 kg/s. If the overall heat transfer coefficient is 800W/m^{2}K, determine the area of heat exchange required for both the parallel as well as counter current arrangement (6)

C) A shell and tube condenser consists of tubes of 20mm diameter. Cooling water enters the tubes ta 20°C with a flowrate of 1kg/s. The heat transfer coefficient for condensation on the outer surface of the tube is 15500 W/m^{2}K. If the heat load on the condenser is 2300 MW when the steam condenses at 50°C determine the outlet temperature of the cooling water. And the overall heat transfer coefficient. Given $Nu=0.023(Re^{4/5}Pr^{2/5})$, $\mu=855*10^{-6}Ns/m^2$, k=0.613W/mK, Pr=5.83 (6)

5) A) A continuous single-effect evaporator concentrates 9832 kg/h of a 1.5 wt% salt solution entering at 313.0 K to a final concentration of 3.0 wt %. The vapor space of the evaporator is at 1atm and the steam supplied is saturated at 143.3 kPa. Calculate the amounts of vapor and liquid given that the overall U = 1504 W/m^{2}K product and the heat-transfer area required. Assume that, since it is dilute, the solution has the same boiling point as water. Given H_f = 158.37kJ/kg, h_L =419.04 kJ/kg, H_v=2676.1kJ/kg, H_s = 2691.5kJ/kg , h_c = 461.3kJ/kg, Ts=110°C , T_1=100°C (10)

B) Explain the agitated film type evaporator and one of the feeding methods (10)

6) A) Show that the mass transfer rate through a spherical shell is directly proportional to concentration difference and inversely proportional to the thickness. List all the assumptions (10)

B) Explain the Kirchoff's law of radiation (6)

C) The radiant heat transfer from a plate of 2 cm^2 area at 1100K to a very cold enclosure is 3.0W. What is the emissivity of the plate at this temperature? State and explain the Stefan-Boltzmann law of radiation. (4)

7) A) Explain the physical significance of Sherwood number, Schmidt number, Lewis number. (6)

B) Dry air at 25°C and 1 atm flows over a wet flat plat 50cm long at a velocity of 50m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate. Given: D_{AB} = 0.26*10^{-4} m^2/s, ρ= 1.16 kg/m^3, μ=184.6*10^{-7} Ns/m^2, Pr=0.707; Jm=$St_m Sc^{2/3}$=0.029$Re^{-1/5}$. (4)

C) Solute A is distributed between air and water at low concentration. Its equilibrium y=1.2m. At a certain point in a mass transfer device the concentration of solute A in the bulk is 0.04 mole fraction and that in the bulk aqueous phase is 0.025. In which direction does the transport of the solute A occur. Calculate the overall gas phase and the overall liquid phase driving force for mass transfer. At the same point the local individual mass transfer coefficient for the transport of A are : k_y=7.2 kmol/h m^2Δy ; ky=4.6 kmol/h m^2Δx. (10)
(a) Calculate the interfacial concentration in both the gas and liquid phase (b) the overall mass transfer coefficient K_x and K_y and (c) the local mass flux N_A.

8) A) Explain the Reynolds and the Chilton-Colburn analogy (5)

B) An open pan 20cm in diameter and 6 cm in depth contains water at 25°C and is exposed to atmospheric air. If the rate of diffusion of water vapour is 8.54*10^{-4} kg/hr estimate the diffusion coefficient of water in air given saturation pressure of water is 0.0316 bar. (5)

C) A horizontal high pressure steam pipe of 0.1m outside diameter passes through a large room whose wall and air temperatures are 23°C. The pipe has an outside surface temperature of 165°C and an emissivity of 0.85. Estimate the heat loss from the pipe per unit length. State the assumptions. Use the following expression Nu=0.53$(Gr.Pr)^{1/4}$ and explain the physical significance of the dimensionless numbers appearing in the equation. Properties: k=0.0301W/mK, α=32.18*$10^{-6}$$m^2/s$, viscosity=22.8*$10^{-6}$$m^2/s$, Pr=0.697, β=2.725*$10^{-3}$$K^{-1}$ (10)

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