C 3306

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2007.

Sixth Semester

(Regulation 2004)

Mechanical Engineering

ME 1351 — HEAT AND MASS TRANSFER

(Common to B.E. (Part–Time) Fifth Semester, Regulation–2005)

Time : Three hours Maximum : 100 marks

Heat and Mass Transfer Data Handbook is permitted.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Distinguish between Fin Efficiency and Fin Effectiveness.

2. What is the use of Heislers chart?

3. What is overall heat transfer co-efficient?

4. What is the significance of Dimensional number?

5. What is condensation process?

6. What is Fouling factor?

7. Explain electrical analogy.

8. What is grey body?

9. Define Fourier Number for Mass Transfer.

10. Explain Mass Transfer Co-efficient.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Derive the heat conduction equation in cylindrical co-ordinates using an elemental volume for a stationary isotropic solid. (8)

(ii) A 3 cm OD steam pipe is to be covered with two layers of insulation each having a thickness of 2.5 cm. The average thermal conductivity of one insulation is 5 times that of the other. Determine the percentage decrease in heat transfer if better insulating material is next to pipe than it is the outer layer. Assume that the outside and inside temperatures of composite insulation are fixed. (8)

Or

(b) (i) Explain briefly the concept of critical thickness of insulation and state any two applications of the same. (8)

(ii) A 6 cm long copper rod (k = 300 W/mK) 6mm in diameter is exposed to an environment at 20°C. The base temperature of the rod is maintained at 160°C. The heat transfer co-efficient is 20 W/m^{2}K. Calculate the heat given by the rod and efficiency and effectiveness of the rod. (8)

12. (a) (i) Explain for fluid flow along a flat plate:

(1) Velocity distribution in hydrodynamic boundary layer

(2) Temperature distribution in thermal boundary layer

(3) Variation of local heat transfer co-efficient along the flow. (8)

(ii) The water is heated in a tank by dipping a plate of 20 cm X 40 cm in size. The temperature of the plate surface is maintained at 100°C. Assuming the temperature of the surrounding water is at 30° C, Find the heat loss from the plate 20 cm side is in vertical plane. (8)

Or

(b) (i) Define the Biot and Fourier numbers. (4)

(ii) What is meant by lumped capacity? What are the physical assumptions necessary for a lumped capacity unsteady state analysis to apply? (4)

(iii) A slab of Aluminum 5 cm thick initially at 200°C is suddenly immersed in a liquid at 70°C for which the convection heat transfer co-efficient is 525 W/m^{2}K. Determine the temperature at a depth of 12.5 mm from one of the faces 1 minute after the immersion. Also calculate the energy removed per unit area from the plate during 1 minute of immersion.

Take p = 2700 bar, Cp = 0.9 kJ/kg.°K,

k=215 W/mK, α = 8.4X 10^{-5} m^2/s. (8)

13. (a) (i) With a neat and labeled sketch explain the various regimes in boiling heat transfer. (8)

(ii) A vertical plate 0.5 m^2 in area at temperature of 92°C is exposed to steam at atmospheric pressure. If the steam is dry and saturated estimate the heat transfer rate and condensate mass per hour. The vertical length of the plate is 0.5 m. Properties of water at film temperatures of 96°C can be obtained from tables. (8)

Or

(b) (i) Compare LMTD and NTU method of heat exchanger analysis. (6)

(ii) Hot exhaust gases which enters a finned tube cross flow heat exchanger at 300°C and leave at 100°C, are used to heat pressurized water at a flow rate of 1 kg/s from 35 to 125°C. The exhaust gas specific heat is approximately 1000 J/kg.K, and the overall heat transfer co-efficient based on the gas side surface area is U_h = 100W/m^2K. Determine the required gas side surface area A_h using the NTU method.

Take Cp,c at T_c = 80°C is 4197 kJ/kg.K and Cp,h = 1000 J/kg.K . (10)

14. (a) (i) State and prove the following laws:

(1) Kirchoff's law of radiation

(2) Stefan — Boltzmann law (8)

(ii) Show from energy balance consideration that the radiation heat transfer from a plane composite surface area A_4 and made up of plane surface areas A_2 and A_3 to a plane surface area A_1 is given by:

$A_4F_{41} = A_3F_{31} + A_2F_{21}$ and

$F_{14} = F_{12} + F_{13}$ (8)

Or

(b) (i) Using the definition of radiosity and irradiation prove that the radiation heat exchange between two grey bodies is given by the relation: (8)

$$Q_{net} = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1-\varepsilon_1}{A_1 \varepsilon_1} + \frac{1}{A_1 F_{1-2}} + \frac{-\varepsilon_2}{A_2 \varepsilon_2}}$$

(ii) A surface at 100K with emissivity of 0.10 is protected from a radiation flux of 1250 W/m^2 by a shield with emissivity of 0.05. Determine the percentage cut off and the shield temperature. Assume shape factor as 1. (8)

15. (a) (i) Explain Fick's first and second laws of diffusion. (8)

(ii) Explain the phenomenon of equimolar counter diffusion. Derive an expression for equimolar counter diffusion between two gases or liquids. (8)

Or

(b) (i) Define the Schmidt ,Sherwood and Lewis numbers. What is the physical significance of each? (8)

(ii) Dry air at 27°C and 1 atm flows over a wet flat plate 50 cm long at a velocity of 50 m/s. Calculate the mass transfer co-efficient of water vapour in air at the end of the plate. Take the diffusion co-efficient of water vapour in air is $D_{AB} = 0.26 \text{ X } 10^{-4}$ m²/s. (8)
