R 8494

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2006.

Sixth Semester

Mechanical Engineering

ME 340 — HEAT AND MASS TRANSFER

Time : Three hours Maximum : 100 marks

(Use of Steam Tables, Mollier Chart and HMT Data Book is permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Calculate the rate of heat transfer per unit area through a copper plate 45 mm thick whose one face is maintained at 350° C and the other face at 50° C. Take thermal conductivity of copper as 370 W/m° C.

2. What do you understand by critical radius of insulation and give its expression?

3. Define total emissive power and Radiosity.

4. Mention the physical significance of view factor.

5. Define Reynolds number and Grashoff number.

6. What is the importance of boundary layer?

7. Draw the film growth, velocity and temperature profiles when laminar film condensation takes place on a vertical plate.

8. Why fouling factors are considered in the design of heat exchangers?

9. What are the mechanisms of mass transfer by diffusion and convection?

10. A vessel contains a binary mixture of O_2 and N_2 with partial pressures in the ratio 0.21 and 0.79 at 15° C. The total pressure of the mixture is 1.1 bar. Calculate the mass densities of O_2 and N_2.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Obtain an expression for the general heat conduction equation in Cartesian coordinates. (8)

(ii) An exterior wall of a house is covered by a 0.1 m layer of common brick (k = 0.7 W/m° C) followed by a 0.04 m layer of gypsum plaster (k = 0.48 W/m° C). What thickness of loosely packed rock wool insulation (k = 0.065 W/m° C) should be added to reduce the heat loss or gain through the wall by 80%? (8)

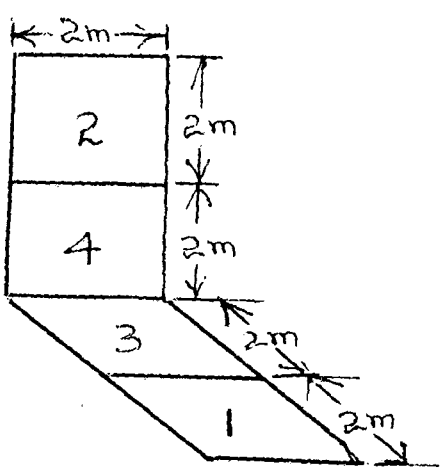
Or

(b) (i) Find out the amount of heat transferred through an iron fin of length 50 mm, width 100 mm and thickness 5 mm. Assume k = 58 W/m° C and h = 12 W/m² C for the material of the fin and the temperature at the base of the fin as 80° C. Also determine the temperature at tip of the fin if the atmosphere temperature is 20° C. (8)

(ii) An electrical wire of 10 m length and 1 mm diameter dissipates 200 W in air at 25° C. The convection heat transfer coefficient between the wire surface and air is 15 W/m²K. Calculate the critical radius of insulation and also determine the temperature of the wire if it is insulated to the critical thickness of insulation. (8)

12. (a) (i) Write a note on black body and grey body. (6)

(ii) Find the shape factor F_{1-2} and F_{2-1} for the figure shown below. (10)



Or

(b) (i) Discuss how the radiation from gases differ from that of solids. (6)

(ii) Two very large parallel plates with emissivities 0.5 exchange heat. Determine the percentage reduction in the heat transfer rate if a polished aluminium radiation shield of $\varepsilon = 0.04$ is placed in between the plates. (10)

13. (a) (i) Consider laminar hydrodynamically fully developed couette flow (that is flow between parallel plates) fluid being viscous. The upper plate at temperature T_2 moves with a velocity U while the lower plate at T_1 less than T_2 is stationary. The distance between the plates is w. Write the appropriate governing flow and energy equations for the above and obtain expressions for the velocity and temperature profiles across the flow. (12)

(ii) Air at 20° C is flowing along a heated plate at 134° C at a velocity of 3 m/s. The plate is 2 m long and 1.5 m wide. Calculate the thickness of the hydrodynamic boundary layer and the skin friction coefficient at 40 cm from the leading edge of the plate. The kinematic viscosity of air at 20° C is 15.06×10^{-6} m²/s. (4)

Or

(b) A hot plate 1.2 m wide, 0.35 m high and at 115° C is exposed to the ambient still air at 25° C. Calculate (i) the maximum velocity at 180 mm from the leading edge of the plate, (ii) the boundary layer thickness at 180 mm from the leading edge of the plate, (iii) the local heat transfer coefficient at 180 mm from the leading edge of the plate, (iv) the average heat transfer coefficient over the surface of the plate, (v) the heat loss from the plate and rise in temperature of the air passing through the boundary. (16)

14. (a) (i) Discuss the various regimes of boiling. (8)

(ii) An aluminium pan of 15 cm diameter is used to boil water and the water depth at the time of boiling is 2.5 cm. The pan is placed on an electric stove and the heating element raises the temperature of the pan to 110° C. Calculate the power input for boiling and the rate of evaporation. Take $C_{sf} = 0.0132$. (8)

Or

(b) (i) Describe the principle of parallel flow and counter flow heat exchangers showing the axial temperature distribution. (8)

(ii) In a counter flow double pipe heat exchanger water is heated from 25° C to 60° C by an oil with a specific heat of 1.45 kJ/kg K and mass flow rate of 0.9 kg/s. The oil is cooled from 230° C to 160° C. If the overall heat transfer coefficient is 420 W/m^2 °C, calculate (1) the rate of heat transfer, (2) the mass flow rate of water and (3) the surface area of the heat exchanger. (8)

15. (a) Atmospheric air at 40° C flows over a wet bulb thermometer and it shows 25° C. Calculate the concentration of water vapour in the free stream and also its relative humidity. Take D (air-water) = 0.256×10^{-4} m^2/s. If temperatures of dry and wet bulb are 30° C and 25° C respectively, what would be the corresponding values? (16)

Or

(b) (i) The molecular weights of the two components A and B of a gas mixture are 24 and 28 respectively. The molecular weight of gas mixture is found to be 30. If the mass concentration of the mixture is 1.2 kg/m^3, determine (1) molar fractions, (2) mass fractions and (3) total pressure if the temperature of the mixture is 290 K. (8)

(ii) An open pan 20 cm in diameter and 8 cm deep contains water at 25° C and is exposed to dry atmospheric air. If the rate of diffusion of water vapour is 8.54×10^{-4} kg/h estimate the diffusion coefficient of water in air. (8)
