A 1385

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

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. Write down the three dimensional heat conduction equation in rectangular coordinates.

2. Define fin efficiency.

3. What do you understand by specular and diffuse reflection?

4. State the Kirchoff's law of radiation.

5. What is velocity and thermal boundary layer?

6. Define Nusselt and Prandtl number.

7. How the filmwise condensation is different from dropwise condensation

8. Draw the temperature distribution of a counterflow heat exchanger.

9. Define mole fraction and mass concentration.

10. State Fick's law of diffusion.

PART B — (5 × 16 = 80 marks)

11. (a) (i) The inner surface at $r = a$ and the outer surface at $r = b$ of a hollow cylinder are maintained at uniform temperatures T_1 and T_2, respectively. The thermal conductivity k of the solid is constant. Develop an expression for the one-dimensional, steady-state temperature distribution $T(r)$ in the cylinder. Develop an expression for the radial heat flow rate Q through the cylinder of length H Develop an expression for the thermal resistance of a hollow cylinder of length H. (8)

(ii) A steel rod of diameter $D = 2$ cm, length $L = 25$ cm, and thermal conductivity $k = 50$ W/(m°C) is exposed to ambient air at $T_\infty = 20$°C with a heat transfer coefficient $h = 64$ W/(m²°C). If one end of the rod is maintained at a temperature of 120°C, calculate the heat loss from the rod. (8)

Or

(b) (i) Consider one-dimensional, steady-state heat flow along two stainless-steel bars, each of diameter $D = 2$ cm, length $L = 3$ cm and pressed together with a pressure of 10 atm. The surface has a roughness of about 2.5 μm. An overall temperature difference of $T = 100$°C is applied across the bars. The interface temperature is about 90°C. Calculate the heat flow rate along the bars and the temperature drop at the interface. (8)

(ii) A 5-cm-thick iron plate [$k = 60$ W/(m°C), $C_p = 460$ J/(kg°C), $\rho = 7850$ kg/m³, and $\alpha = 1.6 \times 10^{-5}$ m²/s] is initially at $T_1 = 225$°C. Suddenly, both surfaces are exposed to an ambient at $T_\infty = 25$°C with a heat transfer coefficient $h = 500$ W/(m²°C). Calculate the centre temperature at $t = 2$ min after the start of the cooling, the temperature at a depth 1 cm from the surface at $t = 2$ min after the start of the cooling and the energy removed from the plate per square meter during this time. (8)

12. (a) Two square plates, each 1 m by 1 m, are parallel to and directly opposite to each other at a distance 1 m, The hot plate is at $T_1 = 800$ K and has an emissivity $\varepsilon_1 = 0.8$. The colder plate is at $T_2 = 600$ K and also has an emissivity $\varepsilon_2 = 0.8$. The radiation heat exchange takes place between the plates as well as with a large ambient at $T_3 = 300$ K through the opening between the plates. Calculate the net heat transfer rate by radiation at each plate and to the ambient. (16)

Or

(b) (i) Two parallel plates are temperatures T_1 and T_2 and have emissivities $\varepsilon_1 = 0.8$ and $\varepsilon_2 = 0.5$. A radiation shield having the same emissivity ε_3 on both sides is placed between the plates. Calculate the emissivity ε_3 of the shield in order to reduce the radiation loss from the system to one-tenth of that without the shield. (8)

(ii) Distinguish between solid and gas radiation. (8)

13. (a) (i) Atmospheric air at $T_w = 400$ K flows with a velocity of $u_\omega = 4$ m/s along a flat plate $L = 1$ m long maintained at a uniform temperature $T_w = 300$ K. The average heat transfer coefficient is determined to be $h_m = 7.75$ W/(m^2°C). Using the Reynolds-Colburn analogy, estimate the drag force exerted on the plate per 1 m width. (8)

(ii) Write down the momentum equation and explain the various terms. (8)

Or

(b) (i) Atmospheric air at 300 K at a velocity of 1 m/s flows over a flat plate. Calculate the boundary-layer thickness $\delta(x)$ and the local drag coefficient c_x at $x = 0.75$ m from the leading edge of the plate. What is the drag force F acting on the plate over the length $x = 0$ to $x = 0.75$ m and width $w = 0.5$ m of the plate? (8)

(ii) A vertical plate $L = 5$ m high and $w = 1.5$ m wide has one of its surfaces insulated : the other surface, maintained at a uniform temperature $T_w = 400$ K, is exposed to quiescent atmospheric air at $T_\infty = 300$ K. Calculate the total rate of heat loss from the plate. (8)

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

(ii) Water at atmospheric pressure and saturation temperature is boiled in a 25 cm diameter, electrically heated, mechanically polished, stainless-steel pan. The heated surface of the pan is maintained at a uniform temperature T_ω = 116°C. Calculate the surface heat flux, the rate of evaporation from the pan and the peak heat flux. (8)

Or

(b) Air-free saturation steam at T_v = 65°C (P = 25.03 kPa) condenses on the outer surface of a 2.5 cm OD, 3 m long vertical tube maintained at a uniform temperature T_ω = 35°C by the flow of cooling water through the tube. Assuming film condensation, calculate the average heat transfer co-efficient over the entire length of the tube and the rate of condensate flow at the bottom of the tube. Also determine the average heat transfer coefficient h_m and the total condensation rate when the tube is horizontal. (16)

15. (a) (i) Consider two large vessels, each containing uniform mixtures of nitrogen and carbon dioxide at 1 atm, T = 288.9 K, but at different concentrations. Vessel 1 contains 90 mole percent N_2 and 10 mole percent CO_2, whereas vessel 2 contains 20 mole percent N_2 and 80 mole percent CO_2. The two vessels are connected by a duct of d = 0. 1524 m inside diameter and L = 1.22 m long. Determine the rate of transfer of nitrogen between the two vessels by assuming that steady-state transfer takes place in view of the large capacity of the two reservoirs. The mass diffusivity for the N_2—CO_2 mixture at 1 atm and 288.9 K can be taken as D = 0.16×10^{-4} m²/s. (8)

(ii) Discuss the analogy between heat and mass transfer. (8)

Or

(b) Atmospheric air at T_ω = 40°C flows over a wet-bulb thermometer. The reading of the thermometer, which is called the wet-bulb reading, is T_∞ = 20°C. Calculate the concentration. of water vapor c_ω in the free stream. Also determine the relative humidity of the air stream (i.e., the ratio of the concentration c_ω of water vapor free stream to the saturation concentration at the free-steam temperature T_∞ = 40°C obtained from the steam table). (16)

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