ME-502

HEAT TRANSFER

Time Allotted: 3 Hours | Full Marks: 70

The questions are of equal value.
The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.

GROUP A
(Multiple Choice Type Questions)

1. Answer all questions. 10×1 = 10

(i) The velocity profile for fully developed laminar flow in a tube is

(A) linear (B) exponential
(C) hyperbolic (D) parabolic

(ii) The two significance dimensionless parameter in transient heat conduction are

(A) Fourier and Reynolds numbers
(B) Biot and Fourier numbers
(C) Reynolds and Biot numbers
(D) Reynolds and Prandtl numbers

(iii) The thermal boundary layer thickness is thicker than the momentum boundary layer thickness when Prandtl number is

(A) 0 (B) less than 1
(C) equal to 1 (D) greater than 1

(iv) Which of the following non-dimensional numbers finds application in mass transfer problem

(A) Grashoff number (B) Stanton number
(C) Weber number

(v) Thermal conductivity of pure metal with rise in temperature

(A) decreases (B) increases
(C) remains same (D) none of these

(vi) The temperature of solid surface is raised from 227 °C to 727 °C. The emissive power of body will change from E1 to E2 to such that E1 / E2 is

(A) 400 (B) 16 (C) 4000 (D) 1600

(vii) With increase in fluid viscosity the boundary layer thickness will

(A) decrease
(B) increase
(C) not change
(D) first increase and then decrease

(viii) For opaque body sum of absorptivity and reflectivity is

(A) 0 (B) 1
(C) less than 1 (D) greater than 1

(ix) In a counter flow heat exchanger, the heat capacity for hot and cold fluid is equal. If NTU is equal to 0.5, then the effectiveness of heat exchanger is

(A) 0.2 (B) 0.5 (C) 0.33 (D) 1.0

(x) Heat dissipation from an infinitely long fin is given by

(A) $\sqrt{hPKA}\,(t_o - t_a)$ (B) $\sqrt{hPKA}\,(t_o - t_a)$ tanh ml

GROUP B
(Short Answer Type Questions)

Answer any *three* questions. 3×5 = 15

2. Derive one-dimensional heat conduction equation in Cartesian co-ordinates. 5

3. (a) Define efficiency and effectiveness of a fin and show expressions for these for an infinitely long fin. How effectiveness of a fin can be increased? 3

(b) What is thermal resistance of a fin? Write down expression for thermal resistance of an infinitely long fin. 2

4. A wall is made of plastered material of 25 cm thickness and followed by concrete of 5 cm thickness. Thermal conductivity of plastered material is 0.69 W/m.K and that of concrete is 0.93 W/m.K. The temperature of exposed plastered surface is 30 °C and that of concrete is 5 °C. Find out the heat loss through the wall of area 50 m^2. 5

5. Sketch the boundary layer development of a flow over a flat plate and explain the significance of the boundary layer. 5

6. What is the physical significance of the Biot number? Is the Biot number more likely to be larger for highly conducting solids or poorly conducting ones? 5

GROUP C
(Long Answer Type Questions)

Answer any *three* questions. 3×15 = 45

7. (a) A thermocouple is used to measure the temperature in the gas stream. The junction may be approximated as a sphere having k = 25 W/m.°C, ρ = 8400 kg/m^3 and C_p = 400 J/kg. °C. The heat transfer coefficient between the junction and the gas stream is 560 W/m^2K. Calculate the diameter of the junction if the thermocouple should measure 95 per cent of the applied temperature difference in 3 sec. 8

(b) For a hot solid cylinder of radius r_0 with uniform rate of heat generation q per unit volume, conducting heat radially and losing heat from its surface to the ambient (at temperature T_∞) by convection with heat transfer coefficient h, prove that 7

$$\frac{T_0 - T_r}{T_0 - T_\infty - (qr_0/2h)} = \left(\frac{r}{r_0}\right)^2,$$

where T_r = temperature of the cylinder at a distance r from its axis and T_0 = axis temperature

8. (a) A thin-walled double-pipe counter-flow heat exchanger is to be used to cool oil (C_p = 2200 J/kg.°C) from 150 °C to 40 °C at a rate of 2 kg/s by water (C_p = 4180 J/kg.°C) that enters at 22 °C at a rate of 1.5 kg/s. The diameter of the tube is 2.5 cm, and its length is 6 m. Determine the overall heat transfer coefficient of this heat exchanger. 7

(b) Consider a heat exchanger in which both fluids have the same specific heats but different mass flow rates. Which fluid will experience a larger temperature change: the one with the lower or higher mass flow rate? 5

(c) Discuss when heat exchanger analysis by effectiveness-NTU method is preferred over the LMTD method. 3

9. (a) Using a linear velocity profile $\frac{u}{u_\infty} = \frac{y}{\delta}$ for flow over flat plate obtain an expression for boundary layer thickness as a function of x. 7

(b) Air at 1 atm and 27 °C is forced through a horizontal 25 mm-diameter tube at an average velocity of 30 cm/s. The tube wall is maintained at a constant temperature of 140 °C. Calculate the heat transfer coefficient for this situation if the tube is 0.4 m long. 8

10. (a) Define emissivity of a body. State Kirchhoff's law. 5

(b) Consider two large parallel plates, one at T_1 = 800 K with emissivity ε_1 = 0.9 and the other at T_2 = 300 K with emissivity ε_2 = 0.5. A radiation shield is placed between the two plates. 10

(i) Calculate the heat transfer rate per unit area without using the radiation shield in between.

(ii) Calculate the emissivity of the radiation shield in order to reduce the radiative heat transfer to 10% of that without shield.

(iii) Calculate the temperature of radiation shield.

11. (a) State and prove the Kirchhoff's law of radiation. 7

(b) Two parallel, infinite grey surfaces are maintained at temperatures of 127 °C and 227 °C respectively. If the temperature of the hot surface is increased to 327 °C, by what factor is the net radiation exchange per unit area increased? Assume the emissivities of cooler and hotter surfaces to be 0.9 and 0.7 respectively. 8