Question Paper Code : C 1382

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2010.

Sixth Semester

Mechanical Engineering

ME 1351 — HEAT AND MASS TRANSFER

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

(Regulation 2004)

Time : Three hours   Maximum : 100 marks

Use of Heat and Mass transfer data book permitted.

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Why is the one-dimensional heat-flow assumption important in the analysis of fins?

2. Point out the various factors which affect the thermal conductivity of a material.

3. How boundary layer thickness is defined?

4. What is the difference between Nusselt number and Biot number?

5. Distinguish between mechanism of film wise condensation and drop wise condensation.

6. What advantage does the effectiveness-NTU method have over LMTD method?

7. What are radiation share factors and why are they used?

8. "Radiation from thick layers of polytropic gases approaches black body radiation within the wave length of its bands". Comment upon the validity of this statement.

9. Why cannot atmospheric evaporation rates be calculated with ordinary molecular diffusion equations?

10. State Fick's law of diffusion. Define the various symbols used and given their units.

99

PART B — ($5 \times 16 = 80$ marks)

11\. (a) (i) Write the Fourier rate equation for heat transfer by conduction. Give the physical significance of each form. (10)

(ii) Determine the steady heat transfer per unit area through a 3.8 cm thick homogenous slab with its two faces maintained at uniform temperatures of 35°C and 25°C. The thermal conductivity of wall material is 1.9×10^{-4} kW/m°C. (6)

Or

(b) (i) An internally cooled copper conductor of 2 cm outer radius and 0.75 cm inner radius carries a current density of 5000 amp/cm^2. A constant temperature of 70°C is maintained at the inner surface and there is no heat transfer through insulation surrounding the copper. Set up an equation for temperature distribution through copper. Proceed to calculate the maximum temperature of copper and the radius at which it occurs. Also find the internal heat transfer rate and check that this equals the total energy generation in the conductor.

For copper : thermal conductivity (k) = 380 W/m°C and the resistivity $\rho = 2 \times 10^{-5}\ \Omega$ cm (10)

(ii) A very long copper rod 20 mm in diameter extends horizontally from a plane heated wall maintained at 100°C. The surface of the rod is exposed to an air environment at 20°C with convective heat transfer coefficient of 8.5 W/m^2°C. Workout the heat loss if the thermal conductivity of copper is 400 W/m°C. Further estimate how long the rod be in order to be considered infinite. (6)

12\. (a) (i) Air at 27°C and 1 atm flows over a flat plate at a speed of 2 m/s. Calculate the boundary layer thickness at distances of 20 and 40 cm from the leading edge of the plate. Calculate the mass flow that enters the boundary layer between x = 20 cm and x = 40 cm. The viscosity of air at 27°C is 1.85×10^{-5} kg/m.s Assume unit depth in the z direction. (10)

(ii) Air at 1 atm and 35°C flows across a 5 cm diameter cylinder at a velocity of 50 m/s. The cylinder surface is maintained at a temperature of 150°C. Calculate the heat loss per unit length of the cylinder. (6)

Or

(b) A flat plate 70 cm long and 1.0 m wide is placed in a wind tunnel where the flow conditions are $M = 3$, $\rho = 1/20$ atm and $T = -40$°C. How much cooling must be used to maintain the plate temperature at 35°C? (16)

13. (a) (i) Water at 1 atm boils in a stainless-steel kitchen pan with $\Delta T_X = 8°C$. Estimate the heat flux which will be obtained. If the same pan operates as a pressure cooker at 0.17 MPa, what percent increase in heat flux might be expected? (8)

(ii) Hot oil at 100°C is used to heat air in a shell-and-tube heat exchanger. The oil makes six tube passes and the air makes one shell pass; 2.0 kg/s of air are to be heated from 20 to 80°C. The specific heat of the oil is 2100 J/kg°C and its flow rate is 3.0 kg/s. Calculate the area required for the heat exchanger for $U = 200\ W/m^2\,°C$. (8)

Or

(b) Hot water at 98°C flows through a 2-in schedule 40 horizontal steel pipe (k = 54 W/m°C) and is exposed to atmospheric air at 20°C. The water velocity is 25 cm/s. Calculate the overall heat transfer coefficient for this situation, based on the outer area of pipe. (16)

14. (a) (i) Calculate the radiation equilibrium temperature for a plate exposed to a solar flux of $700\ W/m^2$ and a surrounding temperature of 25°C if the surface is coated with

(1) white paint or

(2) flat black lacquer.

Neglect convection. (8)

(ii) Consider a thin hollow cylinder of 8 cm diameter and 10 cm length. If the radiant shape factor of the circular surface of this cylinder is 0.172, make calculations for the shape factor of the curved surface of the cylinder with respect to itself. (8)

Or

(b) The sun may be regarded as a black body with a surface temperature of 5600 K at a mean distance of 15×10^{10} m from the earth. The diameter of the sun is 1.4×10^9 m and that of the earth is 12.8×10^6 m. Make calculations for

(i) the total energy radiated by the sun,

(ii) the energy received per m^2 just outside the earth's atmosphere,

(iii) the total energy the earth would receive if no energy were blocked by the earth's atmosphere, and

(iv) the energy received by a 1.25×1.25 m solar collector whose perpendicular is inclined at 35°C to the sun. The energy loss through the atmosphere is 35% and the diffuse radiation is 15% of direct radiation. (16)

101

15. (a) (i) Air at 30°C temperature flows at 45 m/s past a wet flat plate 0.5 m long. Make calculations for the mass transfer coefficient of water vapour in air. Assume that the water vapour content of air initially is negligible and take the following thermo-physical properties of air :

$$D = 0.256 \times 10^{-4}\ m^2/s;\ \mu = 1.86 \times 10^{-5}\ kg/m-s;\ C_p = 1.005\ kJ/kg°C;$$

$$P_r = 0.701 \text{ and } \rho = 1.165\ kg/m^3.$$ (10)

(ii) Write out the momentum, energy and concentration equations and bring out their similarities. (6)

Or

(b) Rain left a thin film of water on a tile of the roof of a house in an Indian village. Wind blows over the tile along its 10 cm exposed length. The atmospheric air and the tile surface are both at 25°C. The relative humidity of the air is 40%. Wind speed = 10 Km/h, binary diffusivity = $2.88 \times 10^{-5}\ m^2/s$, $S_c = 0.6$.

(i) Calculate the average mass transfer coefficient between the tile surface and the air

(ii) What is the mass transfer rate (per unit width of the tile) at which water leaves the tile surface? (16)

———————