**Question Paper Code : 10411**

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2012.

Fourth Semester

Mechanical Engineering

ME 2251/113401/ME 41/ME 1251/10122 ME 502/080120015 —
HEAT AND MASS TRANSFER

(Regulation 2008)

(Common to PTME 2251 – Heat and Mass Transfer for Sixth Semester
B.E. (Part-Time) Mechanical Engineering –
Regulation 2009)

Time : Three hours Maximum : 100 marks

Use of HMT databook – permitted.

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Write the three dimensional heat transfer Poisson and Laplace equations in Cartesian co-ordinates.

2. A 3 mm wire of thermal conductivity 19 W/mK at a steady heat generation of 500 MW/m$^3$. Determine the centre temperature if the outside temperature is maintained at 25°C.

3. What are the dimensionless parameters used in forced and free convection heat transfer analysis?

4. Define the term ' Boundary Layer' (Thermal).

5. What is the difference between boiling and condensation?

6. What is meant by compact heat exchanger?

7. Name the laws of variation used in heat transfer analysis.

8. Two parallel radiating planes 100 × 50 cm are separated by a distance of 50 cm. What is the radiation shape factor between the planes?

9. State the Fick's law of diffusion.

10. Define 'Sherwood Number'.

PART B — (5 × 16 = 80 marks)

11. (a) A furnace wall is made up of three layers of thicknesses 25 cm, 10 cm and 15 cm with thermal conductivities of 1.65, k and 9.2 W/mK respectively. The inside is exposed to gases at 1250°C with a convection coefficient of 25 W/m²°C and the inside surface is at 1100°C, the outside surface is exposed to air at 25°C with convection coefficient of 12 W/m²K. Determine (i) The unknown thermal conductivity (ii) The overall heat transfer coefficient (iii) All the surface temperatures. (16)

Or

(b) (i) Pin fins are provided to increase the heat transfer rate from a hot surface. Which of the following arrangement will give higher heat transfer rate?

(1) 6-fins of 10 cm length (2) 12-fins of 5 cm length.

Take K of fin material = 200 W/mK and h = 20 W/m²°C cross-sectional area of the fin = 2 cm²; Perimeter of fin = 4 cm; Fin base temperature = 230°C; Surrounding air temperature = 30°C. (8)

(ii) A steel ball 50 mm in diameter and at 900°C is placed in still air of 30°C. Calculate the initial rate of cooling of ball in °C/min. Take $\rho$ = 7800 kg/m³; C = 2 kJ/kg°C; h = 30 W/m²°C. Neglect the internal resistance of the ball. (8)

12. (a) Caster oil at 25°C flows at a velocity of 0.1 m/s part a flat plate, in a certain process. If the plate is 4.5 m long and is maintained at a uniform temperature of 95°C, calculate the following :

(i) The hydrodynamic and thermal boundary layer thicknesses on one side of the plate

(ii) The total drag force per unit width on one side of the plate

(iii) The local heat transfer coefficient at the trailing edge and

(iv) The heat transfer rate; properties of oil at 60°C are $\rho$ = 956.8 kg/m³; $_{\infty}$ = 7.2 × 10⁻⁸ m²/s; k = 0.213 W/mK; $\nu$ = 0.65 × 10⁻⁴ m²/s. (16)

Or

(b) (i) Find the convective heat loss from a radiator 0.6 m wide and 1.2 m high maintained at a temperature of 90°C in a room at 14°C. Consider the radiator as a vertical plate. (8)

(ii) Calculate the heat transfer from a 60 W incandescent bulb at 115°C to ambient air at 25°C. Assume the bulb as a sphere of 50 mm diameter. Also find the % of power lost by free convection. (8)

13. (a) Water at atmospheric pressure is to be boiled in polished copper pan. The diameter of the pan is 350 mm and is kept at 115°C. Calculate the following :

(i) Power of the burner

(ii) Rate of evaporation in kg/hr;

(iii) Critical heat flux. (16)

Or

(b) Calculate for the following cases, the surface area required for a heat exchanger which is required to cool 3200 kg/hr of benzene ($C_p$ = 1.74 kJ/kgK) from 72°C to 42°C. The cooling water ($C_p$ = 4.18 kJ/kg°C) at 15°C has a flow rate of 2200 kg/hr.

(i) Single pass counter-flow

(ii) 1 – 4 exchanger (one-shell pass and four-tube passes) and

(iii) Cross flow single pass with water mixed and benzene unmixed. Assume all the cases $U$ = 0.28 kW/m²K. (16)

14. (a) (i) Derive Wien's displacement law of radiation from Planck's law. (8)

(ii) Calculate the following for an industrial furnace in the form of a black body and emitting radiation at 2500°C :

(1) Monochromatic emissive power at 1.2 μm length

(2) Wavelength at which the emissive in maximum

(3) Maximum emissive power

(4) Total emissive power. (8)

Or

(b) Two parallel plates of size 1.0 m × 1.0 spaced 0.5 m apart are located in very large room, the walls are maintained at a temperature of 27°C. One plate is maintained at a temperature of 900°C and the other at 400°C. Their emissivities are 0.2 and 0.5 respectively. If the plates exchange heat between themselves and surroundings, find the heat transfer to each plate and to the them. Consider only the plate surfaces facing each other. (16)

15. (a) Air at 20°C ($\rho$ = 1.205 kg/m$^3$; $\nu$ = 15. 06 × 10$^{-6}$ m$^2$/s; D = 4.166 × 10$^{-5}$ m$^2$/s) flows over a tray (length = 32 cm, width = 42 cm) full of water with a velocity of 2.8 m/s. The total pressure of moving air is 1 atm and the partial pressure of water present in the air is 0.0068 bar. If the temperature on the water surface is 15°C, Calculate the evaporation rate of water. (16)

Or

(b) $CO_2$ and air experience equimolar counter diffusion in a circular tube whose length and diameter are 1 m and 50 mm respectively. The system of total pressure of 1 atm and a temperature of 25°C. The ends of the tube are connected to large chambers in which the species concentrations are maintained at fixed values. The partial pressure of $CO_2$ at one end is 190 mm of Hg while at the other end is 95 mm Hg. Estimate the mass transfer rate of $CO_2$ and air through the tube. (16)