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B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2013.

Fourth Semester

Mechanical Engineering

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

(Regulation 2008/2010)

(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 Heat and Mass Transfer Tables Permitted

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define Fourier's law of conduction.

2. A Plane wall 10 cm thick generates heat at the rate of 4×10^4 W/m^3 when an electric current is passed through it. The convective heat transfer coefficient between each face of the wall and ambient air is 50 W/m^{2}K. Determine the surface temperature. Assume the air temperature to be 20°C and k (for wall) = 15 W/mK.

3. Define the term thermal boundary layer.

4. Why heat transfer coefficient for natural convection is much lesser than that for forced convection?

5. Distinguish the pool boiling from forced convection boiling.

6. What are limitation of LMTD method? How is ε-NTU method superior to LMTD method?

7. State Planck's law.

8. How radiation from gases differs from solids?

9. Write general mass diffusion equation.

10. Define Schmidt and Lewis numbers. What is the physical significance of each?

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PART B — ($5 \times 16 = 80$ marks)

11. (a) The door of an industrial furnace is 2 m × 4 m in surface area and is to be insulated to reduce the heat loss to not more than 1200 W/m^2. The interior and exterior walls of the door are 10 mm and 7 mm thick steel sheets (k = 25 W/m K). Between these two sheets, a suitable thickness of insulation material is to be placed. The effective gas temperature inside the furnace is 1200°C and the overall heat transfer coefficient between the gas and door is 20 W/m^{2}K. The heat transfer coefficient outside the door is 5W/m^2°C. The surrounding air temperature is 20°C. Select suitable insulation material and its size.

Or

(b) (i) A turbine blade 6 cm long and having a cross-sectional area 4.65 cm^2 and perimeter 12 cm is made of stainless steel (k = 23.3 W/m.K). The temperature at the root is 500°C. The blade is exposed to a hot gas at 870°C. The heat transfer coefficient between the blade surface and gas is 442 W/m^{2}K. Determine the temperature distribution and rate of heat flow at the root of the blade. Assume the tip of the blade to be insulated. (8)

(ii) An ordinary egg can be approximated as a 5-cm-diameter sphere. The egg is initially at a uniform temperature of 5°C and is dropped into boiling water at 95°C. Taking the convection heat transfer coefficient to be h = 1200 W/m^2 °C, determine how long it will take for the center of the egg to reach 70°C. (8)

12. (a) (i) Explain in detail about boundary layer concept. (6)

(ii) An aeroplane flies with a speed of 450 km/h at a height where the surrounding air has a temperature of 1°C and pressure of 65 cm of Hg. The aeroplane wing idealised as a flat plate 6 m long, 1.2 m wide is maintained at 19°C. If the flow is made parallel to the 1.2 m width calculate : (1) Heat loss from the wing ; (2) Drag force on the wing. (10)

Or

(b) A two stroke motor cycle petrol engine cylinder consists of 15 annular fins. If outside and inside diameters of each tin are 200 mm and 100 mm, respectively. The average fin surface temperature is 475°C and they are exposed in air at 25°C. Calculate the heat transfer rate from the fins for the following condition (i) When motor cycle is at rest. (ii) when motor cycle is running at a speed of 60 km/h. The fin may be idealized as a single horizontal flat plate of same area.

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13. (a) (i) Explain the various regions of flow boiling in detail. (6)

(ii) The outer surface of a vertical tube, which is 1 m long and has an outer diameter of 80 mm, is exposed to saturated steam at atmospheric pressure and is maintained at 50°C by the flow of cool water through the tube. What is the rate of heat transfer to coolant and what is the rate at which steam is condensed at the surface? (10)

Or

(b) A counter-flow concentric tube heat exchanger is used to cool the lubricating oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube (d_i = 20 mm) is 0.18 kg/s while the flow rate of oil through the outer annulus (d_o = 40 mm) is 0.12 kg/s. The inlet and outlet temperatures of oil are 95°C and 65°C respectively. The water enters at 30°C to the exchanger. Neglecting tube wall thermal resistance, fouling factors and heat loss to the surroundings, calculate the length of the tube. Take the following properties at the bulk mean temperature:

Engine oil at 80°C ; C_p = 2131 J/kg°C ; μ = 0.0325 N-s/m^2 ; k = 0.138 W/m°C ;
Water at 35°C : C_p = 4174 J/kg°C, $\mu = 725 \times 10^{-6}$ N-s/m^2 ; k = 0.625 W/m°C, Pr = 4.85.

14. (a) (i) A truncated cone has top and bottom diameters of 10 and 20 cm and a height of 10 cm. Calculate the shape factor between the top surface and the side and also the shape factor between the side and itself. (10)

(ii) Emissivities of two large parallel plates maintained at 800°C and 300°C and 0.3 and 0.5 respectively. Find the net radiant heat exchange per square meter for these plates. (6)

Or

(b) A 12 mm outside diameter pipe carries a cryogenic fluid at 90 K. Another pipe of 15 mm outside diameter and at 290 K surrounds it coaxially and the space between the pipes is completely evacuated (i) determine the radiant heat flow for 3.5 m length of pipe if the surface emissivity for both surface is 0.25 (ii) calculate the percentage reduction in heat flow if a shield of 13.5 mm diameter and 0.06 surface emissivity is placed between pipes.

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15. (a) Air is contained in a tyre tube of surface area 0.5 m^2 and wall thickness 10 mm. The pressure of air drops from 2.2 bar and 2.18 bar in a period of 6 days. The Solubility of air in the rubber is 0.072 m^3 of air per m^3 of rubber at 1 bar. Determine the diffusivity of air in rubber at the operating temperature of 300 K if the volume of air in the tube is 0.028 m^3.

Or

(b) Air at 35°C and 1 atmosphere flows at a velocity of 60 m/s over (i) a flat plate 0.5 m long (ii) a sphere 5 cm in diameter. Calculate the mass transfer coefficient of water in air. Neglect the concentration of vapour in air.

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