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Sixth Semester B.E. Degree Examination, Dec.2017/Jan.2018

### Heat and Mass Transfer

Time: 3 hrs.

Max. Marks:100

- Note:** 1. Answer any FIVE full questions, selecting at least TWO questions from each part.  
2. Use of heat and mass transfer data book is permitted.

#### PART - A

- 1
  - a. Define Thermal Diffusivity. (04 Marks)
  - b. The inside temperature of a furnace wall with  $k = 1.35 \text{ N/m.K}$ , 200 mm thick is  $1400^\circ\text{C}$ . The heat transfer coefficient at the outside surface is a function of temperature difference and is given by  $(h = 7.85 + 0.08\Delta T) \text{ W/m}^2\text{.K}$ . where  $\Delta T$  is the temperature difference between outside wall surface and surroundings. Determine the rate of heat transfer per unit area, if the surrounding temperature is  $40^\circ\text{C}$ . (08 Marks)
  - c. The temperature distribution across a wall, 1 m thick at a certain instant of time is given as  $T(x) = 900 - 300x - 50x^2$ , where  $T$  is in degree Celsius and  $x$  in metre. The uniform heat generation of  $1000 \text{ W/m}^3$  is present in wall of area  $10 \text{ m}^2$  having the properties  $\rho = 1600 \text{ kg/m}^3$ ,  $k = 40 \text{ W/m.K}$  and  $C = 4 \text{ kJ/kg.K}$ . Determine
    - (i) The rate of heat transfer entering the wall at  $x = 0$  and leaving the wall at  $x = 1 \text{ m}$ .
    - (ii) The rate of change of internal energy of the wall
    - (iii) The time rate of temperature change at  $x = 0, 0.5 \text{ m}$ . (08 Marks)
- 2
  - a. Define fin effectiveness. When the use of fins is not justified? (03 Marks)
  - b. A plane wall  $k = 45 \text{ W/m.K}$  10 cm thick, generated at a uniform rate of  $8 \times 10^6 \text{ W/m}^3$ . The two sides of the wall are maintained at  $180^\circ\text{C}$  and  $120^\circ\text{C}$ . Neglect end effects, calculate
    - (i) Temperature distribution across the plate.
    - (ii) Position and magnitude of maximum temperature.
    - (iii) The heat flow rate from each surface of the plate. (09 Marks)
  - c. A very long rod, 25 mm in diameter, has one end maintained at  $100^\circ\text{C}$ . The surface of the rod is exposed to ambient air at  $25^\circ\text{C}$  with convection coefficient of  $10 \text{ W/m}^2\text{.K}$ . What are the heat losses from the rods, constructed of pure copper with  $K = 398 \text{ W/m.K}$  and stainless steel with  $K = 14 \text{ W/m.K}$ ? Also, estimate how long the rods must be to be considered infinite. (08 Marks)
- 3
  - a. Define Biot number and Fourier number. (03 Marks)
  - b. An aluminium wire, 1 mm in diameter at  $200^\circ\text{C}$  is suddenly exposed to an environment at  $30^\circ\text{C}$  with  $h = 85.5 \text{ W/m}^2\text{.K}$ . Estimate the time required to cool the wire to  $90^\circ\text{C}$ . If the same wire to place in air stream ( $h = 11.65 \text{ W/m}^2\text{.K}$ ), what would be time required to reach it to  $90^\circ\text{C}$ . Assume thermophysical properties  $C = 900 \text{ J/kg.K}$ ,  $\rho = 2700 \text{ kg/m}^3$ ,  $k = 204 \text{ W/m.K}$ . (09 Marks)
  - c. A long cylindrical shaft 20 cm in diameter is made of steel  $k = 14.9 \text{ W/m.k}$ ,  $\rho = 7900 \text{ kg/m}^3$ ,  $C = 477 \text{ J/kg.K}$  and  $\alpha = 3.95 \times 10^{-6} \text{ m}^2/\text{s}$ . It comes out an oven at a uniform temperature of  $600^\circ\text{C}$ . The shaft is then allowed to cool slowly in an environment at  $200^\circ\text{C}$  with an average heat transfer coefficient of  $80 \text{ W/m}^2\text{.K}$ . Calculate the temperature at the centre of the shaft, 45 min after the start of cooling process. Also calculate the heat transferred per unit length of the shaft during this period. (08 Marks)
- 4
  - a. Explain velocity and thermal boundary layer. (04 Marks)
  - b. A fan provides air speed upto  $50 \text{ m/s}$  is used in low speed wind tunnel with atmospheric air at  $27^\circ\text{C}$ . If this wind tunnel is used to study the boundary layer behavior over a flat plate upto  $Re_c = 10^8$ . What should be the minimum plate length? At what distance from the leading edge would transition occur, if critical Reynolds number  $Re_{cr} = 5 \times 10^5$ ? (08 Marks)



c. Calculate the approximate Reynolds numbers and state if the flow is laminar or turbulent for the following:

(i) A 10 m long yacht sailing at 13 km/h in sea water,  $\rho = 1000 \text{ kg/m}^3$  and  $\mu = 1.3 \times 10^{-3} \text{ kg/m.S}$ .

(ii) A compressor disc of radius 0.3 m rotating at 15000 rpm in air at 5 bar and  $400^\circ\text{C}$

$$\text{and } \mu = \frac{1.46 \times 10^{-6} T^{\frac{3}{2}}}{(110 + T)} \text{ kg/m.S}$$

(08 Marks)

**PART – B**

- 5 a. Define Grashof number and Stanton number. (04 Marks)
- b. Air at  $27^\circ\text{C}$  and 1 atmosphere pressure flows over a heated plate with a velocity of 2 m/s. The plate is at uniform temperature of  $60^\circ\text{C}$ . Calculate the heat transfer rate from first 0.2 m of the plate. (08 Marks)
- c. Air at velocity of 3 m/s and at  $20^\circ\text{C}$  flows over a flat plate along its length. The length, width and thickness of the plate are 100 cm, 50 cm and 2 cm respectively. The top surface of the plate is maintained at  $100^\circ\text{C}$ . Calculate the heat lost by the plate and temperature of bottom surface of the plate for the steady state conditions. The thermal conductivity of the plate may taken as 23 W/mK. (08 Marks)
- 6 a. Classify heat exchange in three broad classes. (04 Marks)
- b. Hot engine oil is to be cooled in a double pipe counter flow heat exchanger. The copper tube has a diameter of 2 cm with negligible thickness. The inner diameter of outer tube is 3 cm. The water flow through the inner tube at a rate of 0.5 kg/s and oil flows through the annular space at a rate of 0.8 kg/s. Taking the average temperature of water and oil as  $47^\circ\text{C}$  and  $80^\circ\text{C}$  respectively. Assume fully developed flow, calculate overall heat transfer coefficient of flow conditions of the heat exchanger. (12 Marks)
- c. Calculate the overall heat transfer coefficient based on outer surface of a steel pipe  $K = 54 \text{ W/mK}$  with inner and outer diameters as 25 mm and 35 mm respectively. The inside and outside heat transfer coefficients are  $1200 \text{ W/m}^2\text{K}$  and  $2000 \text{ W/m}^2\text{K}$  respectively. (04 Marks)
- 7 a. Discuss modes of condensation. (04 Marks)
- b. Saturated steam at  $90^\circ\text{C}$  and 70 kPa is condensed on outer surface of a 1.5 m long, 2.5 m diameter vertical tube maintained at uniform temperature of  $70^\circ\text{C}$ . Assuming film wise condensation, calculate the heat transfer rate on the tube surface. (08 Marks)
- c. A tube 13 mm in outer diameter and 1.5 m long is used to condense the steam at 40 kPa ( $T_{\text{sat}} = 76^\circ\text{C}$ ). Calculate the heat transfer coefficient for this tube in: (a) horizontal position (b) vertical position. Take average tube wall temperature as  $52^\circ\text{C}$ . (08 Marks)
- 8 a. State and explain Kirchoff's law of radiation. (02 Marks)
- b. A pipe carrying steam runs in a large room and exposed to air at  $30^\circ\text{C}$ . The pipe surface temperature is  $200^\circ\text{C}$ . Diameter of the pipe is 20 cm. If the total heat loss per metre length of the pipe is 1.9193 kW/m, determine the emissivity to the pipe surface. (08 Marks)
- c. In an isothermal enclosure at uniform temperature two small surfaces A and B are placed. The irradiation to the surface by the enclosure is  $6200 \text{ W/m}^2$ . The absorption rates by the surfaces A and B are  $5500 \text{ W/m}^2$  and  $620 \text{ W/m}^2$ . When steady state is established, calculate the following:
- What are the heat fluxes to each surface? What are their temperatures?
  - Absorptivity of both surfaces.
  - Emissive power of each surface
  - Emissivity of each surface.

(10 Marks)

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