

CBCS SCHEME

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Sixth Semester B.E. Degree Examination, June/July 2023 Heat and Mass Transfer

Time: 3 hrs.

Max. Marks: 100

**Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Use of HMT data handbook is permitted.**

Module-1

- 1 a. Derive the three dimensional heat conduction equation in Cartesian coordinates. (10 Marks)
b. A reactor's wall of 320 mm thick is made up of an inner layer of fire brick ($k = 0.84 \text{ W/m}^\circ\text{C}$) covered with a layer of insulation ($k = 0.16 \text{ W/m}^\circ\text{C}$). The reactor operates at a temperature of 1325°C and the ambient temperature is 25°C .
(i) Determine the thickness of firebrick and insulation.
(ii) Calculate the heat loss assuming the insulating material has a maximum temperature of 1200°C . (10 Marks)

OR

- 2 a. Derive the temperature distribution and heat conduction equation for Hollow sphere. (10 Marks)
b. A standard cast iron pipe (ID = 50 mm and OD = 55 mm) is insulated with 85% magnesium insulation ($K = 0.02 \text{ W/m}^\circ\text{C}$). Temperature at the interface between pipe and insulation is 300°C . The allowable heat loss through the pipe is 600 W/m . The temperature of outside surface of insulation must not exceed 100°C for safety. Determine :
(i) Minimum thickness of insulation
(ii) Temperature of inside surface of pipe assuming its conductivity as $20 \text{ W/m}^2\text{C}$. (10 Marks)

Module-2

- 3 a. Obtain an expression for temperature distribution and heat flow through a fin of uniform cross section with insulated end. (10 Marks)
b. A rod ($K = 200 \text{ W/mK}$) 10 mm in diameter and 5 cm long has its one end maintained at 100°C . The surface of the rod is exposed to ambient air at 30°C with convective heat transfer coefficient of $100 \text{ W/m}^2\text{K}$. Assuming other end insulated, determine:
(i) The temperature of the rod at 25 mm distance from the end at 100°C
(ii) Heat dissipation rate
(iii) Efficiency of fin (10 Marks)

OR

- 4 a. Derive an expression for instantaneous heat transfer and total heat transfer using lumped heat analysis for unsteady state heat transfer from a body to surroundings. (10 Marks)
b. A $50 \text{ cm} \times 50 \text{ cm}$ copper slab 6.25 mm thick has a uniform temperature of 300°C . Its temperature is suddenly lowered to 36°C . Calculate the time required for the plate to reach the temperature of 108°C . Take $\rho = 9000 \text{ kg/m}^3$, $C = 0.38 \text{ kJ/kg}^\circ\text{C}$, $K = 370 \text{ W/m}^\circ\text{C}$ and $h = 90 \text{ W/m}^2\text{C}$. (10 Marks)

Module-3

- 5 a. Explain the significance of :
 (i) Reynolds number (ii) Prandtl number (iii) Grashoff number
 (iv) Stanton number (v) Nusselt number (10 Marks)
- b. Air at atmosphere pressure of 40°C flows with a velocity of $V = 5 \text{ m/s}$ over a 2m long flat plate whose surface is kept at a uniform temperature of 120°C . Determine the average heat transfer coefficient over the 2 m length of the plate (Air at 1 atm and 80°C , $\nu = 2.107 \times 10^{-5} \text{ m}^2/\text{s}$, $K = 0.03025 \text{ W/mK}$, $\text{Pr} = 0.6965$). (10 Marks)

OR

- 6 a. Explain the following briefly with sketches:
 (i) Boundary layer thickness
 (ii) Thermal boundary layer thickness (10 Marks)
- b. Using dimensional analysis show that for free convection heat transfer $\text{Nu} = C \text{Gr}^m \text{Pr}^n$ with usual notations. (10 Marks)

Module-4

- 7 a. Derive the expression for LMTD of a parallel flow heat exchanger. (10 Marks)
- b. A counter flow heat exchanger is employed to cool 0.55 kg/s ($C_p = 2.45 \text{ kJ/kg}^\circ\text{C}$) of oil from 115°C to 40°C by the use of water. The inlet and outlet temperatures of cooling water are 15°C and 75°C respectively. The overall heat transfer coefficient is expected to be $1450 \text{ W/m}^2^\circ\text{C}$ using NTU method. Calculate the following:
 (i) The mass flow rate of water
 (ii) Effectiveness of heat exchanger
 (iii) Surface area required (10 Marks)

OR

- 8 a. With a neat sketch, explain the different regimes of pool boiling. (10 Marks)
- b. A vertical plate 350 mm high and 420 mm wide at 40°C is exposed to saturated steam at 1 atm. Calculate the following:
 (i) Film thickness at the bottom of the plate
 (ii) Average heat transfer coefficient
 (iii) Total heat transfer (10 Marks)

Module-5

- 9 a. Explain: (i) Stefan-Boltzman law (ii) Wein's displacement law (iii) Radiation shield
 (iv) Radiosity (v) Black body (10 Marks)
- b. Two large parallel plates having emissivity of 0.8 and 0.4 maintained at a temperature of 727°C and 227°C . A radiation shield having an emissivity of 0.05 on both sides is placed between the two plates. Calculate the percentage reduction in heat transfer rate due to shield. (10 Marks)

OR

- 10 a. Prove that total emissive power of a diffuse surface is equal to π times the intensity of radiation. (10 Marks)
- b. Two concentric spheres 210 mm and 300 mm in diameter are used to store liquid air (-153°C) in a room at 27°C . The space between the spheres is evacuated and surfaces of the spheres are highly polished as $\epsilon = 0.03$. Find the rate of evaporation of liquid air per hour. (10 Marks)

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