**Registration No.:** | | | | | | | | | | |

**Total Number of Pages: 02**

**Course: B.Tech/IDD**
**Sub_Code: RME5C003**

**5th Semester Back Examination: 2025-26**
**SUBJECT: Heat Transfer**
**BRANCH(S): MECH, ME**
**Time: 3 Hours**
**Max Marks: 100**
**Q.Code: U208**
**Answer Q1 (Part-I) which is compulsory, any eight from Part-II and any two from Part-III.**
**The figures in the right-hand margin indicate marks.**



## Part-I

**Q1 Answer the following questions:** **(2 x 10)**

- **a)** State Fourier's law of heat conduction.
- **b)** Define fin efficiency and fin effectiveness.
- **c)** Define lumped system analysis. What is its main condition of applicability?
- **d)** Differentiate between forced convection and natural convection with suitable examples.
- **e)** Define Grashof number and state its significance.
- **f)** What is the difference between local and average heat-transfer coefficients?
- **g)** Differentiate between hydrodynamic and thermal boundary layers.
- **h)** Define absorptivity, reflectivity, and transmissivity.
- **i)** Differentiate between emissive power and emissivity.
- **j)** Define overall heat-transfer coefficient.

## Part-II

**Q2 Only Focused-Short Answer Type Questions- (Answer Any Eight out of Twelve)** **(6 x 8)**

- **a)** Derive the general heat conduction equation in Cartesian coordinates and mention physical significance of each term.
- **b)** Explain the concept of critical thickness of insulation and derive the expression for a cylinder.
- **c)** Derive the governing equation of a straight fin of uniform cross-section and obtain the solution for a fin of infinite length.
- **d)** Derive the lumped heat capacity model and solve the temperature-time relationship for transient conduction.
- **e)** Discuss the physical significance of Reynolds, Prandtl, Nusselt, Stanton numbers.
- **f)** Explain the development of velocity profile inside a circular tube. Distinguish between hydrodynamically developing and developed regions.
- **g)** Describe the boundary layer separation phenomenon and its influence on convective heat transfer.
- **h)** Derive Wien's displacement law and explain its physical meaning.
- **i)** Explain the concept of a radiation shape factor. Discuss its role for (I) two parallel plates, and (II) a small surface facing a large surface.

**j)** Discuss the various regimes of pool boiling with the help of a pool boiling curve.

**k)** Describe heat transfer characteristics during film boiling on a heated surface.

**l)** Explain NTU-effectiveness method for parallel and counter-flow heat exchangers.

## Part-III

**Only Long Answer Type Questions (Answer Any Two out of Four)**

**Q3 a)** A steel pipe with 50 mm OD is covered with 6.4mm asbestos insulation (K = 0.166 w/m k) followed by a 25 mm layer of fibre glass insulation (K = 0.0485 w/m k). The pipe wall temperature is 393 k, and the outside insulation temp is 311 k. Calculate the interface temperature between the asbestos and fibre glass. **(8)**

**b)** The temperature of a gas stream is to be measured by a thermocouple whose junction can be approximated as a 1 mm diameter sphere. The properties of the junction are K = 35 w/m k, $\rho$ = 8500 kg/m$^3$ and $C_p$ = 320 J/kg k. The convective heat transfer coefficient between the junction and the gas is h = 210 w/m$^2$ k. Determine how long it will take for the thermocouple to read 99 % of the initial temperature difference. **(8)**

**Q4 a)** Air at 25°C flows over a flat plate at 3 m/s. Plate temperature is 75°C. Plate length = 1 m. Properties at mean film temperature: $\nu = 1.7 \times 10^{-5}$ m$^2$/s, k = 0.028 W/m·K, Pr = 0.71. Compute: (i) Local heat transfer coefficient at x = 0.5 m (ii) Average heat transfer coefficient over the entire plate. **(8)**

**b)** Explain the development of hydrodynamic and thermal boundary layers over a flat plate. Show the velocity and temperature profiles. **(8)**

**Q5 a)** Discuss the use of radiation shields. Derive how adding 'n' shields reduces radiation heat transfer. **(8)**

**b)** Explain three-body radiation exchange using electrical network analogy. **(8)**

**Q6 a)** Water is to be boiled at atmospheric pressure in a mechanically polished stain less steel pan placed on top of a heating unit. The inner surface of the bottom of the pan is maintained at 108°C. If the diameter of the bottom of the pan is 30 cm, determine (a) the rate of heat transfer to the water and (b) the rate of evaporation of water. The properties of water at the saturation temperature of 100 °C are: $\sigma$ (surface tension) = 0.0589 N/m, $\rho_l$ = 957.9 kg/m$^3$, $h_{fg} = 2257 \times 10^3$ J/kg, $\rho_v$ = 0.6 kg/m$^3$, $\mu_l = 0.282 \times 10^{-3}$ kg/m·s, $Pr_l$ = 1.75, $Cp_l$ = 4217 J/kg·K. For the boiling of water on a mechanically polished stainless-steel surface, consider $C_{sf}$ = 0.0130 and n = 1. **(8)**

**b)** Hot oil is to be cooled in a double-tube counter-flow heat exchanger. The copper inner tubes have a diameter of 2 cm and negligible thickness. The inner diameter of the outer tube (the shell) is 3 cm. Water flows through the tube at a rate of 0.5 kg/s, and the oil through the shell at a rate of 0.8 kg/s. Taking the average temperatures of the water and the oil to be 45 $^0$C and 80 $^0$C, respectively, determine the overall heat transfer coefficient of this heat exchanger. The properties of water at 45 $^0$C are: $\rho$ = 990.1 kg/m$^3$, k = 0.637 W/m.K , Pr = 3.91, $\nu$ (kinematic viscosity) = $0.602 \times 10^{-6}$ m$^2$/s. And, the properties of water at 80 $^0$C are: $\rho$ = 852 kg/m$^3$, k = 0.138 W/m.K, Pr = 499.3, $\nu$ (kinematic viscosity) = $3.794 \times 10^{-5}$ m$^2$/s. **(8)**