G/E/TY

Reg. No:

Final Assessment Test – April 2025

Vellore Institute of Technology

Course: BMEE402L - Heat and Mass Transfer

Class NBR(s): 3593 / 4023 / 4090 / 6122 / 6612

Slot: F2+TF2

Time: Three Hours

Max. Marks: 100

- **KEEPING MOBILE PHONE/ANY ELECTRONIC GADGETS, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE**
- **DON'T WRITE ANYTHING ON THE QUESTION PAPER**

General Instructions:

i) **Heat and Mass Transfer data book authored by C. P. Kothandaraman is permitted.**

ii) **Assume suitable data wherever necessary.**

Answer ALL Questions

(10 X 10 = 100 Marks)

1. Derive the 3-D steady-state heat conduction equations for a cylindrical coordinate system. Highlighting suitable assumptions, deduce the 1-D Laplace equation from this.

2. The inside layer of a wall furnace is made of Silica Brick which is 120 mm thick and is covered with a magnetite brick layer of 240 mm thick. The temperatures at the inner surface of the Silica Brick wall and the outer surface of the Magnetite Brick wall are 725 °C and 110 °C, respectively. The thermal contact resistance between these two walls is 0.0035 K/W per unit wall area. If the thermal conductivities of Silica and Magnetite bricks are 1.7 W/mK and 5.8 W/mK, respectively, determine the (a) interface temperatures (b) rate of heat loss per unit area of walls (c) overall heat transfer coefficient.

3. An Aluminium slab of 10 cm thick is originally at a temperature of 500 °C. It is suddenly immersed in a liquid at 100 °C resulting in a heat transfer coefficient of 1200W/m^{2}K. Determine (a) the temperature at the center line of the slab (b) at the surface 1 minute after the immersion (c) the total thermal energy removed per unit slab area during this period. The Aluminium properties for the given conditions are $\alpha = 8.4 \times 10^{-5}$ m^2/s, k = 215 W/mK, ρ = 2700 kg/m^3, c = 0.9 kJ/kg K.

4. A tube bank consists of a square array of 144 tubes (12 x 12) arranged in an in-line position. The tube diameter is 1.5 cm and the length is 1 m with the center-to-center tube spacing of 2 cm. If the surface temperature of the tubes is maintained at 350 K and air enters the tube bank at 1 atm, 300 K, and 6 m/s, calculate (a) the total heat loss by the tubes and (b) the exit temperature of the air.

5. A household oven door of 0.5 m height and 0.7 m width reaches an average surface temperature of 32 °C during an operation. Estimate the heat loss from the oven to the room assuming the room air at 22 °C.

6. In a counter-flow double pipe heat exchanger, water is heated from 25 °C to 65 °C using an oil with a specific heat of 1.45 kJ/kg K and mass flow rate of 0.9 kg/s. In this process, the oil is cooled from 230 °C to 160 °C. If the overall heat transfer coefficient is 420 W/m²K, calculate (a) the rate of heat transfer (b) the mass flow rate of water, and (c) the surface area of the heat exchanger.

7. A diecast component (mass of 1.2 kg) comes out of the machine at 345 °C and is exposed to air at 20 °C with a convective heat transfer coefficient of 56.8 W/m²K. The properties of the component are: ρ = 7150 kg/m³, k = 95 W/mK, c_p = 385 J/kg K. If the surface area of the component is 0.075 m², determine (a) the component temperature after 5 minutes (b) the time required to reach 50 °C (c) the time constant (d) the value of convective heat transfer coefficient up to which the lumped parameter model can be used.

8. Engine oil flows over a 50 mm diameter tube at an average temperature of 147 °C with a velocity of 80 cm/s. Calculate the average heat transfer coefficient if the tube wall is maintained at a temperature of 200 °C and is 2 m long.

9.a) A thin Aluminium sheet with an emissivity of 0.1 on both sides is placed between two very large parallel plates that are maintained at uniform temperatures T_1=800 K and T_2=500 K and have emissivity $\varepsilon_1 = 0.2$ and $\varepsilon_2 = 0.7$, respectively. Determine (a) the rate of radiation heat transfer between the two plates per unit surface area of the plates (b) compare the result with the result that of without the shield, and (c) the temperature of the shield.

OR

9.b) Two very large parallel plates are maintained at uniform temperatures of 1000 K and 800 K respectively. The emissivity of both the plates are 0.2. The net rate of radiative heat transfer is reduced to 1/5 by inserting thin aluminium sheets of emissivity 0.15 on both sides between the plates. Determine the number of sheets needed to be inserted. Comment on the result.

10.a) An old-fashioned glass apothecary jar contains a patent medicine. The neck of the glass jar is closed with a rubber stopper of 20 mm tall, with a diameter of 10 mm at the bottom end, and widening to 20 mm at the top end. The molar concentration of medicine vapor in the stopper is 0.002 kmol/m³ at the bottom surface and is negligible at the top surface. If the mass diffusivity of medicine vapor in rubber is 0.2×10^{-9} m²/s, determine the rate (kmol/s) at which vapor exits the stopper.

OR

10.b) Give the fundamental difference between heat and mass transfer. Define molecular diffusion and state Fick's law of diffusion. Highlight the effect of temperature and pressure on the diffusivity of the gases.

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