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Question Paper Code : 81662

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2025.

Sixth/Eighth Semester

Mechanical Engineering

ME 3691 — HEAT AND MASS TRANSFER

(Common to : Mechanical Engineering (Sandwich))

(Regulations 2021)

Time : Three hours

Maximum : 100 marks

(Use of heat and Mass Transfer Data book is permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. State Fourier law of heat conduction.
2. Write the significance of Biot number Fourier number in heat conduction.
3. Define boundary layer thickness.
4. What is Richardson number?
5. What is filmwise condensation?
6. Define Logarithmic mean temperature difference.
7. Define view factor.
8. How Stefan-Boltzmann law and Planck's law are related?
9. What are the different modes of mass transfer?
10. Define Schmidt number and mention its significance.

PART B — ($5 \times 13 = 65$ marks)

11. (a) A wall of a furnace is made up of an inside layer of silica brick 120 mm thick covered with a layer of magnesite brick 240 mm thick. The temperatures at the inside surface of silica brick wall and outside surface of magnesite brick wall are 725°C and 110°C respectively. The contact thermal resistance between the two walls at the interface is 0.0035°C/W . per unit wall area. If thermal conductivities of silica and magnesite bricks are $1.7 \text{ W/m}^{\circ}\text{C}$ and $5.8 \text{ W/m}^{\circ}\text{C}$. Calculate (i) the temperature distribution (ii) The rate of heat loss per unit area of walls, and (iii) The temperature drop at the interface.

Or

- (b) (i) One end of a long rod is inserted into a furnace with the other end projecting into the outside air. After steady state is reached, the temperature of the rod is measured at two points 10 cm apart and found to be 125°C and 91°C . when the ambient temperature is 28°C . If the rod is 2 cm in diameter and heat transfer coefficient $(h) = 17.5 \text{ W/m}^2^{\circ}\text{C}$. Determine the thermal conductivity of the rod. (7)
- (ii) The rate of heat generation in a slab of thickness 160 mm ($k = 180 \text{ W/m}^{\circ}\text{C}$) is $1.2 \times 10^6 \text{ W/m}^3$. If the temperature of each of the surface of solid is 120°C , determine the temperature at the mid and quarter planes. (6)
12. (a) (i) Assuming a man can be represented by a cylinder 30 cm in diameter and 1.7 m high with a surface temperature of 30°C . Calculate the heat he would lose while standing in a 36 km/hr wind at 10°C . (7)
- (ii) The main trunk duct of an air conditioning system is rectangular in cross section ($400 \text{ mm} \times 800 \text{ mm}$) and has air at atmosphere pressure and at 20°C flowing with a velocity of 7 m/s. Estimate the heat leakage per metre length per unit temperature difference. The physical properties of air is $\nu = 15.06 \times 10^{-6} \text{ m}^2/\text{s}$, $\alpha = 7.71 \times 10^{-2} \text{ m}^2/\text{hr}$, $k = 0.0259 \text{ W/m}^{\circ}\text{C}$. (6)

Or

- (b) (i) A 30 cm long glass plate is hung vertically in the air at 27°C while its temperature is maintained at 77°C . Calculate the boundary layer thickness at the trailing edge of the plate. If a similar plate is placed in a wind tunnel and air is blown over it in a velocity of 4 m/s. Estimate the boundary layer thickness at its trailing edge. Determine and comment on the thickness of the boundary layer for both the cases. (7)
- (ii) A vertical pipe of 100 mm outer diameter and 3 m long is at 100°C and is surrounded by still air at 20°C . Determine the heat loss from the vertical pipe. (6)

13. (a) (i) In a double pipe counter flow heat exchanger, 10,000 kg/hr of an oil having a specific heat of 2095 J/kg K is cooled from 80 °C to 50 °C by 8000 kg/hr of water entering at 25 °C. Determine the heat exchanger area for an overall heat transfer coefficient of 300 W/m² K, Take Cp for water as 4180 J/kg K. (7)

- (ii) With neat sketch and assumptions, derive the LMTD expression for parallel flow heat exchanger configuration. (6)

Or

- (b) (i) Water enters a cross flow heat exchanger (both fluids unmixed) at 5°C and flows at the rate of 4600 kg/h of air that is initially at 40 °C. Assume the U value to be 150 W/m² K. For an exchanger surface area of 25 m², calculate the exit temperature of air and water. (7)

- (ii) With neat diagram, discuss the various regimes of pool boiling. (6)

14. (a) Two large parallel plates are maintained at 500 K ($\epsilon = 0.4$) and 700 K ($\epsilon = 0.8$). Determine the heat transfer by radiation. If another plate of emissivity of 0.04 is introduced exactly in between them. Determine the percentage of reduction in heat transfer and shield temperature.

Or

- (b) (i) The net radiations from the surfaces of two parallel plates maintained at T₁ and T₂ is to be reduced by 99%. calculate the number of screens to be placed between the two surfaces to achieve this reduction in heat exchange assuming the emissivity of the screens as 0.05 and that of surface as 0.8. (7)

- (ii) Two black discs of 1m diameter are kept 1 m apart facing each other. Their temperature are 500 °C and 300 °C. Determine the heat exchange by radiation. (6)

15. (a) (i) A well of 40 m deep, 9 m diameter is exposed to atmospheric air at 25 °C 50% RH. Determine rate of evaporation of water from the well. (7)

- (ii) Air at 25 °C 20% RH is flowing through a 25 mm diameter pipe at a velocity of 5.2 m/s. The inner surface is wetted with water. Determine mass rate of water evaporation per metre length. (6)

Or

- (b) (i) Determine the rate of evaporation of Toluene from bottom of a deep -narrow vessel of 1.525 m depth into dry stagnant air at 19°C. The partial pressure of toluene vapour is 0.026 atm. The diffusion coefficient is 0.826×10^{-5} m²/s. (7)

- (ii) Air at 25°C 50 % RH flows over a swimming pool of 12 m × 6 m. The velocity of air in the length direction is 2 m/s. Determine (1) mass transfer coefficient (2) mass rate of water evaporation. (6)

PART C — ($1 \times 15 = 15$ marks)

16. (a) Derive the 3D general heat conduction equation both in cartesian and cylindrical coordinates. (15)

Or

- (b) Water is boiled at a rate of 30 kg/hr in a copper pan of 30 cm in diameter and at atmospheric pressure. Estimate the critical heat flux and temperature of the bottom surface of the pan assuming nucleate boiling conditions. (15)