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Question Paper Code : 11668

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2026.

Sixth/Eighth Semester

Mechanical Engineering

ME3691 – 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 — ($10 \times 2 = 20$ marks)

1. Write 3-D general heat conduction equation in Cartesian form.
2. What do you mean by lumped capacity analysis?
3. For $Pr \ll 1$, draw the thermal and hydrodynamic boundary layer for the flow over a flat plate.
4. Define Rayleigh number.
5. What is dropwise condensation?
6. Give the significance of the term NTU in heat exchanger.
7. What do you mean by black body and list out two examples?
8. What do you mean by radiation shield?
9. State Fick's law of diffusion.
10. Give the significance of the Lewis number.

PART B — ($5 \times 13 = 65$ marks)

11. (a) A metal plate of 6 mm thickness ($k = 96 \text{ W/mK}$) is exposed to vapour at 100°C on one side and cooling water at 20°C on the opposite side. The heat transfer coefficient on vapour side and water side are $15 \text{ kW/m}^2 \text{ K}$ and $2200 \text{ W/m}^2 \text{ K}$ respectively. Calculate the following :
- (i) Draw the temperature distribution (3)
 - (ii) The rate of heat transfer per m^2 (5)
 - (iii) Temperature drop at each side (vapour, metal plate and cooling water) of heat transfer. (5)

Or

- (b) (i) It is required to heat oil to about 300°C for frying purpose in a ladle. The cross section of the long handle is $20 \text{ mm} \times 6 \text{ mm}$. The ambient temperature is 35°C . The conductivity of the ladle and hand material is 200 W/mK . If the convective heat transfer coefficient is $30 \text{ W/m}^2\text{K}$, determine the temperature of the long handle at a distance of 350 mm from the oil. (6)
- (ii) Briefly explain about the fins and the significance of biot number. (7)
12. (a) Air at 20°C , 20 m/s flows over a horizontal flat plate. The width of the flat plate is 1 m. The plate is heated to a constant temperature of 75°C starting at a distance of 75 mm from the leading edge. Determine the heat transfer rate from leading edge to a point 350 mm.

Or

- (b) (i) Air at 200°C and 2 bar is heated as it flows through a 2.5 cm diameter at a velocity of 10 m/s. A constant flux is maintained at the wall and the wall temperature is 20°C above the air temperature. How much will the bulk temperature of air increase over a 5 m length of the tube? (10)
- (ii) Briefly explain about boundary layer theory. (3)
13. (a) With neat sketch and assumptions, derive the LMTD expression for counter flow heat exchanger configuration.

Or

- (b) Two fluids A and B exchange heat in a counter current heat exchanger. Fluid A enters at 420°C and has a mass flow rate of 1 kg/s. Fluid B enters at 20°C and has a mass flow rate of 1 kg/s. Effectiveness of heat exchanger is 75%. Determine the heat transfer rate, and exit temperature of fluid B. The specific heat of fluid A is 1 kJ / kg K and that of fluid B is 4 kJ/kg K .

14. (a) (i) A glass plate is used as a cover for a solar collector employed for heating water. The glass plate has transmissivity zero in the entire wavelength except in the band of $0.1 \mu\text{m}$ to $2 \mu\text{m}$ and $3 \mu\text{m}$ to $4 \mu\text{m}$ where $\tau = 0.09$. Determine the heat flux transmitted through glass plate, if the surface temperature of sun is assumed to be 5555 K . (10)
- (ii) Explain the term Stefan Boltzmans law of radiation. (3)

Or

- (b) (i) Two parallel plates of $2 \text{ m} \times 1 \text{ m}$ are kept at 400 K (T_1) and 600 K (T_2) with 0.5 m distance. Determine the heat exchange by radiation. (6)
- (ii) The inner sphere of a liquid oxygen container is 40 cm diameter and outer sphere is 50 cm diameter. Both inner and outer surface emissivities, $\varepsilon = 0.05$. Determine the rate at which liquid oxygen would evaporate at -183°C , when the outer sphere temperature is 20°C . Take latent heat of oxygen is 210 kJ/kg . (7)
15. (a) (i) Ammonia and air experiences diffusion through a 3 mm diameter, 20 m long pipe. Total pressure 1 atm and temperature 25°C . Determine the diffusion rate of ammonia and diffusion rate of air. (6)
- (ii) Determine the rate of evaporation of water from bottom of a test tube of 10 mm diameter, 150 mm long into dry stagnant air at 25°C . (7)

Or

- (b) (i) CO_2 and air experience diffusion through a circular tube of 50 mm diameter and 1 m long. The system is at 1 atm , 25°C . Partial pressure of CO_2 at one end of tube is 190 mm of Hg and the other end of the tube is 95 mm of Hg . Determine the mass rate of flow of CO_2 and air. (6)
- (ii) Air at 25°C , and atmospheric pressure flows with a velocity of 3 m/s inside a 10 mm diameter tube of 1 m length. The inside surface of the tube contains a deposit of naphthalene. Determine the average mass transfer coefficient. (7)

PART C — (1 × 15 = 15 marks)

16. (a) Explain in detail about critical thickness of insulation and also derive the relation of critical thickness of insulation for cylinder and sphere.

Or

- (b) Two parallel plates of $2 \text{ m} \times 1 \text{ m}$ are placed 1 m apart. Their temperatures are maintained at 500°C ($\varepsilon = 0.8$) and 300°C ($\varepsilon = 0.5$). Determine the heat transfer by radiation. If another identical plate of emissivity of 0.6 is introduced exactly in between them. Determine the percentage of reduction in heat transfer and shield temperature.