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**Question Paper Code : 60927**

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

Sixth/Eighth Semester

Mechanical Engineering

ME8693 — HEAT AND MASS TRANSFER

(Common to : Mechanical Engineering (Sandwich))

(Regulations 2017)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — ( $10 \times 2 = 20$  marks)

1. A brick wall ( $k = 0.7 \text{ W/mK}$ ) is 0.3 m thick. Inner surface is maintained at  $45^\circ\text{C}$  and outside surface at  $25^\circ\text{C}$ . Calculate the heat transfer rate per  $1 \text{ m}^2$  of area. Also find the temperature at the mid plane.
2. Write the physical significance of Biot number and Fourier number.
3. Draw the boundary layer for a flat plate and show the various region of flow.
4. A hot plate  $1 \text{ m} \times 1.5 \text{ m}$  is maintained at  $300^\circ\text{C}$ . Air at  $20^\circ\text{C}$  blows over the plate. If the convective heat transfer coefficient is  $20 \text{ W/m}^2\text{C}$ . calculate the rate of heat transfer.
5. Differentiate film wise condensation with drop wise condensation.
6. Draw a boiling curve.
7. What is reciprocity theorem?
8. Incident radiation  $577 \text{ W/m}^2$  strikes an object. The amount of energy absorbed is  $472 \text{ W/m}^2$  and the amount of energy transmitted is  $78.8 \text{ W/m}^2$ . What is the value of reflectivity?
9. What is mass transfer?
10. Write the significance of Lewis number.

PART B — ( $5 \times 13 = 65$  marks)

11. (a) The interior of a refrigerator has inside dimensions 60 cm  $\times$  45 cm base area and 120 cm high. The composite wall is made of two 3 mm mild steel sheets with 6 cm of glass wool insulation sandwiched between them. The average values of convective heat transfer coefficients at the interior and exterior wall are 40.8 and 52.3 W/m<sup>2</sup>C respectively.

(i) Calculate the overall conductance (6)

(ii) For the air temperature inside the refrigerator at 6.5°C and outside of 25°C, determine the rate at which heat must be removed from the refrigerator. Also, calculate the interface temperatures. (7)

Or

- (b) Derive a relation to trace the maximum temperature in a plane wall in which the 0 endothermic chemical reactions take place while one dimensional heat is being transferred by conduction mode alone step by step.

12. (a) Assuming a man as a cylinder of 40 cm diameter and 1.72 m high with a surface temperature of 37°C. Calculate the heat lost from its body, while standing in wind flowing at 20 km per hour at 17°C.

Or

- (b) A vertical pipe 80 mm diameter and 2 m height is maintained at a constant temperature of 120°C. The pipe is surrounded by still atmospheric air at 30°C. Find the heat loss.

13. (a) Derive effectiveness relation for a heat exchanger using parallel flow arrangement with neat sketch.

Or

- (b) A counter-flow double-pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate of 2 kg/s. The inner tube is thin-walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m<sup>2</sup> °C, determine the length of the heat exchanger required to achieve the desired heating.

14. (a) Two concentric pipes 20 cm and 30 cm in diameter, with the space between them evacuated are, used to store liquid air (boiling point=150°C, in room at 25°C. The surface of both the pipes are flushed with aluminium for which emissivity  $\epsilon = 0.03$ . Estimate the rate of heat flow by radiation to the air and the rate of its evaporation. Given that the latent heat of vaporization of liquid air is 208 kJ/kg.

Or

- (b) The absorber surface of a solar collector is made of aluminum coated with black 10 chrome ( $\alpha = 0.87$  and  $\varepsilon = 0.09$ ). Solar radiation is incident on the surface at a rate of  $600 \text{ W/m}^2$ . The air and the effective sky temperatures are  $25^\circ\text{C}$  and  $15^\circ\text{C}$ , respectively, and the convection heat transfer coefficient is  $10 \text{ W/m}^2\text{C}$ . For an absorber surface temperature of  $70^\circ\text{C}$ , determine the net rate of solar energy delivered by the absorber plate to the water circulating behind it.
15. (a) Pressurized hydrogen gas is stored at  $358 \text{ K}$  in a  $4.8\text{-m}$ -outer-diameter spherical container made of nickel. The shell of the container is  $6 \text{ cm}$  thick. The molar concentration of hydrogen in the nickel at the inner surface is determined to be  $0.087 \text{ kmol/m}^3$ . The concentration of hydrogen in the nickel at the outer surface is negligible. Determine the mass flow rate of hydrogen by diffusion through the nickel container.

Or

- (b) The tyre tube of a vehicle has a surface area  $0.62 \text{ m}^2$  and wall thickness  $12 \text{ mm}$ . The tube has air filled in it at a pressure  $2.4 \times 10^5 \text{ N/m}^2$ . The air pressure drops to  $2.3 \times 10^5 \text{ N/m}^2$  in 10 days. The volume of air in the tube is  $0.034 \text{ m}^3$ . Calculate the diffusion coefficient of air in rubber at the temperature of  $315 \text{ K}$ . Gas constant value =  $287$ . Solubility of air in rubber tube =  $0.075 \text{ m}^3$  of air/ $\text{m}^3$  of rubber tube at one atmosphere.

PART C — ( $1 \times 15 = 15$  marks)

16. (a) A solid steel ball  $5 \text{ cm}$  in diameter and initially at  $450^\circ\text{C}$  is quenched in a controlled environment at  $90^\circ\text{C}$  with convection coefficient of  $115 \text{ W/m}^2\text{K}$ . Determine the time taken by centre to reach a temperature of  $150^\circ\text{C}$ .

Or

- (b) In an open heart surgery under hypothermic conditions, the patient's blood is cooled before the surgery and rewarmed afterwards. It is proposed that a concentric tube counter flow heat exchanger of length  $0.5 \text{ m}$  is to be used for this purpose, with a thin-walled inner tube having a diameter of  $55 \text{ mm}$ . If water at  $60^\circ\text{C}$  and  $0.1 \text{ kg/s}$  is used to heat blood entering the exchanger at  $18^\circ\text{C}$  and  $0.05 \text{ kg/s}$ , what is the temperature of the blood leaving the exchanger and the heat flow rate. Take the overall heat transfer coefficient is  $500 \text{ W/m}^2\text{K}$ , specific heat of blood =  $3.5 \text{ kJ/kgK}$ .

