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Question Paper Code : 51346

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2024.

Sixth Semester

Mechanical Engineering

ME 3691 – HEAT AND MASS TRANSFER

(Regulations 2021)

Time : Three hours Maximum : 100 marks

["Heat and Mass transfer Data Book is permitted"]

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Consider a medium in which the heat conduction equation is given in its simplest form as $\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$ Is heat transfer steady or transient? , Is heat transfer one-, two-, or three-dimensional?

2. What is meant by Lumped System analysis?

3. Write the physical significance of the Nusselt number.

4. How does the Rayleigh number differ from the Grashof number?

5. Differentiate between pool boiling and flow boiling?

6. Sketch the Variation of the fluid temperatures in a parallel-flow double-pipe heat exchanger.

7. Define: Emissivity.

8. Specify the purpose of radiation shield.

9. Give examples for liquid-to-gas mass transfer and solid-to liquid mass transfer.

10. State Fick's Law of Diffusion.

PART B — (5 × 13 = 65 marks)

11. (a) The wall of a cold storage consists of three layers: an outer layer of ordinary bricks, 25 cm thick, a middle layer of cork, 10 cm thick and an inner layer of cement, 6 cm thick. The thermal conductivities of the materials are 0.7, 0.043 and 0.72 W/m.K, respectively. The temperature of the outer surface of the wall is 30°C and that of inner is — 15°C. Calculate: (i) Steady state rate of heat gain per unit area, (ii) Temperature at the interfaces of composite wall, (iii) What additional thickness of cork should be provided to reduce the heat gain 30% less than the present value? (4+4+5)

Or

(b) (i) Consider two finned surfaces that are identical except that the fins on the first surface are formed by casting or extrusion, whereas they are attached to the second surface afterwards by welding or tight fitting. For which case do you think the fins will provide greater enhancement in heat transfer? Explain. (3)

(ii) In a quenching process, a copper plate of 3 mm thick is heated upto 350°C and then suddenly, it is dropped into a water bath at 25°C. Calculate the time required for the plate to reach the temperature of 50°C. The heat transfer coefficient on the surface of the plate is 28 W/m²K. The plate dimensions may be taken as length 40 cm and width 30 cm. Also calculate the time required for infinite long plate to cool to 50°C. Other parameters remain same. Take the properties of copper as $C = 380$ J/kg.K, $\rho = 8800\,\text{kg/m}^3$, $k = 385\text{W/m.K}$. (10)

12. (a) (i) Explain the development of the velocity boundary layer for flow over a flat plate, and the different flow regimes. (6)

(ii) Air at a local atmospheric pressure of 83.4 kPa and 20°C flows with a velocity of 8 m/s over a 1.5 m × 6 m flat plate whose temperature is 140°C. Determine the rate of heat transfer from the plate if the air flows parallel to the 6-m-long side. (7)

Or

(b) (i) Explain thermally developing region and thermal entry length for flow in a circular tube. (6)

(ii) A 6-m-long section of an 8-cm-diameter horizontal hot water pipe passes through a large room whose temperature is 20° C. If the outer surface temperature of the pipe is 70°C, determine the rate of heat loss from the pipe by natural convection. (7)

13. (a) (i) Discuss the various regimes of pool boiling. (7)

(ii) A vertical tube of 6.5 cm outside diameter and 1.5 m long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of 60°C by circulating cold water through tube. Calculate the rate of heat transfer to the coolant. Take latent heat of condensation 2256.9 kJ/kg. (6)

Or

(b) Explain how the ε-NTU method is superior to the LMTD method and derive an expression for the effectiveness of a parallel flow heat exchanger. (13)

14. (a) An industrial furnace (black body) emitting radiation at 2650°C. Calculate the following quantities:

(i) Spectral emissive power at $\lambda = 1.2\,\mu m$,

(ii) Wavelength at which the emissive power is maximum,

(iii) Maximum spectral emissive power,

(iv) Total emissive power, and

(v) Total emissive power of the furnace, if it is treated as gray and diffuse body with an emissivity of 0.9. (3+2+3+3+2)

Or

(b) Two large parallel planes with emissivity 0.6 are at 900 K and 300 K. A radiation shield with one side polished and having emissivity of 0.05, while the emissivity of other side is 0.4 is proposed to be used. Which side of the shield to face the hotter plane, if the temperature of shield is to be kept minimum? Justify your answer. (13)

15. (a) An open pan 20 cm in diameter 20 mm deep is filled with water to a level of 10 mm and is exposed to air at 25°C. Assuming mass diffusivity of $0.25 \times 10^{-4}\, m^2/s$, calculate the time required for all the water to evaporate. Take The partial pressure of water vapour, corresponding to saturation temperature of 25°C as 3.169 kPa. (13)

Or

(b) The water in a $5m \times 15m$ outdoor swimming pool is maintained at a temperature of 27°C. The average ambient temperature and relative humidity are 27°C and 40%, respectively. Assuming a wind speed of 2 m/s in the direction of long side of the pool, estimate the mass transfer coefficient for the evaporation of water from the pool surface. (13)

PART C — ($1 \times 15 = 15$ marks)

16. (a) (i) Cold water at 1495 kg/h enters at 25°C through a parallel flow heat exchanger to cool 605 kg/h of hot water entering at 70°C and leaving at 50°C. The individual convective heat transfer coefficients on both sides are 1590 W/m².K Using LMTD method, find the area of the heat exchanger. (7)

(ii) If the flow of hot water is doubled, in the above said heat exchanger, for the same heat exchanger area, Using NTU method, find the exit temperatures of cold and hot fluid streams. Assume overall heat transfer coefficient (U) as 1010 W/m²K for this case. Take $C_{p,water} = 4.180\,kJ/kg\,K$ for both cases. (8)

Or

(b) A 60 mm thick iron plate is initially at 250°C. Its both surfaces are suddenly exposed to air at 25°C with convection coefficient of 510 W/m².K. (i) Calculate the centre temperature, 3 minutes after the start of exposure. (ii) Calculate the temperature at the depth of 10 mm from the surface, after 3 minutes of exposure. (iii) Calculate the energy removed from the plate per square metre during this period.

Take thermophysical properties of iron plate:

$k = 60\,W/m.K$, $\rho = 7850 kg/m^3$, $C = 460\,J/kg$, $\alpha = 1.6 \times 10^{-5} m^2/s$. (15)