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Question Paper Code : X60843

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2020
Fourth/Fifth/Sixth Semester
Mechanical Engineering
ME 2251/ME 1251/10122 ME 502/ME41/080120015 – HEAT AND MASS TRANSFER
(Common to Mechanical and Automation Engineering)
(Regulations 2008/2010)
(Also Common to PTME 2251 – Heat and Mass Transfer for B.E. (Part-Time) Sixth semester – Mechanical Engineering – Regulations 2009)

Time : Three Hours Maximum : 100 Marks

Use of Heat and Mass Transfer Tables permitted
Answer ALL questions

PART – A **(10×2=20 Marks)**

1. State Fourier's Law of conduction.
2. What is meant by lumped heat capacity analysis ?
3. Air at 27°C and 1 atmospheric flows over a flat plate at a speed of 2 m/s. Calculate boundary layer thickness at distance 40 cm from loading edge of plate. At 27°C viscosity (air) = 1.85×10^{-5} kg m/s.
4. A square plate 40 cm × 40 cm maintained at 400 K is suspended vertically in atmospheric air at 300 K. Determine the boundary layer thickness at trailing edge of the plate.
5. How does laminar flow differ from turbulent flow ?
6. What is burnout point in boiling heat transfer ? Why is it called so ?
7. Define LMTD of a heat exchanger.
8. What is thermal radiation ? What is its wavelength band ?
9. State Fick's Law of diffusion.
10. Write down the analogous terms in heat and mass transfer.

PART – B **(5×16=80 Marks)**

11. a) i) Derive general heat conduction equation in Cartesian coordinates. **(10)**

ii) Compute the heat loss per square meter surface area of a 40 cm thick furnace wall having surface temperatures of 300°C and 50°C if the thermal conductivity k of the wall material is given by $k = 0.005\,T - 5 \times 10^{-6}\,T^2$ where T = temperature in °C. **(6)**

(OR)

b) i) A furnace wall consists of 200 mm layer of refractory bricks, 6 mm layer of steel plate and a 100 mm layer of insulation bricks. The maximum temperature of the wall is 1150°C on the furnace side and the minimum temperature is 40°C on the outermost side of the wall. An accurate energy balance over the furnace shows that the heat loss from wall is 400 W/m^2. It is known that there is a thin layer of air between the layers of refractory bricks and steel plate. Thermal conductivities for the three layers are 1.52, 45 and 0.138 W/m°C respectively. Find

1) To how many millimeters of insulation brick is the air layer equivalent ?

2) What is the temperature of the outer surface of the steel plate. **(8)**

ii) Find out the amount of heat transferred through an iron fin of length 50 mm, width 100 mm and thickness 5 mm. Assume k = 210 kJ/mh°C and h = 42 $kJ/m^2h°C$ for the material of the fin and the temperature at the base of the fin as 80°C. Also determine the temperature at tip of the fin, if atmosphere temperature is 20°C. **(8)**

12. a) i) Define velocity boundary layer and thermal boundary layer. **(4)**

ii) Air at 200 kPa and 200°C is heated as it flows through a tube with a diameter of 25 mm at a unit length of the tube. If a constant heat flux condition is maintained at the wall and the wall temperature is 20°C above the air temperature, all along the length of the tube. How much would the bulk temperature increases over 3 m length of the tube. **(12)**

(OR)

b) i) A 0.5 m high flat plate of glass at 93°C is removed from an annealing furnace and hung vertically in the air at 28°C. 1 atm. Calculate the initial rate of heat transfer to the air. The plate is 1 m wide. **(10)**

ii) A fine wire having a diameter of 0.02 mm is maintained at a constant temperature of 54°C by an electric current. The wire is exposed to air at 1 atm and 0°C. Calculate the electric power necessary to maintain the wire temperature if the length is 50 cm. **(6)**

13. a) Discuss briefly the pool boiling regimes of water at atmospheric pressure.

(OR)

b) i) What are the different types of fouling in heat exchangers ? **(4)**

ii) Hot exhaust gases which enter a cross-flow heat exchanger at 300°C and leave at 100°C are used to heat water at a flow rate of 1 kg/s from 35 to 125°C. The specific heat of the gas is 1000 J/kg.K and the overall heat transfer coefficient based on the gas side surface is 100 $W/m^2.K$. Find the required gas side surface area using the NTU method and LMTD method. **(12)**

14. a) Consider a cylindrical furnace with outer radius = 1 m and height = 1 m. The top (surface1) and the base (surface 2) of the furnace have emissivites 0.8 and 0.4 and are maintained at uniform temperatures of 700 K and 500 K respectively. The side surface closely approximates a black body and is maintained at a temperature of 400 K. Find the net rate of radiation heat transfer at each surface during steady state operation.

(OR)

b) Emissivities of two large parallel plates maintained at 800°C and 300°C are 0.3 and 0.5 respectively. Find the net radiant heat exchange per square meter for these plate. Find the percentage reduction in heat transfer when a polished aluminium radiation shield ($\varepsilon = 0.05$) is placed between them. Also find the temperature of shield.

15. a) Explain different modes of mass transfer and derive the general mass diffusion equation in stationary media.

(OR)

b) Explain Reynold's number, Sherwood number, Schmidt number and solve the following :

A vessel contains a binary mixture of oxygen and nitrogen with partial pressures in the ratio 0.21 and 0.79 at 15°C. The total pressure of the mixture is 1.1 bar. Calculate the following :

i) Molar concentrations **(4)**

ii) Mass densities **(4)**

iii) Mass Fractions **(4)**

iv) Molar fractions of each species. **(4)**