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**Question Paper Code : 11522**

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2012.

Fourth Semester

Mechanical Engineering

ME 2251/113401/ME 41/ME 1251/10122 ME 502/080120015 — HEAT AND MASS TRANSFER

(Regulation 2008)

(Common to PTME 2251 — Heat and Mass Transfer for Sixth Semester B.E. (Part-Time) Mechanical Engineering – Regulation 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. Define the term thermal conductivity. Also list the behavior of metal, liquid and gases thermal conductivity for increase in temperature.

2. A plate 2 cm thick and 10 cm wide is used to heat a fluid at 30°C. The heat generation rate inside the plate is $7 \times 10^6$ W/m². Determine the heat transfer coefficient to maintain the temperature of the plate below 180°C. Take K(plate) = 26 W/m°C. Negelect the heat loss from the edge of the plate.

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) = $1.85 \times 10^{-5}$ kg/ms.

4. A square plate 40 × 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. Differentiate between pool boiling and forced convection boiling.

6. What advantage does the effectiveness – NTU method has over the LMTD method?

7. What is Kirchoff's identity? When does it apply?

8. In what way does radiation from gases differ from that from solids?

9. State Fick's law of diffusion.

10. In what case convective mass transfer will happen? Give examples for free and forced convective mass transfer.

PART B — (5 × 16 = 80 marks)

11. (a) (i) A 150 mm steam pipe has inside diameter of 120 mm and outside diameter of 160 mm. It is insulated at the outside with asbestos. The steam temperature is 150°C and the air temperature is 20°C h (steam side)= 100 W/m²C, h (air side)= 100 W/m²°C, K(asbestos) = 0.8W/m°C and K (steel) = 42 W/m°C. How thick should the asbestos be provided in order to limit the heat losses to 2.1 kW/m²? (10)

(ii) It is required to heat the oil to 300°C for frying purpose. A long ladle is used in frying pan. The section of the ladle is 5 mm × 18 mm. The surrounding air is at 30°C. Thermal conductivity of the material is 205 W/m.K. If the temperature at a distance of 380 mm from the oil should not exceed 40°C, determine convective heat transfer coefficient. (6)

Or

(b) A slab of aluminum 10 cm thick is originally in a temperature of 500°C. It is suddenly immersed in a liquid at 100°C resulting in a heat transfer coefficient of 1200 W/m²K. Determine the temperature at the centerline and the surface 1 minute after the immersion. Also calculate the total thermal energy removed per unit area of the slab during this period. The properties of aluminum for the given conditions are $\alpha$ = 8.4 × $10^{-5}$ m²/s; k = 215 W/m K; $\rho$ = 2700 kg/m³; C = 0.9 kJ/kg K.

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) The bottom of copper pan, 300 mm in diameter is maintained at 120°C by an electric heater. Calculate the power required to boil water in this pan. What is the evaporation rate? Estimate the critical heat flux.

Or

(b) Water at the rate of 4 kg/s is heated from 40°C to 55°C in a shell and tube heat exchanger. On shell side one pass is used with water as heating fluid ($\dot{m}$ = 2 kg/s), entering the exchanger at 95°C. The overall heat transfer coefficient is 1500 W/m²°C and the average water velocity in the 2 cm diameter tubes is 0.5 m/s. Because of space limitations the tube length must not exceed 3 m. Calculate the number of tube passes, keeping in mind the design constraint.

14. (a) (i) A gray, diffuse opaque surface ($\alpha$ = 0.8) is at 100°C and receives an irradiation 1000 W/m². If the surface area is 0.1 m². Calculate

(1) Radiosity of the surface

(2) Net radiative heat transfer rate from the surface

(3) Calculate above quantities, if surface is black. (10)

(ii) Emissivities of two large parallel plate maintained at 800°C and 300°C and 0.3 and 0.5 respectively. Find the net radiant heat exchange per square metre for these plates. (6)

Or

(b) Two rectangles 50 × 50 cm are placed perpendicular with common edge. One surface has $T_1$ = 1000 K, $\in$ = 0.6, while the other surface is insulated and in radiant balance with a large surrounding room at 300 K. Determine the temperature of the insulated surface and heat lost by the surface at 1000 K.

15. (a) Air is contained in a tyre tube of surface area 0.5 m² and wall thickness 10 mm. the pressure of air drops from 2.2 bar to 2.18 bar in a period of 6 days. The solubility of air in the rubber is 0.072 m³ of air per m³ of rubber at 1 bar. Determine the diffusivity of air in rubber at operating temperature of 300 K if the volume of air in the tube is 0.028 m³.

Or

(b) Along a horizontal water surface an air stream with velocity $u_\alpha$ = 3 m/s is flowing. The temperature of the water on the surface is 15°C, the air temperature is 20°C the total pressure is 1 atm (10⁵ N/m²), and the saturation pressure of the water vapour in the air at 20°C is 2337 N/m². The relative humidity of the air is 33%. The water surface along the wind direction has a length of 10 cm. Calculate the amount of water evaporated per hour per meter from the water surface. The binary diffusivity of water vapour in the air may be taken as 3.3 × 10⁵ m²/s. The saturation vapour pressure of water at 15°C 1705 N/m² and kinematic viscosity of the air is 1.5 × 10⁻⁵ m²/s.

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