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Question Paper Code : 23844

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2018.

Fourth Semester

Mechanical Engineering

ME 2251 — HEAT AND MASS TRANSFER

(Common to Mechanical and Automation Engineering/Mechanical Engineering (Sandwich))

(Regulations 2008)

(Also common to PTME 2251 – Heat and Mass Transfer for Third semester B.E. (Part-Time) 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 heat conduction.

2. What is lumped system analysis? When is it used?

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/ms.

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 heat exchangers are classified?

6. Discuss the advantage of NTU method over the LMTD method.

7. Name the laws of variation used in heat transfer analysis.

8. Two parallel radiating planes 100 x 50 cm are separated by a distance of 50 cm. What is the radiation shape factor between the planes?

9. How mass transfer takes through diffusion and convection?

10. What do you mean by equimolar counter diffusion?

PART B — (5 × 16 = 80 marks)

11. (a) (i) A reactor's wall 320 mm thick is made up of an inner layer of fire brick (k = 0.84 W/m°C) covered with a layer of insulation (k = 0.16 W/m°C). The reactor operates at a temperature of 1325°C and the ambient temperature is 25°C. Determine the thickness of the firebrick and insulation which gives minimum heat loss. Calculate the heat loss presuming that the insulating material has a maximum temperature of 1200°C. (8)

(ii) Derive an expression for the heat conduction through a hollow cylinder from the general heat conduction equation. Assume steady state unidirectional heat flow in radial direction and no internal heat generation. (8)

Or

(b) (i) A 25 mm diameter rod of 360 mm length connects two heat sources maintained at 127°C and 227°C respectively. The curved surface of the rod is losing heat to the surrounding air at 27°C. The heat transfer coefficient is 10 $W/m^2{}^\circ C$. Calculate the loss of heat from the rod if it is made of Copper (k = 335 W/m°C) and steel (k = 40 W/m°C). (8)

(ii) A thermocouple junction is in the form of 8 mm diameter sphere. The properties of the material are c = 420 J/kg°C; p = 8000 kg/m^3 k = 40 W/m°C and h = 40 W/m°C. The junction is initially at 40°C and inserted in a stream of hot air at 300°C. Find the time constant of the thermocouple. The thermocouple is taken out from the hot air after 10 seconds and kept in still air at 30°C. Assuming the heat transfer coefficient in air of 10 W/m°C, find the temperature attained by the junction 20 seconds after removing from hot air. (8)

12. (a) Caster oil at 25°C flows at a velocity of 0.1 m/s part a flat plate, in a certain process. If the plate is 4.5 m long and is maintained at a uniform temperature of 95°C, calculate the following:

(i) The hydrodynamic and thermal boundary layer thicknesses on one side of the plate

(ii) The total drag force per unit width on one side of the plate.

(iii) The local heat transfer coefficient at the trailing edge and

(iv) The heat transfer rate; properties of oil at 60°C are $\rho = 956.8$ mg/m^3; $\infty = 7.2 \times 10^{-8} m^2/s$; $k = 0.213 W/mK$; $\upsilon = 0.65 \times 10^{-4} m^2/s$. (16)

Or

(b) (i) Find the convective heat loss from a radiator 0.6 m wide and 1.2 m high maintained at a temperature of 90°C in a room at 14°C. Consider the radiator as a vertical plate. (8)

(ii) Calculate the heat transfer from a 60 W incandescent bulb at 115°C to ambient air at 25°C. Assume the bulb as a sphere of 50 mm diameter. Also find the % of power lost by free convection. (8)

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/m20°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) Consider a cylindrical furnace with outer radius 1 m and height = 1 m. The top (surface 1) and the base (surface 2) of the furnace have emissivities 0.8 & 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) (i) Explain equimolal counter diffusion in gases. (8)

(ii) Discuss briefly the Analogy between heat and mass transfer. (8)

Or

(b) Define mass transfer coefficient. Air at 1 bar pressure and 25°C containing small quantities of iodine flows with a velocity of 5.2 m/s inside a tube having an inner diameter of 3.05 cm. Find the mass transfer coefficient for iodine transfer from the gas stream to the wall surface If C_m is the mean concentration of iodine in kg.mol/m^3 in the air stream, find the rate of deposition of iodine on the tube Surface by assuming the wall Surface is a perfect sink for iodine deposition. Assume $D = 0.0834$ cm^2/s.

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