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10ME63

Sixth Semester B.E. Degree Examination, Dec.2023/Jan.2024
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

Note:* 1. *Answer any FIVE full questions, selecting at least TWO questions from each part.
2. *Use of Heat and Mass Transfer data hand book is permitted.*

PART – A

1 a. Enumerate various laws governing heat transfer relation. **(04 Marks)**

b. Discuss the following modes of heat transfer considering their boundary conditions:
(i) Conduction (ii) Convection (iii) Radiation **(06 Marks)**

c. Write the heat conduction equation for one dimensional, steady state heat flow in a solid having a constant 'K' and a constant rate of energy generation 'g_0' W/m^3 within the medium for (i) slab (ii) cylinder (iii) a sphere **(03 Marks)**

d. Derive one dimensional steady state heat conduction equation for sphere without heat generation. **(07 Marks)**

2 a. Derive the expression for temperature distribution and rate of heat transfer through slab with variable thermal conductivity. **(10 Marks)**

b. A wire of 8 mm diameter at a temperature of 60°C is to be insulated by a material having K = 0.174 W/m°C. Heat transfer coefficient on the outside, h_a = 8 W/m^{2}K. Ambient temperature T_a = 25°C. For maximum heat loss, what is the minimum thickness of insulation and the heat loss per meter length? Find the increase in heat dissipation due to insulation. Also calculate increase in current carrying capacity due to insulation? **(10 Marks)**

3 a. What are Biot and Fourier numbers? Explain their physical significance. **(06 Marks)**

b. What are Heisler charts? Explain the importance of these charts in problem solving related to transient convection. **(06 Marks)**

c. A carbon steel shaft of diameter 0.2 m which is heat treated in a gas-fired furnace whose gases are at 1200 K and provide a convection coefficient of 80 W/m^{2}K. If the shaft enters the furnace at 300 K, how long must it remain in the furnace to achieve a centre line temperature of 900 K? Given the properties of carbon steel are ρ = 7854 kg/m^3, K = 48.8 W/mK and C_p = 559 J/kgK **(08 Marks)**

4 a. Discuss the following in view of flow over a body:
(i) Velocity Boundary Layer
(ii) Thermal boundary Layer **(05 Marks)**

b. Discuss the following in view of flow inside a duct:
(i) Velocity Boundary Layer
(ii) Thermal Boundary Layer **(05 Marks)**

c. Consider a square plate 0.5 m by 0.5 m with one surface insulated and the other surface maintained at a uniform temperature of 385 K which is placed in quiescent air at atmospheric pressure of 315 K. Calculate the average heat transfer coefficient for free convection for the following three orientations of the hot surface:
(i) The plate is horizontal, and the hot surface faces up
(ii) The plate is vertical
(iii) The plate is horizontal and the hot surface faces down. **(10 Marks)**

PART – B

5 a. Discuss the importance of dimensional analysis for forced convection with related to;
(i) Reynold's number (ii) Prandtle number
(iii) Nusselt number (iv) Stanton number **(08 Marks)**

b. With boundary layer profile, discuss the importance of hydrodynamic and thermal layers for flow inside a tube. **(04 Marks)**

c. Air at 35°C flows across a cylinder of diameter 50 mm at a velocity of 50 m/ρ. The cylinder surface is maintained at 145°C. Find the heat loss per unit length. Properties at mean temperature of 90°C are $\rho = 1$ kg/m^3, $\mu = 20 \times 10^{-6}$ kg/ms, K = 0.0312 W/m°C and $C_p = 1.0$ kJ/kg°C. Use the relation to solve the problem $Nu = 0.027(Re)^{0.805}(Pr)^{\frac{1}{3}}$. **(08 Marks)**

6 a. Derive an expression to find the LMTD for counter flow heat exchanger. **(10 Marks)**

b. Oil at 100°C with $C_p = 3.6$ kJ/kgK flows at a rate of 30000 kg/hr and enters into a parallel flow heat exchanger. Cooling water with $C_p = 4.2$ kJ/kgK enters the heat exchanger at 10°C at the rate of 50000 kg/hr. The heat transfer area is 10 m^2 and V = 1000 W/m^{2}K. Calculate the following:
(i) Outlet temperature of oil and water
(ii) Maximum possible outlet temperature of water **(10 Marks)**

7 a. With profile diagram, explain laminar film condensation on vertical plate in view of Nusselt's theory. **(06 Marks)**

b. With the help of boiling curve discuss different regimes of boiling of water at one atmospheric pressure. **(08 Marks)**

c. Air free saturated steam at a temperature of 85°C (P = 57.83 kPa) condenses on the outer surface of 225 horizontal tubes of diameter 1.2 cm (outer dia) arranged in a 15 by 15 array. Tube surfaces are maintained at a uniform temperature of 75°C. Evaluate total condensate rate per meter length of the tube bundle. **(06 Marks)**

8 a. State and discuss the following briefly:
(i) Stefan-Boltzman law
(ii) Kirchoff's law
(iii) Wein's displacement law **(09 Marks)**

b. Briefly highlight the importance of perfect black body. **(03 Marks)**

c. A hemispherical furnace of radius 1m has a roof temperature of $T_1 = 800$ K and emissivity $\varepsilon_1 = 0.8$. The flat circular floor of the furnace has a temperature of $T_2 = 600$ K and emissivity $\varepsilon_2 = 0.5$. Calculate the net radiant heat exchange between the roof and the floor. **(08 Marks)**

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