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10ME63

Sixth Semester B.E. Degree Examination, June/July 2014
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

Note: 1. *Answer FIVE full questions, selecting at least TWO questions from each part.*
2. *Use of heat and mass transfer data handbook is permitted.*

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

PART – A

1 a. What is thermal diffusivity? Explain its importance in heat conduction problems. **(04 Marks)**

b. Describe different types of boundary conditions applied to heat conduction problems. **(04 Marks)**

c. Consider a one dimensional steady state heat conduction in a plate with constant thermal conductivity in a region $0 \le x \le L$. A plate is exposed to uniform heat flux q W/m^2 at $x = 0$ and dissipates heat by convection at $x = L$ with heat transfer coefficient h in the surrounding air at T_∞. Write the mathematical formulation of this problem for the determination of one dimensional steady state temperature distribution within the wall. **(04 Marks)**

d. An industrial freezer is designed to operate with an internal air temperature of -20°C when the external air temperature is 25°C and the internal and external heat transfer coefficients are 12 W/m^2°C and 8 W/m^2°C, respectively. The wall of the freezer are composite construction, comprising of an inner layer of plastic 3 mm thick with thermal conductivity of 1 W/m°C. An outer layer of stainless steel of thickness 1 mm and thermal conductivity of 16W/m°C. Sandwiched between these layers is a layer of insulation material with thermal conductivity of 0.07 W/m°C. Find the width of the insulation required to reduce the convective heat loss to 15 W/m^2. **(08 Marks)**

2 a. What is critical thickness of insulation on a small diameter wire or pipe? Explain its physical significance and derive an expression for the same. **(10 Marks)**

b. A set of aluminium fins (K = 180 W/mK) that are to be fitted to a small air compressor. The device dissipates 1 KW by convecting to the surrounding air which is at 20°C. Each fin is 100 mm long, 30 mm high and 5 mm thick. The tip of each fin may be assumed to be adiabatic and a heat transfer coefficient of 15 W/m^{2}K acts over the remaining surfaces. Estimate the number of fins required to ensure the base temperature does not exceed 120°C. **(10 Marks)**

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

b. What are Heisler charts? Explain their significance in solving transient convection problems. **(06 Marks)**

c. The temperature of a gas stream is measured with a thermocouple. The junction may be approximated as a sphere of diameter 1 mm, K = 25 W/m°C, ρ = 8400 kg/m^3 and C = 0.4 kJ/kg°C. The heat transfer coefficient between the junction and the gas stream is h = 560 W/m^2°C. How long will it take for the thermocouple to record 99% of the applied temperature difference? **(08 Marks)**

4 a. Establish a relation between Nusselt, Prandtl and Grashof numbers using dimensional analysis. **(08 Marks)**

b. Explain velocity and thermal boundary layers. **(06 Marks)**

c. A 30 cm long glass plate is hung vertically in the air at 27°C while its temperature is maintained at 77°C. Calculate the boundary layer thickness at the trailing edge of the plate. Take properties of air at mean temperature $K = 28.15 \times 10^{-3}$ W/mK, $\gamma = 18.41 \times 10^{-6}$ m^2/s, $P_r = 0.7$, $\beta = 3.07 \times 10^{-3}$ K^{-1}. **(06 Marks)**

PART – B

5 a. Explain the significance of: i) Reynolds number, ii) Prandtl number, iii) Nusselt number, iv) Stanton number. **(08 Marks)**

b. Atmospheric air at 275 K and free stream velocity 20 m/s flows over a flat plate of length 1.5 m long maintained at 325 K. Calculate:

i) The average heat transfer coefficient over the region where the boundary layer is laminar.

ii) Find the average heat transfer over the entire length 1.5 m of the plate.

iii) Calculate the total heat transfer rate from the plate to the air over the length of 1.5 m and width 1 m. assume transition occurs at a Reynolds number 2×10^5. Take air Properties at mean temperature of 300 K.

$K = 0.026$ W/m°C, $P_r = 0.708$, $\gamma = 16.8 \times 10^{-6}$ m^2/s, $\mu = 1.98 \times 10^{-5}$ kg/m-s. **(12 Marks)**

6 a. Derive an expression for the effectiveness of a parallel flow heat exchanger. **(10 Marks)**

b. Engine oil is to be cooled from 80°C to 50°C by using a single pass counter flow, concentric-tube heat exchanger with cooling water available at 20°C. Water flows inside a tube with an internal dia of 2.5 cm with a flow rate of 0.08 kg/s and oil flows through the annulus at a rate of 0.16 kg/s. The heat transfer coefficient for the water side and oil side are respectively 1000 W/m^2°C and 80 W/m^2°C. The fouling factors are 0.00018 m^2°C/W and 0.00018 m^2°C/W, the tube wall resistance is negligible. Calculate the tube length required. Take specific heat of water as 4180 J/kg°C and for oil, 2090 J/kg°C. **(10 Marks)**

7 a. Explain film wise and drop wise condensation. **(04 Marks)**

b. Draw the boiling curve and discuss the different regimes of boiling. **(08 Marks)**

c. Derive an expression for the total mass of water vapour diffused from a water column to the air passing over the water container. **(08 Marks)**

8 a. Explain briefly the concept of a black body. **(04 Marks)**

b. State: (i) Kirchoff's law, ii) Plank's law, iii) Wien's displacement law. **(06 Marks)**

c. Calculate the net radiant heat exchange per m^2 area for two large parallel plates at temperature of 427°C and 27°C respectively $\in$ for hot plates is 0.9 and for cold plate it is 0.6. If polished aluminum shield is placed between them, find percentage reduction in the heat transfer. Assume $\in$ for shield = 0.4. **(10 Marks)**

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