10ME63

Sixth Semester B.E. Degree Examination, Dec.2014/Jan.2015

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 transfer data hand book and steam tables are permitted.*

PART – A

1 a. State the laws governing three basic modes of heat transfer. (06 Marks)

b. Write the 3-D heat conduction equation in Cartesian co-ordinate system. Explain the terms involved. (04 Marks)

c. A furnace has a composite wall constructed of a refractory material for the inside layer and an insulating material on the outside. The total wall thickness is limited to 60 cm. The mean temperature of the gases within the furnace is 850°C, the external ambient temperature is 30°C and the interface temperature is 500°C. The thermal conductivities of refractory and insulating materials are 2 W/m – K and 0.2 W/m – K. The combined co-efficient of heat transfer by convection and radiation between gases and the refractory surface is 200 W/m^2–K and between outside surface and atmosphere is 40 W/m^2–K. Find :

i) The required thickness of each material.
ii) The rate of heat loss to atmosphere is kW/m^2.
iii) The temperatures of the external and internal surfaces. (10 Marks)

2 a. Derive an expression for critical thickness of insulation for a cylinder. Discuss the design aspects for providing insulation scheme for cable wires and steam pipes. (10 Marks)

Find the amount of heat transferred through an iron fin of thickness of 5 mm, height 50 mm and width 100 cm. Also, determine the temperature difference 'θ' at the tip of fin assuming atmospheric temperature of 28°C and base temperature of fin to be 108°C. Take K_{fin} = 50 W/m – K, h = 10 W/m^2-K. (10 Marks)

3 a. Define Biot number and explain its significance. (02 Marks)

b. Derive an expression for the instantaneous and total heat flow in terms of the product of Biot number and Fourier number is one dimensional transient heat conduction. (08 Marks)

c. Aluminium rod of 5 cm diameter and 1 metre long at 200°C is suddenly exposed to a convective environment at 70°C. Calculate the temperature of a radius of 1 cm and heat lost per metre length of the rod 1 minute after the cylinder is exposed to the environment – properties of Al ρ = 2700 kg/m^3, C_p = 900 J/KG-K, K = 215 W/m-K, h = 500 W/m^2-K, $\alpha = 8.5\times10^{-5}$ m^2/S. (10 Marks)

4 a. Using dimensional analysis, derive an expression relating Nusselt number, Prandtl and Grashoff numbers for natural convection. (10 Marks)

b. A plate of length 750 mm and width 250 mm has been placed longitudinally in a stream of crude oil which flows with a velocity of 5 m/s. If the oil has a specific gravity of 0.8 and kinematic visocosity of 10^{-4} m^2/s, calculate:

i) Boundary layer thickness at the middle of plate.
ii) Shear stress at the middle of plate and
iii) Friction drag on one side of the plate. (06 Marks)

4 c. Two horizontal steam pipes having 100 mm and 300 mm are so laid in a boiler house that the mutual heat transfer may be neglected. The surface temperature of each of the steam pipes is 475°C. If the temperature of the ambient air is 35°C, calculate the ratio of heat transfer co-efficients and heat losses per metre length of the pipes. **(04 Marks)**

PART – B

5 a. Define stanton number and explain its physical significance. **(04 Marks)**

b. Prove that $\frac{N_{u_x}}{R_{e_x} \cdot Pr} = \frac{C_{fx}}{2}$ with usual notations. **(08 Marks)**

c. Air at a temperature of 20°, flows over a flat plate at 3 m/s. The plate is $50cm \times 25cm$. Find the heat lost per hour if air flow is parallel to 50 cm side of the plate. If 25 cm side is kept parallel to the air flow, what will be the effect on heat transfer? Temperature of the plate is 100°C. **(08 Marks)**

6 a. Derive an expression for LMTD of parallel flow heat exchanger. State the assumptions made. **(10 Marks)**

b. A heat exchanger is used for cooling oil at 180°C using water available at 25°C. The mass flow rates of oil and water are 2.5 kg/s and 1.2 kg/s respectively. If the heat exchanger has 16 m^2 area available for heat transfer. Calculate the outlet temperatures of oil and water for,
i) Parallel flow and
ii) Counter flow arrangement.
Take $C_{P(oil)} = 1900\,J/KG - K$, $C_{P(water)} = 4184\,J/KG - K$, $U = 285\,W/m^2$-K. **(10 Marks)**

7 a. Explain the influence of the non-condensable gases in condensation process. **(04 Marks)**

b. Differentiate between the mechanism of filmwise and dropwise condensation. Explain why dropwise condensation is preferred over filmwise condensation. **(06 Marks)**

c. A metal-clad heating element of 10 mm diameter and of emissivity 0.92 is submerged in a water bath horizontally. If the surface temperature of the metal is 260°C under study boiling conditions, csalculate the power dissipation per unit length of the heater. Assume that the water is exposed to atmospheric pressure and is at uniform temperature. **(10 Marks)**

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

b. State and explain the following laws:
i) Stefan-Boltzman law.
ii) Kirchoff's law.
iii) Planck's law.
iv) Wiens displacement law. **(08 Marks)**

c. Calculate the net radiant heat exchange per m^2 area for two large parallel planes at temperatures of 427°C and 27°C respectively. Take $\in$ for hot and cold planes to be 0.9 and 0.6 respectively. If a polished aluminium shield is placed between them, find the percentage reduction in the heat transfer, given $\in$ for shield = 0.04. **(08 Marks)**

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