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Sixth Semester B.E. Degree Examination, Dec.2013/Jan.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 transfer data book is permitted.

PART – A

1 a. Explain briefly the mechanism of conduction, convection and radiation heat transfer. **(06 Marks)**

b. With sketches, write down the mathematical representation of three commonly used different types of boundary conditions for one dimensional heat equation in rectangular coordinates. **(08 Marks)**

c. A plate of thickness 'L' whose one side is insulated and the other side is maintained at a temperature T_1 is exchanging heat by convection to the surrounding area at a temperature T_2, with atmospheric air being the outside medium. Write mathematical formulation for one dimensional, steady state heat transfer, without heat generation. **(06 Marks)**

2 a. An electric cable of 10mm diameter is to be laid in atmosphere at 20°C. The estimated surface temperature of the cable due to heat generation is 65°C. Find the maximum percentage increase in heat dissipation, when the wire is insulated with rubber having K = 0.155 W/mK. Take h = 8.5 W/m^2K. **(06 Marks)**

b. Differentiate between the effectiveness and efficiency of fins. **(04 Marks)**

c. In order to reduce the thermal resistance at the surface of a vertical plane wall (50 × 50cm), 100 pin fins (1 cm diameter, 10cm long) are attached. If the pin fins are made of copper having a thermal conductivity of 300 W/mK and the value of the surface heat transfer coefficient is 15 W/m^2K, calculate the decrease in the thermal resistance. Also calculate the consequent increase in heat transfer rate from the wall if it is maintained at a temperature of 200°C and the surroundings are at 30°C. **(10 Marks)**

3 a. Show that the temperature distribution in a body during Newtonian heating or cooling is given by $\frac{T - T_a}{T_i - T_a} = \frac{\theta}{\theta_i} = \text{Exp}\left(\frac{-hA_s t}{\rho C V}\right)$. **(06 Marks)**

b. The steel ball bearings (K = 50 W/mK, α = 1.3 × 10^{-5} m^2/sec), 40mm in diameter are heated to a temperature of 650°C. It is then quenched in a oil bath at 50°C, where the heat transfer coefficient is estimated to be 300 W/m^2K. Calculate:

i) The time required for bearings to reach 200°C.

ii) The total amount of heat removed from a bearing during this time and

iii) The instantaneous heat transfer rate from the bearings, when they are first immersed in oil bath and when they reach 200°C. **(14 Marks)**

4 a. With reference to fluid flow over a flat plate, discuss the concept of velocity boundary and thermal boundary layer, with necessary sketches. **(05 Marks)**

b. The exact expression for local Nusselt number for the laminar flow along a surface is given by $Nu_x = \frac{h_x x}{k} = 0.332\ R_{ex}^{1/2}\ P_r^{1/3}$. Show that the average heat transfer coefficient from x = 0 to x = L over the length 'L' of the surface is given by $2h_L$ where h_L is the local heat transfer coefficient at x = L. **(05 Marks)**

c. A vertical plate 15cm high and 10cm wide is maintained at 140°C. Calculate the maximum heat dissipation rate from both the sides of the plates to air at 20°C. The radiation heat transfer coefficient is 9.0 W/m^2K. For air at 80°C, take $r = 21.09 \times 10^{-6}\ m^2/sec$, $P_r = 0.692$, $k_f = 0.03$ W/mK. **(10 Marks)**

PART – B

5 a. Explain the physical significance of i) Nusselt number; ii) Groshoff number. **(04 Marks)**

b. Air at 2 atm and 200°C is heated as it flows at a velocity of 12 m/sec through a tube with a diameter of 3cm. 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. Calculate:

i) The heat transfer per unit length of tube.

ii) The increase in bulk temperature of air over a 4m length of the tube.

Take the following properties for air $Pr = 0.681$, $\mu = 2.57 \times 10^{-5}$ kg/ms, $K = 0.0386$ W/mK and $C_p = 1.025$ kJ/kg K. **(10 Marks)**

c. Obtain a relationship between drag coefficient, c_m and heat transfer coefficient, h_m for the flow over a flat plate. **(06 Marks)**

6 a. Derive an expression for LMTD of a counter flow heat exchanger. State the assumptions made. **(08 Marks)**

b. What is meant by the term fouling factor? How do you determine it? **(04 Marks)**

c. Engine oil is to be coded 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 inner diameter of 2.5cm and at a rate of 0.08 kg/sec and oil flows through the annulus at the rate of 0.16 kg/sec. The heat transfer coefficient for the water side and oil side are respectively $h_w = 1000\ W/m^2{}^\circ C$ and $h_{oil} = 80\ W/m^2{}^\circ C$. The fouling factors is $F_w = 0.00018 m^2{}^\circ C/W$ on both the sides and the tube wall resistance is negligible. Calculate the tube length required. **(08 Marks)**

7 a. Sketch a pool boiling curve for water and explain briefly the various regimes in boiling heat transfer. **(06 Marks)**

b. Define mass transfer coefficient. **(02 Marks)**

c. A 12cm outside diameter and 2m long tube is used in a big condenser to condense the steam at 0.4 bar. Estimate the unit surface conductance i) in vertical position; ii) in horizontal position. Also find the amount of condensate formed per hour in both the cases.

The saturation temperature of the steam = 74.5°C.

Average wall temperature = 50°C.

The properties of water film at average temperature of $\frac{75.4+50}{2} = 62.7^\circ C$ are given below

$\rho = 982.2\ kg/m^3$, $h_{fg} = 2480$ kJ/kg, $K = 0.65$ W/mK, $\mu = 0.47 \times 10^{-3}$ kg/ms. **(12 Marks)**

8 a. State and prove Wiens displacement law of radiation. **(06 Marks)**

b. The temperature of a black surface $0.2m^2$ in area is 540°C. Calculate:

i) The total rate of energy emission.

ii) The intensity of normal radiation.

iii) The wavelength of maximum monochromatic emissive power. **(06 Marks)**

c. Derive an expression for a radiation shape factor and show that it is a function of geometry only. **(08 Marks)**

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