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14MTP21

Second Semester M.Tech. Degree Examination, June/July 2016

Advanced Heat Transfer

Time: 3 hrs. Max. Marks: 100

Note: 1. *Answer any FIVE full questions.*
2. *Use of heat transfer data hand book is permitted.*

1 a. Derive 3-D governing heat conduction equation in Cartesian co-ordinate system. **(08 Marks)**

b. A brick work of a furnace is built up of layers laid up of fire clay (K_1 = 0.93 W/m-K) and red brick (K_3 = 0.7 W/m-K) and the space between the two is filled with crushed diatomite brick (K_2 = 0.13 W/m-K). The thickness of fire clay, diatomite filling and red brick are 12 cm, 5 cm and 25 cm respectively.
What should be thickness of the red brick layer if the brick work is to be laid without diatomite filling between the two layers, so that heat flux remains constant? **(06 Marks)**

c. A wire of 6.5 mm diameter at a temperature of 60°C is to be insulated by a material having K= 0.17 W/m°C, convection heat transfer co-efficient h_0 = 8.722 W/m^2°C. The ambient temperature is 20°C. For maximum, heat loss, what is the thickness of insulation and heat loss per metre length? Find the percentage increase in the heat dissipation too. **(06 Marks)**

2 a. Consider steady state heat conduction in a rectangular region $0 \le x \le 3b$, $0 \le y \le 2b$, subjected to the boundary conditions shown in Fig. Q2 (a). Using finite difference method, determine the system of equations for nodal temperatures T_m, m = 1 to 6. **(10 Marks)**

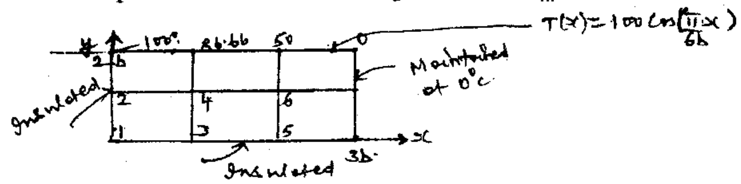

Fig. Q2 (a)

b. A marble slab $\left[(K = 2W/m^\circ C),\left(\alpha = 1\times10^{-6}\frac{m^2}{s}\right)\right]$ that is L = 2 cm, thick is initially at a uniform temperature $T_i = 200^0C$. Suddenly, one of the surfaces (right) is lowered to 0°C and is maintained at that temperature, while the other surface (left) is kept insulated. Develop the explicit finite difference scheme using explicit method for determination of transient temperatures upto 24 seconds. Take $\Delta x = 0.4$ cm. **(10 Marks)**

3 a. A flat surface with area A, is completely enclosed by a second surface with area A_2. Determine the view factors F_{1-2}, F_{2-1} and F_{2-2}. **(08 Marks)**

b. Two large parallel planes with emissivity 0.6 are at 900 K and 300 K. A radiation shield with one side polished with $\in = 0.05$, while the emissivity of the other side 0.4 is proposed to be used. Which side of the shield should face the hotter plane, if the temperature of the shield is to be kept minimum? Justify your answer. **(12 Marks)**

4 a. Derive the momentum equation for laminar boundary layer over a flat plate. **(12 Marks)**

b. Derive the Reynolds – Colburn analogy for flow over flat plate : $St_x.PV^{2/3} = \frac{C_{fx}}{2}$. **(08 Marks)**

5 a. A sheet metal air duct carries air conditioned air at an average temperature of 10°C. The duct size is 320 mm × 200 mm and length of the duct exposed to the surrounding air at 30°C is 15 m long. Find the heat gain by the air in the duct. Assume 200 mm side is vertical and top surface of the duct is insulated. Use the following correlations:

$N_u = 0.6(Gr.Pr)^{0.25}$ for vertical surfaces

$N_u = 0.27(Gr.Pr)^{0.25}$ for horizontal surfaces. **(12 Marks)**

b. A transformer is cooled by immersing in an oil bath, which is housed in a cylindrical tank which is 0.8 m in diameter and 1.3 m long. If the electrical loss is 1.3 kW, calculate the surface temperature of the tank; the electrical energy may be assumed to be entirely lost to the ambient by free convection from the bottom of the tank. Use following correlations,

$h = 1.35\left(\frac{\Delta T}{L}\right)^{0.25}$ - for cylindrical plane.

$h = 1.45\left(\frac{\Delta T}{L}\right)$ - for vertical plane.

Assume ambient temperature to be 20°C. **(08 Marks)**

6 a. The underside of a crank core of an automobile engine is cooled by air flowing past it at the speed of the automobile. For a particular engine which can be approximated as a flat plate of 100cm × 25cm. Find the rate of heat loss if surface temperature is 75°C when the automobile is moving at 72 km/hr. Assume that the boundary layer becomes turbulent from the leading edge.

Take properties of air as:

$\gamma = 16.6 \times 10^{-6}$ m²/s, K = 0.028 W/m.K, $P_r = 0.7$, Air temperature = 25°C.

Use colburn's Rocal equation: $Nu_x = 0.029(Re_x)^{0.8}(P_r)^{0.33}$. **(10 Marks)**

b. Air at 35°C flows across a cylinder of 50 mm diameter at a velocity of 50 m/s. The cylinder surface is maintained at 145°C. Calculate heat loss per unit length of the cylinder. Take properties of air at mean temperature of 90°C.

$\rho = 0.97$ kg/m³, $\mu = 20 \times 10^{-6}$ kg/m-s, K = 0.0312 W/m-K, $P_V = 0.7$ **(10 Marks)**

7 a. Derive an expression for effectiveness of a counter flow heat exchanger in terms of NTU and heat capacity ratio of fluids (C). **(10 Marks)**

b. Water at a mean temperature of $T_m = 80^\circ C$ and a mean velocity of $u_m = 0.15$ m/s flows inside a 2.5 cm-ID, thin walled copper tube.

Atmospheric air at $T_\infty = 20^\circ C$ and a velocity of $u_\infty = 10$ m/s flows across the tube. Neglecting the tube well resistance. Calculate the overall heat transfer co-efficient and the rate of heat loss per meter length of the tube. **(10 Marks)**

8 a. Using Nusset's theory derive the expression for local heat transfer co-efficient for film condensation on a vertical surface. **(10 Marks)**

b. A 12 cm outside diameter and 2 m long tube is used in a big condenser to condense the steam of 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 cases.

The saturation temperature of the steam = 74.5°C and average well temperature = 25°C. Properties of water film at mean temperature are:

$\rho = 982.2$ kg/m³, $h_{fg} = 2480$ kJ/kg, K = 0.85 W/m-K, $\mu = 0.47 \times 10^{-3}$ kg/m-s. **(10 Marks)**

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