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Second Semester M.Tech. Degree Examination, June/July 2015
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. Consider a solid cylinder of radius r = b in which energy is generated at constant rate of g_0 W/m^3, while the boundary surface at rature T_2. Develop an expression for the one dimensional, radial, steady state temperature distribution T(r) and the heat flux q (r) Calculate the center temperature (T(0) and the heat flux at the boundary surface r =b for b =1cm, $g_0 = 2 \times 10^8$ W/m^3. **(10 Marks)**

b. In a semi infinite cylinder of radius R, the flat surface of the cylinder is insulated and the curved surface is exposed to a medium at T_∞ with a surface heat transfer coefficient h, The cylinder is generating heat at a uniform rate of $q''' \, W/m^3$. Write the governing differential equation and the relevant boundary conditions to determine the two dimensional steady state temperature distribution T (r, o) in the semi cylinder.. **(06 Marks)**

c. Explain briefly how do you measure the temperature error of a thermometer pocket by using the fin analysis. **(04 Marks)**

2 a. A metallic sphere of radius 10mm is initially at a uniform temperature of 400°C. it is heat treated by first cooling it in air (b = 10W/m^{2}k) at 20°C until its central temperature reaches 335°C. It is then quenched in a water until the centre of the sphere cools from 335°C to 50°C. Compute the time required for cooling in air and water for the following physical properties of the sphere.
p = 3000 kg/m^3, C_p= 1000 J/kg k, k = 20 W/mk
$\alpha = 6.66 \times 10^{-6}$ m^2/Sec.
Also calculate the surface temperature at the end of cooling in water. **(10 Marks)**

b. What do you mean by conduction shape factor. **(02 Marks)**

c. A small cubical furnace 0.5m × 0.5m × 0.5m on the inside is constructed of fireclay brick (k = 1.04 W/m°C) with a wall thickness of 100mm. The inside surface of the furnace is maintained at 500°C and the outside surface of the furnace is maintained at 50°C. Calculate the conductions shape factor for the furnace and determine the heat loss through the walls. **(08 Marks)**

3 a. Define the following wits respect to radiation i) solid angle ii) Radiosity iii) Intensity of radiation iv) Irradiation. **(04 Marks)**

b. Show that the radiation shape factor for a small area dA_1 to a circular disk A_2 of diameter D which are parallel to each other with a normal distance L between them is given by

$$F_{dA_1-A_2} = \frac{D^2}{4L^2 + D^2}$$ **(06 Marks)**

c. A room 5m × 5m × 2.5m is heated by electric beating provided in the ceiling. If the ceiling surface temperature is maintained at 45°C and the temperature of the wall is 25°C in equilibrium condition, find the total heat lost from ceiling by radiation
ε (emissivity of ceiling) = 0.75
ε(emissivity of wall) = 0.65
Assume the floor is non sensitive to radiation. **(10 Marks)**

4 a. Derive the wavier stokes differential equation for two dimensional income pressible viscous fluids. Reduce the equation for the laminar boundary layer on a flat plate. State also the assumptions made. **(12 Marks)**

b. Air at 30°C flows over C flat plate. With a velocity of 20m/Sec. the plate is 0.4m wide and 0.75m long. Estimate the length of the plate over which the flow is laminar and the rate of heat transfer from the entire plate. Assuming the plate is maintained at 90°C. Properties of air at $\frac{30+90}{2} = 60^\circ C$ are

$v = 18.97\times10^{-6}\ m^2/Sec$, $Pr = 0.696$

$k = 28.96\times10^{-3}\ W/mk$. **(08 Marks)**

5 a. Air at atmospheric pressure and temperature T_1 = 325k flows through a tube bundle in inline tube arrangement. Tubes have an outside diameter D = 1.9cm and are maintained at a uniform temperature T_w = 375k. The longitudnal and transverse. Pitches for the bundle are given by $\frac{S_T}{D} = \frac{S_L}{D} = 2$

The bundle consists of tubes L = 0.75m long tubes, N = 15 tube rows in the direction of flow, and m = 20 tubes per row. The air velocity just before the tube bank is $U_\infty = 8m/Sec$

i) Determine the heat transfer coefficient hm

ii) Find the exit temperature of air

iii) Determine the total heat transfer rate Q.

The properties of air are evaluated at mean temperature of 350k. **(12 Marks)**

b. Water is heated while flowing through a 2cm × 4cm rectangular cross section tube at a velocity of 1.5 m/Sec. The entering temperature of water is 40°C and the tube wall is maintained at 85°C. Determine the length of the tube required to raise the temperature of water to 70°C. Properties of water to be taken at the mean bulk temperature of 55°C are

$\rho = 985.5 Kg/m^3$ $c_p = 4.18 kJ/kg\ k$

$r = 0.517 \times 10^{-6}\ m^2/Sec$ k = 0.654 W/mk, pr = 3.26 **(08 Marks)**

6 a. Define and explain the significance of i) Reynold number ii) Groshoff number iii) Nusselt number. **(06 Marks)**

b. A block 10cm × 10cm × 10cm in size is exposed in still air of 10°C with one of its surface in horizontal position. All surfaces of the block are maintained at 150°C. Determine the total heat transfer rate from the block. **(14 Marks)**

7 a. Obtain expression for the effectiveness of the Heat exchanger. Operating in counter flow mode. **(08 Marks)**

b. In a parallel flow Heat exchanger engine oil enters a heat exchanger at 150°C and leaves at 80°C. The cooling water enters at 30°C and leaves at 65°C.

For the same flow rates and the inlet conditions, find

i) Exit temperature of each stream in counter flow heat exchanger.

ii) Maximum effectiveness that can be obtained for both parallel and counter flow Heat exchanger by increasing the length of the heat exchangers. **(12 Marks)**

8 a. A 12cm outside diameter and 2m long tube is used in a big condenser to condense the steam at 0.4 bar. Estimate the heat transfer coefficient and the amount of condensate formed per hour when the tube is held in

i) Vertical position

ii) Horizontal position

The saturation temperature of steam at 0.4 bar $= 75.4^\circ C$

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

$\rho = 982.2\ Kg/m^3$, $h_{fg} = 2480 kJ/Kg$

$K = 0.65$, $\tau = 0.47 \times 10^{-3}\ kg/ms$ **(10 Marks)**

b. Water at atmospheric pressure and saturation temperature is boiled in a 25cm diameter, electrically heated, mechanically polished, stanless steel pan. The heated surface of the pan is maintained at a uniform temperature $T_w = 116^\circ C$.

i) Calculate the rate of evaporation for the pan.

ii) Calculate the peak heat flux. **(10 Marks)**

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