USN

15ME63

Sixth Semester B.E. Degree Examination, July/August 2021
Heat Transfer

Time: 3 hrs. Max. Marks: 80

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

1 a. Define the following giving units : (i) Overall heat transfer coefficient. (ii) Radiations heat transfer coefficient. (iii) Thermal resistance. **(06 Marks)**

b. A composite slab is made of two layers of different materials A and B such that, layer A has conductivity as $K_A = 0.5(1+0.08T)$ and is 5 cm thick, while the layer B has conductivity 24 W/mK and is 2 cm thick. The exposed surface of layer A is insulated while that of the layer B is exposed to the fluid at 20°C where the heat transfer coefficient is 30 W/m^2K. If the temperature at the interface between the two layers is 70°C, find
(i) Rate of heat flux from the slab to fluid. (ii) Maximum temperature in the system.
(iii) Distance of a point at 80°C from insulated surface. **(10 Marks)**

2 a. Explain in brief the terms initial and boundary conditions. What are the boundary conditions of I, II and IIIrd kinds. **(06 Marks)**

b. A square plate heater size (15 cm × 15 cm) is inserted between two slabs, slab A is 2 cm thick (K = 50 W/mK) and slab B is 1 cm thick (K = 0.2 W/mK). The outside heat transfer coefficient on both sides of A and B are 200 and 50 W/m^2K respectively. The temperature of surrounding air is 25°C. If the rating of the heater is 1 kW, find
(i) Maximum temperature in the system. (ii) Outer surface temperature of two slabs.
Draw equivalent electrical circuit of system. **(10 Marks)**

3 a. Obtain an expression for the critical radius of insulation for a spherical shell. Give a physical explanation for the fact that certain thickness of insulation may increase the rate of heat loss rather than reduce it. **(06 Marks)**

b. Differentiate between effectiveness and efficiency of fin. **(02 Marks)**

c. Two rods A and B of equal diameter and equal length, but of different materials are used as fins. Both the rods are attached to a plain wall maintained at 160°C, while they are exposed to air at 30°C. The end temperature of rod A is 100°C, while that of the rod is 80°C. If the thermal conductivity of rod A is 380 W/mK, calculate the thermal conductivity of rod B. This fin can be assumed as short with end insulated. **(08 Marks)**

4 a. Obtain an expression for the instantaneous heat transfer and total heat transfer for lumped heat analysis treatment of unsteady state heat conduction problem. **(08 Marks)**

b. A metallic sphere of radius 10 mm is initially at a uniform temperature of 400°C. It is heat treated by first cooling it in air (h = 10 W/m^2K) at 20°C until its central temperature reaches 335°C. It is then quenched in a water bath at 20°C with $h = 6000\ W/m^2K$ 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:
$\rho = 3000\ kg/m^3$, C_p = 1000 J/kgK, K = 20 W/mK, $\alpha = 6.66 \times 10^{-6}\ m^2/sec$. **(08 Marks)**

5 a. An iron rod L = 5 cm long of diameter D = 2 cm with thermal conductivity K = 50 W/m°C protrudes from a wall and is exposed to an ambient at T_∞ = 20°C and h = 100 $W/m^2{}^\circ C$. The base of the rod is at T_o = 320°C and its tip is insulated. Assuming one dimensional steady state heat flow, calculate the temperature distribution along the rod and the rate of heat loss into the ambient by using finite differences. **(12 Marks)**

b. Explain the graphical method of solving two dimensional heat conduction problems. **(04 Marks)**

6 a. For a black body enclosed in a hemispherical space, prove that emissive power of the black body is π times the intensity of radiation. **(08 Marks)**

b. Consider two large parallel plates, one at 1000 K with emissivity 0.8 and other is at 300 K having emissivity 0.6. A radiation shield is placed between them. The shield has emissivity as 0.1 on the side facing hot plate and 0.3 on the side facing cold plate. Calculate percentage reduction in radiation heat transfer, as a result of radiation shield. **(08 Marks)**

7 a. With reference to fluid flow over a flat plate, discuss the concepts of velocity boundary layer and thermal boundary layer with necessary sketches. **(06 Marks)**

b. Air at 20˚C and at a atmospheric pressure flows over a flat plate at a velocity of 3 m/sec. If the plate is 30 cm length and at a temperature of 60˚C, calculate

(i) Velocity and thermal boundary layer thicknesses at 20 cm

(ii) Average heat transfer coefficient and total drag force over the entire plate per unit width.

Take the following properties of air $\rho = 1.18\ \text{kg/m}^3$, $\gamma = 17 \times 10^{-6}\ \text{m}^2\text{/sec}$, K = 0.0272 W/mK, C_P = 1.007 kJ/kgK, P_r = 0.705 **(10 Marks)**

8 a. Water is heated while flowing through a circular pipe of 2.1 cm diameter, with a velocity of 1.2 m/sec. The entering temperature of water is 40˚C and the tube wall is maintained at 80˚C. Determine the length of the tube required to raise the temperature of water to 70˚C. Properties of water at mean bulk temperature of 55˚C are,

$\rho = 985.5\ \text{kg/m}^3$; C_p = 4.18kJ/kgK, $\gamma = 0.517 \times 10^{-6}$, K = 0.654 W/mK, P_r = 3.26. **(08 Marks)**

b. A hot square plate 50 cm × 50 cm maintained at uniform temperature of $T_W = 385\text{K}$ which is placed in quiescent air at atmospheric pressure and T_∞ = 315 K. Find the heat loss from both surfaces of the plate if the plate is kept in vertical plane.

The physical properties of atmospheric air at,

$T_f = \frac{1}{2}(385 + 315) = 350\ \text{K}$ are taken as $\gamma = 2.076 \times 10^{-5}\ \text{m}^2\text{/sec}$, P_r = 0.697,

K = 0.03 W/m˚C, $\beta = \frac{1}{T_f} = 2.86 \times 10^{-3}\ \text{K}^{-1}$. **(08 Marks)**

9 a. For a heat exchanger with equal heat capacity rates of hot and cold fluids $\left[(mC_P)_{hot} = (mC_P)_{cold}\right]$ obtain the expressions for the effectiveness of heat exchanger operating in parallel and counter flow mode as,

$\varepsilon = \frac{1 - \exp(-2NTU)}{2}$ and $\varepsilon = \frac{NTU}{NTU + 1}$ respectively. **(08 Marks)**

b. An automobile radiator has 40 tubes of inner diameter of 0.5 cm and 60 cm long in a closely spaced plate finned matrix, so that both fluids are unmixed. Hot water enters the tubes at 90˚C at a rate of 0.6 kg/sec and leaves at 65˚C. Air flows across the radiator through the interfin spaces and is heated from 20˚C to 40˚C. Calculate the overall heat transfer coefficient based on inner surface of the radiator. **(08 Marks)**

10 a. Explain the following terms as applied to heat exchangers:

(i) LMTD correction factor.

(ii) Fouling factor. **(08 Marks)**

b. Clearly explain the regimes of pool boiling with neat sketches. **(06 Marks)**

c. Differentiate between dropwise and filmwise condensation. **(02 Marks)**

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