Code : 021616

B.Tech 6th Semester Exam., 2019

HEAT AND MASS TRANSFER

Time : 3 hours *Full Marks* : 70

Instructions :

(i) The marks are indicated in the right-hand margin.

*(ii) There are **NINE** questions in this paper.*

*(iii) Attempt **FIVE** questions in all.*

(iv) Question No. 1 is compulsory.

1. Choose the correct answer of the following (any *seven*) : 2×7=14

(a) Up to the critical radius of insulation

(i) added insulation will increase heat loss

(ii) added insulation will decrease heat loss

(iii) convective heat loss will be less than conductive heat loss

(iv) heat flux will decrease

(b) Unit of thermal diffusivity is

(i) m^2/hr *(ii)* $m^2/hr\,°C$

(iii) $kcal/m^2\,hr$ *(iv)* $kcal/m\,hr\,°C$

(c) The rate of energy transferred by convection to that by conduction is called

(i) Stanton number

(ii) Nusselt number

(iii) Biot number

(iv) Peclet number

(d) Thermal conductivity of wood depends on

(i) moisture

(ii) density

(iii) temperature

(iv) All of the above

(e) LMTD in case of counter flow heat exchanger as compared to parallel flow heat exchanger is

(i) higher

(ii) lower

(iii) same

(iv) depends on the area of heat exchanger

(f) The transfer of heat by molecular collision is smallest in

(i) solids

(ii) liquids

(iii) gases

(iv) None of the above

(g) In a shell and tube heat exchanger, baffles are provided on the shell side to

(i) improve heat transfer

(ii) provide support for tubes

(iii) prevent stagnation of shell side fluid

(iv) All of the above

(h) Joule-sec is the unit of

(i) universal gas constant

(ii) kinematic viscosity

(iii) thermal conductivity

(iv) Planck's constant

(i) Which of the following is the case of heat transfer by radiation?

(i) Blast furnace

(ii) Heating of buildings

(iii) Cooling of parts in furnace

(iv) Heat received by a person from fireplace

(j) The thickness of thermal and hydrodynamic boundary layer is equal, if Prandtl number is

(i) equal to one

(ii) greater than one

(iii) less than one

(iv) equal to Nusselt number

2. (a) What is the difference between thermodynamics and heat transfer? 3

(b) What are the mechanisms of heat transfer? How are they distinguished from each other? 3

(c) The temperature distribution across a wall 1 m thick at a certain instant of time is given as

$$T(x) = a + bx + cx^2$$

where T is in degrees Celsius and x is in meters, while $a = 900\ °C$, $b = -300\ °C/m$ and $c = -50\ °C/m^2$. A uniform heat generation $q = 1000\ W/m^3$ is present in the wall of area $10\ m^2$ having the properties $\rho = 1600\ kg/m^3$, $k = 40\ W/m.K$ and $C_p = 4\ kJ/kg\text{-}K$.

(i) Determine the rate of heat transfer entering the wall ($x = 0$) and leaving the wall ($x = 1$ m).

(ii) Determine the rate of change of energy storage in the wall.

(iii) Determine the time rate of temperature change at $x = 0$ m, 0·25 m and 0·5 m. 8

3. *(a)* Consider a large plane wall of thickness $L = 0 \cdot 2$ m, thermal conductivity $k = 1 \cdot 2$ W / m °C and surface area $A = 15$ m^2. The two sides of the wall are maintained at constant temperatures of $T_1 = 120$ °C and $T_2 = 50$ °C, respectively, as shown in Fig. 1 below :

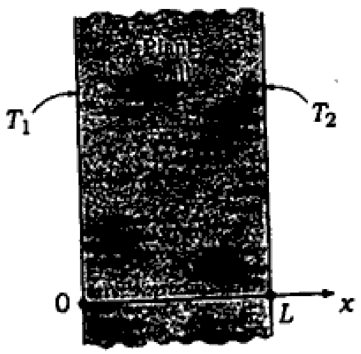


Fig. 1

Determine *(i)* the variation of temperature within the wall and the value of temperature at $x = 0 \cdot 1$ m and *(ii)* the rate of heat conduction through the wall under steady conditions. 7

(Turn Over)

(b) Find the heat flow rate through the composite wall as shown in Fig. 2 below. Assume one-dimensional flow : 7

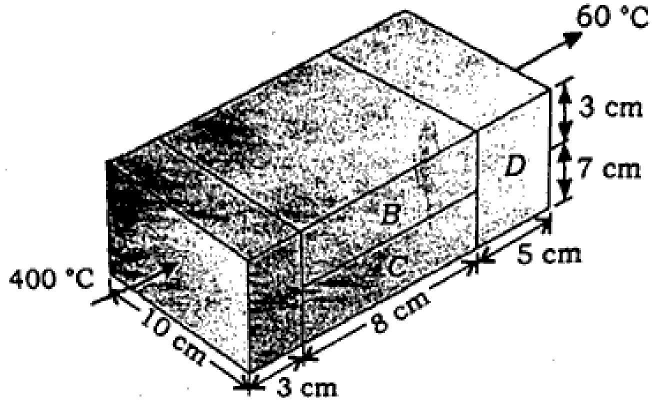


Fig. 2

4. *(a)* What is the difference between the fin effectiveness and the fin efficiency? 5

(b) One end of copper rod ($k = 380$ W / m°C) 300 mm long is connected to wall which is maintained at 300 °C. The other end is firmly connected to a wall which is maintained at 100 °C. Air is blown across the rod so that heat transfer coefficient of 20 W / m^2 °C is maintained. The diameter of the rod is 15 mm and temperature of air is 40 °C. Determine the net heat transferred to the air and the heat conducted to the other end which is at 100 °C. 9

5\. (a) What is lumped system analysis? When is it applicable? 5

(b) A refrigerant suction line having outer diameter 30 mm is required to be thermally insulated. The outside air-film coefficient of heat transfer is 12 $W/m^2 °C$. The thermal conductivity of the insulation is 0·3 W/m°C.

(i) Determine whether the insulation will be effective.

(ii) Estimate the maximum value of thermal conductivity of insulating material to reduce heat transfer.

(iii) Determine the thickness of cork insulation to reduce the heat transfer to 22 percent if the thermal conductivity of the cork 0·038 W/m°C. 9

6\. (a) What is the physical significance of the Prandtl number? Does the value of the Prandtl number depend on the type of flow or the flow geometry? Does the Prandtl number of air change with pressure? 5

(b) The temperature of a gas stream is to be measured by a thermocouple whose junction can be approximated as a 1 mm diameter sphere, as shown in Fig. 3 below. The properties of the junction are $k = 35\ W/m°C$, $\rho = 8500\ kg/m^3$, $C_p = 320\ J/kg°C$ and the convection heat transfer coefficient between the junction and the gas is $h = 210\ W/m^2 °C$:

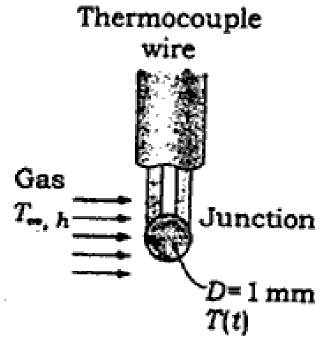


Fig. 3

Determine how long it will take for the thermocouple to read 99 percent of the initial temperature difference. 9

7\. (a) Air is flowing over a flat plate 5 m long and 2·5 m wide with a velocity of 4 m/s at 15 °C. If $\rho = 1 \cdot 208\ kg/m^3$ and $\nu = 1 \cdot 47 x\ 10^{-5}\ m^2/s$, calculate—

(i) the length of plate over which the boundary layer is laminar and thickness of the boundary layer (laminar);

(ii) shear stress at the location where boundary layer ceases to be laminar;

(iii) the total drag force on the both sides on that portion of plate where boundary layer is laminar. 7

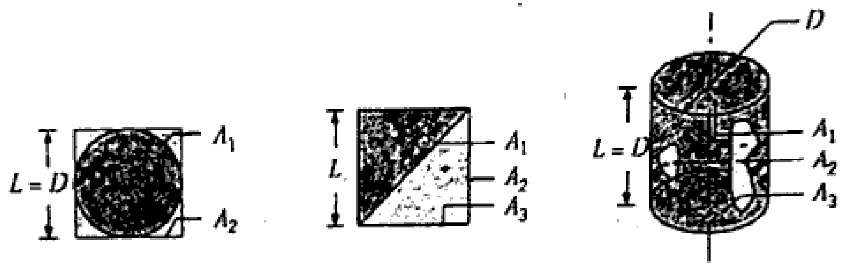
(b) A double-pipe (shell and tube) heat exchanger is constructed of a stainless steel ($k = 15 \cdot 1$ W/m.°C) inner tube of inner diameter $D_i = 1 \cdot 5$ cm and outer diameter $D_o = 1 \cdot 9$ cm and an outer shell of inner diameter 3·2 cm. The convection heat transfer coefficient is given to be $h_i = 800$ W/m^2°C on the inner surface of the tube and $h_o = 1200$ W/m^2°C on the outer surface. For a fouling factor of $R_{f,i} = 0 \cdot 0004$ m^2°C/W on the tube side and $R_{f,o} = 0 \cdot 0001$ m^2°C/W on the shell side, determine (i) the thermal resistance of the heat exchanger per unit length and (ii) the overall heat transfer coefficients, U_i and U_o based on the inner and outer surface areas of the tube, respectively. 7

8. (a) Derive an expression for logarithmic mean temperature difference (LMTD) in case of counter flow heat exchanger. 5

(Turn Over)

(b) Define the terms absorptivity, reflectivity and transmissivity of the radiation with the diagram. 3

(c) Determine the view factors F_{12} and F_{21} for the following geometries (Fig. 4) : 6



(1) (2) (3)

Fig. 4

9. (a) Consider two large parallel plates at $T_1 = 727$ °C with emissivity $\varepsilon_1 = 0 \cdot 8$ and other at $T_2 = 227$ °C with emissivity $\varepsilon_2 = 0 \cdot 4$. An aluminium radiation shield with emissivity $\varepsilon_s = 0 \cdot 05$ on the both sides is placed between the plates. Calculate the percentage reduction in heat transfer rate between two plates as a result of the shield. 7

(Continued)

(b) State Fick's law of diffusion. What are its limitations? 5

(c) Give examples for (i) liquid to gas, (ii) solid to liquid, (iii) solid to gas and (iv) gas to liquid mass transfer. 2

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