Code : 122101

M.Tech 1st Semester Exam., 2018

HEAT TRANSFER—I; CONDUCTION AND RADIATION HEAT 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.*

(v) Heat Transfer data book is allowed.

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

(a) What is the advantage of using the spherical vessel to store fluids at low temperature?

(i) Heat transfer in sphere is restricted in all directions by insulation

(ii) Sphere has the smallest volume per unit surface area

(iii) Sphere has the largest volume per unit surface area

(iv) None of the above

(b) The critical radius of a hollow sphere having thermal conductivity k and h_0 as convecting heat transfer coefficient of outer fluid is given by

(i) h_0 / k

(ii) k / h_0

(iii) $2k / h_0$

(iv) $h_0 / 2k$

(c) Gases absorb and emit radiant energy

(i) in all wavelengths over the entire spectrum ($\lambda = 0$ to ∞)

(ii) only between narrow ranges of wavelengths

(iii) only at single-constant wavelength

(iv) Unpredictable

(d) Which of the following gases is/are capable to emit and to absorb radiant heat energy?

(i) Carbon dioxide (CO_2)

(ii) Sulphur dioxide (SO_2)

(iii) Ammonia (NH_3)

(iv) All of the above

(e) Consider a plane wall of finite thickness having energy generation in it. The sum of the rate of heat energy generation in the wall and rate of energy transfer by conduction into the wall is equal to

(i) rate of heat transfer by conduction out of the wall

(ii) rate of heat transfer by convection out of the wall

(iii) Both (i) and (ii)

(iv) None of the above

(f) What is the purpose of using fins in a particular heat transfer system?

(i) To decrease rate of heat transfer

(ii) To increase rate of heat transfer

(iii) To maintain rate of heat transfer at a constant rate

(iv) Cannot say

(g) Internal resistance in heat transfer means

(i) radiation resistance

(ii) convective resistance

(iii) conductive resistance

(iv) None of the above

(h) Laplace equation in heat transfer deals with

(i) steady state of heat transfer

(ii) unsteady state of heat transfer

(iii) steady as well as unsteady states of heat transfer

(iv) None of the above

(i) In transient heat conduction, the two significant dimensionless parameters are

(i) Reynolds number and Fourier number

(ii) Reynolds number and Biot number

(iii) Reynolds number and Prandtl number

(iv) Biot number and Fourier number

(j) According to lumped system analysis, solid possesses thermal conductivity that is

(i) infinitely large

(ii) infinitely small

(iii) moderate

(iv) 50% small

2. 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 degree Celsius and x is in meter, 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 $C_p = 4\ kJ/kg\ K$.

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

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

   (c) Determine the time rate of temperature change at $x = 0$, $0 \cdot 25$ and $0 \cdot 5$ m. 14

3. A spherical electronic device of 10 mm diameter generates 1 W. It is exposed to air at 20 °C with a convection coefficient of $20\ W/m^2K$. Find the surface temperature. The heat transfer consultant advices to enclose it in a glass-like material of $k = 1 \cdot 4\ W/m\ K$, to a thickness of 5 mm all around to reduce the temperature. Investigate the problem and also find the thickness to obtain 50 °C surface temperature. 14

4. A cylinder of 12 cm diameter has a heat generation rate $106\ W/m^3$. The conductivity of the material is 200 W/m K. The surface is exposed to air at 30 °C. The convection coefficient is $500\ W/m^2K$. Determine the temperatures at the center and also at mid radius. Also determine the heat flow at the surface on unit area basis. Calculate the temperature gradients at the mid radius and surface. 14

5. (a) In a sphere of radius R, the heat generation rate varies with the radius r as $q = q_0[1 - (r/R)^2]$. If the thermal conductivity is k, derive the expression for the temperature variation with radius. 7

   (b) A nuclear fuel element is in the form of a solid sphere of $12 \cdot 5$ mm radius. Its thermal conductivity is $24 \cdot 2\ W/m\ K$. The heat generation rate is $50 \times 106\ W/m^3$. The heat generated is absorbed by a fluid at 200 °C. If the maximum temperature is limited to 360 °C, determine the convection coefficient required. 7

(Continued)

6. *(a)* Explain how the fin effectiveness and fin efficiency vary with length. 7

(b) The outer diameter of a small engine cylinder is 56 mm. Determine the heat dissipation by a circumferential fin of 4 mm thickness and 40 mm length if $k = 210\ \mathrm{W/m\ K}$ and $h = 115\ \mathrm{W/m^2K}$. The base temperature is 200 °C and surroundings are at 35 °C. 7

7. *(a)* Explain an analytical method for solving two-dimensional steady-state heat conduction problem. 7

(b) A heater of 5 mm diameter and 90 mm length is fitted in a vertical hole in a metal with a conductivity of 12·5 W/m K, whose surface is at 20 °C. If the heater dissipates 60 W, determine the temperature of the heater surface. 7

8. *(a)* State and prove Kirchhoff's law for heat radiation. 7

(b) Determine the shape factor from the base of a cylinder to the curved surface. Also find the shape factor from curved surface to base and the curved surface to itself. 7

9. Two large parallel planes are at 1000 K and 600 K. Determine the heat exchange per unit area *(a)* if surfaces are black, *(b)* if the hotter one has an emissivity of 0·8 and the cooler one 0·5 and *(c)* if a large plate is inserted between these two, the plate having an emissivity of 0·2. 14

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