Name : DIBYAnarayan Hazra

Roll No. : 071480107045

Invigilator's Signature : ....

CS/B.Tech(ME/PE/PWE)/SEM-5/ME-502/2009-10

2009

HEAT TRANSFER

Time Allotted : 3 Hours   Full Marks : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives of the following :

$10 \times 1 = 10$

i) A composite wall consists of three different materials having thermal conductivities, k, $2k$, $4k$ respectively. The temperature drop across different materials will be in the ratio

a) 1 : 1 : 1 b) 1 : 2 : 4

c) 4 : 2 : 1 d) 2 : 4 : 1.

ii) A decrease in heat transfer coefficient over the surface of a pin fin

a) decreases its effectiveness

b) increases its effectiveness

c) does not affect its effectiveness

d) first increases and then decreases its effectiveness.

iii) For free convection, Nusselt number is a function of

a) Prandtl and Grashoff numbers

b) Reynolds and Grashoff numbers

c) Grashoff number only

d) Reynolds and Prandtl numbers.

iv) Thermal diffusivity of substance is given by

a) $\rho c/k$

b) $k/\rho c$.

c) $k c/\rho$

d) $d/k\rho$.

v) For fluid having Prandtl number unity the thickness of thermal boundary layer is

a) equal to velocity boundary layer

b) more than velocity boundary layer

c) less than velocity boundary layer

d) none of these.

vi) The dimensionless number which represents the relative importance of momentum and energy transport by diffusion is

a) Nusselt number

b) Prandtl number

c) Reynolds number

d) Eckert number.

vii) Transient conduction means

a) heat transfer wtih small temperature difference

b) variation of temperature with time

c) heat transfer for a short time

d) very little heat transfer.

viii) Stanton number is the ratio of

a) Reynolds number to Prandtl number

b) Prandtl number to Nusselt number

c) Nusselt number to Peclet number

d) Peclet number to Reynolds number.

ix) Rayleigh-Jeans law holds for radiation of

a) large frequencies

b) short wavelengths

c) large wavelengths

d) any wavelength.

x) The radiant heat exchange between two surfaces depends on

a) their view factors

b) their emissivity and absorptivity

c) the intervening medium

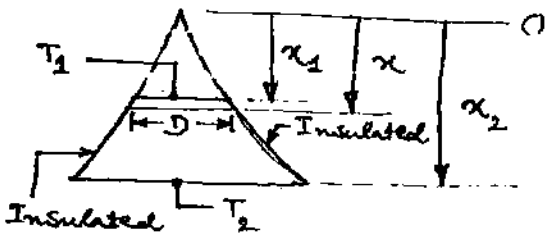
d) all of these.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 1$

2. A truncated solid cone is of circular cross-section, and its diameter is related to the axial coordinate by an expression of the form $D = ax^{3/2}$, where $a = 1{\cdot}0\ \text{m}^{-1/2}$. The sides are well-insulated, while the top surface of the cone at x_1 is maintained at T_1 and the bottom surface at x_2 is maintained at T_2.



i) Obtain an expression for the temperature distribution.

ii) What is the rate of heat transfer across the cone if it is constructed of pure aluminium ($k = 235$ W/m.K) with $x_1 = 0{\cdot}075$ m, $T_1 = 100$°C, $x_2 = 0{\cdot}225$ m and $T_2 = 20$°C ?

3. Write down the governing differential equations of velocity and temperature fields for a steady, two-dimensional flow of an incompressible, viscous fluid with constant properties. Explain the significance of each term in these equations.

fins are provided to increase the heat transfer rate from hot body surface. Find out which of the following arrangements will provide higher heat transfer rate ?

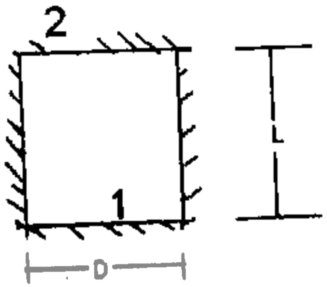
6 fins of 10 cm length

12 fins of 6 cm length.

given $k = 210$ W/mK, $h = 20\ \text{W/m}^2\text{K}$, cross-sectional area of fin $= 3\ \text{cm}^2$, perimeter of fin = 5 cm, fin base temperature = 240°C and surrounding temperature = 35°C.

What is critical thickness of insulation on a small diameter ? Explain its physical significance and derive an expression for the same.

What are radiation shape factors and why are they used ? Calculate the shape factor of a cylinder cavity, shown in *fig*. with respect to itself.



GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 =$

7. a) A plane wall of thickness $2L = 40$ mm and thermal conductivity $k = 5$W/m.K experiences uniform volumetric thermal energy generation at a rate $\dot{q}$ per unit volume, while convection heat transfer occurs at both of its surfaces ($x = -L, +L$), each of which is exposed to a fluid of temperature $T_\infty = 20$°C. Under steady state conditions, the temperature distribution in the wall is of the form $T(x) = a + bx + cx^2$, where, $a = 82$°C, $b = -210$°C/m, $c = -2 \times 10^4$°C/m² and x is in metres. The origin of the x-coordinate is at the mid-plane of the wall.

i) Sketch the temperature distribution.

ii) Determine $\dot{q}$.

iii) Obtain an expression for the heat flux distribution, $q_x''(x)$. Is the heat flux zero at any location ?

iv) What are the convection coefficients for the surfaces at $x = -L$ and $x = +L$?

v) If the source of thermal energy generation is suddenly deactivated ($\dot{q} = 0$), what is the rate of change of energy stored in the wall at this instant ?

vi) What temperature will the wall eventually reach with $\dot{q} = 0$? How much energy must be removed by the fluid per unit area of the wall (J/m ^{2}) to reach this state ? The density and specific heat of the wall material are 2600 kg/m ^{3} and 800 J/kg.K respectively. **8**

b) Two-dimensional, steady-state conduction occurs in a hollow cylindrical solid of thermal conductivity $k = 16$ W/m.K, outer radius $r_0 = 1$ m and overall length $2z_0 = 5$ m, where the origin of the coordinate system is located at the mid-point of the centre-line. The inner surface of the cyclinder is insulated, and the temperature distribution within the cylinder has the form $T(r, z) = a + br^2 + c\ln r + dz^2$ where $a = 20$°C, $b = 150$°C/m ^{2} , $c = -12$°C, $d = -300$°C/m ^{2} and r and z are in metres.

i) Determine the inner radius r_i of the cylinder.

ii) Find the volumetric rate of thermal energy generation per unit volume $\dot{q}$ (W/m^3).

iii) Determine the heat flux and the heat transfer rate at the outer surface. Are they into or out of the cylinder ?

iv) Determine the heat flux at the end faces of the cylinder. What are the corresponding heat transfer rates ? Are they into or out of the cylinder ?

v) Verify that your results are consistent with an overall energy balance on the cylinder. 7

8. a) An aluminium plate [$k = 160$ W/mK, $\rho = 2790$ kg/m^3, $C_p = 0.88$kJ/kg K] of thickness $L = 3$ cm and at a uniform temperature of $T_0 = 225^\circ$ C is suddenly immersed at time $t = 0$ in a well-stirred fluid maintained at a constant temperature $T_\infty = 25^\circ$ C. The heat transfer co-efficient between the plate and the fluid is $h = 320$ W/m^2 K. Determine the time required for the centre of the plate to reach 50° C. 8

b) Derive the expression for steady-state temperature in a slab for mixed boundary condition regarding lumped system analysis. 7

9. a) Derive the expression for effectiveness of counter-flow heat exchanger. 7

b) Engine oil is to be cooled from 80°C to 50°C by using a single pass, counter-flow, concentric tube heat exchanger with cooling water available at 20°C. Water flows inside a tube with an ID of $D_i = 25$ mm at a rate of $m_w = 0.08$ kg/s and oil flows through the annulus at a rate of $m_{oil} = 0.16$ kg/s. The heat transfer coefficient for water side and oil side are respectively $h_w = 1000$ W/m^2 K and $h_{oil} = 80$ W/m^2 K. The fouling factors are $F_w = 0.00018$ m^2 K/W and $F_{oil} = 0.00018$ m^2 K/W. Neglecting tube wall resistance, calculate tube length required.

Take :

$C_{p\ oil} = 2090$ J/kg K

$C_{p\ water} = 4180$ J/kg K. 8

10. a) Show that for parallel flow heat exchanger

$$\epsilon = \frac{1 - \exp[-NTU(1+R)]}{1+R}$$

$R = \frac{C_{min}}{C_{max}}$ with C_{min} and C_{max} having their usual meanings. 7

b) Water at the rate of 80 kg/min is heated from 40°C to 70°C by an oil having a specific heat of 1.85 kJ/kg-K. The fluids are used in a counter-flow double pipe heat exchanger and the oil is cooled from 100°C to 60°C in a counter-flow heat exchanger. Calculate the heat exchanger area assuming overall heat transfer coefficient of 300 W/m^2 K.

Using the same entering fluid temperatures, calculate the exit water temperature when only 40 kg of water per minute is heated and the same quanity of oil is used. **8**

11. a) Derive the equation for heat dissipation by a fin with an insulated tip

$$Q = \sqrt{hPkA}\,(T_0 - T_\infty)\tanh(mL)$$

by integrating the convective losses along its surface. 7

b) A sphere 30 mm in diameter initially at 800 K is quenched in a large bath having a constant temperature of 320 K with a heat transfer co-efficient of 75 W/m^2 K. The thermophysical properties of sphere material are $\rho = 400\ kg/m^3$, $C_p = 1600$ J/kg K, $k = 17$ W/m K.

i) Calculate the time required for the sphere to reach 415 K

ii) Calculate the time constant

iii) Determine the instantaneous heat flux at the outer surface of the sphere at the end of cooling

iv) Determine the energy that has been lost by the sphere during the whole process of cooling. **8**