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2013

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 for the following : $10 \times 1 = 10$

   i) The coefficient of thermal conductivity is defined as

      a) Quantity of heat transfer per unit area per one degree drop in temperature

      b) Quantity of heat transfer per one degree temperature drop per unit area

      c) Quantity of heat transfer per unit time per unit area

      d) Quantity of heat transfer per unit time per unit area per one degree temperature drop per unit length.

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ii) Thermal diffusivity of a substance is

a) Directly proportional to thermal conductivity

b) Inversely proportional to density of the substance

c) Inversely proportional to specific heats

d) All of these.

iii) The dimensionless number representing the relative importance of momentum and energy transport by diffusion process is

a) Nusselt number b) Prandtl number

c) Reynolds number d) Eckert number.

iv) Insulating materials which are used for low temperature application are

a) Asbestos b) Glass wool

c) Magnesia d) Diatomaceous earth.

v) With the rise in temperature, thermal conductivity of solid materials

a) increases

b) decreases

c) remains the same

d) first increases then decreases.

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vi) In the heat flow equation $Q = -kA(\nabla T/x)$, x/kA is known as

a) Thermal coefficient b) Thermal conductivity

c) Thermal resistance d) Temperature gradient.

vii) The temperature variation for heat conduction through a cylindrical wall having uniform k is

a) Linear b) Parabolic

c) Logarithmic d) Hyperbolic.

viii) Critical radius of insulation for wire is

a) k/h b) $2k/h$

c) $h/2k$ d) $2h/k$.

ix) At an insulated surface

a) Temperature drop per unit length is infinity

b) Temperature drop per unit length is zero

c) Temperature drop per unit length remains constant

d) Temperature drop per unit length is negative.

x) It is considered appropriate that area of cross-section, for a finned surface, be

a) Reduced along length

b) Increased along length

c) Maintained constant along length

d) None of these.

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GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. A steel ball [c = 0.46 kJ/kg °C, k = 35 W/m °C] 5.0 cm in diameter and initially at a uniform temperature of 450 °C is suddenly placed in a controlled environment in which the temperature is maintained at 100 °C. The convective heat transfer coefficient is 10 W/m °C. Calculate the time required for the ball to attain the temperature of 150 °C.

3. Air at atmospheric pressure and 40°C flows with a velocity of U = 5 m/s over a 2 m long flat plate whose surface is kept at a uniform temperature of 120°C. Determine the average heat transfer coefficient over the 2 m length of the plate by using exact solution. Also find out the rate of heat transfer between the plate and the air per 1 m width of the plate. [Air at 1 atm. and $\frac{120+40}{2}$ = 80°C, $\nu = 2.107 \times 10^{-5}$ m²/s, k = 0.03025 W/m°C; Pr = 0.7]

4. For a hot solid cylinder of radius r_0 with uniform rate of heat generation q per unit volume, conducting heat radially and losing heat from its surface to the ambient (at temperature T_∞ by convection with heat transfer coefficient h) prove that :

$$\frac{T_0 - T(r)}{T_0 - T_\infty - (qr_0/2h)} = \left(\frac{r}{r_0}\right)^2$$

Where $T(r)$ = temperature of the cylinder at a distance r from its axis And T_0 = axis temperature.

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5. a) Explain with the help of basic mechanisms of heat conduction, the reason behind low conductivity achieved in an insulating material.

   b) Derive an expression for "critical insulation thickness" for a sphere. 2 + 3

6. What is the physical significance of Biot number ? Is the Biot number more likely to be large for highly conducting solids or poorly conducting ones ?

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. a) If A is thin and long and tip loss is negligible, show that the heat transfer from the fin is given by $Q_0 = m\,k\,A\,\theta_0 \tanh(ml)$, where $m = (hP/kA)^{1/2}$. 7

   b) Fins, 12 in number, having k = 75W/mK and 0.75mm thickness protrude 25mm from a cylindrical surface of 50mm diameter and 1m length placed in an atmosphere of 40⁰C. If the cylindrical surface is maintained at 150⁰C and the heat transfer coefficient is 23W/m²K calculate (a) the rate of heat transfer, (b) the percentage increase in heat transfer due to fins, (c) the temperature at the centre of fins and (d) the fin efficiency and the fin effectivencess. 8

8. a) Show that total heat transfer from a finned wall is given by $Q = h\,\theta_0\,[A-(1-\eta_f)A_f]$ where A = total area of fin and unfinned surface, A_f = area of the finned surface. η_f = fin efficiency and $\theta_0 = T_0 - T_\infty$. 7

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b) A tube 2cm O.D. maintained at uniform temperature of T_i is covered with insulation (k = 0.20W/mK) to reduce heat loss to the ambient air at T_∞ with h_a = 15W/m^{2}K.

Find : (i) The Critical thickness r_c of insulation, (ii) the ratio of heat loss from the tube with insulation to that without insulation, (I) if the thickness of insulation is equal to r_c, (II) if the thickness of insulation is (r_c + 2) cm. 8

9. a) Write down the expression for X and Y momentum & energy equation for steady two-dimensional flow of an incompressible, constant property Newtonian flow. Also describe significance of each term. 6

b) A large vertical plate of 4m height is maintained at 60°C and exposed to air at 10°C. Calaculate the heat transfer if plate is 10m wide. It is given at 35°C Pr=0.7, K = 0.02685W/mK & v = 1.65 × 10^{-6} m^2/s. 3

c) Define Grashoff Number. What is the significance of Grashoff Number ? 6

10. a) Derive the expression for temperature distribution between moving & stationary plate for one-dimensional couette flow problem. 10

b) Develop the expression for maximum temperature rise of lubricating oil contained between journal & bearing if the velocity of rotating surface is 10m/s and journal & bearing are maintained at same temperature of 20°C. Given μ = 0.8Ns/m^2 & K = 0.15W/mK at 20°C. 5

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11. a) Derive the expression of rate of heat transfer between the cold and hot fluids in terms of overall heat transfer coefficient, heat exchanger area and LMTD for a counter flow heat transfer. 7

b) A counter flow heat exchanger is to heat air entering at 400°C with a flow rate of 6 kg/s by the exhaust gas entering at 800°C with a flow rate of 4 kg/s. The overall heat transfer coefficient is 100 W/m^2 K and the outlet temperature of the air is 551.5°C. Specific heat at constant pressure for both air and exhaust gas can be taken as 1100J/kg K. Calculate : (i) The heat transfer area needed, (ii) The number of transfer units. 8

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