Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech(ME)(N)/PWE(N)/PE(N)/SEM-5/ME-502/2012-13

2012
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) Unit of thermal diffusivity is

   a) m/s^2 b) m^2/s^2

   c) m^2/s d) m^3/s^2.

   ii) Thermal conductivity is highest for

   a) Cu b) Ag

   c) Steel d) Al.

   iii) The temperature variation in Lumped heat capacity analysis is

   a) linear with time b) quadratic with time

   c) cubic with time d) exponential with time.

iv) Characteristic length in Biot number is the ratio of

a) volume of solid to its surface area

b) surface area to perimeter of the solid

c) perimeter to surface area of solid

d) none of these.

v) Effectiveness of a fin of uniform cross-section will be high if

a) k is less b) P is less

c) h is less d) A is large.

vi) Expression for the critical radius of insulation for sphere is

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

c) $r_c = 3k/h$ d) $r_c = 4k/h$.

vii) 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.

viii) Thermal conductivity of pure metal with rise in temperature

a) Decreases b) Increases

c) Remains same d) None of these.

ix) LMTD of counter flow heat exchanger as compared to parallel flow heat exchanger for a given heat transfer will be

a) More b) Same

c) Less d) Unpredictable.

x) The velocity profile for fully developed laminar flow in a tube is

a) Linear b) Exponential

c) Hyperbolic d) Parabolic.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. Derive one dimensional heat conduction equation in Cartesian co-ordinates.

3. (i) Define efficiency and effectiveness of a fin and show expressions for these for an infinitely long fin. How effectiveness of a fin can be increased ?

(ii) What is thermal resistance of a fin ? Write down expression for thermal resistance of an infinitely long fin. 3 + 2

4. a) Define solid angle and explain Lambert's cosine law. Explain a perfect grey body.

b) A grey body has an emissivity of 0·35 and is at a temperature of 550 K. If the body is opaque, calculate its reflectivity for a black body radiation coming from a 550 K source. 3 + 2

5. In forced convection through a pipe explain the effect of the following on heat transfer coefficient, when other things remain unchanged :

   (i) The fluid velocity is doubled

   (ii) The diameter of the pipe is doubled

   (iii) The thermal conductivity is doubled. 5

6. Sketch the boundary layer development of a flow over a flat plate and explain the significance of the boundary layer.

GROUP – C
(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) What is the physical significance of thermal diffusivity of a metal ?

   b) Consider a plane composite wall that is composed of two materials whose conductivities are K_1= 0·1 W/m K and K_2 = 0·04 W/m K and thickness L_1 = 1 cm and L_2 = 2 cm. The contact resistance at the interface between the two materials is known to be 0·3 m^2K/W. The material 1 adjoins a fluid at 200° C for which h = 10 W/m^2K and material 2 adjoins a fluid at 40°C for which h = 20 W/ m^2K.

   Find :

   (i) The rate of heat transfer through the composite wall

   (ii) What is the temperature drop at the interface of two materials ?

c) A plane wall is made by fire clay brick. The wall thickness L = 300 mm, the temperature of wall surface T_1 = 1550°C and T_2 = 50°C. Thermal conductivity of brick K = 0·96 (1 + 0·0008T) W/m°C. Calculate and represent graphically the temperature distribution through wall. 2 + 6 + 7

8. 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 LMDT for a parallel flow heat transfer.

b) What advantage does the effectiveness of NTU method have over the LMDT method ?

c) Hot oil with capacity rate of 2500 W/K flows through a double pipe heat exchanger. It enters at 360°C and leaves at 300°C. Cold fluid enters at 30°C and leaves at 200°C. If the overall heat transfer coefficient is 800 W/m^2K, determine the heat exchanger area required for

(i) parallel flow

(ii) counter flow. 6 + 3 + 6

9. a) Using a linear velocity profile $\frac{u}{u_\infty} = \frac{y}{\delta}$

For flow over flat plate, obtain an expression for boundary layer thickness as a function of x.

b) Air at 20°C and at atmospheric pressure flows over a flat plate at a velocity of 1·8 m/sec. If the length of the plate is 2·2 m and is maintained at 100°C, Calculate using exact method (Blasius solution)

(i) thickness of hydrodynamic boundary layer

(ii) average heat transfer coefficient

(iii) heat transfer rate from the plate.

Take properties of air as : ρ = 1·06 kg/m^3, K = 0·02894 W/m.K, υ = 18·97 × 10^{-6} m^2/s. C_p=1·005 kJ/kg, P_r = 0·696. 7 + 8

10. 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 unfined surface, A_f = area of the finned surface. η_f = fin efficiency and $\theta_0 = T_0 - T_\infty$. 7

b) One end of a long rod is inserted into a furnace while the other projects into ambient air. Under steady state the temperature of the rod is measured at two points 75 mm apart and found to be 125°C and 88·5°C, respectively, while the ambient temperature is 20°C. If the rod is 25 mm in diameter and h is 23·36 W/m^{2}K find the thermal conductivity of the rod material. 8

11. a) State and prove the Kirchhoff's law of radiation.

b) Two parallel, infinite gray surfaces are maintained at temperatures of 127°C and 227°C respectively. If the temperature of the hot surface is increased to 327°C by what factor is the net radiation exchange per unit area increased ? Assume the emissivities of cooler and hotter surfaces to be 0·9 and 0·7 respectively. 7 + 8