Name : ....

Roll No. : ....

Invigilator's Signature : ....

2013

PROCESS 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 any ten of the following questions : 10 × 1 = 10

   i) Critical insulation radius for a spherical surface with insulating material of thermal conductivity k and outside film coefficient h is

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

      c) $4k/h$ d) $k/2h$.

   ii) A satellite in space exchanges heat with surroundings essentially by

      a) conduction

      b) convection

      c) radiation

      d) both conduction and convection.

   iii) The thicker the insulation, the less is the total heat loss. The statement is

      a) true for flat and curved surfaces

      b) true for flat surfaces only

      c) true for curved surfaces only

      d) none of these.

iv) If the surface temperature of the black body is 516 K, the wavelength of emitted radiation from its surface is

a) 3·3 μm b) 5·63 μm

c) 4·02 μm d) none of these.

v) Finned surfaces have better rate of heat dissipation due to

a) decrease in ambient temperature

b) increase in the surface area exposed to the surrounding

c) increase in the convective film coefficient

d) none of these.

vi) With increase in excess temperature, the heat flux in boiling

a) increases continuously

b) decreases and then increases

c) increases and then decreases

d) increases, then decreases and again increases.

vii) Expansion bellows are provided in a shell and tube heat exchanger to

a) facilitate increase in length of the shell

b) impart structural strength to the exchanger

c) account for uneven expansion of shell and tube bundle

d) reduce the pressure drop.

viii) The Prandtl number will be lowest for

a) Water
b) Mercury
c) Lube Oil
d) Sugar solution.

ix) Fruit juice can be concentrated using

a) long tube evaporator
b) falling film evaporator
c) high pressure evaporator
d) none of these.

x) Dietus-Bolter equation used for the determination of heat transfer coefficient is valid

a) for fluids in laminar flow
b) for fluids in turbulent flow
c) when Grashoff number is very important
d) for liquid metals.

xi) Baffles are provided in heat exchanger to increase the

a) fouling factor
b) heat transfer area
c) heat transfer coefficient
d) heat transfer rate.

xii) Stanton number is

a) $\frac{Re}{Nu \times Pr}$
b) $\frac{Nu}{Re \times Pr}$
c) $\frac{Pr}{Nu \times Re}$
d) $\frac{Re \times Pr}{Nu}$.

GROUP – B

(Short Answer Type Questions)

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

2. What is critical thickness of insulation ? Deduce an expression for critical insulation radius on a cylindrical surface in terms of thermal conductivity of the insulating material and surrounding air film co-efficient. What would be your recommendation if you find that the value of critical insulation radius is greater than the outer radius of the pipe ? 1 + 3 + 1

3. A hot fluid is passing through a long pipe of 4cm outer diameter and covered with 2 cm thick insulation. It is proposed to reduce the conduction heat loss to the surroundings to one-third of the present rate by an additional covering with same insulating material. Calculate the additional thickness of insulation.

4. a) How would you find the shell side equivalent diameter of a shell and tube heat exchanger when the tubes are arranged in :

   (i) square pitch

   (ii) triangular pitch.

   b) Show that the capacity of each effect in triple effect evaporator is one-third the capacity of a single effect evaporator operating under same overall pressure difference. 3 + 2

5. Two very large parallel planes with emissivities 0·4 and 0·8 exchange heat. Find the percentage reduction in the heat transfer when a polished aluminium radiation shield (ε = 0·05) is placed between them.

6. Calculate the heat transfer coefficient for water at 60°C flow through a 0·625 cm diameter tube with a velocity of 0·9 m/sec. The tube wall temperature is 40°C. The following property values for water at 50°C were observed.

   μ = 2·17 kg/m-hr.

   k = 0·63 W/m. K = 2·27 kJ/m.hr.K.

   C_p = 4·187 kJ/kg.K

   ρ = 1000 kg/m^3

GROUP – C

(Long Answer Type Questions)

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

7. a) Derive an expression on rate of heat conduction through a hollow cylinder under steady-state condition. 7

   b) A furnace wall consists of three layers. The inner layer of 20 cm thickness is made of fire brick (k = 1·04 W/m°C), the intermediate layer of 5 cm thickness is made of masonry brick (k = 0·7 W/m °C). followed by a 10 cm thick concrete wall (k = 1·4 W/m °C). When the furnace is in continuous operation, the inner surface of the furnace is at 800°C while the outer concrete surface is at 50°C. Calculate (i) the rate of heat loss per unit area of the wall (ii) the temperature at the interface of the fire brick and masonry brick (iii) the temperature at the interface of the masonry brick and concrete. 8

8. a) In a double-pipe heat-exchanger hot fluid flows through the inner pipe. If the dia quarters of the pipe are considered as D_i and D_0 *wall thickness is* x_w, conductivity k_m, inside and outside film coefficients are h_i and h_0 then find out the expression for overall heat transfer coefficient based on outside area. 8

b) A steel ball 80 mm in diameter is initially at 485 °C. It is suddenly dipped in a bath having uniform temperature of 85°C. The convective heat transfer coefficient at the surface of the ball is 20 W/m^{2}K. Calculate the time required to attain a temperature of 115°C if the physical properties of the ball are as follows :

Sp. Heat = 460 W/mK, Density = 7800 kg/m^3. Thermal Conductivity = 43 W/mK. 7

9. a) Cold water at the rate of 3·8 kg/s is heated from 35°C to 55°C in a shell and tube heat exchanger with hot water entering at 95°C at a rate of 1·9 kg/s. Hot water flows through the shell side in a single pass while cold water flows through the tubes. Because of size limitation, the tube length must not exceed 2·5 m. The overall heat transfer coefficient is expected to be 1419 watt/m^2.K. The average velocity inside the tube must be 0·38 m/s. The ID and OD of the tubes are 1·905 cm and 2·15 cm respectively. Density of water is 1000 kg/m^3 and specific heat of water is 4·18 kJ/kg.K

Calculate :

(i) Outlet temperature of hot water

(ii) Heat transfer rate

(iii) Driving force assuming 1–1 counter flow

(iv) Heat transfer area for counter flow. 10

b) A plate fin of 10 mm thickness, 1 m width and 80 mm length is dissipating heat from a surface at 190°C. The fin is exposed to air at 25°C with a convection coefficient of 22 W/m^2°C. If thermal conductivity of the fin material is 200 W/m°C, determine the heat dissipation, What is the % increase in heat dissipation in case of two fins of 5 mm thickness each ? $2\frac{1}{2} + 2\frac{1}{2}$

10. a) Define view factor. Consider two large grey parallel surfaces at absolute temperatures T_1 and T_2 with emissivities ε_1 and ε_2 respectively. Prove that the net radiation between two surfaces are given by

$$q_{12} = \frac{\sigma\,(T_1^{\,4} - T_2^{\,4})}{(1/\varepsilon_1) + (1/\varepsilon_2) - 1}$$ 2 + 5

b) Discuss the different methods of feeding multiple effect evaporators. 5

c) Deduce the energy balance equation for triple effects backward feed evaporators. 3

11. a) What is nucleate boiling ? 2

b) Why is drop-wise condensation preferred over film-wise condensation in industrial application ? 2

c) Consider a cold plate maintained at uniform temperature T_w is placed vertically in a saturated vapour at T_v ($T_w < T_v$). The condensate film that is generated over plates is flowing downward due to gravity. Derive an expression for the thickness of condensate film at a distance x from the top edge of the plate. 6

d) Water is flowing through a 0·5 m long vertical tube of diameter 5 cm at the rate of 0·1 kg/s. The tube is exposed to saturated vapour at 1 atmospheric pressure. Water condensing on tube surface flows down in continuous laminar film. The tube surface is maintained at 40°C. Calculate film thickness and outlet temperature of cooling water.

Data :

Cooling Water : Inlet Temperature = 20°C, C_{pw} = 4200 J/kgK

Water Vapour : ρ_v = 0·6 kg/m^3, T_{sat} = 100°C, λ = 2257 kJ/kg

Condensate :

ρ_l = 980 kg/m^3, μ = 375 × 10^{-6} N.s/m^2, K = 0·7 W/mK, C_{pl} = 4195 J/kg.K. 5