

Name : .....

Roll No. : .....

Invigilator's Signature : .....

**CS/B.Tech/CHE/NEW/SEM-4/CHE-402/2013**

**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.







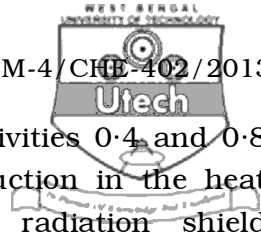
**GROUP – B**

**( Short Answer Type Questions )**

Answer any *three* of the following.

3 × 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 ( $\epsilon = 0.05$ ) 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.
- $\mu = 2.17 \text{ kg/m-hr.}$   
 $k = 0.63 \text{ W/m. } K = 2.27 \text{ kJ/m.hr.K.}$   
 $C_p = 4.187 \text{ kJ/kg.K}$   
 $\rho = 1000 \text{ kg/m}^3$

**GROUP – C**

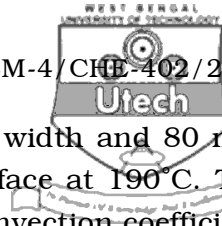
**( Long Answer Type Questions )**

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

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 ( $k = 1.04 \text{ W/m}^\circ\text{C}$ ), the intermediate layer of 5 cm thickness is made of masonry brick ( $k = 0.7 \text{ W/m}^\circ\text{C}$ ), followed by a 10 cm thick concrete wall ( $k = 1.4 \text{ W/m}^\circ\text{C}$ ). 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 diameters of the pipe are considered as  $D_i$  and  $D_o$ , wall thickness is  $x_w$ , conductivity  $k_m$ , inside and outside film coefficients are  $h_i$  and  $h_o$  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<sup>2</sup>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<sup>3</sup>. 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<sup>2</sup>.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<sup>3</sup> 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

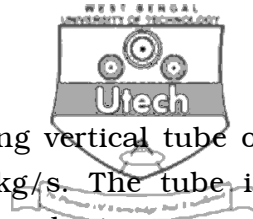


- b) A plate fin of 10 mm thickness, 1 m width and 80 mm length is dissipating heat from a surface at 190°C. The fin is exposed to air at 25°C with a convection coefficient of 22 W/m<sup>2</sup>°C. If thermal conductivity of the fin material is 200 W/m°C, determine the heat dissipation, What is the % 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  $\epsilon_1$  and  $\epsilon_2$  respectively. Prove that the net radiation between two surfaces are given by

$$q_{12} = \frac{\sigma (T_1^4 - T_2^4)}{(1/\epsilon_1) + (1/\epsilon_2) - 1} \quad 2 + 5$$

- 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,  
 $C_{pw} = 4200 \text{ J/kgK}$

Water Vapour :  $\rho_v = 0.6 \text{ kg/m}^3$ ,  $T_{sat} = 100^\circ\text{C}$ ,  
 $\lambda = 2257 \text{ kJ/kg}$

Condensate :

$\rho_l = 980 \text{ kg/m}^3$ ,  $\mu = 375 \times 10^{-6} \text{ N.s/m}^2$ ,  
 $K = 0.7 \text{ W/mK}$ ,  $C_{pl} = 4195 \text{ J/kg.K}$ . 5

=====