B.TECH/CHE/4TH SEM/CHEN 2201/2017

PROCESS HEAT TRANSFER
(CHEN 2201)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The inside and outside surface temperature of a flat furnace wall of thickness δ are T_1 and T_2 respectively ($T_1 > T_2$). The rate of conduction through the wall is given by

$Q = -KA\, dT/dx = -KA(T_2 - T_1)/\delta$.

Which amongst the following is not a correct statement?

(a) the term δ / KA is called thermal resistance
(b) The term KA/ δ is called thermal conductance
(c) Q/A is called heat flux
(d) temperature gradient dT/dx is positive.

(ii) Consider a composite wall comprising two layers of thickness δ_1 and δ_2 and thermal conductivities k and 2k respectively. The two extreme surfaces are maintained at 200°C and 100°C. If the junction temperature is desired to be 150°C, than the ratio of thicknesses δ_1 / δ_2 should be

(a) 1:1 (b) 2:1 (c) 1:2 (d) 2:3.

(iii) Critical thickness of insulation on a spherical surface is given by

(a) k/h (b) h/2k (c) 2k/h (d) h/k.

(where k is the thermal conductivity of insulation and h is convective heat transfer coefficient.)

(iv) In a counter flow heat exchanger, cold fluid enters at 30°C and leaves at 50°C, where as the hot fluid enters at 150°C and leaves at 130°C. The driving force for heat transfer in the heat exchanger is

(a) 20°C (b) 80°C (c) 0°C (d) 100°C.

(v) Minimum baffle space for a shell and tube heat exchanger as recommended by TEMA is
(a) ID of the shell (b) 1/5th ID of the shell
(c) 1/4th ID of the shell (d) 1/5th ID of the shell or 5 cm whichever is greater.

(vi) LMTD correction factor for a 1, 2, shell and tube condenser will be
(a) less than 1 (b) greater than 1 (c) equal to 1 (d) (d) 0.95.

(vii) Thermal radiations occur in the portion of electromagnetic spectrum between the wavelengths
(a) 10^{-2} to 10^{-4} micron (b) 10^{-1} to 10^{-2} micron
(c) 0.1 to 102 micron (d) 10^{2} micron onward.

(viii) Drop wise condensation occurs on
(a) clean surface (b) polished surface
(c) rough and contaminated surface (d) black surface.

(ix) Boiling point rise of the solution in an evaporator
(a) decreases evaporator capacity (b) increases evaporator economy
(c) increases evaporator capacity (d) decreases evaporator economy.

(x) 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.

Group – B

2. (a) A steam pipe of 10 cm outside diameter is covered with two layers of insulations, each having a thickness of 2.5 cm. The average thermal conductivity of one insulating material is 3 times that of the other. Find the percentage saving in heat loss if the better insulating material is next to the pipe than when it forms the outer layer.

(b) Consider a solid cylinder of radius R and length L. Within the body heat is generated at a constant volumetric rate Q. Under steady plate condition the outer surface temperature is T_0. Assume temperature gradient exists only along radial direction.
(i) Derive the differential equation for steady-state conduction along radial direction.
(ii) State boundary conditions.
(iii) Solve the differential equation to get steady state temperature profile of the body.

6 + (3 + 1 + 2) = 12

9. (a) Define capacity and steam economy of an evaporator.

(b) Show that capacity of each effect of a multiple evaporator system decreases with increase in number of effects.

(c) What are the functions of baffles in a shell and tube heat exchanger?

(d) What are the advantages and disadvantages of increasing the number of passes in a shell and tube heat exchanger?

(1 + 1) + 4 + 2 + (2 + 2) = 12

3. (a) During heat treatment, cylindrical pieces of 25 mm diameter and 30 mm height at 30^0C are placed in a furnace at 750^0C with convection coefficient 80 W/m^{2}K. Calculate the time required to heat the pieces to 600^0C. What will be the shortfall in temperature if the pieces are taken out from the furnace after 280 seconds? The physical properties of the material of cylindrical pieces are as follows:

Density= 7850 kg/m^3

Specific heat = 480 J/Kg K

Thermal conductivity = 40 W/mK

(b) Define efficiency and effectiveness of fin. Show that fin efficiency drops with increase in its length. What would you recommend to improve fin effectiveness?

(4 + 3) + (2 + 1 + 2) = 12

Group – C

4. (a) Average heat transfer coefficient for turbulent flow through tube is given by

$Nu=0.023\ (Re)^{0.8}(Pr)^{0.33}$

Water is allowed to flow at a volumetric flow rate Q through two tubes of diameter D and 2D. Will the film coefficients be different? If so, what will be the relation between the two?

(b) Saturated steam at 110^0C flows inside a copper pipe (k = 450 W/mK) having an internal diameter of 10 cm and external diameter of 12 cm. Steam side and outer surface film co-efficient are 12000 W/m^{2}K and 18 W/m^{2}K, respectively. Determine the heat loss from 1 m length of the pipe if it is located in a space at 25^0C. If the pipe is lagged with 5 cm thick insulation of thermal conductivity 0.22 W/mK, determine the percent decrease in heat loss.

4 + (4 + 4) = 12

5. (a) Deduce Colburn analogy to establish the inter-relationship between skin friction coefficient and film heat transfer to coefficient. For what value of PrandIt number the Colburn analogy and Reynolds analogy become identical?

(b) A hot fluid is to be cooled from 150^0C to 80^0C by transferring heat to a cold fluid available at 30^0C and to be heated to 60^0C. Calculate LMTD when the flow is (i) counter and (ii) parallel.

(c) State the advantages of counter flow arrangement over parallel flow arrangement. When would you prefer parallel flow? Under what condition parallel flow and counter flow arrangement become equally efficient?

(3 + 1) + (2 + 2) + (2 + 1 + 1) = 12

Group – D

6. Derive an expression for local film coefficient and average film coefficient of a condensing film on a vertical surface, clearly mentioning the assumption made by Nuselt.

12

7. (a) A thin aluminum sheet with an emissivity of 0.15 on both sides is placed between two very large parallel plates, which are maintained at uniform temperatures T_1 = 900 K and T_2 = 650 K and have emissivities 0.5 and 0.8, respectively. Determine the net rate of radiation heat transfer between the two plates per unit surface area of the plates and Compare the result with that without the shield.

(b) A 2m internal-diameter double-walled spherical tank is used to store iced water at 0^0C. Each wall is 0.5 cm thick, and the 1.5 cm thick air space between the two walls of the tank is evacuated in order to minimize heat transfer. The surfaces surrounding the evacuated space are polished so that each surface has an emissivity of 0.15. The temperature of the outer wall of the tank is measured to be 20^0C. Assuming the inner wall of the steel tank to be at 0^0C, determine (a) the rate of heat transfer to the iced water in the tank and (b) the amount of ice at 0^0C that melts during a 24h period.

5 + 7 = 12

Group – E

8. (a) A heat exchanger is to be designed to condense 8 kg/s of an organic vapour which passes through the shell. Cooling water at 15^0C will flow through 25 mm outer diameter, 4.85 m long tubes having wall thickness of 2mm at rate of 60kg/s. The overall heat transfer coefficient is 480 W/m^{2}K. |The latent heat of condensation of vapour is 600 KJ/Kg. Calculate:

(i) outlet temperature of water
(ii) driving force of heat transfer
(iii) heat load
(iv) no of tubes required
(v) no of tube passes if velocity of cooling water is not to exceed 2 m/s
(vi) if the number of tube passes is more than one would you require to incorporate LMTD correction factor in your design calculation? Justify your answer.

(b) Deduced the expression for shell side equivalent diameter of a shell and tube heat exchanger when the tubes are arrange in (i) triangular pitch (ii) square pitch.

(1 + 1 + 1 + 2 + 2 + 1) + (2 + 2) = 12