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 amount of heat flow through a body by conduction is
(a) directly proportional to the surface area of the body
(b) directly proportional to the temperature difference on the two faces of the body
(c) dependent upon the material of the body
(d) all of the above.

(ii) Conduction is a process of heat transfer
(a) from one particle of the body to another without the actual motion of the particles
(b) from one particle of the body to another by the actual motion of the heated particles
(c) from a hot body to a cold body, in a straight line, without affecting the intervening medium
(d) none of the above.

(iii) The ratio of kinematic viscosity to thermal diffusivity is known as
(a) Prandlt number (b) Nusselt number
(c) Peclet number (d) Schimdt number.

(iv) Heat transfer rate of film wise condensation is
(a) equal to the drop wise condensation
(b) lower than the drop wise condensation
(c) higher than the drop wise condensation
(d) half of the drop wise condensation.

(v) The rate of heat transfer between two large parallel planes with one radiation shield is _____of the radiation heat transfer between them in absence of radiation shield.
(a) double (b) half (c) equal (d) logarithmic value

(vi) Prandlt analogy states that
(a) $S_t = f/2$ (b) $S_t = f/4$
(c) $S_t = \sqrt{f}$ (d) $S_t = (f/2)/(1+5\sqrt{f/2})(Pr-1)$.

(vii) The Sieder and Tate equation is used for the determination of heat transfer co-efficient of fluid
(a) flows through a circular tube when flow is laminar
(b) flows through a circular tube when flow is turbulent
(c) flows over a flat plate when flow is laminar
(d) flows over a flat plate when flow is turbulent.

(viii) The Dittus-Boelter equation is used for the determination of heat transfer co-efficient of fluid
(a) flows through a circular tube when flow is laminar
(b) flows through a circular tube when flow is turbulent
(c) flows over a flat plate when flow is laminar
(d) flows over a flat plate when flow is turbulent.

(ix) The value of shape factor for a convex surface is
(a) $F_{1-1} = 0$ (b) $A_2F_{1-2} = 1/F_{1-1}$ (c) $(A_2/A_1)F1_{-2} = 0$ (d) $F_{1-1} = 1$.

(x) For a 2-4 exchanger where steam is condensing outside the tubes, the value of LMTD correction factor is
(a) 0 (b) 0.5 (c) 1 (d) Infinity.

Group- B

2. (a) Deduce the steady state heat conduction through a hollow sphere. [(CO1)(Remember/LOCQ)]

(b) A furnace wall is made up of 20 cm of magnesite brick and 20 cm of common brick. The magnesite brick is exposed to hot gases at 1355^0C and common brick outer surface is exposed to 45^0C room air. The convective and radiation heat transfer coefficient towards gas side are 16.5 W/m^2 and 17.5 W/m^2 ^{0}C respectively. The convective and radiation heat transfer coefficient towards air side are 12.5 W/m^2 and 7.5 W/m^2 ^{0}C respectively. Thermal conductivities of magnesite and common brick are 3.8 W/m and 0.66 W/m ^{0}C respectively. Determine the heat loss per m^2 area of the furnace wall and the maximum temperature to which the common brick is subjected. [(CO1)(Evaluate/HOCQ)]

4 + 8 = 12

3. (a) Deduce the equation for one dimensional unsteady state conduction through a large slab of thickness 2s. Show also the temperature profile in such case. [(CO1)(Understand/LOCQ)]

(b) Write short notes on:
(i) Critical thickness of insulation
(ii) Optimum thickness of insulation.

[(CO1)(Remember/LOCQ)]

6 + (3 + 3) = 12

Group - C

4. (a) Find out the numerical value of Nusselt number for a sphere in stagnant air. [(CO2, CO5) (Analyse/HOCQ)]

   (b) The hot air enters at 150^{0}C through an uninsulated sheet metal duct with a mass rate of 0.02 kg/s and after a distance of 10 m cools at 80^{0}C. The duct outer surface heat transfer coefficient is 6 W/m^{2}K. The air temperature is 273K. Calculate the heat flux. *Properties: air (T_m = 388K): Cp = 1010 J/Kg.K, Air ($T_{m,i}$ = 348K), K = 0.030 W/m.K, μ = 208.2 X 10^{-7} N.s/m^2, Pr =0.70.* [(CO2, CO3) (Analyze/IOCQ)]

7 + 5 = 12

5. (a) Determine the average convection heat transfer coefficient for the 2.5-m-high vertical walls of a home having respective interior air and wall surface temperatures of (a) 20 and 10°C and (b) 27 and 37°C.
   Thermo-physical properties of *Air at 288K, 1 atm are, $\beta = 1/T_f$ = 3.472 ×10^{-3} K^{-1}, ν = 14.82 × 10^{-6} m^2/s, k = 0.0253 W/m-K, α = 20.9 × 10^{-6} m^2/s, Pr = 0.710*
   Thermo-physical properties of Air at 305K, 1 atm are, $\beta = 1/T_f$ = 3.279 × 10^{-3} K^{-1}, ν = 16.39 ×10^{-6} m^2/s, k = 0.0267 W/m-K, α = 23.2 × 10^{-6} m^2/s, Pr = 0.706.
   [(CO4)(Evaluate/HOCQ)]

   (b) Prove that for a parallel flow in flat plate, $Nu_x = \frac{h_x x}{k} = 0.332 Re^{1/2} Pr^{1/3}$, when 0.6 ≤ Pr ≤ 50. [(CO3)(Analyze/IOCQ)]

6 + 6 = 12

Group - D

6. (a) A vertical square plate (30 cm × 30 cm) is exposed to steam at atmospheric pressure. The plate temperature is maintained at 90^{0}C. Calculate the mass of steam condensed per hour. *Properties: (Tmin = 95^{0}C), ρ = 960 Kg/m^3, μ = 282 ×10^{-6} Kg/ms, K = 0.61 W/mK, T_s = 100^{0}C, h_{fg} = 2255 KJ/Kg.*
   [(CO3,CO5)(Analyse/HOCQ)]

   (b) Why do we get minimum heat flux at Leiden frost Pont? [(CO4)(Understand/IOCQ)]

   (c) Define saturated boiling. [(CO4)(Remember/LOCQ)]

7 + 3 + 2 = 12

7. (a) Determine the geometric shape factor for a very small disc and large parallel disc located at a distance directly above the smaller one. Both are placed in horizontal plane. [(CO3,CO5)(Analyse/HOCQ)]

   (b) Derive the Kirchhoff's law. [(CO4)(Understand/IOCQ)]

   (c) Define Blackbody radiation function. [(CO4)(Remember/LOCQ)]

7 + 3 + 2 = 12

Group - E

8. (a) A heat exchanger is to be designed to condense 8 kg/sec of an organic liquid (t_{sat} = 80°C, h_{fg} = 600 KJ/kg) with cooling water available at 15°C and at a flow rate of 60 kg/sec. The overall heat transfer coefficient is 480 W/m²°C calculate:
   (i) The number of tube required. The tubes are to be of 25 mm outer diameter, 2 mm thickness and 4.85 m length.
   (ii) The number of tube passes. The velocity of the cooling water is not to exceed 2 m/sec. [(CO3, CO5)(Analyse/HOCQ)]

   (b) Draw the temperature profile of parallel flow heat exchanger when cold fluid rate of heat capacity is greater than hot fluid rate of heat capacity. [(CO4)(Remember/LOCQ)]

   (c) Why multi-pass heat exchanger is used? [(CO4)(Understand/IOCQ)]

(4 + 3) + 2 + 3 = 12

9. (a) Explain why backward feed arrangement is advantageous than the forward feed arrangement in triple–effect evaporator when feed is concentrated liquid? [Draw a diagram also]. [(CO3,CO5)(Understand/HOCQ)]

   (b) Discuss the temperature profile of an evaporator with a help of a diagram. [(CO4)(Analyse/IOCQ)]

   (c) Define capacity ratio of a heat exchanger. [(CO4)(Remember/LOCQ)]

6 + 4 + 2 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	25	50

Course Outcome (CO):

After the completion of the course students will be able to

1. Justify the practical importance and relevance of energy transfer and its conservation in chemical industry.
2. Categorize the technological methods related to heat transfer in process plant.
3. Identify a detailed overview of heat transfer equipment and problems associated at preliminary stage of design.
4. Construct a bridge between theoretical and practical concept used in industry.
5. Analyze heat transfer processes of industrial operation and identify modes of heat transfer.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.