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) In liquids and gases, heat transmission is primarily caused by
(a) convection (b) radiation
(c) conduction (d) conduction as well as convection.

(ii) The appropriate rate equation for convective heat transfer between a surface and adjacent fluid is prescribed by
(a) Newton's law of cooling (b) Kirchhoff's law
(c) Newton's first law (d) Wein's displacement law.

(iii) In the lumped system parameter model, the variation of temperature with time is
(a) linear (b) exponential
(c) sinusoidal (d) cube.

(iv) Fins are provided on a heat transfer surface for
(a) pressure drop of the fluid should be minimized
(b) increase turbulence in flow for enhancing heat transfer
(c) surface area is maximum to promote the rate of heat transfer
(d) increase temperature gradient so as to enhance heat transfer.

(v) Radiation heat transfer is characterized by
(a) movement of discrete packets of energy as electromagnetic waves
(b) due to bulk fluid motion, there is a transport of energy
(c) there is the circulation of fluid by buoyancy effects
(d) thermal energy transfer as vibration energy in the lattice structure of the material.

(vi) The value of film coefficient is dependent upon
(a) boundary layer configuration
(b) geometry and orientation of the surface
(c) surface conditions
(d) all of the above.

(vii) Forced air flows over a convection heat exchanger in a room heater, resulting in a convective heat transfer coefficient 1.136 $kW/m^2 K$. The surface temperature of heat exchanger may be considered constant at 65 degree Celsius, and the air is at 20 degree Celsius. The heat exchanger surface area required for 8.8 kW of heating is
(a) 0.272 m^2 (b) 0.472 m^2 (c) 0.172 m^2 (d) 0.672 m^2.

(viii) In spite of the large heat transfer coefficient in boiling liquids, fins are used advantageously when the entire surface is exposed to
(a) nucleate boiling (b) film boiling
(c) transition boiling (d) all modes of boiling.

(ix) Which quantity signifies the ratio of temperature gradient at the surface to a reference temperature gradient?
(a) Reynolds number (b) Nusselt number
(c) Fourier number (d) Stanton number.

(x) For the same type of shapes, the value of the radiation shape factor will be higher when
(a) surfaces are closer (b) surfaces are larger and held closer
(c) surfaces are moved further apart (d) surfaces are smaller and held closer.

Group- B

2. (a) Deduce the steady state heat conduction equation for a solid rectangular shaped body. [(CO1)(Remember/LOCQ)]

(b) Prove that the heat loss per sq. meter of outside surface area of a hollow sphere heated from within is equal to $Q = \dfrac{2k(T_1 - T_2)}{(D_2 - D_1)\dfrac{D_2}{D_1}}$, where T_1 and T_2 are temperatures and D_1 and D_2 are the diameters of the inner and outer surfaces respectively. [(CO1)(Remember/LOCQ)]

(c) A steam pipe 170/160 mm in diameter is covered with two layers of insulation. The thickness of the first layer is 39 mm and that of the second layer is 50 mm. The thermal conductivities of the pipe and insulating layers are 50, 0.15 and 0.08 kcal/m hr ^{0}C respectively. The temperature of the inner surface of the steam pipe is 300^{0}C and that of the outer surface of the insulating layer is 50^{9}C. Determine the quantity of heat lost per metre length of steam pipe and layer contact resistance. [(CO1)(Remember/LOCQ)]

4 + 4 + 4 = 12

3. (a) Deduce the steady state conduction equation through rectangular fin. [(CO1)(Understand/LOCQ)]

(b) Write short notes on:
(i) Critical thickness of insulation (ii) Optimum thickness of insulation. [(CO1)(Remember/LOCQ)]

4 + (4 + 4) = 12

Group - C

4. (a) Show that if the heat exchanger material resistance is neglected, the relation between the individual heat transfer coefficients and the overall heat transfer coefficient is given by: $U = \frac{h_i h_o}{h_i + h_o}$, Notations bear their usual meaning.

[(CO2)(Analyse/IOCQ)]

(b) An organic solvent flowing in the inner pipe of a double pipe heat exchanger is cooled with water flowing in the jacket. The inner pipe is made from stainless steel having inside diameter 26.64 mm and outside diameter 33.41 mm. The thermal conductivity of stainless steel is 16.3 W/m-K. The film coefficients and fouling factors in kcal/hr.m^2.^{0}C are:
Alcohol film coefficient = 878.40, Water film coefficient = 1464.00, Neglect fouling. What is the overall heat transfer coefficient based on the inside area of the inner pipe? [(CO2)(Evaluate/HOCQ)]

6 + 6 = 12

5. (a) A liquid metal flows at a rate of 4.00 kg/s through having an inside diameter of 0.05 m. The liquid enters at 500 K in the tube. The tube wall is maintained at a temperature of 30 K above the fluid bulk temperature and constant heat flux is maintained. Calculate the required tube length. The average physical properties are as follows: $\mu = 7.1x10^{-4}\,Pa.s.$, $\rho = 7400 kg/m^3$, C_P = 120 J/kg. K, k = 13 W/m.K
For liquid metal heat transfer: $N_{Nu} = 0.625\ N_{Pr}^{0.4}$. [(CO3)(Evaluate/HOCQ)]

(b) A hot plate 20 cm in height and 60 cm wide is exposed to ambient air at 30^{o}C. Assuming the temperature of the plate is maintained at 110°C, find the heat loss from both surfaces of the plate:
The properties of air at the average temperature at 70^{0}C are as follows:
$\rho = 1.03 kg/m^3$ $\nu = \frac{\mu}{\rho} = 20.02x10^{-6} m^2/s$ C_P = 0.24 kcal/kg ^{0}C
k = 2.55 × 10^{-2} kcal/m. hr. °C For Gr.Pr ≤ ≤ 10^8, $N_{Nu} = 0.56\ (Gr\ Pr)^{0.25}$.

[(CO3)(Understand/LOCQ)]

7 + 5 = 12

Group - D

6. (a) Using Nusselt's theory, prove that the heat transfer coefficient of condensing steam on a flat vertical wall of height L is given by:

$$h_l = 0.943 \left[\frac{k_f^3 \rho_f^2 g h_{fg}}{\mu L (T_s - T_w)}\right]^{\frac{1}{4}}.$$

[(CO3)(Evaluate/HOCQ)]

(b) 12 cm od and 2 m long tube used in a big condenser to condense the steam at 0.4 atm. Estimate the amount of condensate formed per hour in both surfaces.
Data: The saturation temperature of steam = 74.5^{0}C
Average wall temperature = 50^{0}C
The properties of water film at average temperature of 62.7^{0}C
$\rho = 982.2 kg/m^3$ h_{fs}= 591.3 kcal / kg k = 0.567 kcal/m.hr.^{0}C
$\mu = 1.59 kg/m.hr$. [(CO3)(Evaluate/HOCQ)]

6 + 6 = 12

7. (a) State and prove the Kirchoff's law of radiation. [(CO4)(Remember/LOCQ)]

(b) Determine in kcal/hr radiation heat loss from each meter of 20 cm diameter heating pipe when it is placed centrally in the brick duct of square section 30 cm wide.

Data;

Temperature of pipe surface = 200^0C

Brick duct temperature = 20^9C

Emissivity of pipe surface = 0.8

Brick duct emissivity = 0.9

Assume only radiation heat transfer between pipe and brick wall.

If the system is in steady state condition then find the surface heat transfer cofficientof the brick duct assuming the temperature of the surrounding of the duct is 10^0C. [(CO4)(Evaluate/HOCQ)]

6 + 6 = 12

Group - E

8. Classify different types if heat exchangers and explain the construction and working principle of shell and tube heat exchanger. [(CO4)(Analyse/LOCQ)]

12

9. (a) Write down the mass and energy balance equation of backward feed triple effect evaporators. [(CO5)(Remember/LOCQ)]

(b) A continuous single effect evaporator concentrates 10,000 kg/h of a 1.5 wt% salt solution entering at 38^0C to a final concentration of 2.5 wt%. The vapour space of the evaporator is at 1.0 atm and the steam supplied is saturated at 143.3 kPa. The overall heat transfer coefficient (U) = 2000 W/m^2 K. Calculate the amounts of vapour and liquid products and the heat transfer area required. Assule negligible boiling point rise.

Data: Heat capacity of feed = 4.14 kJ/kg K

Latent heat of water at 373.2 K = 2257 kJ/kg

Latent heat of steam at 143.3 kPa (saturation temperature = 383.2 K) = 2230 kJ/kg. [(CO5)(Evaluate/HOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	55.2	6.3	38.5

Course Outcome (CO):

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.