PROCESS HEAT TRANSFER
(CHEN 2201)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) When heat is transferred from one particle of hot body to another by actual motion of the heated particles, it is referred to as heat transfer by
(a) conduction (b) convection
(c) radiation (d) conduction and convection.

(ii) For conduction heat transfer, the heat energy propagation will be minimal for _____.
(a) copper (b) air
(c) water (d) lead

(iii) Stanton number is
(a) $St = \frac{Gz}{RePr}$ (b) $St = \frac{Nu}{Re}$
(c) $St = \frac{Nu}{RePr}$ (d) $St = \frac{Nu}{Pr}$.

(iv) The value of critical Rayleigh number is
(a) $Ra > 10^3$ (b) $Ra \cong 10^9$
(c) $Ra \cong 10^3$ (d) $Ra < 10^3$.

(v) In case of perfect natural convection
(a) $Nu = f(Gz, Re)$ (b) $Nu = f(Gz, Pr)$
(c) $Nu = f(Ra, Gr)$ (d) $Nu = f(Ra, Pr)$.

(vi) The average heat transfer co-efficient for flat plate in laminar flow is
(a) $\frac{hL}{K} = 0.664(R_{eL})^{1/2}(Pr)^{1/3}$ (b) $\frac{hL}{K} = 0.332(R_{eL})^{1/2}(Pr)^{2/3}$
(c) $\frac{hL}{K} = 0.664(R_{eL})^{4/5}(Pr)^{1/3}$ (d) $\frac{hL}{K} = 0.332(R_{eL})^{1/2}(Pr)^{1/3}$.

(vii) Kirchhoff law states that
(a) $\tau = \alpha$ (b) $\varepsilon = 4\pi\alpha$
(c) $\varepsilon\tau = \mu\alpha$ (d) $\varepsilon = \alpha$.

(viii) LMTD correction factor is applicable for
(a) shell and tube heat exchanger (b) 1 – 1 heat exchanger
(c) 2 – 4 heat exchanger (d) all of these.

(ix) In sugar industry which type of evaporators are used?
(a) Short tube vertical evaporator (b) Falling film type evaporator
(c) Long tube vertical evaporator (d) Forced circulation evaporator.

(x) For single effect evaporator steam economy is about
(a) higher than 0.1 (b) higher than unity
(c) less that unity (d) equal to 0.1.

Fill in the blanks with the correct word

(xi) Unit of thermal conductivity in S.I. units is_____.

(xii) The value of Stefan Boltzman constant is _____.

(xiii) Baffles are used in the shell side heat exchanger to _____ the heat transfer co-efficient.

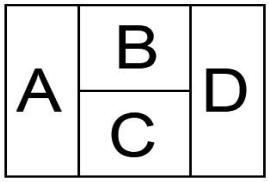
(xiv) The heat transfer rate for dropwise condensation is _____ than film wise condensation.

(xv) The LMTD correction factor becomes _____ for condensation or evaporation.

Group - B

2. (a) Deduce the steady state unidirectional heat conduction equation through hollow cylinder with uniform conductivity without heat generation. *[(CO1)(Remember/LOCQ)]*

(b) Find the heat transfer through the composite wall shown in the Figure below per unit area. Assume one dimensional heat flow. Temperatures of surfaces A and D are respectively 400^0C and 60^0C.



Data:

Thermal conductivity (K), kcal/hr. m. ^{0}C	Area (A), m^2	Thickness, cm
K_A = 150	A_A = 1.0	X_A =3
K_B = 30	A_B = 0.5	X_B = 8
K_C = 65	A_C = 0.5	X_C = 8
K_D = 50	A_D = 1.0	X_D = 5

[(CO1)(Analyse/HOCQ)]

5 + 7 = 12

3. (a) Deduce the steady state conduction equation through rectangular fin.

[(CO1)(Understand/IOCQ)]

(b) 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)(Analyse/HOCQ)]*

7 + 5 = 12

Group - C

4. (a) Derive Reynold's analogy from Newton's viscosity law and Fourier conduction law. *[(CO2,CO5)(Understand/IOCQ)]*

   (b) A 200 mm thick concrete wall having thermal conductivity K = 0.8 W/m^{0}C is exposed to air at 80^{0}C on one side and to air at 20^{0}C on the opposite side. The average convective heat transfer coefficients are 40 W/m^{20}C on the 80^{0}C and 10 W/m^{20}C on the 20^{0}C. Determine the heat transfer rate per unit surface area of the wall and the surface temperature of the wall on both the sides. *[(CO2,CO3)(Analyse/HOCQ)]*

8 + 4 = 12

5. (a) In summer, interior air temperature of a home is 27^{0}C while the outside temperature of 2.5m high vertical walls is 37^{0}C. Determine the average heat transfer coefficient for this wall. The properties of air at 305K and 1 atm are, $\beta = 3.279 \times 10^{-3}$ K^{-1}, $\nu = 16.39 \times 10^{-6}$ m^2/s, K = 0.0267 W/m.k, $\alpha = 23.2 \times 10^{-6}$ m^2/s, Pr = 0.706. *[(CO3, CO5)(Analyse/HOCQ)]*

   (b) What is significance of Grashof number? *[(CO4)(Remember/LOCQ)]*

   (c) Explain the concept of Prandlt number. *[(CO4)(Apply/IOCQ)]*

6 + 2 + 4 = 12

Group - D

6. (a) Prove that, $Q_{1-2} = \frac{J_1 - J_2}{\frac{1}{A_1 F_{1-2}}}$, Where, Q_{1-2} = Net heat lost, J_1 = Radiosity of surface 1, J_2 = Radiosity of surface 2 and $1/(A_1F_{1-2})$ = Space resistance. *[(CO3, CO5)(Analyse/IOCQ)]*

   (b) Discuss the different boiling regime of water at atmospheric pressure. *[(CO4)(Remember/LOCQ)]*

5 + 7 = 12

7. (a) (i) Calculate the net radiant heat exchange per square meter area for two large parallel planes at temperatures of 427^{0}C and 27^{0}C respectively. The emissivity of hot plane and cold planes are 0.9 and 0.6 respectively.
   (ii) If a polished aluminium shield is placed between them, find the percentage reduction in the heat transfer. The emissivity of the shield is 0.04. *[(CO3, CO5)(Analyse/HOCQ)]*

   (b) Discuss the properties of view factor. *[(CO4)(Remember/LOCQ)]*

8 + 4 = 12

Group - E

8. (a) In a counter flow double pipe heat exchanger,water is heated from 25°C to 65°C by oil with specific heat of 1.45 kJ/kg K and mass flow rate of 0.9 kg/s. The oil is cooled from 230°C to 160°C. If overall Heat transfer coefficient is 420 W/m^2°C, Calculate the followings:
(i) The rate of heat transfer
(ii) The mass flow rate of water, and
(iii) The surface area of heat exchanger. *[(CO3,CO5)(Analyse/HOCQ)]*

(b) Derive LMTD for parallel flow heat exchanger. *[(CO4)(Understand/IOCQ)]*

8 + 4 = 12

9. Explain any **two** of the followings:
(i) Temperature profile of an evaporator
(ii) Working principle of backward feed arrangement in triple effect evaporator
(iii) Enthalpy balance of a single effect evaporator. *[(CO4)(Understand/IOCQ)]*

(2 × 6) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	18.75	41.67	39.58

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.*