PROCESS HEAT TRANSFER
(CHE2201)

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) For a long cylinder with a uniformly distributed heat source, relation between steady state temperature with the radius is
(a) logarithmic (b) cubic
(c) parabolic (d) exponential

(ii) Which dimensionless number represents the ratio of internal conductive resistance within a solid to the external convective resistance at its surface?
(a) Fourier Number (b) Biot Number
(c) Reynolds Number (d) Nusselt Number

(iii) Which of the following has the highest thermal conductivity?
(a) Brick (b) Water
(c) Air (d) Silver

(iv) Choose the wrong statement with respect to Nusselt number and convective heat transfer co-efficient
(a) Nusselt number represents the ratio of temperature gradient at the surface to an overall or reference temperature gradient
(b) Nusselt number represents the dimensionless slope of the temperature distribution curve at the surface
(c) The convective co-efficient can be evaluated from a knowledge of fluid temperature distribution in the neighbourhood of the surface
(d) For a given Nusselt number, the convective co-efficient is inversely proportional to thermal conductivity of the fluid

(v) Heat is being transferred by convection from water at 48^0C to glass plate whose surface that is exposed to water is 40 ^{0}C. the thermal conductivity of water and glass are 0.6 W/mK and 1.2 W/mK respectively. The spatial gradient of temperature in the water at the water glass interface is $dT/dy = 1\times 10^4$ K/m. The heat transfer co-efficient h in W/m^{2}K is
(a) 0 (b) 4.8 (c) 6.0 (d) 750

(vi) Heat is lost from a 100 mm diameter steam pipe placed horizontally in ambient air at $30^{o}C$. if the Nusselt number is 25 and thermal conductivity of air is 0.03 W/mK, then the heat transfer co-efficient will be

(a) 7.5 W/m^2K (b) 16.5 W/m^2K

(c) 25 W/m^2K (d) 30 W/m^2K

(vii) Milk spills over when it is boiled in an open vessel. The boiling of milk at this instant is referred to as

(a) Interface evaporation (b) Sub-cooled boiling

(c) Film boiling (d) Saturated nucleate boiling

(viii) The ratio of emissive power of a body to that of a perfectly black body is called

(a) Absorptivity (b) Emissivity

(c) Reflectivity (d) Transmittivity

(ix) Multi pass heat exchangers are used to

(a) Reduce the pressure drop

(b) Get a compact unit

(c) Obtain high heat transfer co-efficient

(d) Facilitate very large temperature drop through the tube wall

(x) The LMTD correction factor must be in what range for the design to be feasible?

(a) < 0.6 (b) between 0.6 and 0.7

(c) between 0.5 and 0.6 (d) > 0.75

Fill in the blanks with the correct word

(xi) Thermal conductivity of most of the liquids _____ with rise in temperature

(xii) The convection heat transfer co-efficient in drop-wise condensation is _____ than that in case of film condensation.

(xiii) Thermal radiation is limited to a range of wavelength between _____ of the spectrum of electromagnetic radiation.

(xiv) The effect of multi tubes, several shell passes or cross flow on the logarithmic mean temperature difference is considered by identifying a _____.

(xv) In the study of transient heat conduction, the _____ Number is a dimensionless time that represents the ratio of the heat conduction rate to the rate of thermal energy storage.

Group - B

2. (a) Can the energy loss increase with growth in the thickness of insulation being added to the steam pipe? Justify your answer. *[(CO4)(Analyse/HOCQ)]*

(b) A wire of radius 3 mm and 1.25 m length is to be maintained at 60°C by insulating it by a material of thermal conductivity 0.175 W/m-K. The temperature of the surrounding air is 25°C with heat transfer coefficient 8.5 W/m^2-K. For maximum heat dissipation determine the thickness of insulation. Also determine percentage change of heat loss due to that insulation. *[(CO4)(Apply/IOCQ)]*

4 + (4 + 4) = 12

3. (a) Two slabs, each 100 mm thick and made of materials with thermal conductivities of 16 W/m-K and 1600 W/m-K are placed in contact which is not perfect. Due to roughness of surface only 40% area is in contact and air fills 0.02 mm thick gap in the remaining area. If the extreme surfaces of the arrangement are at temperatures of 250°C and 30°C, determine the heat flow rate per unit area through the composite system. Take the thermal conductivity of air as 0.032 W/m-K and assume both the metals share equal contact area. *[(CO1)(Evaluate/HOCQ)]*

(b) A slab of 50 mm thickness and 0.1 m^2 cross-sectional area has its side maintained at temperatures of 300°C and 30°C respectively. Measurements indicate that when 1 kW of energy as heat flows through it, the temperature at its centre plane is 125°C. Determine an expression for thermal conductivity of the slab material if it varies linearly with temperature. *[(CO1)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - C

4. (a) Explain the significance of Grashof number in connection with Free convection. *[(CO2)(Analyse/IOCQ)]*

(b) Derive Reynolds' analogy from Newtons' viscosity Law and Fourier conduction law. *[(CO2)(Understand/IOCQ)]*

4 + 8 = 12

5. (a) Hot air flows with a mass rate of $\dot{m}$ = 0.050 Kg/s through an uninsulated sheet metal duct of diameter D = 0.15 m, which is in the house. The hot air enters at 103^0C and, after a distance of L = 5m, cools to 77 ^{0}C. the heat transfer coefficient between the duct outer surface and the ambient air at 0^0C is known to be h_a = 6 W/m^2K. Determine the heat flux and the duct surface temperature at x = L.
The properties of air at 363K are, Cp = 1010J/Kg.k
Air at 350K are, K = 0.030 W/m.K, μ = 208.2 × 10^{-7} N.s/m^2, Pr = 0.70
[(CO2)(Analyse/IOCQ)]

(b) Liquid mercury flows through a copper tube of 2 cm inner diameter at the rate of 1.25 Kg/s. the mercury enters at 15^0C and is heated to 25^0C as it passes through the tube. Determine the tube length which would satisfy the condition of constant heat flux at the wall which is at an average temperature of 40^0C. For liquid metals, the following correlation is presumed to agree well with experimental results:
$Nu = 7 + 0.025\ Pe^{0.8}$
At 20^0C, the thermo physical properties of the liquid mercury are:
P = 13580 Kg/m^3, K = 8.685 W/mK, Cp = 139.35 J/Kg K, υ = 1.145 × 10^{-7} m^2/s, Pr = 0.0249. *[(CO3)(Apply/IOCQ)]*

6 + 6 = 12

Group - D

6. (a) Discuss in detail the various regimes in boiling and explain the condition for the growth of bubbles. *[(CO4)(Remember/LOCQ)]*

(b) What is the effect of bubble size on boiling? *[(CO4)(Understand/IOCQ)]*

(c) When does radiation play a role in boiling heat transfer? What is Leidenfrost phenomenon? *[(CO4)(Apply/IOCQ)]*

6 + 2 + 4 = 12

7. (a) State and prove Kirchoff's law of radiations. What restrictive conditions are inherent in the derivation of Kirchoff's law? *[(CO3)(Apply/LOCQ)]*

(b) Define radiation shield. *[(CO4)(Remember/LOCQ)]*

(c) A steel plate is placed on a non-conducting opaque surface normal to incident solar radiation of 750 W/m^2. Neglecting convection effects, workout the equilibrium temperature of the plate when it is
(i) Oxidised with emissivity $\varepsilon = 0.80$ and
(ii) Polished with emissivity $\varepsilon = 0.07$
Assumption may be made of the grey body behaviour.
Take $\sigma_b = 5.67 \times 10^{-8}$ W/m^2K^4. Comment on the results. *[(CO2)(Analyse/IOCQ)]*

5 + 1 + 6 = 12

Group - E

8. (a) Define economy of an evaporator. *[(CO5)(Remember/LOCQ)]*

(b) Explain boiling point elevation of an evaporator. *[(CO5) (Understand/IOCQ)]*

(c) Write a short note on falling film evaporator. *[(CO5)(Remember/LOCQ)]*

2 + 5 + 5 = 12

9. (a) A counter flow heat exchanger is used to cool 2000 Kg/hr of oil (Cp = 2.5 KJ/Kg K) from 105^0C to 30^0C by the use of water entering at 15 ^{0}C. If the overall heat transfer coefficient is expected to be 1.5 KW/m^2K, make calculation for the water flow rate, the surface area required and the effectiveness of heat exchanger. Presume that the exit temperature of the water is not to exceed 80 ^{0}C. Use NTU-effectiveness approach. *[(CO6)(Analyse/IOCQ)]*

(b) Derive the relationship between the effectiveness and the number of transfer units for a counter flow heat exchanger. *[(CO4, CO6)(Remember/LOCQ)]*

7 + 5 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	58.33	16.67