B.TECH/CHE/4TH SEM /CHEN 2201/2016
2016

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. Identify the correct answer: **10 x 1=10**

(i) The inside and outside film coefficients on a hot cylindrical pipe line are h_1 and h_2 respectively. ($h_1 > h_2$). Then:-
(a) inside film shall control heat transfer rate
(b) outside film shall control heat transfer rate
(c) pipe wall shall control heat transfer rate
(d) both inside film and pipe wall shall control heat transfer rate.

(ii) For lumped parameter model to be applicable Biot Number should be
(a) less than 10 (b) less than 1
(c) less than 0.1 (d) greater than 10.

(iii) Drop wise condensation occurs on
(a) polished surface (b) black surface
(c) rough contaminated surface (d) gray surface.

(iv) Two spheres A and B of same material have radii 1m and 2m and temperatures 4000 K and 2000 K respectively. The energy radiated by sphere A is
(a) greater than that of sphere B (b) less than that of sphere B
(c) equal to that of sphere B (d) equal to double that of sphere B.

(v) The ratio between Kinematic viscosity to Thermal diffusivity is known as
(a) Prandtl number (b) Nusselt number
(c) Peclet number (d) Schmidt number

(vi) The hydro-dynamic and thermal boundary layer are identical at Prandtl number equal to
(a) 0.5 (b) 1 (c) 10 (d) 50

(vii) The limiting value of LMTD correction factor, F_T in a multipass heat exchanger is
(a) 1 (b) 10 (c) 0.5 (d) 50

(viii) Uneven expansion of Shell and tube bundles in a Shell and tube heat exchanger is accounted for by use of
(a) baffles (b) tie-rods
(c) bellows (d) both (a) & (b)

(ix) Increased number of effects in multiple effect evaporator
(a) increases steam economy (b) decreases evaporator capacity
(c) increases evaporator capacity (d) both (a) & (b)

(x) Parallel flow arrangement is recommended for
(a) cooling of heat sensitive material
(b) heating of heat sensitive material
(c) cooling of high viscous fluids
(d) heating of high viscous fluids

Group - B

2. (a) A furnace wall 25 cm thick has a mean thermal conductivity of 1.384 w/mK. The inside surface temperature is 1500°C. The surrounding temperature is 45°C. The heat transfer co-efficient at the outside surface is a function of temperature difference and is given by

$$h = (8.05 + 0.085\ \Delta T)\ w/m^2K.$$

Where ΔT is the temperature difference between outside wall surface and surroundings. What is the rate of heat loss per unit area of the wall?

(b) The wall of problem 2(a) has to be insulated in such a manner that the thermal losses do not exceed 500 watt /m^2. This is done by putting an intermediate insulation formed by porous heat resisting bricks of thermal conductivity 0.58 w/mk followed by an insulation of silica bricks of thermal conductivity 0.14 w/mK. If the thickness of the porous brick is 25 cm, what should be the thickness of silica brick?

(c) What is the value of overall heat transfer co-efficient of problem 2(b)?

4 + 6 + 2 = 12

3. (a) A cylindrical stainless steel (k = 25 w/mK) ingot 10 cm in diameter and 25 cm long, passes through a heat treatment furnace 5 meter in length. The initial ingot temperature is 90°C, the furnace gas is at 1260°C and combined radiation and convective co-efficient of heat transfer is 100 w/m^2K. Determine the maximum velocity at which the ingot moves through the furnace, if the ingot has to attain a temperature of 830°C. Thermal diffusivity of stainless is 0.45 x 10^{-5} m^2/s.

(b) What is critical insulation radius? Derive an expression for critical insulation radius on a cylindrical surface, if the thermal conductivity of the insulating material is k and the film co-efficient on the outer surface is h.

(c) Define efficiency and effectiveness of a fin. What should be the value of effectiveness of a fin to improve heat dissipation from the primary surface and how can that be achieved?

5 + (1+2) + (2+2) = 12

Group – C

4. (a) Air at 200°C is heated as it flows through a 2.5 cm diameter tube at a velocity of 10m /sec. The wall temperature is always 20°C above the air temperature. How much will the bulk temperature of air increase over a 5 m length of the tube? Given the following properties of air:
Density = 1.493 kg/m^3, viscosity = 2.57 x 10^{-5} kg/m sec, thermal conductivity = 0.0386 w/mk and sp. Heat = 1025 J/kg K.
Under turbulent flow condition Dittus – Boielter equation applies.

(b) What is LMTD? Between parallel flow and counter flow, which one will have higher LMTD for a given set of inlet and outlet temperatures of hot and cold fluids? Under what conditions LMTD for parallel flow and counter flow will be equal? For cooling of fruit juice concentrate would you recommend counter flow? Justify your answer.

7 + (1+1+1+2) = 12

5. (a) Define hydrodynamic boundary layer and thermal boundary layer. For what value of Prandtl number the thickness of hydrodynamic and thermal boundary layers are equal?

(b) Establish Reynold's analogy with the help of Newton's law of viscocity and Fourier's law of conduction.

(c) A hot square plate 40 cm x 40 cm at 100°C is exposed to atmospheric air at 20°C. Calculate the rate of heat loss from the surfaces of the plate if the plate is kept horizontal. Assume that the following correlations can be used for calculating film co-efficient by natural convection.
Nu = 0.72 (Gr. Pr)$^{0.25}$ for upper surface
= 0.35 (Gr. Pr)$^{0.25}$ for lower surface
Average physical properties of air are as follows:
ρ = 1.06 kg/m^3, κ = 0.028 w/m k, C_p = 1.008 KJ/kg k
γ = 18.97 x 10^{-6} m^2/s.

(2+1) + 4+ 5 = 12

Group – D

6. (a) The spectral emissivity of a grey surface at 1227 ^{0}C can be approximated by a step function of wavelength as shown in fig 1. Calculate the total emissive power.

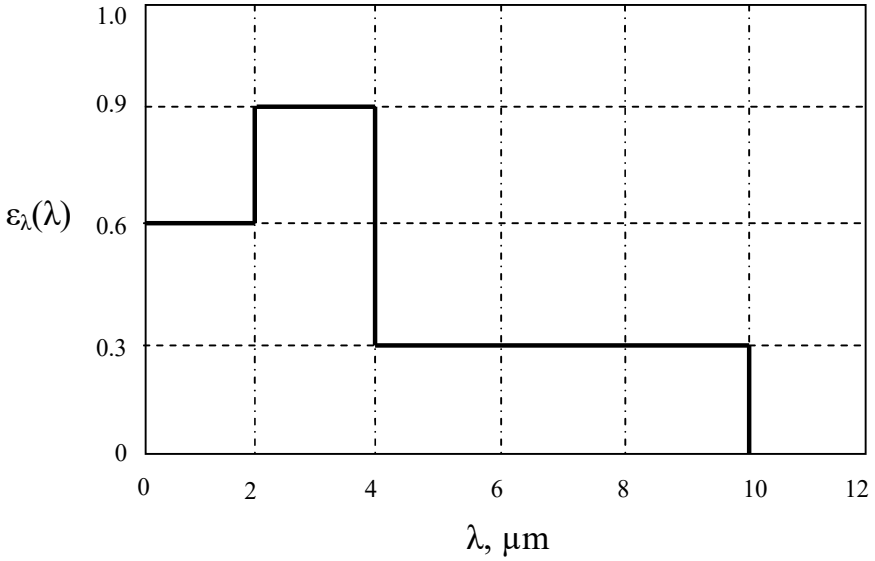

Fig. 1

Planck's radiation functions Table

λT (μm K)	$F_{b,(0-\lambda)}$	λT (μm K)	$F_{b,(0-\lambda)}$	λT (μm K)	$F_{b,(0-\lambda)}$	λT (μm K)	$F_{b,(0-\lambda)}$
1222.2	0.0025	3333.3	0.3474	5666.7	0.7076	9444.4	0.9017
1333.3	0.0053	3666.7	0.4171	6000.0	0.7383	10555.6	0.9247
1666.7	0.0254	4000.0	0.4809	6333.3	0.7643	11666.7	0.9411
2000.0	0.0667	4333.3	0.5381	7000.0	0.8081	15000.0	0.9689
2222.2	0.1051	4666.7	0.5890	7333.3	0.8262	33333.3	0.9963
2555.0	0.1734	5000.0	0.6337	7666.7	0.8421		
3000.0	0.2733	5333.3	0.6731	8333.3	0.8688		

(b) State 'Kirchhoff's law'.

(c) A surface is lying on the sphere (Fig 2). Find the shape factor for the surface with respect to sphere.

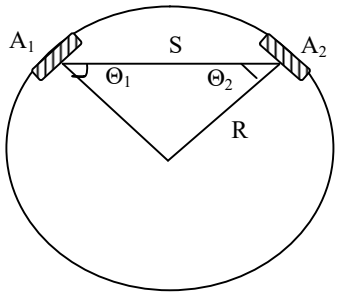

Fig. 2

6 + 2 + 4 = 12

7. (a) Briefly describe the different boiling regimes during pool boiling of saturated liquid.

(b) Explain the significance of 'Leidenfrost point'?

(c) Explain 'the shape of the bubble changes with the surface'.

8 + 2 + 2 = 12

Group - E

8. (a) A 1-2 Shell and tube heat exchanger consisting of 3000 number 20 mm diameter tube is installed in a power plant to condense dry saturated steam at 50°C at a rate of 100 kg/s. Cooling water at 20°C is flowing through the tubes at a rate of 3000 kg/s.
Calculate:
a) heat load
b) overall heat transfer co-efficient
c) outlet temperature of cooling water
d) heat transfer area of the heat exchanger
e) tube length per pass

Given:
film co-efficient for condensation on the outer surface is 15500 Watt/m^2 K

latent heat of condensation of steam is 2380 KJ/kg.
Also given the following property values of water:
C_p = 4180 J/kg K, μ = 855 X 10^{-6} Ns/m^2, k = 0.613 Watt/m K and P_r = 5.83
For turbulent flow the following correlation may be used:
$N_u = 0.023 (R_e)^{0.8} (P_r)^{0.4}$

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

9. (a) Discuss relative merits and demerits of triangular pitch arrangement and square pitch arrangement of the tubes in a Shell and tube heat exchanger.

(b) What is the advantage of increasing the number of effects in multiple effect evaporator system? How does increased number of effects affects the capacity of each evaporator unit?

(c) When would you prefer backward feed in a multiple effect evaporator unit and why? What is the adverse effect of backward feed?

(d) Briefly discuss how heat exchanger network synthesis leads to minimisation of energy consumption in chemical process plant.

3 + 3 + 3 + 3 = 12