*Name* : .....

*Roll No.* : .....

*Invigilator's Signature* : .....

**CS / B.TECH (CHE) / SEM-5 / CHE-502 / 2010-11**

**2010-11**

# PROCESS HEAT TRANSFER

*Time Allotted* : 3 Hours *Full Marks* : 70

*The figures in the margin indicate full marks.*

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

## GROUP – A

## ( Multiple Choice Type Questions )

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) If $k_s$, $k_l$ and $k_g$ are the thermal conductivities of aluminium, water and air at the same temperature, then

   a) $k_s > k_l > k_g$ b) $k_s > k_g > k_l$

   c) $k_l > k_g > k_s$ d) $k_g > k_l > k_s$.

   ii) Transfer of heat by molecular collision is known as

   a) Conduction b) Convection

   c) Radiation d) all of these.

iii) The unit of thermal conductivity is

a) K/W.m b) W.m/K

c) W/m.K d) none of these.

iv) For a multi pass shell and tube heat exchanger, the LMTD correction factor is always

a) = 1 b) >1

c) <1 d) between 1 and 2.

v) Biot number is given by

a) $\frac{\mu c_p}{k}$ b) $\frac{hL}{k}$

c) $\frac{\alpha t}{L^2}$ d) none of these.

vi) Increasing number of effects in a multiple effect evaporator system

a) increases system economy

b) decreases system economy

c) increases evaporator capacity

d) none of these.

vii) The surface temperature of a small blackbody having a total emissive power of 4000W/$m^2$ is

a) 515 K b) 515°C

c) 810 K d) 810°C.

viii) In Wien's displacement law, the value of $\lambda_{max} T$ is

a) 2898 micron K b) 5200 micron °R

c) both (a) and (b) d) none of these.

ix) Dropwise condensation occurs on

a) smooth surface

b) rough and contaminated surface

c) grey surface

d) none of these.

x) Baffles are installed in the shell side of the shell-and-tube heat exchanger

a) to promote cross flow of shell side fluid

b) to raise velocity of shell side fluid

c) both (a) and (b)

d) none of these.

xi) If an infinitely long cylinder of radius $r_1$ is enclosed by another infinitely long cylinder of radius $r_2$, the view factor $F_{22}$ is

a) $r_1 / r_2$ b) 1

c) $1 - (r_1 / r_2)^2$ d) $1 - r_1 / r_2$.

xii) In sub-cooled boiling, the temperature of the liquid mass is

a) below of its boiling point

b) at boiling point

c) either (a) or (b)

d) none of these.

## GROUP – B

## ( Short Answer Type Questions )

Answer any *three* of the following. $3 \times 5 = 15$

2. Derive an expression on rate of heat conduction through a solid slab wall under steady state condition.

3. Calculate the heat transfer coefficient for water at 60°C flow through a 0.625 cm diameter tube with a velocity of 0.9 m/sec. The tube wall temperature is 40°C. The following property for water at 50°C was observed

   $\mu$ = 2.17 kg/m-hr.

   k = 0.63 W/m.K = 2.27 kJ/m.hr.k.

   Cp = 4.187 kJ/kg.K

   $\rho$ = 1000 kg/$m^3$

4. Explain the term 'Regime of Boiling' with a neat diagram. Also compare the essential features of filmwise and dropwise condensation.

5. Two very large parallel planes with emissivities 0.3 and 0.8 exchange heat. Find the percentage reduction in the heat transfer when a polished aluminium radiation shield ($\varepsilon$ =0.04) is placed between them.

6. What is fouling factor ? Derive the expression of overall heat transfer co-efficient taking fouling factor in consideration.

2 + 3

## GROUP – C

## ( Long Answer Type Questions )

Answer any *three* of the following. 3 × 15 = 45

7. a) Explain the terms :

(i) Critical insulation thickness

(ii) Optimum insulation thickness.

b) Heat is being transferred under steady state condition through a cylindrical fire clay pipe whose *k* varies linearly from 0.86 to 1.52 kcal/hr.m.°C over the temperature range 100°C to 1400°C. The inside of the pipe ( inside diameter 60 cm & outside 200 cm ) is maintained at 1220°C and outside at 120°C. Calculate the rate of heat transfer per linear meter of the pipe.

8 + 7

8. a) Draw the temperature profiles for parallel and counter flow heat exchangers and explain which one is more efficient. When would you recommended parallel flow ?

b) 4550 kg/hr of water is to be heated from 10°C to 77°C with flue gases having an initial temperature of 166°C. The mass flow rate of the gases is 18200 kg/hr. If the overall heat transfer coefficient is 114 $W/m^2k$, calculate the area of heating surface required for parallel and counter flow. Given sp. heats of water and flue gases are $4.187 \times 10^3$ kJ/kg.k and $1.05 \times 10^3$ kJ/kg.k respectively.

( 4 + 2 ) + 9

9. a) Establish the LMTD equations in terms of hot fluid inlet and outlet temperatures ($T_1$ and $T_2$) and cold fluid inlet and outlet temperatures ($t_1$ and $t_2$) for a parallel flow double pipe heat exchanger in which hot fluid flows through the inner pipe and cold fluid passes through the annular space.

   b) What are the empirical equations generally used for determination of convective heat transfer coefficients in laminar and turbulent flows ? Discuss briefly. 10 + 5

10. a) What are the assumptions made during the derivation of Nusselt's equation for heat transfer to condensing vapour (film type condensation) over a vertical tube.

   b) Steam saturated at 68.9 Kpa is condensing at 89.44°C on a vertical tube of 0.305 m long having an outside dia of 0.0254 m and a surface temperature of 86.11°C. Calculate the average heat transfer coefficient of the condensing steam and rate of condensation of steam. Neglect fouling factors and tube wall resistance.

   Data : At the mean film temperature of the condenser : Latent heat = $2.283 \times 10^6$ J/kg, Density of film = 966.7 kg/m$^3$, Viscosity of the film = $3.24 \times 10^{-4}$ Pa.s, Thermal conductivity of the film = 0.675 watt/m-K, Density of vapour can be neglected.

   c) Prove that the rate of radiation heat transfers between two large parallel planes with one radiation shield is one half of the radiation heat transfer between them in absence of radiation shield.

d) How do you differentiate gray body from black body ?

3 + 6 + 5 + 1

11. a) A single effect evaporator is used to concentrate 12000 kg/hr of solution containing 20% solute to 50% solute. Stream used for heating the solution has saturation temperature 120°C and the pressure in vapour space is maintained at 103.4 mmHg at which pure water boils at 72°C and latent heat of vaporization 2320 KJ/kg. Feed enters the evaporator at 40°C. Assuming the boiling point elevation of the solution to be 10°C, calculate the heat transfer area required and the economy of the system.

Data : Latent heat of vaporization of stream at
120°C = 2190 KJ/kg,
Specific heat of feed = 3.7 KJ/kgK,
Specific heat of concentrated liquor = 3.1 KJ/kgK,
Specific heat of water vapour = 2.1 KJ/kgK,
Overall heat transfer coefficient = 1.25 k watt/$m^2$K.

b) Define capacity and economy of an evaporator.

c) What is the recommended method of feeding of concentration of viscous fluid in the multiple effect evaporators ?

d) How does concentration of solute in the solution affect evaporation ?

8 + 2 + 2 + 3

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