Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech(CHE)/SEM-5/CHE-502/2011-12

2011

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) Most metals are good conductor of heat because of

      a) energy transport due to molecular vibration

      b) migration of neutrons from hot end to cold end

      c) lattice defects such as dislocations

      d) presence of many free electrons and frequent collision of atoms.

   ii) For steady state and constant value of thermal conductivity, the temperature distribution associated with radial conduction through a cylinder has a ..... curve.

      a) linear b) logarithmic

      c) parabolic d) exponential.

iii) Which of the following forms of water have the highest value of thermal conductivity ?

a) Boiling water b) Steam

c) Solid ice d) Melting ice.

iv) Reynolds Analogy states that

a) $St = \frac{f}{2}$ b) $St = \frac{f}{4}$

c) $St = 4f$ d) $St = \sqrt{f}$.

v) The temperature distribution during transient heat conduction in a solid does not depend on

a) Location of point within the solid

b) Biot number

c) Prandtl number

d) Fourier number.

vi) Critical thickness of insulation for spheres is given by

a) $\frac{k}{h}$ b) $\frac{k}{4\pi.h}$

c) $\frac{h}{2k}$ d) $\frac{2k}{h}$.

vii) Heat transfer rate of dropwise condensation is ..... times that of film-types condensation.

a) 5 to 10 b) 10 to15

c) 15 to 20 d) 20 to 25.

viii) In a boiling curve, the point at which the peak heat flux is observed is called

a) Nusselt point b) Leindenfrost point

c) Bubbling point d) Burn – out point.

ix) The Stefan-Boltzman constant is independent of

a) the radiating surface

b) the medium

c) the absolute temperature of the surface

d) all of these.

x) Film-type condensation occurs on

a) clean and dirt free surfaces

b) smooth and clean surfaces

c) contaminated cooling surfaces

d) polished surfaces.

xi) Solid angle subtended by the finite surfaces at the radiating element is

a) called view factor

b) angle of vision

c) expressed in terms of radians

d) proportional to the square of the distance between surfaces.

xii) A cold fluid is heated from 40°C to 120°C by steam entering at 150°C. The LMTD in co-current flow is

a) lower than the LMTD in counter-current flow

b) greater than the LMTD in counter-current flow

c) equal to the LMTD in counter-current flow

d) zero.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. Deduce an expression for critical insulation radius in terms of thermal conductivity of the insulating material and outside film heat transfer coefficient on a cylindrical surface.

3. Show that in an N-effect evaporator system the capacity of each effect is 1/N times the capacity of a single effect evaporator operating under identical operating conditions.

4. In a shell & tube heat exchanger a hot fluid at 180°C is to be cooled to 90°C using cooling water available at 27°C which will be heated to 36°C. What will be the magnitude of LMTD if

a) the flow is parallel

b) the flow is counter ?

5. a) Explain how uneven expansion of shell and tubes is accounted for in a shell and tube heat exchanger.

   b) Derive an expression for shell side equivalent diameter when the tubes are laid in square pitch.

6. What is LMTD correction factor ? What is its limiting value ? Under what condition its value becomes equal to its limiting value ? What is its minimum acceptable value ?

7. Prove that the temperature profile for a steady state heat conduction with heat generation through a hollow cylinder can be expressed as :

   $T - T_0 = QR^2 / 4K [1 - (r/R)^2]$

   where T_0 and T are the temperature at radial position R and r and K is the thermal conductivity of the cylinder.

GROUP – C

(Long Answer Type Questions)

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

8. a) Derive critical radius $\left(r_c = \frac{k}{h} \right)$ for a cylinder in a steady state condition.

   b) A 2 mm diameter wire with 0.8 mm thick layer of insulation (k = 0.15 W/m°C) is used in a certain electric heating application. The insulated surface is exposed to atmosphere with convective heat transfer co-efficient 40 W/m°C. What percentage change in heat transfer rate would occur if critical thickness of insulation is used ? It may be assumed that temperature difference between surface of the wire and surrounding air remains unchanged. 5 + 10

9. a) Derive the general equation of Fourier's Law of heat conduction based on unsteady state conduction of heat.

b) During heat treatment, cylindrical pieces of 25 mm diameter, 30 mm height and at 30°C are placed in a furnace at 750°C with convection coefficient 80 W/m^2 °C. Calculate the time required to heat the pieces to 600°C. What will be the shortfall in temperature if the pieces are taken out from the furnace after 280 seconds ? Assume the following property values : density 7850 kg/m^3 ; specific heat 480 J/kgK; thermal conductivity 40 W/m°C. 6 + 9

10. a) What is the difference between natural and forced convection ?

b) A hot square plate 40 cm ∞ 40 cm at 100°C is exposed to atmospheric air at 20°C. Make calculations for the heat loss from both surfaces of the plate. If (i) the plate is kept vertical (ii) plate is kept horizontal.

The following empirical correlations have been suggested :

$Nu = 0{\cdot}125 (Gr\ Pr)^{0{\cdot}33}$ for vertical position of plate, and

$Nu = 0{\cdot}72 (Gr\ Pr)^{0{\cdot}25}$ for upper surface

$= 0{\cdot}35 (Gr\ Pr)^{0{\cdot}25}$ for lower surface

where the air properties are evaluated at the mean temperature. 3 + 12

11. a) State Wien's displacement law.

b) Assuming the sun to be a black body, emitting radiation with maximum intensity at wavelength of 0·5 micron, estimate the surface temperature of sun and radiant heat flux at its surface.

c) Deduce an expression for heat exchange by radiation between two infinite parallel plates at temperatures T_1 & T_2 assuming the plates to be gray surface.

2 + 5 + 8

12. a) How can steam consumption of an evaporator be determined if capacity and economy of that is known ?

b) A continuous single effect evaporator is to be fed with 5000 kg/hr of solution containing 1 wt% solute. The feed is at a temperature of 303 K. It is to be concentrated to a solution of 2 wt% solute. The evaporation is at atmospheric pressure and the area of the evaporator is 69.7 m^2 . Saturated steam is supplied at 193.3kPa for heating. Calculate the amounts of liquid and vapour product and the overall heat transfer coeffecient.

Data :

Saturation temperature of steam at 193.3 kPa = 383.2 K

Boiling point of the solution = 373.2 K

Enthalpy of feed = 125.79 kJ/kg

Enthalpy of saturated steam = 2691.5 kJ/kg

Enthalpy of liquid = 419.04 kJ/kg

Enthalpy of vapour = 2676.1 kJ/kg

Enthalpy of condensed steam = 461.30 kJ/kg.

c) What is steam trap ? Where steam traps are used in chemical industries ? 3 + 9 + 3

13. a) 15000 kg/hr of a solution of an organic solute in water containing 10 per cent solid is to be concentrated to 50 per cent solid in a single effect evaporator. Dry saturated steam is available at 120°C and the vapour space of the evaporator will be maintained at 103 mm Hg at which boiling point of water is 72°C. Latent heat of steam is 2190 kJ/kg K at 120°C & 2320 kJ/kg K at 72°C. Feed will enter the evaporator at 45°C. The overall heat transfer coefficient is 1280 Watt/m^2 K. Sp. Heat of the solution is 3.9 kJ/kg K. Calculate heat transfer area of the evaporator and steam economy.

b) Discuss the advantages and disadvantages of forward & backward feed in a multiple effect evaporator system.

10 + 5