Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH (CHE-NEW)/SEM-4/CHE-402/2012

2012

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.

Answer Question No. **1** and any *five* from the rest taking at least *one* from each Module.

1. Choose the correct alternatives for the following :

$10 \times 1 = 10$

i) What happens when the thickness of insulation on a pipe exceeds the critical value ?

a) There is decrease in the heat flow rate

b) There is decrease in the heat flow rate

c) The heat flow rate remains constant

d) The temperature rises at the junction between pipe and insulation.

ii) Finned surfaces have improved rate of heat dissipation due to

a) decrease in ambient temperature

b) increase in surface area exposed to the surrounding

c) increase in the convecting film coefficient

d) all of these.

iii) Forced convection in a liquid bath is caused by

a) density difference brought about by temperature gradients

b) molecular energy interactions

c) flow of electrons in a random fashion

d) intense stirring by an external energy.

iv) Increasing the number of effects in a multiple effect evaporator system increases

a) evaporator capacity

b) evaporator economy

c) both evaporator economy & capacity

d) none of these.

v) Expansion bellows are employed in shell & tube heat exchangers

a) as a safety measure

b) to reduce pressure drop of the shell side fluid

c) to account for uneven expansion between shell & tube

d) to provide more heat transfer area.

vi) Drop wise condensation occurs on

a) clean surface

b) polished surface

c) rough and contaminated surface

d) black surface.

vii) Boiling point rise of the solution in an evaporator

a) decreases evaporator capacity

b) increases evaporator economy

c) increases evaporator capacity

d) decreases evaporator economy.

viii) Two individual film coefficients in a heat exchanger are h_1 and h_2 $(h_1 > h_2)$. The magnitude of overall heat transfer coefficient will be

a) higher than h_1 b) between h_1 & h_2

c) lower than h_2 d) none of these.

ix) The ratio of kinematic viscosity to thermal diffusivity is known as

a) Prandtl number b) Nusselt number

c) Peclet number d) Schmidt number.

x) Up to critical radius of insulation

a) heat loss decreases with addition of insulation

b) heat loss increases with addition of insulation

c) there occurs a decrease in heat flux

d) conduction heat loss is more than convection heat loss.

MODULE – I

2. A cylindrical tank having a diameter of 1·2 m, a length of 6 m and hemispherical ends is to be used for storing liquid oxygen. The boiling point of liquid oxygen is –182°C and its latent heat of vaporization is 214 kJ/kg. To reduce the boil off rate of oxygen the tank needs to be insulated. If the maximum boil off rate of oxygen is restricted to 10 kg/hr, what should be the thermal conductivity of the insulating material when the maximum thickness of insulation is limited to 7·5 cm and the outside temperature is 25°C ? 12

3. During a heat treatment process, alloy steel spherical balls of 12 mm diameter are initially heated to 800°C in a furnace. Subsequently these are cooled to 100°C by keeping them immersed in an oil bath at 35°C. The convective heat transfer coefficient between ball surface and oil is 20 W/m^2K.

   a) Determine the time required for the cooling process.

   b) If it is desired to complete the cooling process in a period of 10 minutes, what should be the value of convective heat transfer coefficient ?

   Properties of steel balls are

   Density = 7750 kg/m^3, sp. heat = 520 J/kg K,

   thermal conductivity = 50 W/mK.

   Lumped parameter model can be adopted. 7 + 5

MODULE – II

4. A rectangular plate is 15 cm^2 area maintained at 200°C is exposed to still air at 30°C. When smaller side of the plate is held vertical, convective heat transfer rate is 15% higher than when the bigger side of the plate is held vertical. Calculate the side lengths of the plate and heat transfer rate in both cases.

   Physical properties of air at mean film temperature of 115°C are

density	=	0·91 kg/m^3
C_p	=	1·008 kJ/kg K
μ	=	22·65 NS/m^2
K	=	0·033 W/mK

   The appropriate correlation for natural convection coefficient is

   $Nu = 0{\cdot}60\ (\text{Gr. Pr.})^{0{\cdot}25}$. 12

5. 3000 kg/hr of water is rated from 30°C to 70°C by pumping it through a certain heated section of a 25 mm diameter tube. If the surface of the heated section is maintained at 110°C estimate

   a) length of the heated section

   b) rate of heat transfer from tube to water.

   Physical properties of water are

   Density = 971·6 kg/m^3

   Viscosity = $0{\cdot}355 \times 10^{-3}$ kg/ms

   Thermal conductivity = 0·667 W/mK

   Specific heat = 4195 J/kg K.

   For turbulent flow :

   $Nu = 0{\cdot}023\ (Re)^{0{\cdot}8}\ (Pr)^{0{\cdot}4}$

   where the notations have their usual significance. 8 + 4

MODULE – III

6. a) Name and explain different forms of boiling.

   b) Draw boiling curve in the form of surface heat flux as a function of excess temperature and discuss different regimes of boiling. What is critical heat flux ?

   c) Make a comparative study between horizontal and vertical condensation. 2 + (5 + 1) + 4

7. a) Deduce an expression for net radiant heat exchange between two non-black infinitely long parallel surfaces arranged at small distance from each other.

   b) Two parallel square plates each 4 m^2 area, are large compare to a gap of 5 mm separating them. One plate has a temperature of 800 K and surface emissivity of 0·6, while the other has a surface temperature of 300 K and a surface emissivity of 0·9. Find the net energy exchange by radiation between the plates. 7 + 5

MODULE – IV

8. 36000 kg/hr of dry saturated steam at 50°C is to be condensed in a shell and tube heat exchanger consisting of tubes having inside and outside diameter of 22·5 mm respectively. Cooling waster at 15°C flows through the tubes with a velocity of 2 m/s and leaves at 25°C. Heat transfer coefficient on the steam side is 5000 W/m^2K. Find

   a) mass flow rate of water and number of tubes required

   b) overall heat transfer coefficient and heat transfer surface area

   c) number of tube passes if the length of each tube per pass is not to exceed 2·5 m.

Physical properties of water are :

Density = 998·8 kg/m ^{3}

Sp. heat = 4186 J/kg K.

Kinematic viscosity = 1×10^{-6} m ^{2}/s

Thermal conductivity = 0·6 W/mK

Latent heat of condensation of steam = 2375 kJ/kg.

Given for turbulent flow :

$Nu = 0{\cdot}023 (Re)^{0{\cdot}8} (Pr)^{0{\cdot}4}$. 12

9. a) Define steam economy of an evaporator. How the steam economy can be improved ?

b) What are the different modes in which dilute feed can be introduced into a multiple effect evaporator ? Discuss the merits and demerits of each mode.

c) Why evaporator tubes are shorter in length as compared to heat exchange tubes ?

d) How does boiling point rise of solution affects the performance of evaporator ? 2 + 6 + 2 + 2