(Set-K)

B. Tech. –5(Chem Engg)

Heat Transfer

Full Marks : 70

Time : 3 hours

Answer any **six** questions including **Q.No.1** which is compulsory.

The figures in the right-hand margin indicate marks.

Symbols carry usual meaning.

1. Answer *all* questions : 2 × 10

(*a*) How does thermal conductivity of solids, liquids and gases depend upon temperature ?

(*b*) Write down the expression for thermal resistances of a wall, an annular cylinder and a spherical shell.

(*c*) In case of insulating and electrical wire, should the outer radius of insulation be more or less than the critical radius and why ?

(*d*) What are the influences of fin length and fin thickness on efficiency of a fin ?

(*e*) Why is the heat transfer coefficient in forced convection greater than that in free convection ?

(*Turn Over*)

(*f*) Under what condition thermal boundary layer remain within hydrodynamic boundary layer ?

(*g*) Which boiling regime is preferred in industrial boiler and vaporizer ?

(*h*) A piece of metal reflects 30% of the incident solar radiation, what are its absorptivity and transmissivity ?

(*i*) If the length of counter flow heat exchanger is increased, what will happen to the effectiveness of the exchanger–Will it increase or decrease ?

(*j*) What type of evaporator is suitable for concentrating a highly viscous solution ?

2. (*a*) The temperature of the gas stream is to be measured by thermocouple whose junction can be approximated as a 1.5 mm diameter sphere. The properties of the junction are $k = 40$ W/(mK), $\rho = 8000$ kg/m^3, $C_p = 300$ J/ (kg K) and the heat transfer coefficient between the junction and the gas is $h = 75$ W/(m^2 °C). Determine the time constant of the thermocouple junction and the time it takes to read a temperature which corresponds to a temperature difference (the difference in temperature between the gas stream and the thermocouple junction) of 99 percent of its initial value. 5

(b) What is meant by steady state heat conduction through a medium ? Explain the situation physically in the case of medium without the generation of thermal energy. 5

3. (a) What are the influences of fin length and fin thickness on the efficiency of a fin ? 5

(b) A 1.0 mm diameter wire is maintained at a temperature of 400 °C and exposed to a convection environment at 40 °C with h = 120 W/(m^2 / K), calculate the thermal conductivity which will just cause an insulation thickness of 0.2 mm to produce a critical radius. What should be the insulation thickness to reduce the heat transfer by 75 percent from that which would be experienced by the bare wire ? 5

4. (a) What is the difference between Reynolds analogy and Prandtl analogy ? What is the significance of Colburn j-factor ? 5

(b) Air flows over a flat surface, 2 m in length oriented in the direction of flow and of sufficient breadth, maintained at 150 °C. The pressure is 1 atm and the bulk air temperature is 30 °C. If the air velocity is 12 m/s, determine (*i*) the local heat transfer coefficient as a function of longitudinal position, (*ii*) the average heat transfer coefficient and (*iii*) the rate of heat loss from the surface. Data: The relevant physical properties of air are taken at the mean film temperature that is at 90 °C. These are $\rho = 0.962$ kg/m^3; $\mu = 2.131 \times 10^{-5}$ kg/m s; k = 0.031 W / m °C, C_p = 1.01 kJ/kg °C. 5

5. (*a*) Steam at 100 °C is being condensed on the outer surface of a horizontal tube of 3 m length and 50 mm outer diameter, while the tube surface is maintained at 90 °C. Determine the average heat transfer coefficient and the total rate of condensation over the tube surface. Data: The properties of condensate are evaluated at the mean film temperature i.e 95 °C as $\rho = 962$ kg/m^3; $k = 0.677$ $W/m\,K$; $\mu = 3.0 \times 10^{-4}$ kg/(m s). The value of ρ_v and f_g at 100 °C are 0.598 kg/m^3 and 2.27×10^6 J/kg. 5

   (*b*) Write the pertinent dimensionless terms governing the phenomenon of forced convection and free convection. 5

6. (*a*) What is the difference between dropwise condensation and film condensation ? Which of the two is the more effective way of condensation and why ? 5

(*b*) What are the different boiling regimes ? When does radiation play a role in boiling heat transfer ? What is Leiden frost phenomenon ? 5

7. (*a*) What is Wien's displacement law ? At what wavelength does a body at 2000 K emit maximum radiation ? 5

(*b*) It is required to concentrate a dilute solution of NaOH from 8% to 45% concentration using a forward feed triple effect evaporator. The total evaporation rate is 8000 kg water per hour. The feed enters at 60 °C and a vacuum of 0.85 bar is maintained in the last effect. Steam is available at 5 bar absolute pressure. The overall heat transfer coefficients corrected for boiling point elevation are estimated to be 5000, 3400, and 2400 W/m^2 °C for the first, second and third effect respectively. Calculate the evaporation areas, steam rate and steam economy. 5

8. (*a*) What are the selection criteria of Heat Exchanger ? Define fouling factor. 5

(*b*) A shell and tube heat exchanger cools oil which flows at the rate of 5 kg/s with an inlet temperature of 80 °C and the outlet temperature of 40 °C. The cold fluid is water which flows at the rate of 10 kg/s with an inlet temperature of 20 °C. The overall heat transfer coefficient is 555 W/(m² °C). Determine the heat transfer surface area required for (*i*) a parallel flow heat exchanger and (*ii*) a counter flow heat exchanger.

Take $C_{p,\ oil}$ = 2 kJ/(kg °C),

$C_{p,\ water}$ = 4.2 kJ/(kg °C) 5
