Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/M.TECH (CHE)/SEM-1/CHE-1/2010-11

2010-11

ADVANCED 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 any *five* questions taking at least *one* from each Module.

MODULE – 1

1. a) Consider a rectangular block of solid having sides a, b, c. The initial temperature of the body is T_i and it is raised to T_s in time t. Formulate the unsteady state three-dimentional heat conduction equation, if the volumetric heat flow rate is given by Q_v. Hence establish the Laplace's equation.

   b) 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 temperatures at radial positions R and r and K is the thermal conductivity. 7 + 7

2. a) Heat is flowing through an annular wall of inside radius r_0 and outside radius r_1. The thermal conductivity varies linearly with temperature from k_0 at T_0 to k_1 at T_1. Develop an expression for the heat flow through the wall at $r = r_0$. Also show how the expression can be simplified when $(r_1 - r_0)$ is very small.

b) Estimate the rate of evaporation of liquid oxygen from a spherical container of 1·8 m inside diameter covered with 30 cm of asbestos insulation. The temperatures at the inner and outer surfaces of the insulation are – 183°C and 0°C respectively. The boiling point of oxygen is – 183°C and the latent heat of vaporization is 212·5 kJ/kg. The thermal conductivity of the insulation is 0·157 and 0·125 W/m°K at 0°C and at – 183°C respectively. 6 + 8

MODULE – II

3. a) Apply Bukinghum π method to establish a correlation between Nu, Pr and Gr in natural convection.

b) A fluid of density ρ and viscosity μ is placed between two vertical walls at a distance of $2b$ apart. The heated wall at $y = -b$ is maintained at temperature T_2 and cooled wall at $y = +b$ is maintaied at temperature T_1. Prove that the final expression of the velocity distribution can be given as the following expression

$$V_z = \rho \,.\, \beta \,.\, gb^2 \ \Delta T \left(\eta_3 - \eta_1 \right) / (12 \,.\, \mu)$$

where β is volume expansion coefficient and η is y/b.

6 + 8

4. a) What do you mean by Reynolds Analogy and Prandtl Analogy. Write down the significance of Colburn j-factor. 5 + 2

b) The reaction gas mixture leaving the catalytic reactor in an aniline plant is condensed in a shell-and-tube heat exchanger. Condensation occurs in the tube side while cooling water flows through the tubes. The tubes are 3 m long and of 25 mm outer dia. Water flows at a rate of 0·057 m^3 /minute per tube. Water enters at 32°C. The tube wall temperature is assumed to remain constant at 80°C. Calculate the rise in temperature of water as it flows trough the tubes considering the heat transfer analogies. Physical properties of water at 32°C are ρ = 995 kg/m^3 , Viscosity = 7·65 ∞ 10^{-4} kg/m.s., k = 0·625 W/m°C, sp. heat = 4·17 kJ/kg°C. 7

MODULE – III

5. a) Starting from energy equation of the laminar boundary layer, $u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2}$, derive an expression for the thermal boundary layer thickness for liquid metal flowing across a flat plate heated over its entire length.

b) Define Jacob number and condensation number.

12 + 2

6. a) Water at the rate of 3·783 kg/s is heated from 37·78°C to 54·44°C in a shell-and-tube heat exchanger. On the shell side one pass is used with water as the heating fluid, 1·892 kg/s, entering the exchanger at 93·33°C. The overall heat transfer coefficient is 1419 W/m^2 °C and the average water velocity in the 1·905 cm diameter tubes is 0·366 m/s. Because of space limitations the tube length must not be longer than 2·438 m. Calculate the number of tube passes, the number of tubes per pass and the length of the tubes consistent with this restriction. For multiple tube passes correction factor F may be taken as 0·88.

b) Derive an expression for calculating nucleation superheat. Can a bubble collapse in a superheated liquid ? 9 + 5

MODULE – IV

7. a) What benefit can be derived by using a radiation shield ?

b) A 2·54 cm *o.d.* tube is used to transpoft a cryogenic liquid at – 196°C from a plant to an adjacent unit. The tube is enclosed in an evacuagted concentric pipe of 52·5 mm *i.d.* having a wall temperature of – 3°C. A thin-walled radiation shield is placed midway in the annular region between the tube and the pipe. Calculate the rate of heat gain by the liquid per metre length of the tube. The following emissivity data are available :

Tube wall - 0·05 ; Pipe wall = 0·1 ; Inner surface of the radiation shield = 0·02 ; Outer surface of the radiation shield = 0·03.

8. a) A rectangular oven is insulated with fibre glass blanket. The oven has outer walls made of carbon steel sheets which do not offer any appreciable heat transfer resistance. The bottom surface is maintained at a constant temperature, T_1 . Heat loss occurs from the outer surfaces (the top and the side walls) by combined radiation and natural convection to an ambient at temperature T_a . All the surfaces are essentially black. Develop the set of equations to calculate the surface temperatures (both inside and outside) and the total rate of heat loss from the oven.

b) Define view factor. Calculate analytically, the radiation shape factor from a small area dA_1 to a circular disc A_2 of radius R which are parallel to each other.

6 + 2 + 6