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Total number of printed pages – 3

B. Tech.  
PCML 4301

**Sixth Semester Examination – 2013**

**TRANSPORT PHENOMENA**

**BRANCH : CHEMICAL**

**QUESTION CODE : A 264**

**Full Marks – 70**

**Time : 3 Hours**

*Answer Question No. 1 which is compulsory and any **five** from the rest.*

*The figures in the right-hand margin indicate marks.*

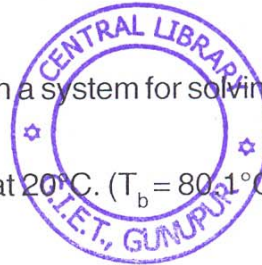
*Assume suitable notations wherever necessary.*

*Assume any missing data suitably.*

1. Answer the following questions :

2×10

- Specify the interface boundary condition in a system for solving momentum transport problems.
- Estimate the viscosity of liquid benzene at 20°C. ( $T_b = 80.1^\circ\text{C}$  and specific molar volume =  $89.0\text{ cm}^3/\text{gmol}$ )
- Define convective momentum transport.
- Define equation of motion.
- What are the boundary conditions used for solving shell heat balance equation ?
- What are the modes of heat transfer process in a double pipe heat exchanger ?
- Write the generalized heat conduction equation for a plane wall with heat generation under unsteady state heat transfer.
- State Eucken formula for thermal conductivity.
- Define Schmidt and Lewis numbers.
- How diffusivity varies with temperature in case of gas and liquid ?



P.T.O.

2. (a) Derive an expression for velocity profile, when non-Newtonian (Power law) fluid flows between two vertical walls, separated by a distance  $2B$ , taking origin at midpoint of  $2B$  distance. 5
- (b) One method for determining the radius of a capillary tube is by measuring the rate of flow of a Newtonian liquid through the tube. Find the radius of a capillary from the following flow data : 5
- Length of capillary tube : 50.02 cm  
 Kinematic viscosity of liquid :  $4.03 \times 10^{-5} \text{ m}^2/\text{s}$   
 Density of liquid :  $955.2 \text{ kg/m}^3$   
 Pressure drop in the horizontal tube :  $4.829 \times 10^5 \text{ Pa}$   
 Mass rate of flow through tube :  $2.997 \times 10^{-3} \text{ kg/sec}$
3. (a) In a pipe flow, if  $v_{av} = (P_0 - P_L)R^2/8\mu L$ , show the head loss is  $32\mu v_{av}L/\rho g d^2$ . 5
- (b) Derive an expression for shear stress profile, when a Newtonian fluid is flowing in an annulus. 5
4. Consider a long cylindrical nuclear fuel rod, surrounded by an annular layer of aluminum cladding. Within the fuel rod heat is produced by fission; this heat source depends on position approximately as :  $S_n = S_{n0} \left[ 1 + b \left( \frac{r}{R_F} \right)^2 \right]$ . Here  $S_{n0}$  and  $b$  are known constants, and  $r$  is the radial coordinate measured from the axis of the cylindrical fuel rod.  $R_F$  and  $R_C$  are the radii of fission and cladding materials. Derive an expression for temperature profile in the cladding material if the temperature at the outer surface of cladding is  $T_0$ . 10
5. (a) A viscous fluid with temperature independent physical properties is in fully developed laminar flow through a vertical tube of radius  $R$ . At  $z = 0$ , the fully developed flow is achieved. For  $z < 0$  the fluid temperature is uniform at  $T = T_1$ . For  $z > 0$ , heat is added radially at a constant, uniform flux  $q_0$ , at the tube surface. Make a shell energy balance to obtain the differential equation for  $T(r, z)$  in the zone  $z > 0$ . 5

- (b) Develop the non-dimensional differential equation of “part a” in terms of the following variables : 5

$$\Theta = (T - T_1)/(q_0 R/K), \quad \xi = r/R, \quad \Phi = Kz/(\rho C_p v_{\max} R^2)$$

6. (a) Diffusion of A through a stagnant gas film. Derive a differential expression for mass flux in z-direction. 5

- (b) Derive the mass flux profile as :  $N_{AZ} = \frac{CD_{AB}}{z_2 - z_1} (x_{A1} - x_{A2})$  by neglecting  $x_A(N_A + N_B)$ . 5

7. (a) A hollow solid sphere has its inner ( $r = R_1$ ) and outer ( $r = R_2$ ) surfaces maintained at concentrations  $C_{A1}$  and  $C_{A2}$  respectively. Obtain the expression for concentration profile in the solid at steady-state condition. 5

- (b) Chloropicrin ( $\text{CCl}_3\text{NO}_2$ ) is evaporating at  $25^\circ\text{C}$  into air inside a cylinder. Make the customary assumption that air is a pure substance. What is the evaporation rate in gm/hr ? 5

Total pressure: 760 mmHg

Diffusivity ( $\text{CCl}_3\text{NO}_2$  - air):  $0.088 \text{ cm}^2/\text{sec}$

Vapor pressure of  $\text{CCl}_3\text{NO}_2$  : 23.81 mmHg

Distance from liquid level to top of tube: 12 cm

Density of  $\text{CCl}_3\text{NO}_2$  :  $1.65 \text{ gm/cm}^3$

Surface area of liquid exposed for evaporation:  $2.8 \text{ cm}^2$

8. Write short notes on any **two** : 5 × 2

- (a) Classify types of fluids  
 (b) Creeping flow around the sphere  
 (c) Conduction and Convection  
 (d) Steady state equimolar counter diffusion.

