SPECIAL SUPPLE B.TECH/CHE/7TH SEM/CHEN 4101/2018

TRANSPORT PHENOMENA
(CHEN 4101)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) For a unit vector δ_1 along x-direction and δ_2 along y-direction, according to definition of unit dyad $\delta_1\delta_2$ yields

(a) $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$ (b) $\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$ (c) $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$ (d) $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

(ii) Tensor is a _____ order system
(a) zero (b) first (c) second (d) third.

(iii) Viscosity of gas is proportional to
(a) T (b) $T^{0.5}$ (c) T^2 (d) $T^{1.5}$
Where T is temperature.

(iv) Hagen-Poiseuille equation relates the mass flow rate of fluid with
(a) the pressure drop inside the pipeline
(b) density of the fluid
(c) viscosity of the fluid
(d) (a), (b) and (c).

(v) Convective energy flux vector is represented by the expression
(a) $[\tau.v]$ (b) $\rho\hat{H}_v$ (c) $(0.5\rho v^2 + \rho\hat{H}_v)v$ (d) $(\rho v^2 + \rho\hat{U}_v)v$

(vi) Thermal conductivity of most liquids
(a) increase with increase in temperature
(b) decrease with increase in temperature
(c) do not change with temperature
(d) is a function of pressure.

(vii) For Reynold's analogy to be valid, Prandtl number (Pr) should be
(a) greater than 1 (b) less than 1
(c) equal to 1 (d) in between 1 and 2.

(viii) In turbulent flow the time smoothed velocity is
(a) independent of time
(b) independent of position
(c) zero
(d) dependent on time, but independent of position.

(ix) For a heterogeneous reaction the Thiele modulus is _____ for a pore diffusion controlled reaction.
(a) more than 1 (b) less than 1
(c) equal to 1 (d) more than or equal to 1.

(x) If $\underline{a}, \underline{b}, \underline{c},$ are 3 vectors, then $\underline{a} \times (\underline{b} \times \underline{c})$ can be written as
(a) $\underline{b}\,(\underline{a} \cdot \underline{c}) - \underline{c}(\underline{a} \cdot \underline{b})$ (b) $\underline{a}\,(\underline{b} \cdot \underline{c}) - \underline{c}(\underline{a} \cdot \underline{b})$
(c) $\underline{c}\,(\underline{b} \cdot \underline{c}) - \underline{b}(\underline{a} \cdot \underline{c})$ (d) $\underline{c}\,(\underline{a} \cdot \underline{b}) - \underline{a}(\underline{b} \cdot \underline{c})$.

Group – B

2. (a) Derive three dimensional forms for a Navier-Stokes equation in Cartesian coordinate for flow of an incompressible fluid of viscosity μ and density ρ.

(b) "Similarity variable in Blasius solution to evaluate momentum boundary layer thickness for a flow over a flat plate is basically used to convert the multidimensional momentum equation into single dimensional equation." – Justify the correctness of the statement.

10 + 2 = 12

3. (a) "Explanation for momentum boundary layer development along the direction of the flow requires understanding of tensor." – Justify the correctness of the statement.

(b) The stress at some point within a balloon is given by: $\sigma_{ij} = \begin{bmatrix} -5 & 2 & -3 \\ 2 & 2 & 1 \\ -3 & 1 & -1 \end{bmatrix}$

MPa. The balloon is kept at 2 atm pressure without any rupture. Write down all the possible tensors acting on the surface of the balloon.

3 + 9 = 12

Group – C

4. (a) Using shell momentum balance, obtain an expression for the mass flow rate (w) for an ideal gas in laminar flow in a long circular tube of length 'L'. The flow is presumed to be isothermal. Assume that the pressure change through the tube is not very large, so that the viscosity can be regarded a constant throughout.

   (b) "For an open channel flow the critical Reynold's number is less than that of for flow inside a closed conduit" – Justify the correctness of the statement.

10 + 2 = 12

5. (a) "The boundary layer growth is much prompt for turbulent flow compared to laminar flow, though the viscous effect is substantially low because of high inertia force." – Elaborate the reason for this after deriving the Reynold's stress term in Reynold's average Navier-Stokes equation.

   (b) In turbulent flow in a circular tube, the time smoothed velocity is given by $\frac{\bar{v}_z}{\bar{v}_{z,max}} = \left(1 - \frac{r}{R}\right)^{1/7}$

   Determine an expression for the volumetric flow rate through the duct.

8 + 4 = 12

Group – D

6. (a) Predict the thermal conductivity of a 2:1 mixture of ethane and methane at 1 atm and 20°C. The molecular weight of ethane is 30 and that of methane is 16. Data for pure components is given in Table 1 to calculate

$$\phi_{AB} = \frac{1}{\sqrt{8}}\left(1 + \frac{M_\alpha}{M_\beta}\right)^{-\frac{1}{2}}\left[1 + \left(\frac{\mu_\alpha}{\mu_\beta}\right)^{1/2}\left(\frac{M_\beta}{M_\alpha}\right)^{1/4}\right]^2$$

Use appropriate formula for mixture of gases.

Table 1

Substance	MW	Lennard-Jones Potential		Critical Properties				
		σ (A°)	ε/k (K)	T_c (K)	p_c (atm)	$\overline{V_c}$ (cm^3/gmole)	μ_c (g/cm.s) X10^6	k_c (cal/s.cm.K) X10^6
C_2H_6	30.07	4.388	232	305.4	48.2	148	210	203
CH_4	16.04	3.780	154	191.9	45.8	98.7	159	158

(b) The density of liquid CCI_4, at 20°C and 1 atm is 1.595 g/cm^3, and its isothermal compressibility (l /ρ) (δρ/ δT) ~90 .7 X 10^{-6} atm^{-1}. What is its thermal conductivity?

7 + 5 = 12

7. (a) Derive an expression for average temperature rise of an electrical conductor (length L cm and radius r cm) from ambient temperature of T_a, when the current density through the wire = I amp/cm^2 and the electrical conductivity of the wire = k_e ohm^{-1}cm^{-1}.

(b) "For a thermal boundary layer development over a hot flat plate, at the plate surface heat is transferred from plate to fluid through conduction because of no slip condition at the surface." – Justify the correctness of the statement.

10 + 2 = 12

Group – E

8. (a) Cl_2 (A)-air mixture is fed to a chamber filled with cyclohexene (C_6H_{10})-CCl_4 solution (B). The rate of disappearance of Cl_2 per unit volume is given by $k_2C_A^2$. Assume that the diffusion can be treated as pseudobinary and air is essentially insoluble in C_6H_{10} - CCl_4 solution. Also assume that the liquid phase is sufficiently deep such that L can be taken to be infinity. So that the concentration profile is given by

$$\frac{C_{A0}}{C_A} = \left(1 + \sqrt{\frac{k_2 C_{A0}}{6D_{AB}}} z\right)^2$$

(b) Obtain an expression for the rate of absorption of Cl_2 by the liquid in case with the above problem.

9 + 3 = 12

9. (a) Explain the significance of Reynold's analogy in transportation of a quantity during fluid flow?

(b) Water containing 0.1 M benzoic acid flows at 0.1 cm/s through a 1cm-diameter rigid tube of cellulose acetate, the walls of which are permeable to small electrolyte molecules. These walls are 0.01 cm thin. Molecular diffusivity of benzoic acid through wall is same as that through water. The tube is immersed in a large well-stirred water bath. Calculate the benzoic acid concentration after 2 meters. The mass transfer coefficient through the wall is 6 × 10^{-5} cm/s and the mass diffusivity through water is 10^{-5} cm^2/s.

2 + 10 = 12