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Code No: 07A70801 **R07** **Set No. 2**

IV B.Tech I Semester Examinations,MAY 2011
TRANSPORT PHENOMENA
Chemical Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. In studying the rate of leaching of a substance A from solid particles by a solvent B, it is postulated that the rate controlling step in diffusion of A from the particle surface through a liquid film out in to the main liquid stream. The solubility of A in B is C_{A0} and concentration in main stream beyond the liquid film of thickness δ is $C_{A\delta}$.

   (a) Obtain a differential equation for C_A as a function of z by making mass balance of A over a thin slab of thickness Δz. Assume that D_{AB} is constant and A is only slightly soluble in B. Neglect the curvature of the particle.

   (b) Show that in the absence of chemical reaction in the liquid phase the concentration profile is linear.

   (c) Show that the rate of leaching is given by
   $N_A=\frac{D_{AB}(C_{A\delta}-C_{A0})}{\delta}$. [16]

2. Consider a cylindrical jar in which gas A dissolves in liquid B and diffuses into liquid phase. As it diffuses A undergoes an irreversible first order chemical reaction. Arrive at steady state concentration distribution of A using equation of continuity for component A. [16]

3. Calculate the thermal conductivity of a mixture containing 20 mole% CO_2 and 80mole% H_2 at 1 atm and 300K. [16]
   Data:

Species	α	Mole fractionx_α	M_α	$\mu_\alpha \times 10^5 (pas.s)$	$K_\alpha (w/m.k)$
CO_2	1	0.2	44.01	1.506	0.01661
H_2	2	0.8	2.016	0.8944	0.1789

4. A liquid flows over a flat plate inclined at an angle θ with the vertical under the force of gravity. Derive an expression for velocity distribution, average velocity and film thickness. How are these equations modified for flow on the outer surface of a cylindrical tube. [16]

5. (a) Explain the concept of molecular theory of the viscosity of gases at low density.

   (b) Compute the viscosity of CO_2 at 200K and 1 atm.
   Data: At 200K and 1atm : $\varepsilon/k = 190K \, and \, \sigma = 3.996A^o \, and \, \Omega_\mu = 1.548$. [8+8]

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6. A fluid with density 'ρ' and viscosity 'μ' is placed between two vertical walls at a distance 2B apart. The heated wall is at T_2 and cooled wall is at T_1. Obtain velocity distribution in dimensionless form. Take necessary assumptions. [16]

7. Consider a fluid (of density ρ) in incompressible, laminar flow in a plane narrow slit of length L and width W formed by two flat parallel walls that are a distance 2B apart. End effects may be neglected because B<< W << L. The fluid flows under the influence of both a pressure difference Δ p and gravity.

   (a) Using a differential shell momentum balance, determine expressions for the steady-state shear stress distribution and the velocity profile for a Newtonian fluid (of viscosity μ).

   (b) Obtain expressions for the maximum velocity, average velocity and the mass flow rate for slit flow. [16]

8. (a) Show that $j_A = -\{C^2/\rho\}M_A M_B D_{AB}\nabla_{XA}$ is an equivalent form of the Fick's law of diffusion.

   (b) Explain the theory of ordinary diffusion in gases at low density. [8+8]

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Code No: 07A70801 **R07** **Set No. 4**

IV B.Tech I Semester Examinations,MAY 2011
TRANSPORT PHENOMENA
Chemical Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. A droplet of substance A is suspended in a stream of gas B. The droplet radius is r_1. It is postulated that there is spherical stagnant film of radius r_2. The concentration of A in the gas phase is X_{A1} at $r=r_1$and X_{A2} at $r=r_2$:
   (a) By shell balance, show that for steady state diffusion r^2N_{Ar} is constant and set the constant equal to $r_1^2N_{Ar1}$, the value at the droplet surface.
   (b) Also show that $r_1^2 N_{Ar1} = \frac{-CD_{AB}}{(1-x_A)}\frac{dx_A}{dr}$. [8+8]

2. (a) Compare Newton's law of viscosity and Hooke's law of elasticity.
   (b) Compute the steady state momentum flux, when the lower plate velocity is 1 ft/sec in the positive x direction, the plate separation is 0.001 ft, and the fluid viscosity is 0.7 cp.
   (c) How does the viscosity vary with temperature and pressure for
      i. dilute gases
      ii. liquids. [6+6+4]

3. A house wall consists of 1.2 cm dry wall, 7.5 cm glass fiber insulation and outside brick wall 11 cm thick. Assume that there is a perfect contact between each layer. The thermal conductivities of dry wall, glass fiber and brick are 0.17, 0.036 and 0.72 W/m K respectively. Inside temperature of the house is 26 ^{0}C and outside temperature is -15 ^{0}C:
   (a) Find the heat flux
   (b) Find the temperature at the junction between the dry wall and glass fiber insulation
   (c) Find the location in cm from the inside surface of the dry wall where moisture freezes. [16]

4. (a) Define and give the dimensions of Thermal conductivity k, Thermal diffusivity α , Heat capacity CP, Heat flux q, and combined energy flux e.
   (b) A plastic panel of area 1 ft^2 and thickness 0.252 in. was found to conduct heat at a rate of 3.0 W at steady state with temperature 24^{o}C and 26^{o}C imposed on the two main surfaces. What is the thermal conductivity of the plastic in cal/cm.s.k at 25^{o}C?

[8+8]

5. (a) Show that $J_A^* = -\left(\frac{\rho^2}{c\,M_A\,M_B}\right) D_{AB}\,\nabla w_A$

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(b) Estimate D_{AB} for the system CO - CO_2 at 296.1^0K and 1 atm total pressure. [8+8]

Data:

label	Compound	M	T_c	P_c
A	CO	28.01	133	34.5
B	CO_2	44.01	304.2	72.9

6. Determine $v_\Theta(r)$ between two coaxial cylinders of R and λR rotating at angular velocities ω_1 and ω_2 respectively. Assume that the space between cylinders is filled with an incompressible isothermal fluid in laminar. [16]

7. Consider a long nuclear fuel rod, which is surrounded by an annular layer of aluminum cladding. With in the fuel rod heat is produced by fission. This heat source is dependent on position with a source strength varying approximately as

   $S_n = S_{n0}\left(1 + b\left[\frac{r}{R_F}\right]^2\right)$

   Here S_{n0} is the heat per unit volume per unit time produced at r=0 and r is the radius is the distance from the axis of the fuel rod. R_F is the radius of the fissionable rod and R_C is the outer radius of the cladding. Calculate the maximum temperature in the fuel rod using equation of energy, if the outer surface of the cladding is in contact with a liquid coolant at a temperature T_L, the heat transfer coefficient at he cladding and the coolant interface is h_L. The thermal conductivity of fuel rod and cladding are K_F and K_C respectively. [16]

8. A fluid (of constant density ρ) is in incompressible, laminar flow through a tube of length L. The radius of the tube of circular cross section changes linearly from R_0 at the tube entrance (z = 0) to a slightly smaller value R_L at the tube exit (z = L). Using the lubrication approximation, determine the mass flow rate vs. pressure drop (w vs. Δ_P) relationship for a Newtonian fluid (of constant viscosity μ). [16]

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Code No: 07A70801 **R07** **Set No. 1**

IV B.Tech I Semester Examinations,MAY 2011
TRANSPORT PHENOMENA
Chemical Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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1. An infinite horizontal slab of uniform width has its upper and lower surfaces maintained at concentration C_{A0} and zero respectively. Determine the steady state concentration profile in the slab. Calculate the flux for both surfaces at steady state conditions. [16]

2. An oil has a kinematic viscosity of 2×10^{-4} m^2/sec and a density of 0.8×10^3 kg/m^3, if we want to have a falling film of thickness of 2.5 mm on a vertical wall, what should the mass rate of flow of the liquid be? [16]

3. A hollow solid sphere has its inner (r=b) and outer (r=a) surfaces maintained at temperatures T_b and T_a respectively. Obtain the relation for temperature distribution in the solid at steady state conditions. Determine the heat flux at both surfaces and comment on the results. [16]

4. (a) Explain the effect of temperature and pressure on thermal conductivity.
   (b) Calculate the heat loss per m^2 of surface area for an insulating wall composed of 25.4 mm thick fiber insulating board, where the inside temperature is 352.7K and the outside temperature is 297.1K. k= 0.048 w/m.K. [8+8]

5. (a) Explain the concept of molecular theory of the viscosity of liquids.
   (b) Estimate the viscosity of liquid benzene at 20^{o}C.
   Data: At 20^{o}C , $\bar{V} = 89.0\, cm^3/gm - mole$, $T_b = 80.1^oC$. [8+8]

6. (a) What is the significance of Sherwood number in mass transport.
   (b) Estimate D_{AB} for the system argon - oxygen at 293.2^{0}K and 1 atm total pressure.
   [6+10]

   Data:

label	Compound	M	T_c	P_c
A	Argon	39.94	151.2	48.0
B	oxygen	32.00	154.4	49.7

7. Derive an expression for momentum flux and velocity distribution of Bingham plastic flow on an inclined plane making an angle θ with the horizontal. [16]

8. A fluid is flowing down a cylindrical tube whose walls are soluble in the fluid. Obtain partial differential equation for variation in concentration with distance. Assume steady state conditions. The velocity profile is flat and equal to U. Indicate the simplifying procedure and boundary conditions. Given the general equation [16]

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$$\left(\frac{\partial C_A}{\partial t} + v_r \frac{\partial C_A}{\partial r} + \frac{v_\theta}{r} \frac{\partial C_A}{\partial \theta} + v_z \frac{\partial C_A}{\partial z}\right) = D_{AB} \left(\frac{1}{r} \frac{\partial}{\partial r} \left[r \frac{\partial C_A}{\partial r}\right] + \frac{1}{r^2} \frac{\partial^2 C_A}{\partial \theta^2} + \frac{\partial^2 C_A}{\partial z^2}\right).$$

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Code No: 07A70801 **R07** **Set No. 3**

IV B.Tech I Semester Examinations,MAY 2011
TRANSPORT PHENOMENA
Chemical Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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1. (a) Discuss the concept of mass diffusivity.
   (b) Show that $\nabla x_A = \frac{1}{cD_{AB}}(x_A N_B - x_B N_A)$. [8+8]

2. Derive expressions (using shell balances) for shear stress and velocity distributions of a laminar flow of a Newtonian fluid flowing through an annulus. Find the average velocity. [16]

3. Consider diffusion system such as the one in a Stefen diffusion tube evaporating liquid A in to gas B. it may be assumed that liquid level in the tube is maintained at z=z_1. A stream of gas mixture A-B flows past slowly at the top of the tube z=z_2. The concentration of A is x_{A1} at z=z_1 and x_{A2} at z=z_2. The system is maintained at constant temperature and pressure. Gases A and B are assumed to form ideal mixture and the solubility of B in liquid A may be assumed negligible. Arrive at the steady state concentration distribution relation using the equation of continuity for A. [16]

4. Estimate the viscosity of the following gas mixture at 1 atm and 293 K from the given data on the pure components at the same pressure and temperature: [16]

S.No.	Species	Mole fraction	Molecular weight	viscosity$\times 10^7$(gm/cm.sec)
1	CO_2	0.133	44.01	1462
2	O_2	0.039	32.0	2031
3	N_2	0.828	28.02	1754

5. Estimate the rate of evaporation of liquid O_2 from a spherical container of 2 m inside diameter covered with 0.3 m of asbestos insulation. The following information is available.
   Temperature of the inner surface of insulation is -183 ^{0}C
   Temperature at the outer surface of insulation is 0 ^{0}C
   Boiling point of O_2 is -183 ^{0}C
   Heat of vaporization of O_2 is 1636 cal/g mol
   Thermal conductivity of insulation at 0 ^{0}C is 0.15 W/m K
   Thermal conductivity of insulation at -183 ^{0}C is 0.12 W/m K. [16]

6. An irreversible chemical reaction 2A → A_2 is being carried out in a reactor filled with spherical particles. The particles are coated with catalyst and reaction is instantaneous at the surface of the particles. The main gas stream compositions may be taken as X_{A0} and X_{A20}. Neglecting the curvature of the particle surface arrive at steady state concentration distribution using shell balance approach. [16]

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7. (a) In determining the thermal conductivity of an insulating material, the temperatures were measured on both sides of a flat slab of 25mm of the material and were 318.4 and 303.2K. The heat flux is measured as 35.1 w/m^2. Calculate the thermal conductivity.

   (b) Are gas viscosities and thermal conductivities related? If so, how?

[8+8]

8. An incompressible isothermal Newtonian fluid is in steady laminar flow through a smooth horizontal tube of length L and radius R under impressed pressure gradient. Neglecting end effects arrive at the relation for volume rate of flow by solving equations of change. [16]

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