7. Show that for fully developed adiabatic laminar Newtonian flow in a circular tube of radius R, the temperature profile is given by

$$T - T_1 = \frac{4\mu u_{max}}{\rho C_p R^2} z + \frac{\mu u_{max}^2}{k}\left[\left(\frac{r}{R}\right)^2 - \frac{1}{2}\left(\frac{r}{R}\right)^4 - \frac{1}{4}\right]$$

T_1: Fluid inlet temperature; u_{max}: Free stream velocity; C_P: Specific heat of the fluid; k: Thermal conductivity of the fluid; μ: Viscosity of the fluid; ρ: Density of the fluid.

12

Group – E

8. Fig.4 shows a tubular membrane separating B from A. B can permeate through the membrane. The flow is in the plug flow regime and the membrane thickness (5 nm) doesn't show any sort of resistances to the permeation. No accumulation is taking place within the membrane material. The permeation rate = 8.33 x 10^{-8} m^3/s. Find out the concentration profile for B. State properly all the assumptions you are considering with judicious explanations.

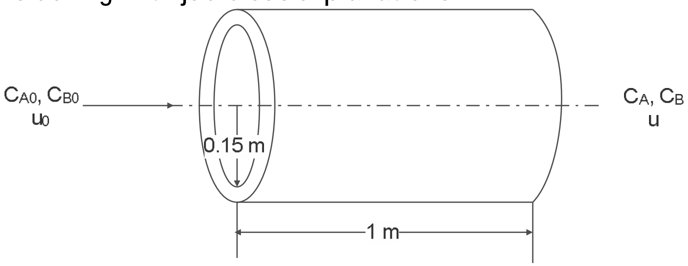

Fig.4

12

9. In studying the rate of leaching of a substance A from solid particles by a solvent B, we may postulate that the rate-controlling step is the diffusion of A from the particle surface through a stagnant liquid film thickness δ out into the main stream. The molar solubility of A in B is c_{A0}, and the concentration in the main stream is $c_{A\delta}$ as shown in Fig.5.
   (i) Show that in absence of chemical reaction in the liquid phase, the concentration profile is linear. Assume that D_{AB} is constant and that A is only slightly soluble in B. Neglect the curvature of the particle.
   (ii) Find out an expression for the rate of leaching.

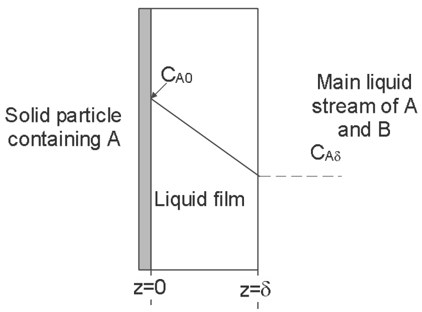

Fig.5

(6 + 6) = 12

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) Distance is a _________ order tensor
(a) 1st (b) 3rd (c) 0th (d) 2nd

(ii) The Lennard-Jones potential function is given by ____________, where r is the actual distance between a pair of molecules, σ is the collision diameter and ε is the characteristic energy of the molecules.
(a) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^6 - \left(\frac{\sigma}{r}\right)^{12}\right]$ (b) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^6\right]$
(c) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^3 - \left(\frac{\sigma}{r}\right)^{12}\right]$ (d) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^3\right]$

(iii) Fourier's law of heat conduction deals with
(a) molecular heat flux tensor (b) convective heat flux tensor
(c) combined heat flux tensor (d) none of these.

(iv) In case with the creeping flow the Reynold's number is
(a) greater than 0.1 (b) less than 0.1
(c) equal to 0.1 (d) both (b) and (c).

(v) Reynold's decomposition is saying about the
(a) average velocity of a fluid flow in case of turbulent flow
(b) local velocity at a point when the fluid flow is turbulent
(c) time averaging procedure for velocity calculation in case with the turbulent flow
(d) velocity fluctuation at a particular location in a domain, where the flow is turbulent.

(vi) Shear stress in x direction due to momentum transferred in z direction is denoted by

(a) τ_{xz} (b) τ_{zy} (c) τ_{yx} (d) τ_{zx}.

(vii) Graetz-Nusselt problem describes
- (a) the temperature profiles in tube flow where the wall temperature undergoes a sudden step change at some position along the tube
- (b) the temperature profiles in tube flow where the wall temperature undergoes a sudden step change at some position around a sphere
- (c) the temperature profiles in tube flow where the wall temperature undergoes a gradual change at some position along the tube
- (d) the temperature profiles in tube flow where the wall temperature undergoes a gradual change at some position around a sphere.

(viii) Boussinesq approximation
- (a) assumes density to be a linear function of temperature
- (b) assumes density to be independent of temperature
- (c) is valid for forced convection flow
- (d) assumes density is constant even for the compressible fluid.

(ix) Brinkman number measures the ratio of
- (a) viscous dissipation and inertia
- (b) viscous dissipation and thermal conduction
- (c) buoyant forces and thermal conduction
- (d) buoyant forces and viscous dissipation.

(x) For a dense gaseous mixture the diffusivities appearing in Maxwell-Stefan equation are ________________

(a) binary diffusivity (b) concentration dependent diffusivity
(c) knudsen diffusivity (d) both (b) and (c)

Group – B

2. (a) State true or false and justify your choice:
a.(b.c) = (a.b).c, where a, b and c are three 1st order tensors.

(b) A Bingham plastic fluid of viscosity $\mu = 10$ Pa.s and yield stress $\tau_0 = 10$ kPa is sheared between flat parallel plates separated by a distance 1mm. The top plate is moving with a velocity of 1m/sec. What is the shear stress on the plate?

6 + 6 = 12

3. (a) Define the components of the molecular momentum flux tensor clearly on a diagram.

(b) Why shear stress is also called momentum flux?

9 + 3 = 12

Group – C

4. Fluid is flown over a flat plate as shown in Fig. 1 at a velocity of 0.5 m/s. The average density (in between temperature 25°C and 80°C) and volumetric expansion coefficient of the fluid are equal to 1000 kg/m³ and 0.005 K^{-1} respectively. Find out the velocity profile with the direction of flow of the fluid. State properly all the assumptions you are considering with judicious explanations.

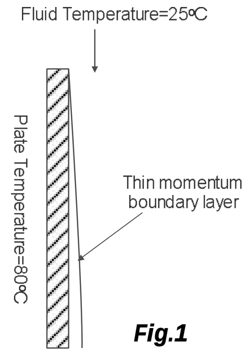

Fig.1

12

5. Using shell momentum balance, develop the differential equation to obtain the velocity profile within the fluid medium (fig. 2). ω is the rotational speed of the stirrer arrangement. R_1 is the stirrer radius and R_2 is the cylinder radius. $R_2 >> R_1$. Assume the fluid is the Newtonian fluid.

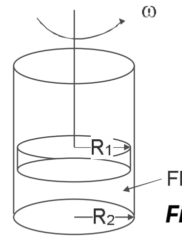

Fig.2

12

Group – D

6. For a plug flow type reactor A and B reactants are introduced within the reactor (Fig.3) to give a product C according to the equation A+B -> C. Show that the temperature profile is given by $T(z) = T_o + (T_S - T_o)\dfrac{\exp\left(\frac{u_o z}{\alpha}\right) - 1}{\exp\left(\frac{u_o L}{\alpha}\right) - 1}$, where α is the thermal diffusivity and Pr>>1. State properly all the assumptions you are considering with judicious explanations.

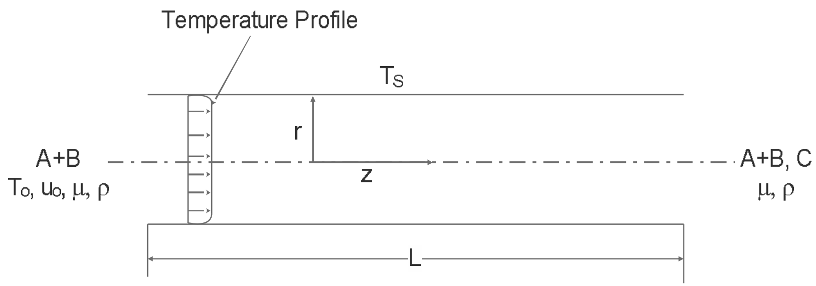

Fig.3

12