Exam. Code: 0909
Sub. Code: 6311

2074
B.E. (Biotechnology) Fifth Semester
BIO-514: Transport Phenomena

Time allowed: 3 Hours **Max. Marks: 50**

NOTE: Attempt five questions in all, including Question No. I which is compulsory and selecting two questions from each Section. Clearly State all assumptions.

x-x-x

Q.1a). List and briefly explain two factors that significantly influence the rate of diffusion.

b). Verify that the Brinkman number is dimensionless.

c). What is the significance of Hagen Poiseuille's law in momentum transfer?

d). What are non-Newtonian fluids? Explain with a suitable example.

e). Apply the law of conservation of mass to each species in a mixture and derive the equation of continuity for a multicomponent reaction mixture. (10)

SECTION-A

Q.2a). The rate of heat loss through a plane slab of thickness 10 cm and a surface area of 4 m^2 is 70 W. The temperature distribution in the slab is given as T = 5x+10, where T (°C) is temperature and x (cm) is the distance measured from one of the surfaces. Determine the thermal conductivity of the slab.

b). A tube of a gel solution of 1.05 wt% agar in water at 278 K is 0.05 m long and connects two agitated solutions of urea in water. The urea concentration in the first solution is 0.25 gmole/L solution and is zero in the other. Calculate the steady-state flux of urea in kg mol/ m^2s. The diffusion coefficient for solute urea at 278 K is 0.727×10^{-9} m^2/s. (5, 5)

Q.3. Consider the steady-state laminar flow of a fluid of constant density and viscosity in a vertical tube of length L and radius R. The fluid flows downwards under the influence of a pressure difference and gravity. Make a differential momentum balance to obtain expressions for (i) shear stress distribution (ii) velocity distribution (iii) maximum velocity (iv) average velocity and (v) mass flow rate. (10)

Q.4. Consider a tangential laminar flow of a Newtonian fluid with constant density and viscosity is occurring between two vertical coaxial cylinders in which the outer cylinder is rotating with an angular velocity ω. The fluid moves in circular motion so that the velocity in the radial and the axial direction is zero and, there is no pressure gradient in the θ direction. Using the equation of motion derive an expression for velocity as a function of radius. The simplified equation of motion in cylindrical coordinates are given

$$r\ component: -\frac{\rho V_\theta{}^2}{r} = -\frac{\partial p}{\partial r}$$

$$\theta\ component:\ 0 = \frac{d}{dr}\left(\frac{1}{r}\frac{d(rV_\theta)}{dr}\right)$$

$$z\ component:\ 0 = -\frac{\partial p}{\partial z} + \rho g_z$$

(10)

SECTION-B

Q.5. Liquid A is evaporating into vapor B in a tube of infinite length. The liquid level is maintained at a fixed position at all times. The entire system is maintained at a constant temperature and pressure and the vapors A and B are assumed to form an ideal gas mixture. The solubility of B in A is negligible. The gas phase concentration of A at the liquid-gas interface expressed as mole fraction x_{A_1} while the concentration of A in the gas mixture away from the lliquid-gas interface is x_{A_2}. Using shell balance approach obtain an expression for the concentration profile and the rate of mass transfer at the liquid gas interface. (10)

Q.6. During the initial stages of refining fermented broth to isolate the desired product, cell sedimentation is employed. In this process, the sedimentation of spherical cells within the broth is influenced by factors such as cell diameter (D). cell density (ρ_1), liquid density (ρ_2). liquid viscosity (μ). and gravitational acceleration (g). using dimensional analysis. derive an equation expressing the settling velocity of the cells to these specific variables. (10)

Q.7. 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. Using shell energy balance develop an expression for the heat flow through the wall. (10)

x-x-x