Exam. Code: 0909
Sub. Code: 33371

2125

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.

x-x-x

Q.1a). What are pseudoplastic fluids? Explain with a suitable example.

b). Discuss the effect of temperature on the viscosity of fluids.

c). List and briefly explain any two factors that significantly influence the rate of diffusion.

d). Define combined energy flux vector.

e). What are the advantages of using dimensionless groups in bioprocess design. (10)

SECTION-A

Q.2a). A Newtonian fluid in steady-state laminar flow flows down a vertical cylindrical tube of length L and radius R under the combined effect of pressure gradient and gravitational force. Using a differential shell momentum balance, derive the expressions for (i) velocity distribution (ii) average velocity and (iii) mass flow rate of the fluid through the tube. Assume density and viscosity of the fluid are constant.

b). A Newtonian fluid with a viscosity of 0.0012 Pa·s and a density of 950 kg/m^3, flows steadily through a capillary of radius 5 mm and length 2 m. The pressure drop across the pipe is 2000 Pa. Calculate the volumetric flow rate of the fluid. (7,3)

Q.3. A Newtonian fluid is flowing in a narrow slit formed by two parallel walls a distance 2B apart. The wall at x = B is moving in the positive z direction at a steady speed υ_0. Using shell momentum balance, obtain expressions for

(i) shear stress distribution in the slit

(ii) velocity distribution in the slit. (10)

Q.4.a) A solute diffuses across a flat stagnant membrane of thickness 2 mm and area 0.050 m^2. The concentration of the solute on one side of the membrane is 2 mol/m^3 and 0.10 mol/m^3

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on the other side of the membrane. Calculate the molar flux in $mol/m^2 \cdot s$ and the number of moles of solute crossing the membrane per minute.

b). Explain the Fourier's law of heat conduction. (5,5)

SECTION-B

Q.5. An electric wire of circular cross section has radius R and electrical conductivity k_e (ohm^{-1} cm^{-1}). A steady electric current flows through the wire, producing a uniform current density I (Amp/cm^2). Due to electrical resistance, heat is generated within the wire at a volumetric rate S_e (W/cm^3). Assume that the thermal conductivity of the wire is constant and equal to K (W/cm K). The outer surface of the wire (r=R) is maintained at a constant temperature T_0. The system is at steady state and heat transfer occurs only by conduction in the radial direction. Using the shell energy balance approach, derive an expression for the temperature distribution within the wire. (10)

Q.6. In a stirred bioreactor, the power input (P) is hypothesized to depend on the fluid density (ρ), impeller diameter (D), rotational speed (N), and fluid viscosity (μ). Use Buckingham Pi theorem to identify the dimensionless groups involved. (10)

Q.7. Consider a vertical column in which a volatile liquid A is evaporating into a stagnant gas B. The system is isothermal and at steady state. The gas-phase mixture of A and B is ideal, and B is insoluble in the liquid phase. The gas phase extends from the gas-liquid interface at $z = z_1$ to a point $z = z_2$, where the mole fraction of A is maintained at x_{A2} by a flowing gas stream. At the interface the mole fraction of A is x_{A1}. Using a shell balance approach derive the concentration profile of species A in the gas phase between z_1 and z_2. (10)

x-x-x