Exam. Code: 0909
Sub. Code: 33371

2076
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 made.

x-x-x

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

b). Define kinematic viscosity. How does it differ from dynamic viscosity?

c). Define the diffusion coefficient. State its SI unit and mention any two factors that influence its magnitude.

d). Differentiate between natural convection and forced convection with one suitable example of each.

e). State Fourier's law of heat conduction and define the thermal conductivity of a material. (10)

SECTION-A

Q.2. Consider a steady-state laminar flow of a Newtonian fluid with constant density and viscosity within a vertical cylindrical tube of length L and radius R. The fluid flows downwards due to the combined effect of a pressure gradient and gravitational force. Using a differential shell momentum balance, derive expressions for (i) shear stress distribution (ii) velocity distribution (iii) maximum velocity and (iv) average velocity of the fluid through the tube. (10)

Q.3. Consider a Newtonian fluid flowing down an inclined plate of length L and width W. The plate is inclined at an angle β with the horizontal. The fluid forms a thin film of thickness δ on the surface of the inclined plate. Using shell momentum balance obtain an expression for i) velocity distribution in the thin film ii) maximum velocity iii) average velocity. Assume steady state and density and viscosity of the fluid to be constant. (10)

Q.4.a). How does an increase in temperature affect the viscosity of fluids? Explain the reason.

b). Compare and analyze the similarities between the transport mechanisms and governing equations for momentum and heat transfer processes. (4,6)

P.T.O.

SECTION-B

Q.5. A heated sphere of radius R is suspended in a large, motionless body of fluid. Heat is transferred from the sphere to the surrounding fluid by conduction. The temperature at the surface of the sphere is T_R and at a distance far away from the sphere is T_∞. Using shell balance approach derive an expression for the temperature profile as a function of radial distance r. Using Fouriers law of heat conduction, determine the heat flux at the surface of the sphere. By equating this heat flux to Newton's law of cooling, obtain an expression for the convective heat transfer coefficient h and hence show that the Nusselt number, $Nu = \frac{hD}{k}$, where D is the diameter of the sphere. Assume k, thermal conductivity to be constant. (10)

Q.6. During the downstream processing of a fermented broth, cells are separated from the liquid phase by sedimentation. The settling velocity V, of a spherical cell is assumed to depend on the cell diameter D, cell density ρ_1, liquid density ρ_2, liquid viscosity μ, and gravitational acceleration g. Using Buckingham's Pi theorem derive a dimensionless relationship for the settling velocity in terms of these variables. (10)

Q.7. During the leaching of a solute A from solid particles into a solvent B, the rate-limiting step is the diffusion of A through a stagnant liquid film of thickness δ surrounding each particle. The concentration of A at the solid-liquid interface is c_{A0} and in the bulk liquid is $c_{A\delta}$. Assume that the diffusivity D_{AB} is constant, and that A is only slightly soluble in B. Neglect the curvature of the particles. Apply steady state mass balance to derive an expression for the concentration profile of c_A as a function of distance z and hence obtain an expression for molar flux of A. (10)

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