Model Question Paper

SIXTH SEMESTER BTECH DEGREE EXAMINATION

(2013 SCHEME)

BRANCH: BIOTECHNOLOGY AND BIOCHEMICAL ENGINEERING

13.601 TRANSPORT PHENOMENA IN BIOPROCESSES (B)

Time: 3 Hours Max. Marks: 100

PART-A

(*Answer all questions. Each question carries two marks*)

1. What are shear thinning fluids? Give two examples.
2. Why does the viscosity of a gas increase with increase in temperature while that of a liquid decrease with increase in temperature?
3. With suitable examples explain how the substrate and product concentrations in the fermentation broth affect its viscosity.
4. A Newtonian fluid flows through the annulus of two concentric tubes in the upward direction. Sketch the velocity and shear stress distributions in the fluid.
5. Write down the Buckingham-Reiner equation for flow of a Bingham fluid through a cylinder.
6. What is Navier-Stokes equation? Explain the significance of each term in this equation.
7. Are gas viscosities and thermal conductivities related? If so, how?
8. Differentiate between free and forced convection heat transfer.
9. State and explain Fick's law of diffusion.
10. Define effectiveness factor for porous catalysts.

PART-B

(Answer any one question from each module)

Module I

11. (a) The space between two flat and parallel plates 25 mm apart is filled with a liquid of viscosity 0.7 N-s/m^2. Within this space a thin flat plate 25 cm x 25 cm is moved parallel

to the plates at a velocity of 0.15 m/s and at a distance of 6 mm from the top plate. Assuming a linear velocity distribution between the plates, determine the force exerted by the liquid on the plate. (10 marks)

(b) Explain how we can make use of the Corresponding states correlation to estimate the viscosity of gases and liquids. (10 marks)

OR

12. (a) State and explain Newton's law of viscosity. Explain how fluids are classified according to their rheological behaviour. (10 marks)

(b) Elucidate how the viscosity of gases at low density may be explained from the point of view of molecular theory. (10 marks)

Module II

13. (a) Discuss the various steps involved in the shell momentum balance approach for solving simple flow problems. (10 marks)

(b) Using shell momentum balance, show that the average velocity is two-third the maximum velocity for the laminar flow of a thin film of Newtonian fluid over a flat plate. State all the assumptions involved. (10 marks)

OR

14. (a) Explain the most common boundary conditions used for solving viscous flow problems. What presumptions are involved in choosing these boundary conditions? (10 marks)

(b) Prove that the velocity profile for laminar, incompressible flow of a Newtonian fluid of constant viscosity μ flowing through a circular tube of radius R and length L in the z-direction is

$$v_z = \frac{(P_o - P_L)R^2}{4\mu L}\left[1 - \left(\frac{r}{R}\right)^2\right]$$

where, r is the radius of the fluid at any shell and v_z is the velocity of fluid in the z-direction. (10 marks)

Module III

15. (a) Explain Fourier's law of heat conduction. Compare the temperature dependence of the thermal conductivities of gases, liquids and solids. (10 marks)

(b) A current of I amp/m^2 is maintained through a current carrying conductor of radius R whose surface temperature is maintained at T_o. The rate of heat generation per unit volume resulting from electrical dissipation within the conductor is equal to S_e (W/m^2) = I^2/k_e, where k_e is the electrical conductivity of the wire. Using a shell energy balance approach, obtain the expressions for the temperature distribution in the wire, maximum temperature and average temperature. (10 marks)

OR

16. (a) Derive the expressions for heat flux and temperature distribution for a spherical nuclear heat source surrounded by a spherical shell of aluminum cladding. (10 marks)

(b) What are the various flow problems in which viscous heating is important? Show that for flow of an incompressible Newtonian fluid between two co-axial cylinders with viscous heat generation, the dimensionless temperature distribution is given by

$$\left(\frac{T-T_o}{T_b-T_o}\right)=\frac{1}{2}Br\frac{x}{b}\left(1-\frac{x}{b}\right)+\frac{x}{b}$$

where, T_o = temperature at the surface of inner cylinder, T_b = temperature at the surface of outer cylinder, b = width of the slit, x = width of the fluid at any shell, Br = dimensionless Brinkman number. (10 marks)

Module IV

17. (a) Explain the theory of ordinary diffusion in gases at low density. (10 marks)

(b) Derive an expression for the concentration distribution for diffusion of component A through a spherical stagnant gas film surrounding a droplet of liquid A. (10 marks)

OR

18. (a) Discuss the pressure and temperature dependence of diffusivity of binary gas mixtures.

(10 marks)

(b) Show that for diffusion of a component A into a falling liquid film (gas absorption)

$$v_z = v_{\max}\left[1-\left(\frac{x}{\delta}\right)^2\right]\frac{\partial c_A}{\partial z} = D_{AB}\frac{\partial^2 c_A}{\partial x^2}$$

where the symbols have their usual significance. (10 marks)