Register No.: .... Name: ....

SAINTGITS COLLEGE OF ENGINEERING (AUTONOMOUS)

(AFFILIATED TO APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY, THIRUVANANTHAPURAM)

SIXTH SEMESTER B.TECH DEGREE EXAMINATION (S), AUGUST 2023
CHEMICAL ENGINEERING
(2020 SCHEME)

Course Code : **20CHT304**

Course Name: **Transport Phenomena**

Max. Marks : 100 **Duration: 3 Hours**

Use of Photostat copies of the following equations duly attested by the concerned faculty shall be permitted in the exam hall.

1. *Tables containing equation of continuity and motion in rectangular, cylindrical and spherical coordinates.*
2. *Tables containing equations of the components of the stress tensor for Newtonian fluids in rectangular, cylindrical and spherical coordinates.*
3. *Tables containing equation of energy in terms of momentum fluxes and transport properties in rectangular, cylindrical and spherical coordinates.*

PART A

(Answer all questions. Each question carries 3 marks)

1. The distance between two parallel plates is 0.00914 m. The lower plate is pulled at a relative velocity of 0.366 m/s greater than the top plate. The fluid used is soya bean oil with a viscosity of 0.4×10^{-2} Pa.s at 303 K. Calculate the shear stress and shear rate.
2. Estimate the viscosity of N_2 gas at 50°C and 854 atm, given M = 28.0 g/g-mole, P_c = 33.5 atm, T_c = 126.2 K and μ_r = 2.39
3. Show that the ratio of average velocity to the maximum velocity for the laminar flow of a Newtonian fluid in a circular tube is 1/2.
4. State equation of motion in rectangular co-ordinate system and reduce the expression to Navier-Stokes and Euler's equation.
5. What is transpiration cooling? Give applications of transpiration cooling.
6. A current of 250 A is passing through a stainless-steel wire having a diameter of 5.08 mm. The wire is 2.448 m long and has a resistance of 0.0843 Ohm. The outer surface is held constant at 427.6 K. The thermal conductivity is k = 22.5 W/m K. Calculate the maximum temperature at steady state if, $k_e = 1.45\times10^6$ S/m.
7. Write the molar flux of substance 'A' with to respect to stationary coordinates and explain each term.
8. Explain the temperature and pressure dependence of gas diffusivity
9. Describe the commonly used boundary conditions to solve mass transport problems.
10. State the analogies between heat, mass and momentum transfer in terms fundamental laws, transport property and driving forces.

PART B

(Answer one full question from each module, each question carries 14 marks)

MODULE I

11. a) Predict the thermal conductivity of a mixture containing chlorine-air mixture at 298 K and 1 atm for 0.5 mole fraction of chlorine. Air may be considered a single substance and the following data may be assumed. (10)

Substance	**μ (pa.s)**	**k (W/m.K)**	**Cp (J/kg.K)**
Air	1.854×10^{-5}	2.614×10^{-2}	1.001×10^{3}
Chlorine	1.351×10^{-5}	8.960×10^{-3}	4.798×10^{2}

b) Are gas viscosities and thermal conductivities related? If so, how? (4)

OR

12. a) Compute the mean molecular velocity of $\bar{\upsilon}$ (in cm/s) and the mean free path λ (in cm) for oxygen at 1atm and 273.2K. A reasonable value of 'd' is 3A°. What is the ratio of the mean free path to the molecular diameter under these conditions? (8)

b) Derive rigid sphere model for the estimation of viscosity. (6)

MODULE II

13. a) Determine the velocity and shear stress distribution for the tangential laminar flow of an incompressible fluid between two vertical coaxial cylinders. The outer one is rotating with an angular velocity Ω_0. (14)

OR

14. A river bed is flowing downhill under laminar flow at an angle β with respect to the horizontal on a calm, windless day. The depth of the river is δ and it may be assumed that the river bed is rectangular and having width W. Define a coordinate system and then uses equations of change to derive the differential equation which can give the velocity distribution in the river. Also state the boundary conditions needed to solve the differential equation. (14)

MODULE III

15. Consider a spherical form of nuclear fissionable material of radius R^F and is surrounded by aluminum cladding of radius R_C. The source is assumed as a parabolic function, (14)

$$S_n = S_{n0}\left[1 + b\left({}^{r}/_{R^F}\right)^2\right]$$

where S_{n0} is the volume rate of production at the center of the sphere and b is a dimensionless positive constant. Derive the expression for temperature distribution in the aluminum cladding and in the fissionable material using shell energy balance.

OR

16. Consider the heating of a cylindrical copper wire due to the flow of current. Show that the temperature profile is parabolic and determine the expression for average temperature distribution. (14)

MODULE IV

17. a) Formulate relationship among flux for a binary system and mention its significance. (10)

b) Describe the steps involved in carrying out shell mass balance and boundary conditions associated with the diffusion of one chemical species over a thin shell of solid or fluid. (4)

OR

18. a) Using the basic definitions of concentrations, velocities and fluxes, show that for a binary mixture of A & B, the mass fraction $'w_i'$ is related to mole fraction 'x_{iA}' by (8)

(i) $w_A = \frac{x_A M_A}{x_A M_A + x_B M_B}$ (ii) $dw_A = \frac{M_A M_B}{(x_A M_A + x_B M_B)^2}$

(iii) $dx_A = \frac{dw_A}{M_A M_B (x_A M_A + x_B M_B)^2}$ (iv) $n_A nA + n_B NB = \rho v$

Where:

n_A, n_B : mass fux reative to fixed spatial position

ρ: Density, V: Mass sverage velocity

M_A, M_B: Molecular weights of A & B respectively

c) Derive the rigid sphere model for estimating diffusivity with suitable assumptions. 6)

MODULE V

19. A gaseous phase reaction $2A \rightarrow B$ is taking place on the surface of a catalyst in a catalytic reactor. Assume that the catalyst particle is surrounded by a stagnant gas film through which A has to diffuse to reach the catalyst surface, where instantaneous reaction occurs and A_2 diffuses back out through the gas film to main gas stream. Develop an expression for concentration profile in the gas film and molar flux through the film. (14)

OR

20. Gas 'A' dissolves in liquid 'B' in a beaker and diffuses isothermally into the liquid phase. As it diffuses, A also undergoes an irreversible first-order homogeneous reaction as given below. (14)

$$A + B \rightarrow AB$$

Derive expressions for the average concentration of 'A' and molar flux of 'A'.

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