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

SAINTGITS COLLEGE OF ENGINEERING (AUTONOMOUS)

(AFFILIATED TO APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY, THIRUVANANTHAPURAM)

SIXTH SEMESTER B.TECH DEGREE EXAMINATION (R,S), MAY 2024
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 water at 0°C and 100°C if the molar volume is 18 cm^3/gmole and $h = 6.624 \times 10^{-27}$ g cm^2 s^{-1}.
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. Deduce the Euler's equation from the Navier – Stokes equation. Write its significance.
5. Explain the types of boundary conditions encountered in solving heat conduction problems.
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 simplified form of the molar diffusion equation for binary systems.
8. Prove that the sum of the molar diffusion fluxes relative to the molar average velocity is zero in a binary mixture.
9. Describe the commonly used boundary conditions to solve mass transport problems.
10. Annotate on the shell balance approach to derive equations for mass transport.

PART B

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

MODULE I

11. a) Deduce a correlation for gas viscosity with temperature and pressure using the kinetic theory of gases. Compare the rigid sphere model with the rigorous model. (10)

b) Compute the mean molecular velocity and mean free path in cm for Chlorine gas at 1 atm and 273.2 K considering d = 4 A°. Calculate the ratio of mean free path to the molecular diameter under these conditions. (4)

OR

12. a) Write the expressions for calculating thermal conductivity of gases, liquids and solids. (6)

b) Calculate the thermal conductivity of molecular oxygen at 300 K and low pressure. The heat capacity of oxygen at 300 K and low pressure is 7.019 cal/gmole K, σ = 3.433 °A and Ω_{μ} = 1.074. (8)

MODULE II

13. Consider the flow of a Newtonian fluid in the annular region of a double pipe heat exchanger. Derive an expression for the velocity distribution, Force exerted by the fluid on the solid surface and the volumetric flow rate of the fluid through the annulus. State the assumptions clearly. (14)

OR

14. Using the equations of change, derive the equations for the velocity profile for the tangential annular flow of the fluid, shear stress distribution, torque generated due to the rotating motion of the cylinder in a couette viscometer. State the assumptions made clearly. (14)

MODULE III

15. 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)

OR

16. Consider the flow of a Newtonian fluid between two co-axial cylinders in which the outer one rotates with an angular velocity Ω. As the outer cylinder rotates, each cylindrical shell of fluids rubs against an adjacent shell of fluids. Derive the expression for temperature distribution in the fluid due to viscous heat dissipation. Show that the temperature will be maximum if Brinkmann number is greater than 2. State the assumptions clearly. (14)

MODULE IV

17. Explain the theory of ordinary diffusion in gases at low density and estimate the D_{AB} for the methane-ethane system at 104 °F and 1 atm using the Chapman – Enskog theoretical equation. (14)

Data: Ω_{DAB} = 1.45, σ_A = 2.745 x 10^{-4}, σ_B = 1.823

OR

18. Describe the theories of ordinary diffusion in liquids and determine the diffusion coefficient for acetone in water at 25 °C using the Wilke-Chang equation. The association parameter for water is 2.6. The viscosity of water is 0.8937 cp and the molar volume of acetone is 74.03 cm^3/gmole. (14)

MODULE V

19. Consider a diffusion system in which liquid A is evaporated and diffused through a stagnant gas B. Derive an expression for the rate of mass transfer at the liquid-gas interface at steady state when the liquid-vapor interface is maintained at a fixed position. (14)

OR

20. a) Discuss the analogies among momentum, energy and mass transport. (4)

b) Consider a heterogeneous chemical reaction $2A \rightarrow B$ taking place on the surface of the solid catalyst. The Chemical reaction is diffusion controlled. Derive an expression for the molar flux at the catalyst surface. (10)

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