GUJARAT TECHNOLOGICAL UNIVERSITY

BE 7 SEMESTER – OLD PAPER – S22 TO S26 – QUESTION BANK

Subject Name & Code: Transport Phenomena - 3170511

Chapter 1: Introduction to Transport Phenomena

Repeated Questions:

1. Diffusivities and Analogy Between Transport Processes:

- **Q.** Discuss the significance of momentum, thermal and mass diffusivities. **(SUMMER 2022, 3 Marks; WINTER 2022, 3 Marks; SUMMER 2023, 4 Marks; WINTER 2023, 3 Marks OR; WINTER 2025, 4 Marks)**
- **Q.** Compare Newton's Law of viscosity with Fourier's Law of heat conduction and Fick's Law of mass diffusion for their analogies. / Compare momentum, heat and mass transport process. **(SUMMER 2022, 7 Marks; SUMMER 2026, 3 Marks)**

2. Scalars, Vectors, Tensors and Velocity Fields:

- **Q.** Compare Scalar, Vector and Tensor. / Differentiate between scalar, vector and tensor in context to transport phenomena. **(SUMMER 2024, 3 Marks; WINTER 2025, 3 Marks)**
- **Q.** Find which of the following velocity fields v(x,y,z) are irrotational? / Examine the following velocity fields for the zero divergence and Irrotational vector. [Diagram required – refer to the original question paper] **(SUMMER 2022, 4 Marks; SUMMER 2024, 4 Marks)**

3. Conservation Laws:

- **Q.** Explain law of conservation of mass / momentum / angular momentum / energy for two colliding homo-nuclear diatomic molecules. **(SUMMER 2026, 3 Marks; SUMMER 2026, 3 Marks - second set; SUMMER 2026, 4 Marks; SUMMER 2026, 4 Marks - second set)**

4. Levels of Study and General Equations of Transport:

- **Q.** Discuss the three levels at which the transport phenomena is studied. / State and discuss the various levels of transport phenomena studies in detail. **(WINTER 2022, 4 Marks; WINTER 2023, 7 Marks)**
- **Q.** State the general equations that govern any transport process. / Write an expression for combined heat, mass and momentum transport. **(SUMMER 2023, 3 Marks; WINTER 2023, 3 Marks; SUMMER 2025, 3 Marks)**
- **Q.** How the equation of change differs in single component and multicomponent system? **(WINTER 2024, 3 Marks OR; SUMMER 2025, 4 Marks)**

Other Important Questions:

1. Dimensionless Numbers and Definitions:

- **Q.** Define Prandtl number. **(WINTER 2022, 3 Marks)**
- **Q.** Define Reynolds number. **(WINTER 2022, 3 Marks OR)**
- **Q.** State the significance of three dimensionless numbers having thermal, momentum and molar diffusivity. (viz. Pr, Sc. and Le.) **(SUMMER 2024, 4 Marks OR)**
- **Q.** Define the following 1. Self-diffusion 2. Biot Number 3. Lewis number. **(SUMMER 2025, 3 Marks)**
- **Q.** Define the following 1. Brinkman Number 2. Thiele modulus 3. Schmidt Number. **(SUMMER 2025, 3 Marks OR)**
- **Q.** Define the following: (1) Biot no. (2) Brinkman number. **(WINTER 2025, 3 Marks)**
- **Q.** What are isotropic fluids? **(SUMMER 2023, 3 Marks)**

2. Vector and Tensor Operations:

- **Q.** Find τ·v (dot product) and τ × v (cross product). τ is a tensor and v is vector. **(SUMMER 2024, 4 Marks)**
- **Q.** Write the expression for 1. Dot product of two vector v and w 2. Cross product of two vector v and w 3. Multiplication of a Tensor τ by a Scalar s. 4. Addition of vector v and w. **(WINTER 2024, 4 Marks)**
- **Q.** Show that tensor τ is antisymmetric, Where, τ = -δ1δ2 + 3δ1δ3 + δ2δ1 + 5δ2δ3 - 3δ3δ1 - 5δ3δ2. **(SUMMER 2026, 3 Marks)**
- **Q.** Show that for tensor τ and vector ν, τ × ν = ΣiΣlδiδl{ΣjΣkεjklτijνk} **(SUMMER 2026, 4 Marks)**

3. Conservation Laws, Control Volume, Coordinate Systems and Derivatives:

- **Q.** Discuss about the conservation laws. **(WINTER 2023, 4 Marks)**
- **Q.** What is control volume? How the shape of control volume is decided? **(WINTER 2024, 3 Marks)**
- **Q.** Differentiate between Cartesian, cylindrical and spherical coordinate systems. **(WINTER 2024, 3 Marks)**
- **Q.** Give the significance of Total time derivative, Partial time derivative and Substantial time derivative with example. **(SUMMER 2024, 4 Marks)**

4. Numerical Problem:

- **Q.** Compute the mean molecular velocity ū (in cm/s) and the mean free path λ (in cm) for oxygen at 1 atm. and 273.2 K. A reasonable value for diameter is 3 Å. What is the ratio of the mean free path to the molecular diameter under these conditions? What would be the order of magnitude of the corresponding ratio in the liquid state? **(SUMMER 2025, 4 Marks)**

Chapter 2: Momentum Transport

Repeated Questions:

1. Continuity and Navier-Stokes Equations:

- **Q.** Derive Continuity equation and prove that for incompressible fluids divergence of velocity vector is zero i.e. $\nabla \cdot v = 0$. **(SUMMER 2022, 7 Marks OR; WINTER 2022, 7 Marks; SUMMER 2024, 7 Marks)**
- **Q.** Derive equation of motion from momentum balance and modify it to the Navier-Stokes equation. / Develop an expression for Navier-Stokes Equation in Cartesian Coordinate system. / Develop the Navier-Stokes equation in Cartesian coordinate with neat diagram and necessary assumptions. [Diagram required – refer to the original question paper] **(SUMMER 2022, 7 Marks; WINTER 2022, 7 Marks OR; WINTER 2025, 7 Marks; SUMMER 2026, 7 Marks OR)**

2. Newton's Law of Viscosity and Shell Momentum Balance (Theory):

- **Q.** Explain Newton's Law of Viscosity. **(SUMMER 2024, 3 Marks; SUMMER 2026, 3 Marks)**
- **Q.** State and explain the general shell momentum balance equation. **(WINTER 2022, 3 Marks; WINTER 2023, 3 Marks OR; SUMMER 2024, 3 Marks OR)**
- **Q.** Explain the molecular momentum flux and write the components of the molecular momentum flux tensor. **(SUMMER 2022, 4 Marks; WINTER 2022, 4 Marks)**

3. Laminar Flow Derivations (Shell Momentum Balance):

- **Q.** A liquid is slowly flowing down an inclined flat plate of length L and width W. Find Velocity distribution as a function of the fluid film thickness. Also find maximum and average velocity. Neglect end effects. / Develop the shear stress and velocity distribution profile for the laminar flow in the inclined plane. State assumptions made while deriving these expressions. [Diagram required – refer to the original question paper] **(SUMMER 2022, 7 Marks OR; SUMMER 2024, 7 Marks OR; WINTER 2025, 7 Marks)**
- **Q.** For steady-state axial flow of an incompressible liquid in an annular region between two coaxial cylinders of radii kR and R, through annulus the velocity profile is given by [equation]. Find the 1. The maximum velocity 2. The average velocity 3. The mass flow rate 4. The force exerted by the fluid on the solid surfaces. / For a steady-state axial flow of an incompressible liquid in a circular pipe, The Momentum flux profile is given by [equation]. Find the Velocity profile as a function of r. Also, find... [Diagram required – refer to the original question paper] [Data truncated in source – refer to the original question paper] **(WINTER 2024, 7 Marks; SUMMER 2025, 7 Marks)**
- **Q.** A Newtonian fluid is flowing in laminar flow through a narrow slit formed by two parallel plates a distance 2B apart (as shown in fig.) where B << W so that end effects can be neglected. Obtain the shear stress and velocity profile for the flow. / A viscous fluid is in laminar flow in a slit formed by two parallel walls at a distance 2B apart. Make a differential momentum balance and obtain the expression for the distributions of momentum flux and velocity. [Diagram required – refer to the original question paper] **(SUMMER 2022, 7 Marks; SUMMER 2024, 7 Marks OR)**
- **Q.** Derive velocity profile and mass flow rate for flow of a falling film formed by a Newtonian, incompressible fluid. **(WINTER 2022, 7 Marks; SUMMER 2026, 7 Marks)**
- **Q.** Develop the shear stress and velocity distribution profile for the laminar flow through the circular pipe. State assumptions made while deriving these expressions. / Develop the shear stress and velocity distribution profile for the downward laminar flow through pipe. State assumptions made while deriving these expressions. **(WINTER 2024, 7 Marks; WINTER 2025, 7 Marks OR)**

4. Numerical Problems:

- **Q.** An oil has a kinematic viscosity of 2×10^{-4} m²/s and a density of 0.8×10^{3} kg/m³. If we want to have a falling film of the oil of thickness 2.5 mm on a vertical wall, calculate the mass rate of flow of the oil per unit width of the film? / Oil has a kinematic viscosity of 2×10^{-4} m²/s and a density

of 0.8×10^3 g/m³. If we want to have a falling film of thickness of 2.5 mm on a vertical wall, what should the mass rate of flow of the liquid be? **(SUMMER 2023, 4 Marks; SUMMER 2024, 3 Marks)**

- **Q.** A fluid of viscosity 0.7 cP is present between two parallel plates separated by a distance 0.001 ft. If the lower plate moves with the velocity 1 ft/sec in positive x direction, compute the steady state momentum flux τyx in Pascal. / Compute the steady-state momentum flux τyx in N/m²? When the lower plate velocity v is 1 ft/s in the positive x direction, The distance Y between the two parallel plates is 0.001 ft, and the fluid viscosity μ is 0.7 cp. **(WINTER 2022, 7 Marks OR; WINTER 2023, 3 Marks)**

Other Important Questions:

1. Viscosity (Theory):

- **Q.** Discuss in details the Newton's law of viscosity and write its equation in three dimensions. **(WINTER 2022, 7 Marks)**
- **Q.** Discuss in brief pressure and temperature dependence of viscosity depicting appropriate equations. **(WINTER 2023, 7 Marks)**
- **Q.** Discuss the general trends of viscosity with temperature and pressure for ordinary fluids. **(SUMMER 2022, 3 Marks OR)**
- **Q.** Discuss with appropriate equation and schematic representation about the molecular transport of momentum. [Diagram required – refer to the original question paper] **(WINTER 2023, 7 Marks)**
- **Q.** Compare and contrast the molecular and convective momentum transport. **(SUMMER 2023, 4 Marks)**

2. Shell Momentum Balance Procedure and Boundary Conditions:

- **Q.** State and discuss the procedure for setting up and solving viscous flow problems with reference to velocity distributions in laminar flow. **(WINTER 2023, 7 Marks OR)**
- **Q.** What are commonly used boundary conditions of shell momentum balance? **(SUMMER 2022, 3 Marks)**
- **Q.** Apply shell momentum balance for steady flow, and write necessary boundary conditions used to solve the same. **(SUMMER 2026, 4 Marks)**
- **Q.** Define the following: (1) efflux time (2) Fully developed flow (3) end effect (4) boundary layer. **(WINTER 2025, 4 Marks OR)**

3. Flow Through Pipes and Annuli (Derivations):

- **Q.** Derive the equation for pressure drop for laminar flow of an Newtonian, incompressible fluid through a circular cross section pipe. **(WINTER 2022, 7 Marks OR)**
- **Q.** Derive the relation for velocity distribution for flow through a circular tube. **(WINTER 2023, 7 Marks)**
- **Q.** Determine the mass flow rate expression for a flow through circular pipe. **(SUMMER 2026, 7 Marks)**
- **Q.** Derive the expression for max velocity, avg. velocity and mass flow rate for a flow through circular pipe system. **(SUMMER 2024, 7 Marks)**
- **Q.** A cylindrical rod of radius kR moves axially with velocity vz = vo along the axis of a cylindrical cavity of radius R as seen in the figure. The pressure at both ends of the cavity is the same, so that the fluid moves through the annular region solely because of the rod motion. Find the velocity distribution in the narrow annular region. [Diagram required – refer to the original question paper] **(SUMMER 2023, 7 Marks OR)**

4. Numerical Problems:

- **Q.** Glycerine at 26.5 °C is flowing through a horizontal tube 1 ft long and with 0.1 in. inside diameter. For a pressure drop of 40 psi, the volume flow rate 0.00398 ft³/min. The density of

glycerine at 26.5 °C is 1.261 g/cm³. From the flow data, find the viscosity of glycerine in centipoises and in Pa.s. **(SUMMER 2022, 4 Marks OR)**

- **Q.** Calculate the radius of a capillary from the following flow data: Length of capillary tube: 50.02 cm, Kinematic viscosity of liquid: 4.03×10^{-5} m²/s, Density of liquid: 0.9552×10^{3} kg/m³, Pressure drop in the horizontal tube: 4.829×10^{5} Pa, Mass rate of flow through tube: 2.997×10^{-3} kg/s. **(SUMMER 2023, 4 Marks OR)**
- **Q.** Estimate the viscosity of the following gas mixture at 1 atm and 293K from the given data on the pure components at the same pressure and temperature. [Diagram required – refer to the original question paper] **(SUMMER 2026, 7 Marks)**

Chapter 3: Steady State Heat Transport

Repeated Questions:

1. Heat Conduction with Heat Sources:

- **Q.** Consider an electric wire of circular cross section with radius R and electric current with current density I amp/cm²... The rate of heat production per unit volume is given by the expression Se = I²/ke... Find the radial temperature profile/distribution. / Derive equation for temperature drop in a conductor wire for an electrical heat source. / Develop the heat flux and temperature distribution profile for heat conduction through electrical heat source. / Derive an expression for heat flux and temperature profile involving heat conduction in electric heat. [Diagram required – refer to the original question paper] [Data truncated in source – refer to the original question paper] **(SUMMER 2022, 7 Marks; WINTER 2022, 7 Marks; SUMMER 2023, 7 Marks OR; SUMMER 2024, 7 Marks; WINTER 2024, 7 Marks OR; SUMMER 2025, 7 Marks)**
- **Q.** Develop the heat flux and temperature distribution profile for heat conduction involving nucleus heat source Sn. [Diagram required – refer to the original question paper] **(WINTER 2023, 7 Marks; SUMMER 2025, 7 Marks)**
- **Q.** Derive the temperature distribution for heat conduction due to the viscous heat dissipation for flow of an incompressible Newtonian fluid between two concentric cylinders. / Consider the flow of an incompressible Newtonian fluid between two coaxial cylinders... develop the temperature distribution due to viscous heat dissipation. [Data truncated in source – refer to the original question paper] **(SUMMER 2022, 7 Marks OR; SUMMER 2023, 7 Marks; SUMMER 2025, 7 Marks OR; WINTER 2025, 7 Marks)**
- **Q.** An oil is acting as a lubricant for a pair of concentric cylindrical surfaces. The outer cylinder rotates leading to the viscous heat dissipation given by equation [equation]. What is the temperature at the center (x = b/2) in the annulus? Both wall temperatures are known to be 70 °C. Data: Angular velocity = 7908 rpm, Radius of the outer cylinder = 5.06 cm, Clearance between the cylinders = 0.027 cm. Viscosity = 92.3 cp, Density = 1.22 g/cm³, Thermal conductivity = 2.303 W/m °C. / An oil acting as a lubricant for a pair of cylindrical surfaces is shown in Fig. The differential form of energy balance expression is given as [equation]... develop a profile for a temperature of the fluid as a function of x using appropriate boundary conditions. ii. The angular velocity of the outer cylinder is 7908 rpm... [Diagram required – refer to the original question paper] [Data truncated in source – refer to the original question paper] **(SUMMER 2022, 7 Marks OR; SUMMER 2025, 7 Marks OR)**
- **Q.** For the fixed-bed axial flow reactor shown in figure, derive the steady state axial temperature distribution. The fluid is flowing axially in plug flow with superficial velocity vo. The reactants enter at z = -∞ and leave at z = +∞. The reaction zone is from z = 0 to z = L. / For the fixed-bed axial flow reactor shown in figure, find the steady state axial temperature distribution... [Diagram required – refer to the original question paper] [Data truncated in source – refer to the original question paper] **(SUMMER 2023, 7 Marks OR; WINTER 2024, 7 Marks OR)**

2. Cooling Fins:

- **Q.** Derive an expression for effectiveness of cooling fin of length L, Width W, and thickness 2B, where B<<W and B<<L. / Construct the expression of effectiveness of Cooling Fin. / Develop the heat flux and temperature distribution profile for heat conduction in a rectangular fin State assumptions made while deriving these expressions. [Diagram required – refer to the original question paper] **(SUMMER 2024, 7 Marks OR; WINTER 2024, 7 Marks; WINTER 2025, 4 Marks; SUMMER 2026, 7 Marks)**

3. Heat Transport Mechanisms, Laws and Boundary Conditions:

- **Q.** Compare and contrast the molecular and convective mechanisms for heat transport. **(WINTER 2024, 3 Marks; WINTER 2025, 4 Marks)**

- **Q.** Compare free convection and forced convection heat transfer. **(WINTER 2024, 4 Marks; WINTER 2025, 4 Marks; SUMMER 2026, 4 Marks)**
- **Q.** Discuss different boundary conditions used for solving shell energy balance. **(WINTER 2022, 4 Marks OR; WINTER 2024, 4 Marks; SUMMER 2025, 3 Marks; SUMMER 2026, 4 Marks)**
- **Q.** Explain Fourier's Law of heat conduction. **(WINTER 2022, 3 Marks OR; WINTER 2023, 4 Marks; SUMMER 2024, 3 Marks; SUMMER 2025, 4 Marks; SUMMER 2026, 3 Marks OR)**
- **Q.** Explain the molecular and convective and total heat flux. **(SUMMER 2022, 3 Marks; SUMMER 2024, 3 Marks OR)**
- **Q.** Discuss about temperature and pressure dependency of thermal conductivity. / Discuss about temperature dependency of thermal conductivity. **(SUMMER 2022, 4 Marks; WINTER 2022, 4 Marks)**

4. Numerical Problems:

- **Q.** A copper wire has a radius of 2 mm and a length of 5 m. For what voltage drop would the temperature rise at the wire axis be 10 °C, if the surface temperature of wire is 20 °C? For copper, Lorentz No. k/(keT0) is 2.23×10^{-8} volt²/K². / A copper wire, 5 mm in diameter and 15 ft long, has a voltage drop of 0.6 volts. Find the maximum temperature in the wire if the ambient air temperature is 25 °C and the heat transfer coefficient h is 32.36 W/m²K. The thermal conductivity of copper is 384.1 W/m.K. Given Data: Lorenz constant: k/(keT0) = 2.33×10^{-8} volt²/K². **(SUMMER 2022, 7 Marks; WINTER 2022, 7 Marks; SUMMER 2023, 4 Marks)**
- **Q.** Estimate the thermal conductivity of following gas mixture at 1 atm and 293 K from given data on the pure components at same pressure and temperature. [Diagram required – refer to the original question paper] **(SUMMER 2024, 7 Marks; SUMMER 2026, 7 Marks OR)**

Other Important Questions:

1. Thermal Conductivity and Diffusivity (Theory):

- **Q.** Define thermal diffusivity and Prandtl number. **(SUMMER 2022, 3 Marks)**
- **Q.** Compare thermal conductivity and thermal diffusivity with necessary equations. **(SUMMER 2024, 4 Marks)**
- **Q.** Compare thermal conductivity, thermal diffusivity and heat capacity in terms of dimensionless number. **(WINTER 2023, 3 Marks)**
- **Q.** Why is the thermal conductivity of a solid generally larger than that of a liquid? Why is the thermal conductivity of a liquid larger than that of a gas? **(WINTER 2024, 3 Marks OR)**
- **Q.** What is the physical significance of thermal diffusivity? How it is defined and what are its units? **(WINTER 2024, 4 Marks OR)**
- **Q.** How thermal conductivity of a material is affected by its size, shape and composition? **(SUMMER 2025, 3 Marks OR)**
- **Q.** Compare the temperature dependence of the thermal conductivities of gases, liquids, and solids. **(SUMMER 2025, 4 Marks OR)**

2. Boundary Conditions, Energy Fluxes and Heat Conduction Concepts:

- **Q.** State the commonest of boundary conditions in molecular energy transport. **(WINTER 2023, 4 Marks)**
- **Q.** State the fundamental law that governs the convective heat transfer. **(SUMMER 2022, 3 Marks OR)**
- **Q.** Write an expression for the following: 1. Convective energy flux vector 2. Molecular work flux vector 3. Molecular heat flux vector. **(SUMMER 2025, 3 Marks)**
- **Q.** What is the purpose of fins in heat exchange device? Classify various types of fins. **(WINTER 2025, 4 Marks)**

- **Q.** Differentiate between steady state and unsteady state heat conduction. **(WINTER 2025, 3 Marks OR)**

3. Derivations:

- **Q.** Derive the equation for temperature distribution for chemical reaction as heat source. **(WINTER 2022, 7 Marks OR)**
- **Q.** Develop the heat flux and temperature distribution profile for heat conduction through composite wall. State assumptions made while deriving these expressions. **(WINTER 2025, 7 Marks OR)**

4. Numerical Problems:

- **Q.** Compute the thermal conductivity of molecular oxygen at low pressure and 300 K. The Lennard-Jones constants for molecular oxygen are σ = 3.433 Å and ε/K = 113 K, and its molecular weight M is 32, and Ωk = 1.074. **(WINTER 2023, 3 Marks)**
- **Q.** Calculate the heat loss per m^2 of surface area for an insulating wall composed of 25.4 mm thick fibre insulating board, where the inside temperature is 352 K and the outside temperature is 297 K. the thermal conductivity of fibre is 0.048 W/mK. **(WINTER 2023, 4 Marks OR)**
- **Q.** The thermal conductivity of a sheet of rigid, extruded insulation is reported to be k = 0.029 W/m.K. The measured temperature difference across a 20-mm-thick sheet of the material is T1 - T2 = 10 °C. (a) What is the heat flux through a 2 m × 2 m sheet of the insulation? (b) What is the rate of heat transfer through the sheet of insulation? Assumptions (1) One-dimensional conduction in the x-direction (2) Steady-state conditions (3) Constant properties. **(WINTER 2024, 4 Marks)**
- **Q.** The wall of an industrial furnace is constructed from 0.15 m thick fireclay brick having a thermal conductivity of 1.7 W/m.K. Measurements made during steady-state operation show 1400 and 1150 K at the inner and outer surfaces, respectively. What is the rate of heat loss through a wall of 0.5 m × 1.2 m on a side? **(SUMMER 2025, 4 Marks)**
- **Q.** A plastic panel of area A = 1 ft^2 and thickness Y = 0.252 in. was found to conduct heat at a rate of 3 W at steady state with temperatures To = 24 °C and T1 = 26 °C imposed on the two main surfaces. What is the thermal conductivity of the plastic at 25 °C? **(SUMMER 2023, 4 Marks OR)**

Chapter 4: Mass Transport

Repeated Questions:

1. Diffusivity:

- **Q.** Explain temperature and pressure dependency of diffusivity. / Explain Temperature and Pressure dependence of diffusivities. / Discuss the effect of temperature and pressure on Diffusivity for 1. Binary gas mixtures 2. Liquid. **(SUMMER 2022, 4 Marks; WINTER 2022, 4 Marks; SUMMER 2023, 4 Marks OR; WINTER 2024, 3 Marks; SUMMER 2025, 4 Marks OR; WINTER 2025, 4 Marks; SUMMER 2026, 4 Marks)**
- **Q.** Show that for equimolar counter diffusion DAB = DBA / Derive the relation for diffusivity in case of equimolar counter diffusion. **(SUMMER 2022, 7 Marks; WINTER 2022, 7 Marks; WINTER 2023, 3 Marks; WINTER 2025, 7 Marks OR)**
- **Q.** Define binary diffusivity. **(WINTER 2022, 3 Marks OR; SUMMER 2023, 3 Marks)**

2. Concentrations, Velocities and Fluxes:

- **Q.** Define Mass and Molar Concentrations, Mass Average and Molar Average Velocities, Molecular Mass and Molar Fluxes. / Explain Mass and Molar Concentrations, Mass Average and Molar Average Velocity. **(SUMMER 2022, 3 Marks; WINTER 2022, 3 Marks; SUMMER 2024, 4 Marks OR; SUMMER 2026, 3 Marks OR)**
- **Q.** Write in brief about Mass average and molar average velocity. **(WINTER 2024, 3 Marks; SUMMER 2025, 3 Marks)**
- **Q.** Differentiate between Molecular mass flux and convective mass flux. / Define the following 1. Molecular mass flux 2. Convective mass flux. **(WINTER 2024, 3 Marks OR; SUMMER 2025, 3 Marks OR; WINTER 2025, 3 Marks)**

3. Fick's Law of Binary Diffusion:

- **Q.** Explain Fick's law of binary diffusion. / State and explain Fick's law of binary diffusion. / What is Fick's law of Diffusion? Discuss it with suitable diagram. [Diagram required – refer to the original question paper] **(WINTER 2022, 3 Marks; SUMMER 2023, 4 Marks; SUMMER 2024, 3 Marks; WINTER 2024, 7 Marks OR; SUMMER 2025, 4 Marks; WINTER 2025, 3 Marks; SUMMER 2026, 3 Marks)**

4. Steady State Diffusion Derivations:

- **Q.** Derive equation of molar flux for steady state diffusion of one gaseous component through stagnant non diffusing second component. / Derive a suitable expression for steady-state diffusion of A through stagnant B with the liquid-vapor interface maintained at a fixed position. / Derive the relation of molar flux for diffusion Through a Stagnant Gas Film. / Derive an expression for diffusion of liquid A evaporating into non-diffusing gas B. **(SUMMER 2023, 7 Marks; SUMMER 2024, 7 Marks; WINTER 2024, 7 Marks; WINTER 2025, 7 Marks; SUMMER 2026, 7 Marks)**
- **Q.** With neat diagram derive an equation of molar flux for the diffusion with heterogeneous chemical reaction as $2A \rightarrow B$. / Deduce the expression for diffusion with a heterogeneous chemical reaction with appropriate schematic diagram. / With neat diagram derive an equation of molar flux for the diffusion with heterogeneous chemical reaction as $2A \rightarrow A_2$. [Diagram required – refer to the original question paper] **(WINTER 2022, 7 Marks OR; SUMMER 2023, 7 Marks OR; WINTER 2023, 7 Marks; SUMMER 2026, 7 Marks OR)**
- **Q.** Discuss in brief about diffusion with homogeneous catalytic reaction. / Derive an equation for the diffusion in homogeneous chemical reaction with appropriate schematic diagram. [Diagram required – refer to the original question paper] **(WINTER 2023, 7 Marks OR; WINTER 2024, 4 Marks OR)**
- **Q.** Distinguish between homogeneous and heterogeneous reactions. Discuss phenomena of diffusion-controlled reaction with a suitable example. / Differentiate between diffusion-controlled

reaction and chemical kinetics controlled reaction with suitable example. **(SUMMER 2025, 7 Marks OR; WINTER 2025, 3 Marks)**

5. Shell Mass Balance:

- **Q.** Write the common boundary conditions used in shell mass balance. / State the shell mass balance equation and boundary conditions used for solving the mass transport problems. / What is the role of boundary conditions in shell mass balance? State the common boundary conditions for shell mass balance. / Write the general shell mass balance equation and necessary assumptions for solving the mass transport problems. **(WINTER 2023, 3 Marks OR; WINTER 2024, 4 Marks OR; SUMMER 2025, 4 Marks OR; WINTER 2025, 4 Marks; SUMMER 2026, 4 Marks OR)**

Other Important Questions:

1. Definitions and Concepts:

- **Q.** Define mass average and molar average velocities. **(SUMMER 2023, 3 Marks)**
- **Q.** Discuss equilibrium counter diffusion. **(SUMMER 2023, 3 Marks)**
- **Q.** Explain Knudsen diffusivity. **(SUMMER 2023, 3 Marks OR)**
- **Q.** Explain Mass and Molar Fluxes, Convective Mass and Molar Fluxes. **(SUMMER 2024, 4 Marks)**
- **Q.** Define Thiele modulus. What is the significance of Thiele modulus? **(WINTER 2024, 4 Marks)**
- **Q.** List out factors affecting diffusion of gas in solid. **(WINTER 2025, 3 Marks OR)**
- **Q.** Explain the Physical Interpretation of Mass Transfer Coefficient with suitable diagram. [Diagram required – refer to the original question paper] **(WINTER 2025, 4 Marks OR)**

2. Theory of Diffusion and Derivations:

- **Q.** Shortly explain the theory of diffusion in gases at low density. **(WINTER 2022, 4 Marks OR)**
- **Q.** State and discuss the various methods of calculating self diffusivity and binary diffusivity. **(WINTER 2023, 7 Marks OR)**
- **Q.** Explain the molecular diffusion in gases with appropriate equations. **(WINTER 2023, 4 Marks)**
- **Q.** Develop mass flux equation for diffusion Into a Falling Liquid Film (Gas Absorption, Forced Convection Mass Transfer). **(SUMMER 2024, 7 Marks OR)**
- **Q.** For the given figure shows the absorption of gas A into falling liquid B, the velocity profile is presented by [equation]. Establish a mass balance on component A considering CA = f(x,z) and formulate the following differential equation: [equation]. Assume: Transport of A in the z direction will be primarily by convection. In the x direction A moves predominantly by diffusion. [Diagram required – refer to the original question paper] [Data truncated in source – refer to the original question paper] **(WINTER 2024, 7 Marks)**

3. Numerical Problems:

- **Q.** Estimate the diffusion coefficient for acetone in water at 25 °C using Wilke-Chang equation. The association parameter ΨB = 2.6, μ for water = 0.8937 cp. The atomic volume for C = 14.8 $cm^3/gmol$, H = 3.7 $cm^3/gmol$, O = 7.4 $cm^3/gmol$. **(WINTER 2023, 4 Marks OR)**
- **Q.** A graduated cylinder cross-sectional diameter of 0.01128 m containing chloropicrin (CCl_3NO_2) is placed in a hood. The hood has a blower system that continually circulates dry air at a constant temperature (25 °C) and pressure (atmospheric). Originally, the liquid surface was 0.0388 m from the top of the cylinder. After one day the liquid level is 0.0412 m below the top. If the vapour pressure and density of chloropicrin are 3178.3 N/m^2 and 1650 kg/m^3 respectively, estimate the substance diffusivity in air. The molecular weight of chloropicrin is 164.39 kg/kmol. **(SUMMER 2025, 7 Marks)**
- **Q.** A tank containing 15 mole % of CO_2 in air is connected to a second tank containing only air. The connection line is 5 cm in diameter and 30 cm long, as shown in Fig. Both tanks are at 1 atmospheric pressure and 298.15 K. The volume of each tank is large compared to the volume of gas in the 30 cm connection line so concentration changes in each tank are negligible for a very long time after the beginning of the experiment. The diffusion coefficient of CO_2 in air at 1 atm.

and 25 °C is 0.164×10^{-4} m^2 s^{-1}. Calculate the initial rate of mass transfer of the CO_2? Assume that both gases are ideal and the diffusional transfer is equimolar counter diffusion. [Diagram required – refer to the original question paper] **(SUMMER 2025, 7 Marks OR)**

- **Q.** Hydrogen gas is maintained at 3 bar and 1 bar on opposite sides of a plastic membrane, which is 0.3 mm thick. The temperature is 25 °C and the binary diffusion coefficient of hydrogen in the plastic is 8.7×10^{-8} m^2/s. The solubility of hydrogen in the membrane is 1.5×10^{-3} $kmol/m^3$ bar. What is the mass diffusive flux of hydrogen through the membrane? **(WINTER 2025, 7 Marks OR)**
- **Q.** Chlorine is being absorbed from a gas in a small experimental wetted-wall tower. The absorbing fluid is water, which is moving with an average velocity of 17.7 cm/s. The local mass flux of chlorine in water at interface is estimated by expression [equation]. What is the absorption rate in gmoles/hr, if the liquid-phase diffusivity of the chlorine-water system is 1.26×10^{-5} cm^2/s and if the saturation concentration of chlorine in water is 0.823 g chlorine per 100 g water (at 16 °C - (Assumption: No chemical reaction between chlorine and water.) [Diagram required – refer to the original question paper] [Data truncated in source – refer to the original question paper] **(WINTER 2025, 7 Marks)**

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