BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: BTECH **SEMESTER: VI**
BRANCH: CHEMICAL ENGG. **SESSION: SP/2025**

SUBJECT: CL329 TRANSPORT PHENOMENA

TIME: 3 Hours **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Before attempting the question paper, be sure that you have got the correct question paper.
5. Tables/Data handbook/Graph paper, etc., to be supplied to the candidates in the examination hall.

			CO	BL
Q.1(a)	(i) A vector field is given by $\vec{v} = \vec{v}(x, y, z)$. State the physical significance (and not merely formula) of $\nabla.\vec{v}$, $\nabla \times \vec{v}$, and $\nabla\vec{v}$ (ii) Using index notation, show that: $\bar{\bar{\tau}}.\vec{v} \neq \vec{v}.\bar{\bar{\tau}}$	[3+2 =5]	1	3
Q.1(b)	Explain the Eulerian and Lagrangian framework in transport phenomena.	[3]	2	2
Q.1(c)	Define forced convention with an example.	[2]	1	1
Q.2(a)	The velocity profile of v_z (axial component) for 1D, laminar, incompressible steady flow of a Newtonian fluid (viscosity - μ) down an inclined plane (inclination angle β) is given by: $$v_z(x) = \frac{\rho g \delta^2 cos\beta}{2\mu}\left[1 - \left(\frac{x}{\delta}\right)^2\right]$$ Show that: (i) $v_{z,avg} (or\ \langle v_z \rangle) = \frac{\rho g \delta^2 cos\beta}{3\mu}$ (ii) $v_{z,max} = \frac{\rho g \delta^2 cos\beta}{2\mu}$	[2+1 =3]	3	3
Q.2(b)	A Newtonian fluid is in laminar flow through a narrow slit formed by two parallel vertical walls kept at a distance 2*B* apart with width *W*. It is understood that *B* << *W*, so that "edge effects" are unimportant. (i) Construct a shell momentum balance with suitable assumptions. (ii) Obtain the expressions for the momentum-flux and velocity distributions. (iii) Draw the velocity profile.	[2+ 3+ 2=7]	3	3
Q.3(a)	In vector notation, the equation for conservation of energy can be expressed as: $$\rho C_p\left[\frac{\partial T}{\partial t} + \vec{v}.\nabla T\right] = k\nabla^2 T - (\bar{\bar{\tau}} : \nabla\vec{v}) - \left(\frac{\partial ln\rho}{\partial \ln T}\right)_p \frac{Dp}{Dt} \pm \rho S_T$$ Explain the physical significance of each term.	[3]	1,3	3
Q.3(b)	A fluid with density ρ and viscosity μ is located between two vertical walls a distance of 2B apart. Two heated walls are maintained at two different temperatures of T_1 (at y=+*B*) and T_2 (at y=-*B*), where T_2>T_1. The system is closed at the top and bottom and the fluid is circulating between the plates due to natural convection. (i) With suitable assumptions, boundary conditions, and energy balance equation show that $T = \bar{T} - \frac{1}{2}\Delta T\frac{y}{B}$, where $\bar{T} = (T_1 + T_2)/2$ and $\Delta T = T_2 - T_1$. (ii) With suitable assumptions, boundary conditions, and equation of motion show that $$\mu\frac{d^2 v_z}{dy^2} = \left(\frac{dp}{dz} + \bar{\rho}g\right) + \frac{1}{2}\bar{\rho}g\bar{\beta}\Delta T\frac{y}{B}$$ Where, $\bar{\rho} = \rho\vert_{T=\bar{T}}$ and $\bar{\beta} = -\frac{1}{\rho}\left(\frac{\partial\rho}{\partial T}\right)_p$	[3+4 =7]	5	3

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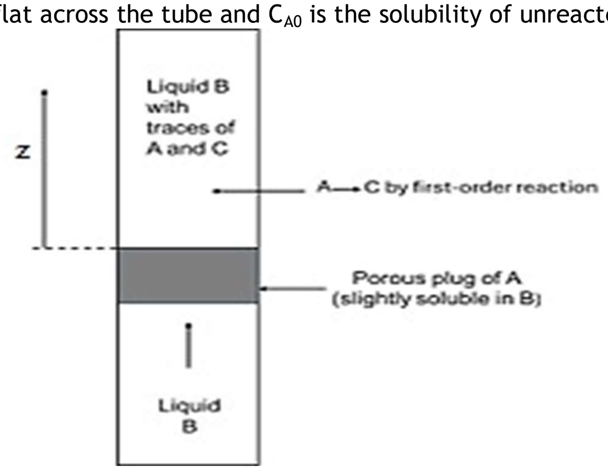
Q.4 In the figure below, a system is shown in which a liquid B moves slowly upward through a slightly soluble porous plug A. Thereafter, A gradually disappears by a first-order reaction to C (A→ C, $-r_A = kC_A$) after it has dissolved. Assume that the velocity profile is approximately flat across the tube and C_{A0} is the solubility of unreacted A in B.



Q.4(a) Using <u>the appropriate species transport equation and assumptions</u>, show that the steady-state governing equation for C_A is expressed by: [3] 3,5 3

$$v_0 \frac{dC_A}{dz} = D_{AB}\frac{d^2C_A}{dz^2} - kC_A$$

Q.4(b) Name the type of transport and mathematical equation obtained in Q.4(a). [2] 2 2

Q.4(c) Using the following dimensionless variables: [5] 4 3

$\tilde{C}_A = {C_A}/{C_{Ao}}$, $\xi = z/L$

show that Eq. in Q.4(a) can be expressed in non-dimensional form as:

$$\frac{d\tilde{C}_A}{d\xi} = \frac{1}{ReSc}\frac{d^2\tilde{C}_A}{d\xi^2} - Da\tilde{C}_A$$

Here, $Re = \frac{\rho v_0 L}{\mu}$ (Reynolds Number), $Sc = \frac{\mu}{\rho D_{AB}}$ (Schmidt Number), and $Da = \frac{kL}{v_o}$ (Damköhler Number)

Q.5(a) (i) Define turbulent flow. [1+2 =3] 1 1,2

(ii) Draw the velocity profiles for turbulent flow in circular pipe and flat plate.

Q.5(b) (i) Define turbulent momentum, thermal and mass diffusivities. [2+2 =4] 2 1,2

(ii) Explain Reynolds Analogy.

Q.5(c) Time-smoothed momentum equation for turbulent flow is given by [3] 1,2 2

$$\frac{\partial}{\partial t}\rho\bar{v} = -\nabla\bar{p} - [\nabla.\rho\bar{v}\bar{v}] - \left[\nabla.\left(\bar{\tau}^{(v)} + \bar{\tau}^{(t)}\right)\right] + \rho g$$

Express the physical significance of each term of the above-mentioned equation.

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