BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(MID SEMESTER EXAMINATION SP/2024)

CLASS: BTECH — **SEMESTER : VI**
BRANCH: CHEMICAL — **SESSION : SP/2024**

SUBJECT: CL329 TRANSPORT PHENOMENA

TIME: 02 Hours — **FULL MARKS: 25**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 5 marks and total 25 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Tables/Data handbook/Graph paper etc., if applicable, will be supplied to the candidates

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		Marks	CO	BL
Q.1(a)	Define total momentum flux in a flowing isothermal fluid. What is the order (vector/tensor) of the momentum flux?	[2]	1,2	1
Q.1(b)	Two vectors are given by $v = 5i + 2j + 3k$ and $w = 2i - 3j - 2k$. Evaluate the followings: i) $v \times w$, ii) vw, and iii) angle between two vectors.	[3]	1	3
Q.2	Consider the laminar flow of a Newtonian fluid with constant properties (ρ and μ) in a cylindrical pipe of length L and radius R. Using relevant equations (see in the next page) of continuity and motion, show the followings:			
Q.2(a)	The sketch of the physical problem with velocity and stress profiles along the radius.	[1]	1	2
Q.2(b)	The z-equation of motion is: $$-\frac{\partial P}{\partial z} + \mu \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) = 0$$ Here, $P(z) = p + \rho g z$	[3]	3	3
Q.2(c)	With proper boundary conditions, the local velocity can be estimated by: $$v_z(r) = \frac{\Delta P R^2}{4\mu L}\left[1 - \left(\frac{r}{R}\right)^2\right]$$ Here, $\Delta P = P_0 - P_L = P(z=0) - P(z=L)$	[3]	3	3
Q.2(d)	The volumetric flow rate (Q) can be estimated from the Hagen–Poiseuille equation which is expressed as: $Q = (\pi R^4 \Delta P)/(8\mu L)$	[3]	3	3
Q.3(a)	An oil has a kinematic viscosity (ν) of 2.5×10^{-4} m^2/s and a density (ρ) of 0.85×10^3 kg/m3 flows down vertically with a film thickness (δ) of 2.8 mm. i) Illustrate the problem with a sketch showing velocity profile of the oil and ii) Estimate the mass flow rate ($\dot{m}$) of the oil if the width (W) of the wall is 10 cm. The δ for a laminar falling film can be calculated from: $$\delta = \left(\frac{3\mu\dot{m}}{\rho^2 g W \cos\beta}\right)^{1/3}$$ Here, μ is absolute viscosity and β is the angle subtended by the vertical wall.	[3]	1	3
Q.3(b)	Depict the mechanism of a Couette viscometer (rotating cylinder type).	[2]	1	2
Q.4	Derive the x-component (Cartesian plane) momentum balance equation and equation of motion for a Newtonian fluid with constant ρ and μ from shell balance.	[5]	3	3

Equations in polar (Cylindrical) Coordinate (r,Θ, and z)

Continuity Equation:

$$\frac{\partial \rho}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(\rho r v_r) + \frac{1}{r}\frac{\partial}{\partial \theta}(\rho v_\theta) + \frac{\partial}{\partial z}(\rho v_z) = 0$$

Equation of Motion (r,Θ, and z components):

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + v_z\frac{\partial v_r}{\partial z} - \frac{v_\theta^2}{r}\right) = -\frac{\partial p}{\partial r} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_r)\right) + \frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2} + \frac{\partial^2 v_r}{\partial z^2} - \frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}\right] + \rho g_r$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + v_z\frac{\partial v_\theta}{\partial z} + \frac{v_r v_\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_\theta)\right) + \frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2} + \frac{\partial^2 v_\theta}{\partial z^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \theta}\right] + \rho g_\theta$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z$$

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