Ref. No. Ex/PG/Ch.E/T/113A/2025

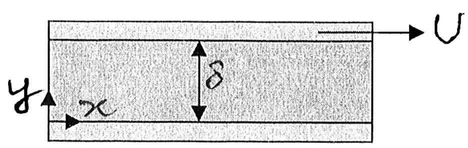
M. E. CHEMICAL ENGINEERING 1st YEAR 1ST SEMESTER EXAMINATION 2025
SUBJECT: ADVANCED TRANSPORT PHENOMENA Time: Three hours
Full Marks 100
ANSWER ANY FIVE QUESTIONS

No. of Questions/ CO		Marks
1.	(i) Write the generalized mass balance and species balance equations over an integral control volume and derive the differential continuity and species balance equations at a single point.	(5+5)
	(ii) Using Reynolds averaging rules derive the expression of Reynold stress and eddy viscosity for turbulent flow of an incompressible fluid.	(10)
2.	(i)Using order of magnitude analysis, prove that the laminar boundary layer thickness over a flat plate varies as the inverse square root of the Reynolds number. (ii)Derive the laminar hydrodynamic boundary layer equations over a flat plate of length L, considering U as the free stream velocity. (iii)Derive the integral momentum equations. (iv)Assuming that the nondimensional axial velocity (v_x/U) is a third order polynomial of (y/δ), derive the expressions for boundary layer thickness $\delta(x)$ and friction factor.	(20)
3.	Consider steady flow (Q) of an incompressible Newtonian fluid through a horizontal circular tube in which the radius varies with axial position as $R(z) = R_o + R_1 \sin(\frac{\pi z}{l})$ That is the mean radius is R_o and the amplitude and period of variations are R_1 and $2l$, respectively.	

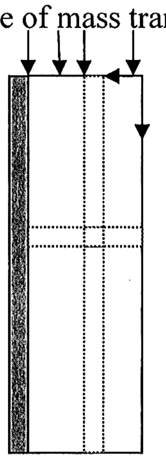
[Turn over

Ref. No. Ex/Ch.E/T/113A/2025

M. E. CHEMICAL ENGINEERING 1st YEAR 1ST SEMESTER EXAMINATION 2025
SUBJECT: ADVANCED TRANSPORT PHENOMENA Time: Three hours
Full Marks 100
ANSWER ANY FIVE QUESTIONS

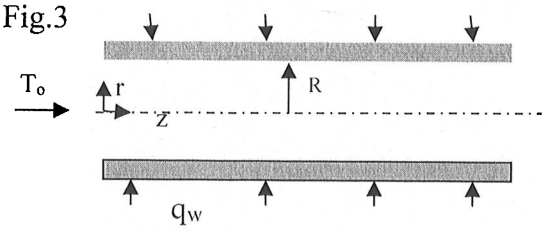
No. of Questions/CO		Marks
3.	(i)For a general case, Nondimesionalize the continuity and steady state Navier Stokes equations using characteristic lengthscale L (=$2R_o$), characteristic velocity U, characteristic pressure π. Derive the expression of pressure scale π for two asymptotic limit Re $\longrightarrow$ 0 and Re $\longrightarrow$ ∞. Name the dimensionless numbers. (ii)Using lubrication approximation and order of magnitude analysis derive the approximated governing equations. (iii)Derive the expression of v_z, v_r and P(r,z).	(20)
4.	A Newtonian fluid confined between two parallel plates was at rest. At t=0 suddenly the upper plate is set in motion at a constant velocity of U towards x direction (refer to figure 1) and a constant pressure gradient (negative) is applied. The distance between the two plates is δ and the width of the plates is large compared to δ. (i)Write the governing equations and initial and boundary conditions. (ii) Nondimensionalize the governing equation. Name the dimensionless numbers. What is the value of Strouhal number? (ii) Derive the steady state velocity profile υ_{xs} that will be attained at large time. (iii)Derive the expression for the start up velocity profile $\upsilon_x(y,t)$ which will attain the steady state at large time. **Figure 1** 	(20)

M. E. CHEMICAL ENGINEERING 1st YEAR 1ST SEMESTER EXAMINATION 2025
SUBJECT: ADVANCED TRANSPORT PHENOMENA Time: Three hours
Full Marks 100
ANSWER ANY FIVE QUESTIONS .

No. of Questions/ CO		Marks
5.	A thin film of a Newtonian liquid B (of thickness δ) flows along (z) a vertical wall while in contact with a gas mixture containing the solute A (refer to figure 2). The solute A diffuses and absorbed in to the liquid B. The length of contact between the two phases is relatively short during normal operation. The concentration of the solute at the liquid gas interface is constant (C_{Ao}) at the value of solubility of A. (i)Derive the expression for falling film velocity profile (ii)Write the governing equation and boundary conditions, that describes the transport of solute. Derive the important dimensionless number involved. (iii)Considering that solute A penetrates only a short distance in to the liquid film (before it is carried by the flow) due to slow rate of diffusion or a short time of exposure, derive the solute concentration profile under steady state. (iv)Derive the expression for local mass flux at the interface (at any z) and the total rate of mass transferred from gas phase to the liquid film. **Figure 2** 	(20)

Ref. No. Ex/PG/Ch.E/T/113A/2025

M. E. CHEMICAL ENGINEERING 1st YEAR 1ST SEMESTER EXAMINATION 2019
SUBJECT: ADVANCED TRANSPORT PHENOMENA Time: Three hours
Full Marks 100

No. of Questions/ CO	ANSWER ANY FIVE QUESTIONS	Marks
6.	Consider that an incompressible Newtonian fluid at a uniform temperature T_o enters a circular tube of radius R with its wall receiving a uniform heat flux q_w (refer to fig.3). The bulk temperature T_b of the fluid increases as the fluid moves through the tube. Beyond a definite thermal entry length the shape of temperature profile does not change. This is called fully developed temperature profile. (i) Considering average fluid properties derive an expression of steady state fully developed laminar velocity profile through the tube. (ii) Write the governing equation and boundary conditions for energy transport and steady state fully developed temperature profile at far downstream. (iii)Nondmensionalize the governing equation and boundary conditions. What are the significant dimensionless numbers involved in this forced convective heat transport? (iv) Derive the fully developed temperature profile. (v) Prove that the value of Nusselt number is 4.364 (48/11). Fig.3  	(20)

Ref. No. Ex/PG/Ch.E/T/113A/2025

M. E. CHEMICAL ENGINEERING 1st YEAR 1ST SEMESTER EXAMINATION 2019
SUBJECT: ADVANCED TRANSPORT PHENOMENA Time: Three hours
Full Marks 100

No. of Questions/CO		Marks
	Navier Stokes equation is given below $$\rho\left[\frac{\partial \vec{V}}{\partial t}+\vec{V}.\nabla\vec{V}\right]=-\nabla p+\rho\vec{g}+\mu\nabla^2\vec{V}$$ Continuity and components of Navier Stokes equations for cylindrical coordinate are given below $$\frac{1}{r}\frac{\partial(rv_r)}{\partial r}+\frac{1}{r}\frac{\partial v_\theta}{\partial\theta}+\frac{\partial v_z}{\partial z}=0$$ $$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial\theta}-\frac{v_\theta{}^2}{r}+v_z\frac{\partial v_r}{\partial z}\right)=-\frac{\partial p}{\partial r}+\mu\left[\frac{\partial}{\partial r}(\frac{1}{r}\frac{\partial(rv_r)}{\partial r})+\frac{1}{r^2}\frac{\partial^2 v_r}{\partial\theta^2}-\frac{2}{r^2}\frac{\partial v_\theta}{\partial\theta}+\frac{\partial^2 v_r}{\partial z^2}\right]+\rho g_r$$ $$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial\theta}+\frac{v_r v_\theta}{r}+v_z\frac{\partial v_\theta}{\partial z}\right)=-\frac{1}{r}\frac{\partial p}{\partial\theta}+\mu\left[\frac{\partial}{\partial r}(\frac{1}{r}\frac{\partial(rv_\theta)}{\partial r})+\frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial\theta^2}+\frac{2}{r^2}\frac{\partial v_r}{\partial\theta}+\frac{\partial^2 v_\theta}{\partial z^2}\right]+\rho g_\theta$$ $$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial\theta}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}(r\frac{\partial v_z}{\partial r})+\frac{1}{r^2}\frac{\partial^2 v_z}{\partial\theta^2}++\frac{\partial^2 v_z}{\partial z^2}\right]+\rho g_z$$	