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

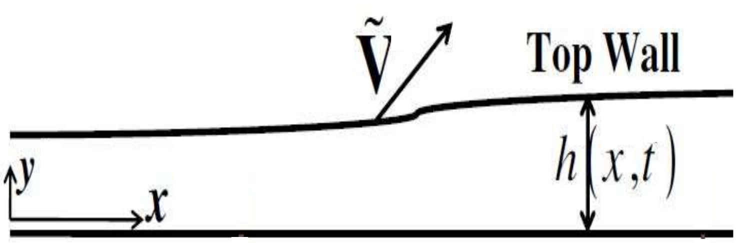
CLASS: BTECH. **SEMESTER : VII**
BRANCH: CHEMICAL **SESSION : MO/2024**

SUBJECT: CL427 MICROFLUIDICS

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 hand book/Graph paper etc. to be supplied to the candidates in the examination hall.
6. All symbols have the usual meanings.

			CO	BL
Q.1	You have a z:z electrolyte solution, and a flat plate is immersed in it; the concentration of the electrolyte is *n* and the ϵ is the effective permittivity. Determine the potential distribution in the system under the Debye Huckel framework (whatever parameters you need apart from the mentioned can be assumed).	[10]		4
Q.2(a)	Find out the Debye length for 0.01 (M) NaCl solution.	[5]		3
Q.2(b)	With neat diagram write down the different steps of photolithography.	[5]		2
Q.3(a)	What do you understand by fully developed flow? Explain this using a sketch. What is entrance length? What is the difference between Newtonian and non-Newtonian fluid?	[1+1+1+1]		1
Q.3(b)	Consider the steady, laminar, incompressible and fully developed flow of a Newtonian fluid through a horizontal pipe (of circular cross-section) driven by a pressure gradient. Draw the schematic of this problem. Considering the *r* and *z* momentum equations of cylindrical coordinate system, simplify the governing equations using appropriate assumptions. Then derive the expression for the velocity profile. Plot the velocity profile and show the location of the maximum and minimum velocities. What is Hagen-Poiseuille equation and what is its physical significance.	[4+1+1]		4
Q.4(a)	Consider the rise of water in a vertical capillary. Draw the physical system, use the appropriate force balances and derive the capillary height as a function of time for both short-time and long-time dynamics. What is equilibrium height?	[4+1]		4
Q.4(b)	What are the similarities and differences between boundary layer theory and lubrication theory? Consider the schematic given in the figure below. The bottom plate is fixed, the top plate is moving with velocity $\tilde{V}$. Length of two plates is *L* and separation between two plates is $h(x,t)$. Perform scaling analysis for continuity equation and *x*-momentum equation. From the *x*-momentum equation, determine the scale of pressure using scaling analysis.	[1+4]		4



Use the equations for rectangular cartesian coordinate system.

PTO

Q.5(a)	Using sketch, briefly explain the tangential and normal stress balance condition and kinematic boundary condition. What are the differences between the theory of thin film and lubrication theory?	[4+1]	3
Q.5(b)	Brief explain how microfluidics can be used in disease detection. What do you understand by paper-based and CD-based medical diagnostics?	[2+3]	2

Momentum equations in cylindrical coordinate system:

***r*-component:**

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

***z*-component:**

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

Here, v_r and v_z are the velocity components in *r* and *z* directions, respectively.

Equations in rectangular cartesian coordinate system:

Continuity equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

***x*-component:**

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+F_x$$

Here, *u* and *v* are the velocity components in *x* and *y* directions, respectively.

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