INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Spring Semester Examination 2022-23

Date of Examination: 22/02/23 **Session: (FN/AN)** AN **Duration: 2 hrs.**

Full Marks: 30

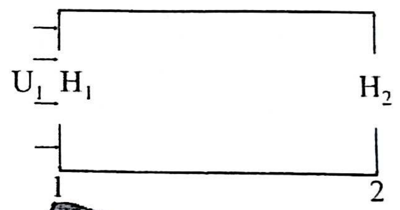
Subject No.: CH30012 **Subject: TRANSPORT PHENOMENA**

Department/Center/School: Chemical Engineering

Specific charts, graph paper, log book etc., required

Special Instructions (if any): **NO**

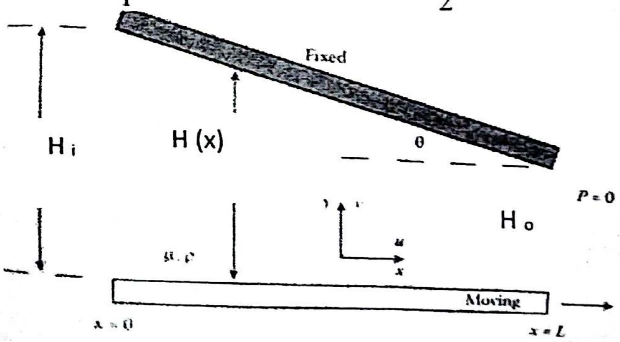
1. Lubrication flows are characterized by incompressible fluids to thin gaps e.g., the layer of water between the ice skate and the ice, the oil that lubricates the moving parts of an internal combustion engine etc. The fluid flows at relatively small velocities and so the inertial terms in the Navier-Stokes equations are insignificant compared to the diffusive terms. Since the gaps are so thin, lubrication flows can be treated as two-dimensional. Finally, if the gap is very thin, there is little effect of gravity.



Consider the lubrication flow occurring between the fixed and moving components of a bearing as shown in the figure (H_i and H_o are the gaps at x = 0 and x = L) in presence of a pressure gradient with one of the plates moving with a constant velocity U_o. Assume that there is a constant volumetric flow rate V of the lubricant in the system as a result of this motion of the plate and the applied pressure gradient.

(i) Solve the governing equations with appropriate boundary conditions to obtain the x-component of the velocity, u, as a function of the pressure gradient and H(x).

Use relevant conditions to obtain expressions for ii) dP/dx and the local pressure P(x) in terms of H(x), U_o and V, (iii) the volumetric flow rate V and (iv) the load the bearing can support in terms of the system parameters (H_i, H_o, θ, U_o) and μ.



4+4+3+3 =14

2. A laboratory wind tunnel has a flexible upper wall that can be adjusted to compensate for boundary-layer growth, giving zero pressure gradient along the test section. The wall boundary layers at both sections 1 and 2 are well represented by the 1/7-power-velocity profile. At the inlet the tunnel cross section is square, with height H_1 and width W_1, each equal to 305 mm. With freestream speed $U_1 = 26.5$ m/s, measurements show that $\delta_1 = 12.2$ mm and downstream $\delta_2 = 16.6$ mm.

(i) Calculate the height of the tunnel walls at section 2.

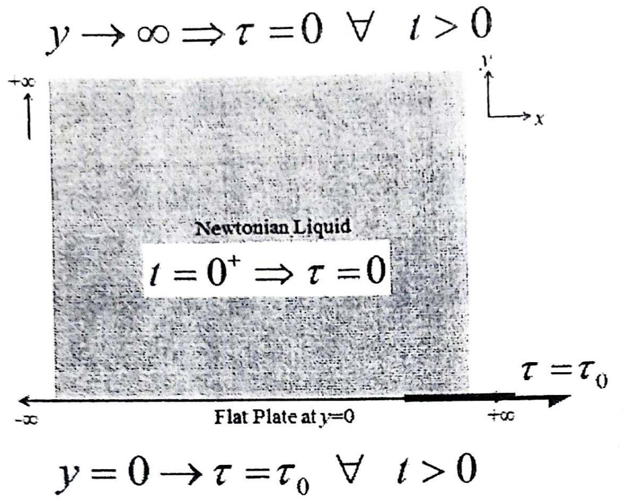
(ii) Determine the equivalent length of a flat plate that would produce the inlet boundary layer thickness.

(iii) Estimate the streamwise distance between sections 1 and 2 in the tunnel. Assume standard air (kinematic viscosity = 1.45×10^{-5} m²/s). **4+3+2=9**

$\frac{H_i - H_o}{L}$

3. Consider an unsteady state momentum transfer event in semi-infinite domain (in +y direction), wherein a flat plat of infinite length (in ± x direction) is kept at $y = 0$, and the domain $0 < y$ contains a Newtonian liquid at rest, as shown in figure on next page. At time $t = 0$, a constant stress τ_0, has been imposed on flat plat in $+x$ direction, which is maintained for $t \geq 0$. Assume 1D momentum transport in $+y$ direction. The constitutive relation for

Newtonian liquid is given by: $\tau_{yx} = -\mu \frac{\partial V_x}{\partial y}$, where τ_{yx} is shear stress in $+x$ direction, working on any plane having normal in $+y$ direction. Viscosity of liquid = μ, Density of liquid = ρ.



a) Write down the momentum transport governing equation in terms of V_x. **(0.5)**

b) Express the equation obtained in (a) in terms of shear stress, τ_{yx}. (Hint: differentiate the equation obtained in (a) w.r.t. y and multiply both sides by $-\mu$.) **(0.5)**

c) Solve the governing equation obtained in (b) in order to get the time – dependent stress profile, $\tau_{yx}(y, t)$. You can express your answer in terms of error function. **(3)**

d) Find out the spatio- temporal velocity profile: expression as well as few qualitative curves (4-5 curves) at 4-5 different early times in a single plot. Also find the velocity + expression of the bottom plate as function of time. **(3)**

Useful Relations

EQUATION OF CONTINUITY (Cartesian and Cylindrical coordinates)

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

EQUATION OF MOTION (Cartesian, Cylindrical and Spherical coordinates)

$$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2}\right) + \rho g_z$$

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

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

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

INTEGRAL EQUATIONS

$$\frac{dN}{dt}\Big|_{system} = \frac{\partial}{\partial t}\int_{CV} \eta \rho d\forall + \int_{CS} \eta \rho \vec{V}.\vec{dA} \qquad \delta^* = \int_0^\delta \left(1 - \frac{v_x}{U}\right) dy, \quad \theta = \int_0^\delta \frac{v_x}{U}\left(1 - \frac{v_x}{U}\right) dy$$

$\frac{\partial v_x}{\partial t} = \nu \frac{\partial^2 v_x}{\partial y^2}$ $\eta = \frac{y}{\delta}$

Indian Institute of Technology Kharagpur

Date of Examination: Session: Duration 3 hrs Full Marks 50
Subject Number: CH30012 Subject: Transport Phenomena Department: Chemical Engineering
Graph paper required: **YES.**
Specific Instructions: Assume and clearly write any assumption and data that you feel are missing.

1. A plane surface, 25 cm wide, has its temperature maintained at 80 C. Atmospheric air, at 25C; flows parallel to the surface with a velocity of 2.8 m/s. Determine the following for a 1-m long plate:
   (i) The total drag force exerted on the plate by the air flow (in mN).
   (ii) The total heat transfer rate from the plate to the air stream (in W).
   For Air at the average temperature the properties can be taken as: $\rho = 1.087$ Kg/m^3, kinematic viscosity = 1.807×10^{-5} m^2/s, $C_p = 1.008$ kJ/(Kg . K), Pr = 0.702, k = 2.816 W/(m . K) **5 + 5 = 10**

2. (a) A crude approximation for the x component of velocity in a laminar boundary layer is a linear variation from $v_x = 0$ at the surface to the freestream velocity, U, at the boundary layer edge ($y = \delta$). The equation for the profile is given below (where C is a constant). Evaluate the maximum value of the ratio v_y / v_x at a location x = 0.5 m and δ = 5 mm.

$$v_x = C\,U\,\frac{y}{x^{1/2}}$$ **3**

   (b) Starting with the governing equation for momentum boundary layer evaluate the value of $\partial^3 u / \partial y^3$ at y = 0 for an incompressible laminar boundary layer on a flat plate with zero-pressure gradient. **2**
   (c) A flat plate, sides a, b in length, is towed through a fluid so that the boundary layer is entirely laminar. Find the ratio of towing speeds so that the drag force remains constant regardless of whether a or b is in the flow direction. U_a is the freestream velocity if side a is in the flow direction and U_b if b is in the flow direction. **5** **3+2+5=10**

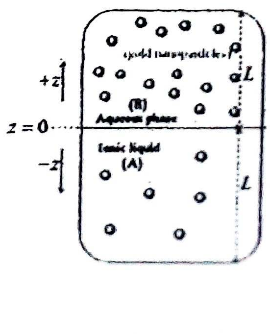
3. A new spray-painting system is being evaluated for the auto industry. The paint is delivered via an atomizer that produces 10 mm particles and propels them toward the surface at a velocity of 10 m/s. The particles are a dilute suspension of pigment agents in a solvent and for modelling purposes can be assumed to be pure solvent. To form a good coating the particles must arrive at the surface with 75% by volume of the solvent remaining. The freestream concentration of the solvent is effectively zero and the solvent has a specific gravity of 0.85 and a molecular weight of 100. The whole system operates at atmospheric pressure and at the temperature of deposition the vapor pressure of the solvent is 250 mm Hg. The diffusivity of the solvent in air was 1×10^{-9} m^2/s, the Schmidt number for the solvent is 500 and R = 8314J/(Kg mol . K). For the specified conditions the relevant mass transfer correlation can be approximated as

$$\overline{Sh}_D = 2 + \left(0.4\,Re_d^{1/2} + 0.06\,Re_d^{2/3}\right)Sc^{0.4}$$

   How far away from the surface should the painting nozzle be located? **10**

4. Air passes through a naphthalene tube, that has an inside diameter of 2.5 cm, flowing at a bulk velocity of 15 m/s. The air is at 283 K and an average pressure of 101300 Pa. Assuming that the change in pressure along the tube is negligible and that the naphthalene surface is at 283 K, determine i) the concentration profile of naphthalene as a function of the axial position in the tube, assuming the bulk velocity to be a constant and ii) the length of tube (approx. in m) that is necessary to produce a naphthalene concentration in the exiting gas stream of 4.75×10^{-4} mol/m^3. At 283 K, naphthalene has a vapor pressure of 3 Pa and a diffusivity in air of 5.4×10^{-6} m^2/s. Use C_f = 0.0058, R=8.314 J/(mol•K). **5+5=10**

5. Phase transfer of gold nanoparticles from aqueous phase to ionic liquid (IL) phase is greatly desired, as the ionic liquid prevents the solvent vaporization significantly as compared to aqueous phase, which in turn prevents agglomeration of gold nanoparticles. One such recent discovery is use water-immiscible ionic liquid 1-butyl-3-methylimidazolium hexafluorophosphate for phase transfer of gold nanoparticles from aqueous phase (**B**) to ionic liquid (phase **A**), as shown in figure on the right side. The initial concentration of gold nanoparticles are $C_{A0}(= 0.05\ mol/m^3)$ and $C_{B0}(= 0.5\ mol/m^3)$ in phase **A** and **B** respectively. Consider that the interface of two phases is always located at $z = 0$. $C_A(z,t)$



and $C_B(z,t)$ represent the gold nanoparticle concentration as a function of space and time in phase A and B respectively. The diffusivities of gold nanoparticle in phase A and B are D_A ($=10^{-10}\ \mathrm{m^2/s}$) and D_B ($=2\times10^{-10}\ \mathrm{m^2/s}$) respectively. L = 10mm.

Make the following assumptions:

- Consider unidirectional mass diffusion (only) in $\pm z$-direction. Fick's law of diffusion is applicable for both phases.
- Interface always remains at chemical equilibrium,
  i.e., $C_B(z=0, t>0) = kC_A(z=0, t>0)$ (k =2).
- Interface always remains in quasi-steady state, which implies that net diffusive mass-flux at interface is equal to zero.
- Ignore gravity driven settling.
- Don't mix up initial condition with any boundary condition (In other words, kindly don't try to validate interfacial equilibrium condition at t =0).

a) Report the concentration values of gold nanoparticles in aqueous phase (C_B) at t = 10s for following z = 0.057, 0.115, 0.285, 1.132, 3.0, 5.66 mm. Similarly, report the concentration values of gold nanoparticles in ionic phase (C_A) at t = 10s for following z = −0.057, −0.115, −0.285, −1.132, −3.0, −5.66 mm. Use these concentration values to draw the concentration profile of gold nanoparticles over z at t = 10s (You are free to avoid any derivation, however with proper justification/logic). **(6)**

b) Calculate the mass transfer flux of gold nanoparticle at z = −0.1mm at t = 10s. **(4)**

EQUATION OF CONTINUITY (Cartesian, cylindrical and spherical coordinates)

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

$$\frac{\partial\rho}{\partial t}+\frac{1}{r^2}\frac{\partial}{\partial r}(\rho r^2 v_r)+\frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(\rho v_\theta\sin\theta)+\frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}(\rho v_\phi)=0$$

EQUATION OF MOTION (Cartesian and Cylindrical coordinates)

$$\rho\left(\frac{\partial v_z}{\partial t}+v_x\frac{\partial v_z}{\partial x}+v_y\frac{\partial v_z}{\partial y}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 v_z}{\partial x^2}+\frac{\partial^2 v_z}{\partial y^2}+\frac{\partial^2 v_z}{\partial z^2}\right)+\rho g_z$$

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

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

INTEGRAL EQUATIONS

$$\left.\frac{dN}{dt}\right|_{system}=\frac{\partial}{\partial t}\int_{CV}\eta\,\rho\,d\forall+\int_{CS}\eta\,\rho\vec{V}.\vec{dA} \qquad \delta^*=\int_0^\delta\left(1-\frac{v_x}{U}\right)dy, \qquad \theta=\int_0^\delta\frac{v_x}{U}\left(1-\frac{v_x}{U}\right)dy$$

$$\frac{\tau_w}{\rho}=\frac{d}{dx}(U^2\theta)+\delta^*U\frac{dU}{dx} \qquad \delta=\frac{5.0x}{\sqrt{Re_x}}\ (laminar\ flow) \quad \delta=\frac{0.37x}{(Re_x)^{\frac{1}{5}}}\ (turbulent\ flow) \qquad \frac{\overline{v_z}}{U}=\left(\frac{y}{R}\right)^{\frac{1}{7}}$$

Laminar Flow: $C_f=\frac{0.664}{\sqrt{Re_x}}$ $\quad C_D=\frac{1.328}{\sqrt{Re_L}}$ $\quad$ Turbulent Flow: $C_f=\frac{0.0594}{(Re_x)^{\frac{1}{5}}}$ $\quad C_D=\frac{0.0742}{(Re_L)^{\frac{1}{5}}}$

STOKES LAW $F=3\pi\mu Vd$

For Mixed Flow, $C_{D_{Turb}}=\frac{0.074}{(Re_L)^{\frac{1}{5}}}-\frac{1740}{Re_L}$, $\quad 10^5<Re<10^7$, $\quad C_{D_{Turb}}=\frac{0.455}{(\log Re_L)^{2.58}}-\frac{1610}{Re_L}$, $Re>10^7$

ENERGY EQUATION (in all coordinate systems)

$$\rho\hat{C}_p\left(\frac{\partial T}{\partial t}+v_x\frac{\partial T}{\partial x}+v_y\frac{\partial T}{\partial y}+v_z\frac{\partial T}{\partial z}\right)=k\left[\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right]+\mu\phi_v+\dot{Q}$$

$$\rho\hat{C}_p\left(\frac{\partial T}{\partial t}+v_r\frac{\partial T}{\partial r}+\frac{v_\theta}{r}\frac{\partial T}{\partial\theta}+v_z\frac{\partial T}{\partial z}\right)=k\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 T}{\partial\theta^2}+\frac{\partial^2 T}{\partial z^2}\right]+\mu\phi_v+\dot{Q}$$

$$\rho\hat{C}_p\left(\frac{\partial T}{\partial t}+v_r\frac{\partial T}{\partial r}+\frac{v_\theta}{r}\frac{\partial T}{\partial\theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial T}{\partial\phi}\right)=k\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial T}{\partial\theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2 T}{\partial\phi^2}\right]+\mu\phi_v+\dot{Q}$$

Suvek... 2...

INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Mid-Spring Semester Examination, 2022-2023

Subject: **Instability and Patterning of Thin Polymer Films** *Subject No.*: **CH 62052**

Date: **21.02.2022 (FN)** *Time*: **2 Hrs** *Full Marks*: **30** **No. of Students: 133**

Instructions:

1. All Questions are compulsory.
2. **Please answer all parts of the same question together. Else marks will be deducted.**
3. **Be Precise with your answers. Long, redundant answers can potentially fetch zero!**
4. **If you feel any question is wrong, make suitable assumptions. NO DOUBTS will be taken during the examination.**

******** **Please answer all parts of the same question together** *********

1. (a) With suitable figure discuss contact angle hysteresis? What is the reason for it? (1+1)

   (b) What is a super-hydrophobic surface? What type of a surface is a rose petal from the standpoint of wetting? (1+1)

   (c) Discuss how a soap bubble remains stable. (2)

   (d) Why pre-soaking in detergent solution and post wash rinsing in fresh water is important from the standpoint of cleaning a fabric. (2)

   Total Marks for Question 1: (8)

2. (a) "Patterning a flat surface **always** increases the effective contact angle" Is the statement correct? Justify with appropriate scientific logic. (3)

   (b) A line grating patterned surface have periodicity of 1.5 μm. What is the height of the features if line roughness is 1.4? What is the line width? (2+1)

   (c) Do you think drop volume has any effect on the value of equilibrium contact angle, or Young's equation? Justify (2)

   Total Marks for Question 2: (8)

3. (a) What is spreading coefficient? What is the significance of the sign of spreading coefficient? (1+1)

   (b) What happens when a drop of a pure liquid evaporates over a defect free, smooth surface? (2)

   (c) In evaporative drying of a solution drop, discuss which internal flow(s) are material independent and which one(s) are material dependent. (3)

   Total Marks for Question 3: (7)

4. (a) Discuss the basic physics and the stages of spin coating, leading to formation of a thin film. How long should spinning be continued to ensure one gets good film quality? (3+1)

   (b) What are the possibilities when instead of one, two solutes are dissolved in a common solvent and spin coated on a flat surface? (3)

   Total Marks for Question 4: (7)

All the best ☺

INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Mid-Spring Semester Examination, 2022-2023

Subject: **Instability and Patterning of Thin Polymer Films** *Subject No.*: **CH 62052**

Date: **28.02.2022 (AN)** *Time*: **3 Hrs** *Full Marks*: **50** **No. of Students: 133**

***Instructions*:**

1. All Questions are compulsory.
2. **Please answer all parts of the same question together. Else marks will be deducted.**
3. **Be Precise with your answers. Long, redundant answers can potentially fetch zero!**
4. **As much as possible, answers should be accompanied with figures.**
5. **If you feel any question is wrong, make suitable assumptions. NO DOUBTS will be entertained during the examination.**

******** **Please answer all parts of the same question together** *********

1. (a) What are the different types of Photo Resist Tones. Explain with suitable figures. (2)

(b) What is Soft Baking? (1)

(c) What are the different Printing modes in photolithography? Discuss which mode offers the possibility of fabrication of features that are smaller (in lateral dimension) than those printed on the photo-mask. (2+1)

(d) Why is the time required for **development** crucial? (2)

(e) What is native oxide layer? Why it is essential to grow the oxide layer in Photolithogaphy?

(1+2) **[Total Marks in Q1: 11]**

2. (a) Explain why the patterns made by NIL have significantly higher levels of residual stress. (2)

(b) What is the role of Solvent Vapor Exposure to a polymer film? (3)

(c) Discuss the method of Micro Contact Printing. On what does proper pattern replication by this method depend on? (2+1)

(d) Discuss briefly the method of Roller NIL. How it is different from standard NIL and consequently what critical control is essential. **(2+1)**

[Total Marks in Q2: 11]

3. (a) What is the fundamental difference between the working of an STM and that of an AFM? In which of the instruments vacuum is required, and why? **(1+1)**

(b) Describe the steps of approach of an AFM in contact mode. **(4)**

(b) How is set point chosen in Tapping (Intermittent Contact) mode. Also describe how "imaging" is performed in this mode. **(2+3=5)**

[Total Marks in Q3: 11]

4. (a) Obtain an expression for the Excess Interfacial Free Energy (ΔG_{Ex}^{LW}) for a thin film of material 1 coated on a semi-infinite substrate of materials 2. You can use the following expressions: $G^{lw}(d) = -(A_{12}/12\pi)\left[\frac{1}{(d_1+d_2+d)^2} + \frac{1}{d^2} - \frac{1}{(d+d_1)^2} - \frac{1}{(d+d_2)^2}\right]$ and $G_{Film}^{LW} = -G_{Interface}^{LW}$. The symbols carry their usual meaning. (3)

(b) Define Effective Interface Potential, Conjoining Pressure and Disjoining Pressure. (2)

(c) Discuss how the Sign of A_E càn be correlated to film stability. (4)

[Total Marks in Q4: 9]

5. **(Thought provoking questions)**

(a) You know that spin coating over a flat substrate leads to a uniform, smooth and flat film. What do you think will happen if you coat the film over a topographically patterned substrate (let's say with simple grating geometry)? (3)

(b) You know that by executing several soft lithography techniques (such as NIL, CFL, REM etc.) properly, one can get a perfect negative replica of the stamp patterns. Can you think of some conceptual technique that would in principle allow you to make patterns that have same lateral dimension as that of the stamp features but will have different feature height (simple terms: Let's say height of the stamp features is h_0, can you now make patterns with any feature height varying between 0 and h_0).

Disclaimer: Roller NIL is NOT the answer I am looking at.

Clue: Please start thinking in terms of material property of the different polymers that you have studied in this course. (5)

[Total Marks in Q5: 8]

******** **Please ensure that you have looked into the instructions on the top of the question paper very seriously and have cared to answer all parts of the same question together** *********

All the best ☺

It was a pleasure to teach Instability to each one of you. Thank you. – RM

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