INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

End-Autumn Semester 2018-19

Date of Examination : 22/11/2018 **Session (FN/AN)** AN **Duration** 3 hrs

Subject No. : CH20001 **Subject Name :** Fluid Mechanics

Department/Center/School : Chemical Engineering

Specific charts, graph paper, log book etc., required: No

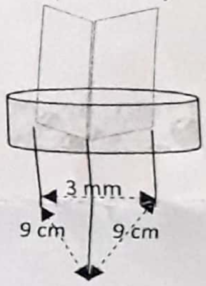
Special Instructions (if any) : Assume any data you feel are missing

Q1. Water at 100°C flows steadily through a venturi. The pressure, upstream from the throat is 100 kPa (gauge). The throat area is 0.001 m^2. The upstream area is 0.01 m^2. Estimate the maximum flow rate this device can handle without cavitation. **(6 Marks)**

Q2. The three Cartesian components of the velocity field for pressure driven flow between two parallel plates is derived as $u = u_{max}\{1-(y/b)^2\}$; $v=0$; and $w=0$; where y is measured from the channel centre line, and $2b$ is the distance between the parallel plates. Evaluate the acceleration, the vorticity, and the rate of angular deformation for this flow. Find the location where the vorticity is maximum. **(6 Marks)**

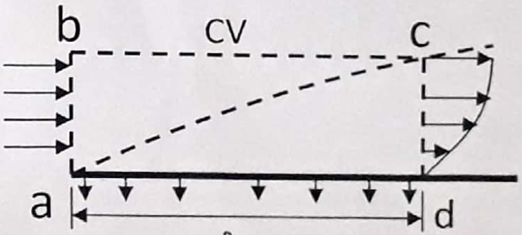
Q3. A source with strength 1 m^2/s, and a vortex with strength 1.0 m^2/s are located at the origin. Determine the equations for potential and stream functions. What are the velocity components v_r and v_θ at (x = 1m, and y = 1 m)? **(7 Marks)**

Q4. Two rectangular glass plates, identical to each other are taped together so that the vertical edge of one plate touches the corresponding edge of the other plate. Along the opposite edges, a 3mm diameter rod is placed as spacer, vertically between two plates. The gap between the two plates forms a wedge with sides 9 cm, 9 cm, and 3 mm. If the assembly is dipped in a shallow pool of liquid of specific gravity 0.8, contact angle 25°, and surface tension 0.07 N/m, what would be the rise or dip of liquid level at a distance x from the taped edge? What would be the shape of liquid-air interface? **(6 Marks)**

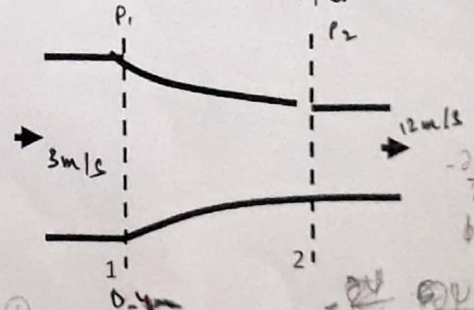


Q5. Consider the steady flow of water past a porous plate with a constant suction velocity of 0.2 mm/s (i.e., V = - 0.2j mm/s). A thin boundary layer grows over the flat plate and the velocity profile at section cd is $\dfrac{u}{U_\infty} = \dfrac{3}{2}\dfrac{y}{\delta} - 2\left(\dfrac{y}{\delta}\right)^{1.5}$,

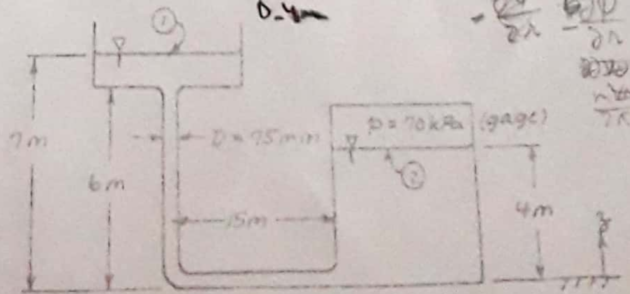
where U_∞ is the velocity of approach at section ab and is equal to 3 m/s. Find the mass flow rate across section bc. Given: width of the plate = 1.5m, length = 2m. **(4 Marks)**



Q6. The figure represents flow of gasoline (of specific gravity equal to 0.72) through a reducer of weight 25 kg and total volume equal to 0.2 m^3. The velocity at the inlet (having diameter equal to 0.4 m) is 3 m/s and at the outlet is 12 m/s. The pressure at the inlet is 58.7 kPa (gage) and at the outlet is 109 kPa (absolute). Calculate the force on the reducer. **(7 Marks)**



Q7. The adjoining figure shows two large reservoirs containing water connected by a constant area, galvanized iron pipe (ε/D = 0.002) that has one right angle bend. The flow can be assumed to be in the fully rough region of the Moody diagram. The surface pressure at the upper reservoir (1 in figure) is atmospheric whereas the pressure (absolute) at the lower reservoir (2



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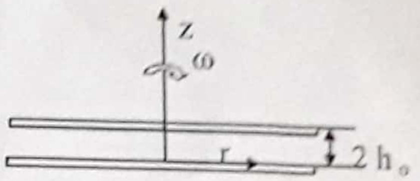
in the figure) surface is 171.3 KPa. The pipe diameter is 75 mm. Assume that the only significant losses occur in the pipe and the bend (L_e/D for the bend is equal to 12). Determine the direction and magnitude of the volume flow rate of water ($\rho = 999\ kg/m^3$, kinematic viscosity = $1.1 \times 10^{-6}\ m^2/s$). **(7 Marks)**

Q8. A parallel plate viscometer consists of a stationary, circular plate over which another identical plate rotates as shown in the figure. Fluid is placed in the gap and the torque on the lower plate is measured. Simplify Navier Stokes equation, clearly stating all assumptions with proper justification. Show that $V_\theta = \omega r z/(2h_o)$ can be a solution for this situation. Using this expression for V_θ obtain an expression for the viscosity of the liquid in terms of the measured torque, T, on the lower plate. The origin should be taken at the centre of the bottom plate. **(7 Marks)**



Relations and Formulae

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

$$\tau_{rz} = -\mu\left(\frac{\partial v_r}{\delta z} + \frac{\delta v_z}{\delta r}\right)$$

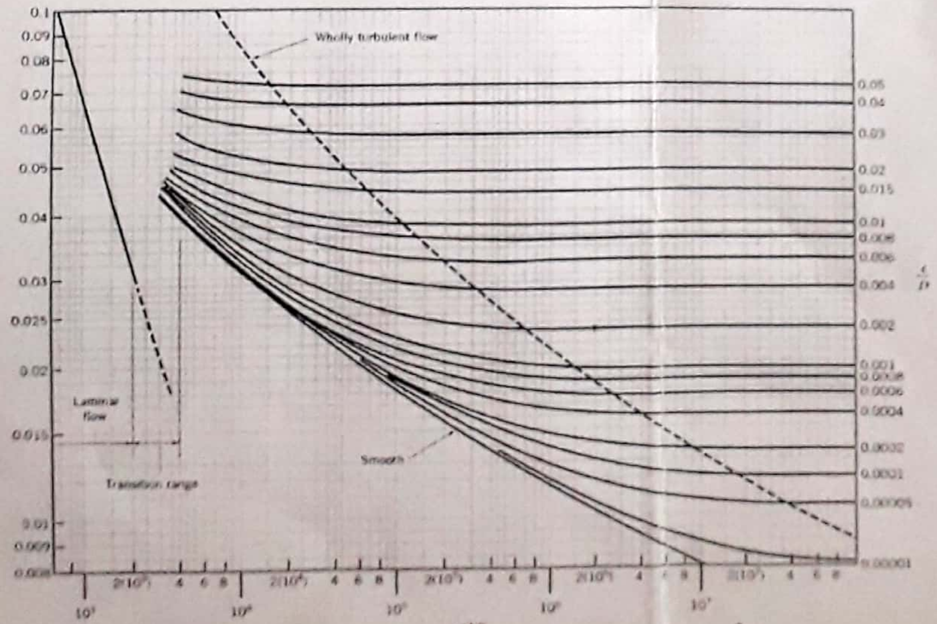
$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = \rho g_z - \frac{\partial p}{\partial z} + \mu\left\{\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial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

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

$$F_{sx} + F_{Bx} = \frac{\partial}{\partial t}\int_{CV} u\,\rho\, dV + \int_{CS} u\,\rho\,\vec{V}\cdot\vec{dA}$$

$$\dot{Q} + \dot{W}_{shaft} + \dot{W}_{shear} + \dot{W}_{other} = \left(u_1 + \frac{V_1^2}{2} + gz_1 + \frac{p_1}{\rho}\right)\left(-\dot{m}\right) + \left(u_2 + \frac{V_2^2}{2} + gz_2 + \frac{p_2}{\rho}\right)\left(\dot{m}\right)$$

$$\frac{P_o}{\rho} + \frac{V_o^2}{2} + gz_o = \frac{p_1}{\rho} + \frac{V_1^2}{2} + gz_1 + f\frac{L}{D}\frac{V_1^2}{2} + h;\quad h_{LM} = K\frac{V^2}{2}\ \text{or}\ f\frac{L_e}{D}\frac{V^2}{2};\ \text{Major Loss} = f\frac{L}{D}\frac{V^2}{2}$$



$P = \frac{F}{A} = \frac{N}{m^2} = \frac{kg\ m/s^2}{m^3 . kg} . m^3 = \frac{m^2}{s^2}$

$\rho g + \nabla p = 0$

$\frac{1}{\lambda}\ 2\frac{\omega r z}{2h_o} = \frac{\omega z}{h_o}$

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