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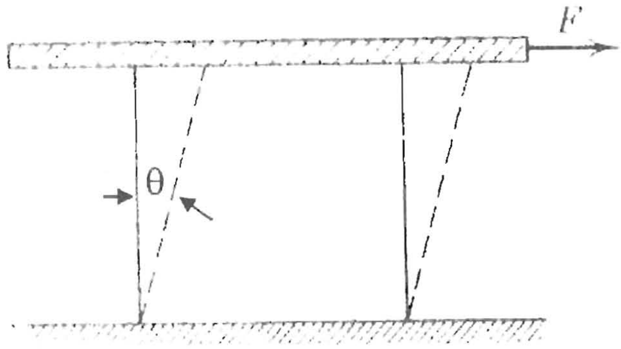
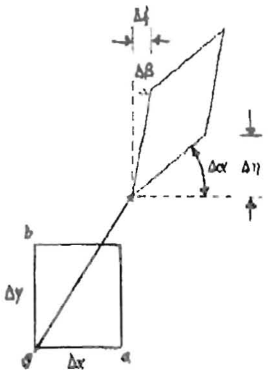
1. Please answer the following questions.

(a) If we place a specimen of substance (either solid or fluid) between two plates (figure below) and then apply a shear force F. Please describe the behavior difference between a solid and fluid under the action of a constant shear force F. Explain what is the so-called Newtonian fluid. (5%)



(b) In a two-dimensional flow field, the velocity distribution is of the form $\vec{v} = u\vec{i} + v\vec{j}$. The initial fluid element at time t is of a square shape as shown below and at time $t+\delta t$ it becomes a general tetragon as shown. $\Delta\alpha$ and $\Delta\beta$ are angular displacement of the original $x-$ and $y-$ edges. Draw suitable schematic diagrams to show that the tetragon can explain as the combination of the followings: translation, rotation, and shear deformation. (5%)



Hints for Prob 2(c)&2(d):

The rotation rate of a fluid element $= \lim_{\Delta t \to 0} \frac{1}{2}\left(\frac{\Delta\alpha - \Delta\beta}{\Delta t}\right)$

The rate of angular deformation of a fluid element

$$= \lim_{\Delta t \to 0} \frac{\Delta\alpha + \Delta\beta}{\Delta t}$$

(c) Density of gas fluid will change according to pressure. Please justify how the flow field of gas flow can be regarding as an incompressible flow. (5%)

(d) A ball with mass M is dropped from rest $y=y_0$ above the ground. Assume the air resistance (drag force) on the ball is neglected. Please express the velocity field of the ball by using Euler coordinate and Lagrangian coordinate respectively. (5%)

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2. Consider the two-dimensional fluid flow with velocity components:

$$u = ax + bx^2 + cy \ ; \ v = dy + exy$$

where a, b, and c, are constants greater than zero.

(a) Assume density is constant and the mass is conserved, what can be said about constant **d** and **e**. (5%)

(b) Determine if the vorticity is zero somewhere in the flow field. Does this imply that the flow is irrotational? (5%)

(c) Find the rate of angular deformation of a fluid element in this flow field? (5%)

(d) Find the rotation rate of a fluid element in this flow field? (5%)

3. Figure below shows a steady incompressible flow over a flat plate. The surface is porous and fluid is drawn off into the porous surface such that the normal component of velocity at the surface in V. The flow velocity outside the boundary layer is a constant U and the kinematic viscosity is a constant ν.

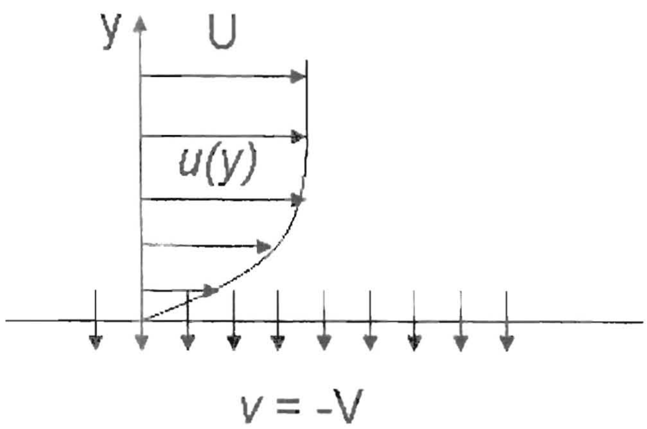
(a) Simply the continuity equation for this flow field. (4%)

(b) Simply the Navier Stokes equations to model this flow field. (4%)

(c) Show the boundary conditions for this flow field. (4%)

(d) Find the boundary layer velocity profile u(y) (4%)

(e) Define boundary layer thickness δ with $u/U=1-e^{-2}$ at $y=\delta$. Find the boundary layer thickness δ (4%)



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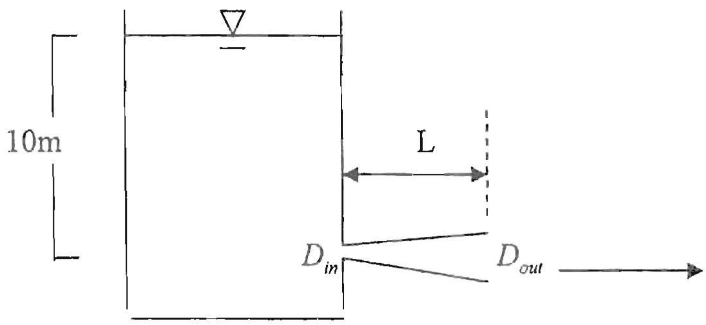
4. Consider a huge water tank with a special arrangement of exit as shown where the distance from the water level to the center line of exit is 10 m. Assume the exit has a properly rounded inlet (with circular shape and diameter D_{in} = 1 cm), where the required parameters are $\rho = 1000\,kg/m^3$, $g = 9.8\,\mathrm{m/sec}^2$. A straight expansion pipe of length L = 10 cm with inlet diameter D_{in} = 1cm and the exit diameter D_{out} = 3cm is connected to the exit. (20%)
   (a) Neglect the viscous loss, estimate the mean mass flow rate through the exit with and without the expanded connecting pipe.
   (b) Why do you get different results?
   (c) If the viscous loss is considered, do you have similar difference that the one with the expanded pipe still has a larger mass flow rate than that without the connecting pipe? Why?



5. Consider the following two-dimensional, incompressible flow through the converging channel as shown. Assume one-dimensional flow and the cross section area per unit depth is $A = \dfrac{1}{[1+0.25\mathrm{x/L}]}$. The inlet velocity is V_1 at x=0 (20%)
   (a) Find the velocity and acceleration of a particle moving along the centerline;
   (b) Explain the method how you find the position of a fluid particle (at x=0 initially) as a function of time (you must not show the corresponding mathematical manipulations explicitly); and
   (c) Explain your answers of item (a) and (b) in terms of the Eulerian and Lagrangian descriptions.