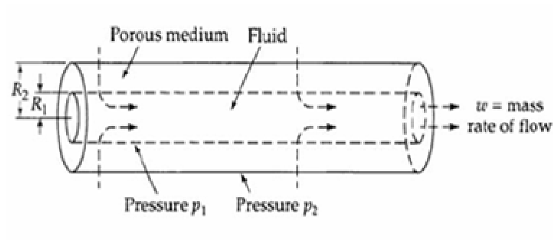
Sahand University of Technology
Chemical Engineering Faculty

Advanced Fluid MechanicsHW5
Return date:

Instructor: Dr. Alizadeh

Fall Semester

1. Radial flow through a porous media. A fluid flows through a porous cylindrical shell with inner and outer radial R_1 and R_2, respectively. At these surfaces, the pressures are known to be p_1 and p_2, respectively. The length of the cylindrical shell is h. find the pressure distribution, radial flow velocity, and mass rate of flow for an incompressible fluid.

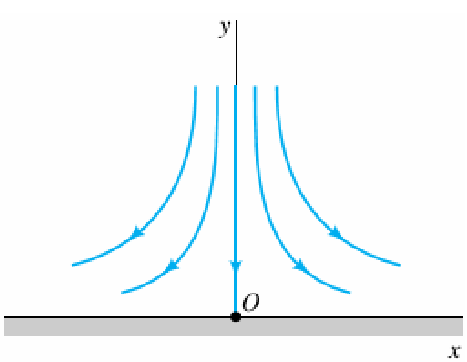


2. A certain flow field is described by the stream function

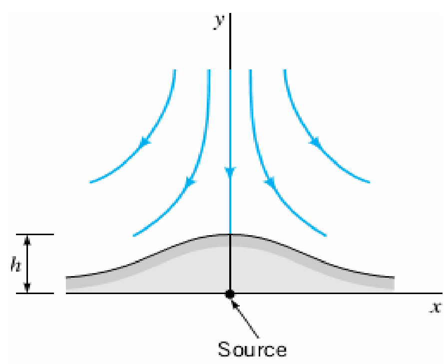
$$\psi = A\,\theta + B\,r\sin\theta$$

Where A and B are positive constants. Determine the corresponding velocity potential and any stagnation points in this flow field.

3. Potential flow against a flat plate (Fig.a) can be described with the stream function
$\Psi = Axy$
Where A is constant. This type of flow is commonly called a “stagnation point” flow since it can be used to describe the flow in the vicinity of the stagnation point at O. by adding a source of strength m at O, stagnation point flow against a flat plate with the “bump” is obtained as illustrated in fig. b. Determine the relantionship between the bump height, h, the constant, A, and the source strenght, m.



(a)



(b)

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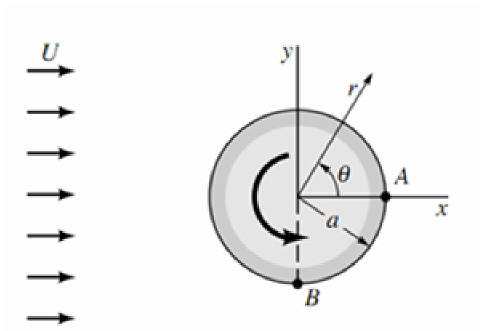
4. The velocity potential for a cylinder shown in figure, rotating in a uniform stream of fluid is

$$\phi = Ur\left(1 + \frac{a^2}{r^2}\right)\cos\theta + \frac{\Gamma}{2\pi}\theta$$

here Γ is the circulation. For what value of the circulation will the stagnation point be located at: (a) point A, (b) point B?



5. Water approaches an infinitely long and thin plate with uniform velocity.
   (a) Determine the velocity distribution u_x in the boundary layer given that

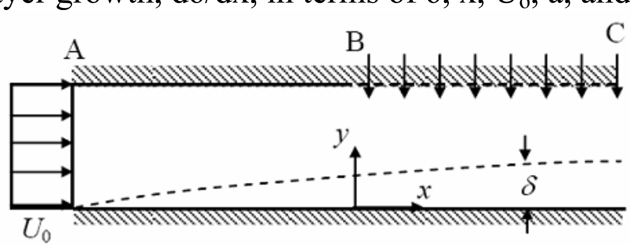
$$u_x(x,y) = a(x)y^2 + b(x)y + c(x) \ .$$

   (b) What is the flux of mass (per unit length of plate) across the boundary layer?
   (c) Calculate the magnitude and the direction of the force needed to keep the plate in place.

6. Air flows between two parallel flat plates as shown in the figure below. The upper plate is porous from point B to point C and additional air is injected through this surface. As a result, the free stream speed, U(x), varies as:

$U(x) = U_o + ax$

Where U_o is the air speed entering the channel (at point A), a is constant, and x is the distance downstream of the point B. a boundary layer develops along the lower surface. Assuming a linear velocity distribution in the boundary layer, estimate the rate of boundary layer growth, dδ/dx, in terms of δ, x, U_o, a, and the air properties.



7. A laminar boundary layer subjected to a favorable pressure gradient is to be approximated by a profile of the form:

$$\frac{u}{U} = \begin{cases} 3\left(\frac{y}{\delta}\right) - 3\left(\frac{y}{\delta}\right)^2 + \left(\frac{y}{\delta}\right)^3 & 0 \le \left(\frac{y}{\delta}\right) \le 1 \\ 1 & \left(\frac{y}{\delta}\right) > 1 \end{cases}$$

a. Using the Karman Momentum Integral Equation, determine the differential equation which must be satisfied by $\delta(x)$ and $U(x)$.
b. Show that if $U(x)=cx^{1/9}$, the solution to this equation is of the form $\delta(x)=Ax^{4/9}$.
c. Find A in terms of c and kinematic viscosity,ν.

8. Derive the governing equations and the von Karman's-type approximation for boundary layer over a 30^o wedge of a liquid stream of density ρ and viscosity η, approaching at velocity V.