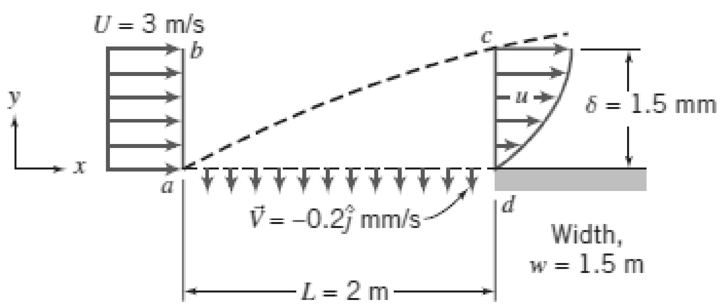
Assignment Sheet in Fluid Mechanics*
Conservation of Mass and Linear Momentum

1. Water flows steadily past a porous flat plate. Constant suction is applied along the porous section. The velocity profile at section cd is

$$\frac{u}{U_\infty} = 3\left(\frac{y}{\delta}\right) - 2\left(\frac{y}{\delta}\right)^{3/2}.$$

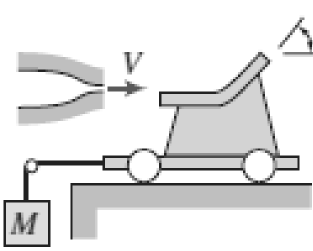
Evaluate the mass flow rate across section bc.



Problem 1

[1.42 $\text{kg}\,\text{s}^{-1}$ (upwards)]

2. A jet of water issuing from a stationary nozzle at 15 m/s (cross-sectional area of jet being 0.05 m^2) strikes a turning vane mounted on a cart as shown. The vane turns the jet through angle $\theta = 50°$. Determine the value of M required to hold the cart stationary.

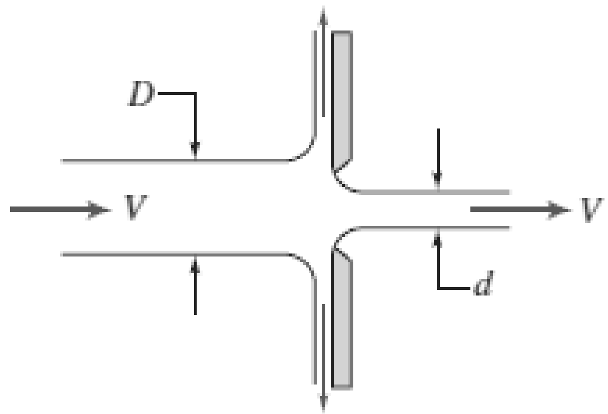


Problem 2

[409 kg]

*Compiled and prepared by Jeevanjyoti Chakraborty. All the problems are from Fox and McDonald, 5th edition. For queries, email: jeevan@mech.iitkgp.ac.in

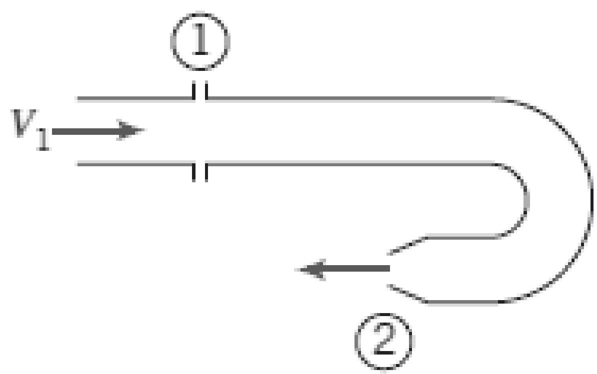
3. A vertical plate has a sharp-edged orifice at its centre. A water jet of speed V strikes the plate concentrically. Obtain an expression for the external force needed to hold the plate in place, if the jet leaving the orifice also has speed V. Evaluate the force for $V = 5$ m/s, $D = 100$ mm, and $d = 25$ mm.



Problem 3

[184 N]

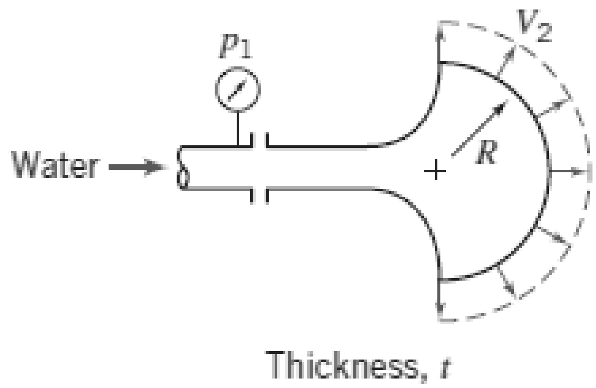
4. Water is flowing steadily through the 180° elbow shown. At the inlet to the elbow the gauge pressure is 96 kPa. The water discharges to atmospheric pressure. Assume properties are uniform over the inlet and outlet areas; $A_1 = 2600$ mm^2, $A_2 = 650$ mm^2, and $V_1 = 3.05$ m/s. Find the horizontal component of force required to hold the elbow in place.



Problem 4

[370 N]

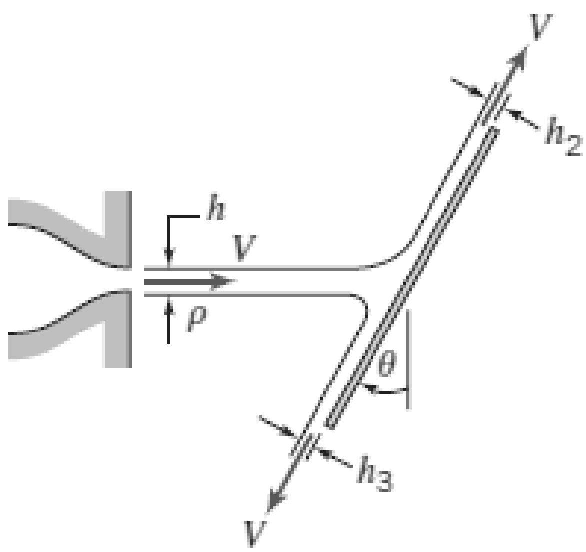
5. A nozzle for a spray system is designed to produce a flat sheet of water. The sheet leaves the nozzle at $V_2 = 10$ m/s, covers 180° of arc, and has thickness $t = 1.5$ mm. The nozzle discharge radius is $R = 50$ mm. The water supply pipe is 35 mm in diameter and the inlet pressure is $p_1 = 150$ kPa (abs). Evaluate the axial force exerted by the spray nozlle on the coupling.



Problem 5

[37.9 N]

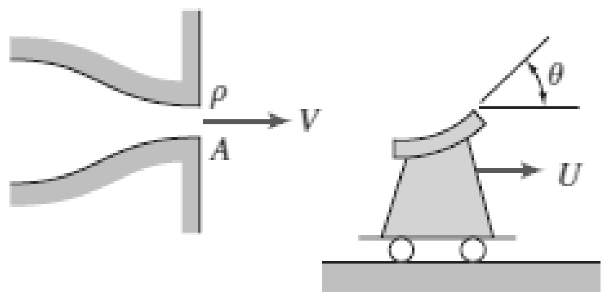
6. When a plane liquid jet strikes an inclined flat plate, it splits into two streams of equal speed but unequal thickness. For frictionless flow there can be no tangential force on the plate surface. Use this assumption to develop an expression for h_2/h as a function of plate angle, θ.



Problem 6

$[h_2/h = 0.5(1 + \sin\theta)]$

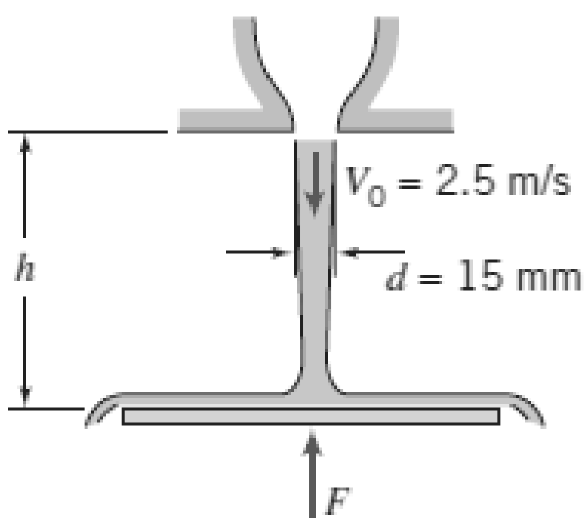
7. A water jet, issuing from a stationary nozzle, encounters a vane curved through angle $\theta = 90°$ that is moving away from the nozzle with constant speed of 15 m/s. The jet has a cross-sectional area of 600 mm^2 and a speed of 30 m/s. Determine the force that must be applied to maintain the vane speed constant.



Problem 7

$[-135\mathbf{i} + 135\mathbf{j}\ \text{N}]$

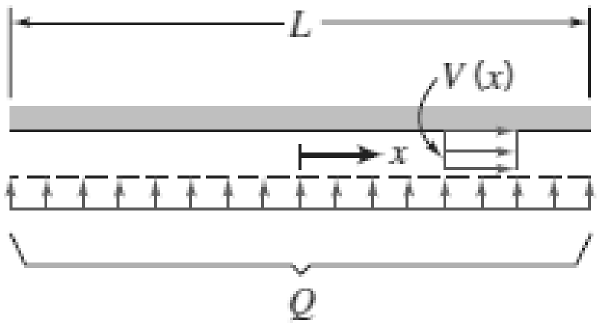
8. A uniform jet of water leaves a 15 mm diameter nozzle and flows directly downward. The jet speed at the nozzle exit plane is 2.5 m s^{-1}. The jet impinges on a horizontal disk and flows radially outward in a flat sheet. Obtain a general expression for the velocity the liquid stream would reach at the level of the disk. Develop an expression for the force required to hold the disk stationary, neglecting the mass of the disk and water sheet. Evaluate for $h = 3$ m.



Problem 8

$[V = \sqrt{V_0^2 + 2gh};\ F = \rho V_0 A_0 \sqrt{V_0^2 + 2gh};\ 3.56\ \text{N (upwards)}]$

9. Incompressible fluid of negligible viscosity is pumped, at total volume flow rate Q, through a porous surface into the small gap between closely spaced parallel plates as shown. The fluid has only horizontal motion in the gap. Assume uniform flow across any vertical section. Obtain an expression for the pressure variation as a function of x. *Hint:* Apply conservation of mass and the momentum equation to a differential control volume of thickness dx, located at x.



Problem 9

$[p(x) = p(0) - \rho(Qx/whL)^2]$

10. The narrow gap between two closely spaced circular plates initially is filled with incompressible liquid. At $t = 0$, the upper plate, initially h_0 above the lower plate, begins to move downward toward the lower plate with constant speed, V_0, causing the liquid to be squeezed from the narrow gap. Neglecting viscous effects (which is a massive simplification!) and assuming uniform flow in the radial direction, develop an expression for the velocity field between the parallel plates. *Hint:* Apply conservation of mass to a control volume with the outer surface located at radius r. Note that even though the speed of the upper plate is constant the flow is unsteady.

$[V(r) = V_0 r/2h]$