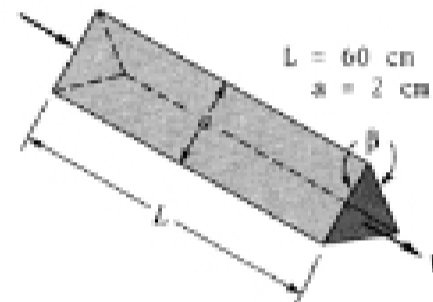
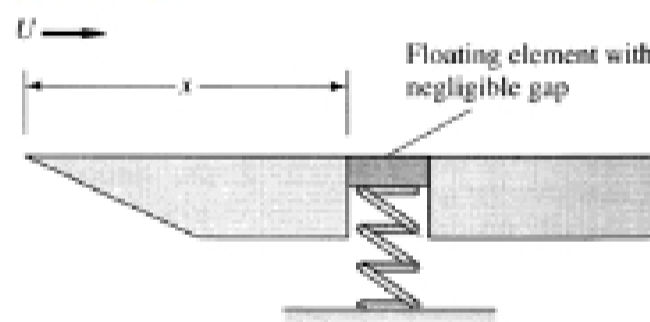


- 1) The viscous sublayer is normally less than 1 percent of the pipe diameter and therefore very difficult to probe with a finite-sized instrument. In an effort to generate a thick sublayer for probing, Pennsylvania State University in 1964 built a pipe with a flow of glycerin. Assume a smooth 12-in-diameter pipe with $V = 60$ ft/s and glycerin at 20°C . Compute a) the sublayer thickness in inches b) the pumping horsepower required at 75 percent efficiency if $L = 40$ ft. (For glycerin at 20°C , take $\rho = 2.44$ slug/ft³ and $\mu = 0.0311$ slug/ft·s)

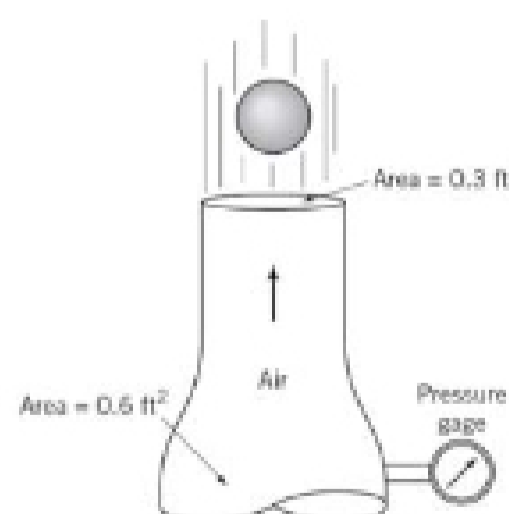
- 2) Heat exchangers often consist of many triangular passages. Typical is figure below, with $L = 60$ cm and an isosceles-triangle cross section of side length $a = 2$ cm and included angle $\beta = 80^\circ$. If the average velocity is $V = 2$ m/s and the fluid is SAE 10 oil at 20°C , estimate the pressure drop. (For SAE 10 oil, take $\rho = 870$ kg/m³ and $\mu = 0.104$ kg/m·s.)



- 3) In the flow of air at 20°C and 1 atm past a flat plate in figure below, the wall shear is to be determined at position x by a *floating element* (a small area connected to a strain-gage force measurement). At $x = 2$ m, the element indicates a shear stress of 2.1 Pa. Assuming turbulent flow from the leading edge, estimate (a) the stream velocity U , (b) the boundary layer thickness δ at the element, and (c) the boundary-layer velocity u , in m/s, at 5 cm above the element. (For air at 20°C , take $\rho = 1.2$ kg/m³ and $\mu = 1.8\text{E}-5$ kg/m·s.)



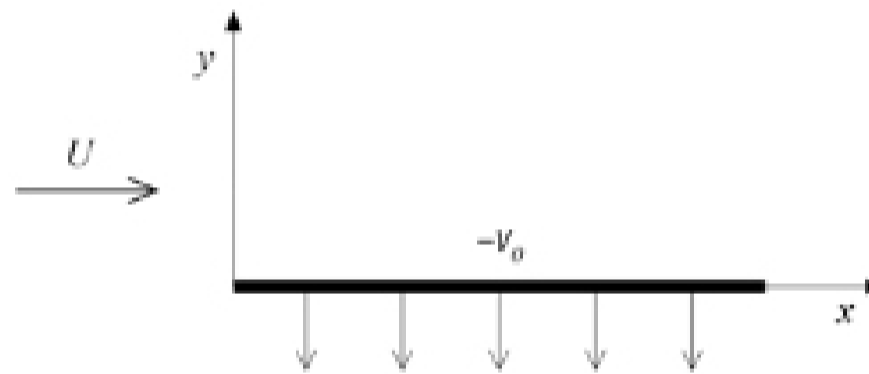
- 4) A 2-in-diameter sphere weighting 0.14 lb is suspended by the jet of air shown in figure below. The drag coefficient for the sphere is 0.5. Determine the reading on the pressure gage if friction and gravity effects can be neglected for the flow between the pressure gage and the nozzle exit. (For air, take $\rho = 0.00238$ slug/ft³)



- 5) Consider water at 20°C flowing past a 1-m-diameter cylinder. a) What doublet strength in m^2/s is required to simulate this flow? b) If the stream pressure is 200 kPa, use inviscid theory to estimate the surface pressure at 135°. If circulation K is added to the cylinder flow, (c) for what value of K will the flow begin to cavitate at the surface? (d) Where on the surface will cavitation begin? (e) For this condition, where will the stagnation points lie? (For water at 20°C, take vapor pressure=2337 Pa)

Choose only one of the following problems.

- 6) Consider steady flow at velocity U (at $y=\infty$) past an infinite plane ($y=0$) as shown in the figure. Let the plate be porous and has constant suction $v = -v_0$. Assume that pressure is constant and $v = -v_0$ everywhere in the flow and $u=u(y)$ only. a) By using continuity equation, solve the Navier-Stokes equation for $u(y)$ and apply boundary conditions on it. b) Sketch $u(y)$ roughly. (Hint: for solving differential equation $au_{yy} + bu_y + c = 0$ with constant coefficients a , b , and c , assume that the solution is $e^{\lambda y}$ and find λ .)



- 7) The sluice gate in figure below controls flow in open channels. At sections 1 and 2, the flow is uniform and the pressure is hydrostatic. The channel width is b into the paper. a) Neglecting bottom friction and atmospheric pressure, drive a formula for the horizontal force F required to hold the gate. Express your final formula in terms of the inlet velocity V_1 , and eliminating V_2 . b) Assume that V_1 and h_1 are constant. For what h_2 is the force largest?

