3.20

3.20 Some animals have learned to take advantage of the Bernoulli effect without having read a fluid mechanics book. For example, a typical prairie dog burrow contains two entrances—a flat front door, and a mounded back door as shown in Fig. P3.20. When the wind blows with velocity V_0 across the front door, the average velocity across the back door is greater than V_0 because of the mound. Assume the air velocity across the back door is $1.07V_0$. For a wind velocity of 6 m/s, what pressure differences, $p_1 - p_2$, is generated to provide a fresh air flow within the burrow?

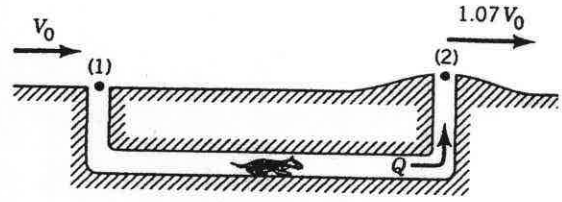


FIGURE P3.20

$$p_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2$$

Thus, with negligible gravitational effects (i.e. $z_1 \approx z_2$)

$$p_1 - p_2 = \frac{1}{2}\rho(V_2^2 - V_1^2)$$

$$= \frac{1}{2}\left(1.23\ \frac{kg}{m^3}\right)\left(\left(1.07\left(6\ \frac{m}{s}\right)\right)^2 - \left(6\ \frac{m}{s}\right)^2\right)$$

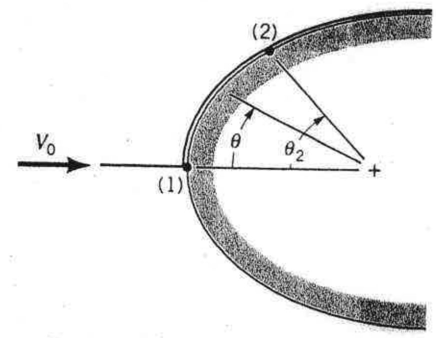
or

$$p_1 - p_2 = \underline{\underline{3.21\ \frac{N}{m^2}}}$$

20 bi

3.23

3.23 An inviscid fluid flows steadily along the stagnation streamline shown in Fig. P3.23 and **Video V3.7**, starting with speed V_0 far upstream of the object. Upon leaving the stagnation point, point (1), the fluid speed along the surface of the object is assumed to be given by $V = 2V_0 \sin\theta$, where θ is the angle indicated. At what angular position, θ_2, should a hole be drilled to give a pressure difference of $p_1 - p_2 = \rho V_0^2/2$? Gravity is negligible.



■ FIGURE P3.23

$$p_0 + \frac{1}{2}\rho V_0^2 = p_1 + \frac{1}{2}\rho V_1^2 = p_2 + \frac{1}{2}\rho V_2^2$$

where $V_1 = 0$

Thus,

$$p_1 - p_2 = \frac{1}{2}\rho\left(V_2^2 - V_1^2\right) = \frac{1}{2}\rho V_2^2$$

so that if

$$p_1 - p_2 = \frac{1}{2}\rho V_0^2 \quad \text{then } V_2 = V_0$$

That is:

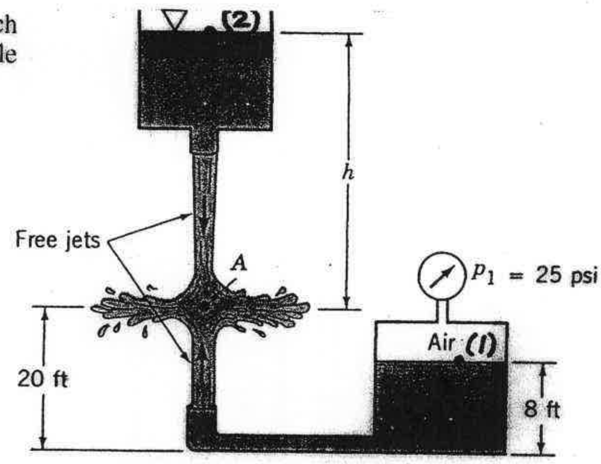
$$V_2 = 2V_0 \sin\theta_2 = V_0 \quad \text{or} \quad \sin\theta_2 = \frac{1}{2}$$

Hence, $\theta_2 = \underline{\underline{30^\circ}}$

23 br

3.33

3.33 Streams of water from two tanks impinge upon each other as shown in Fig. P3.33. If viscous effects are negligible and point A is a stagnation point, determine the height h.



■ FIGURE P3.33

$$\frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2=\frac{p_A}{\gamma}+\frac{V_A^2}{2g}+z_A \quad \text{where } p_2=0,\ V_2=0,\ z_2=h+20\text{ ft}$$
$$V_A=0, \text{ and } z_A=20\text{ ft}$$

Thus,

or $h+20\text{ ft}=\frac{p_A}{\gamma}+20\text{ ft}$

$$h=\frac{p_A}{\gamma} \qquad (1)$$

Also,

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1=\frac{p_A}{\gamma}+\frac{V_A^2}{2g}+z_A \quad \text{where } p_1=25\text{ psi},\ V_1=0 \text{ and } z_1=8\text{ ft}$$

Thus,

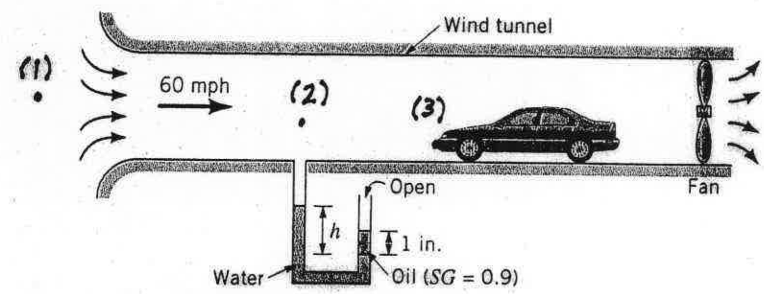
$$\frac{p_A}{\gamma}=\frac{p_1}{\gamma}+z_1-z_A \quad \text{which when combined with Eq. (1) gives}$$

$$h=\frac{p_1}{\gamma}+z_1-z_A=\frac{25\frac{\text{lb}}{\text{in.}^2}\left(144\frac{\text{in.}^2}{\text{ft}^2}\right)}{62.4\frac{\text{lb}}{\text{ft}^3}}+8\text{ ft}-20\text{ ft}=\underline{\underline{45.7\text{ ft}}}$$

33 br

3.37

3.37 Air is drawn into a wind tunnel used for testing automobiles as shown in Fig. P3.37. **(a)** Determine the manometer reading, h, when the velocity in the test section is 60 mph. Note that there is a 1-in. column of oil on the water in the manometer. **(b)** Determine the difference between the stagnation pressure on the front of the automobile and the pressure in the test section.



■ FIGURE P3.37

(a) $\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2$

where

$z_1 = z_2$, $p_1 = 0$, and $V_1 \approx 0$

Thus, with $V_2 = 60\ mph = 88\ \frac{ft}{s}$,

$\frac{p_2}{\gamma} = -\frac{V_2^2}{2g}$ or

$p_2 = -\frac{1}{2}\rho V_2^2 = -\frac{1}{2}(0.00238\ \frac{slugs}{ft^3})(88\ \frac{ft}{s})^2 = -9.22\ \frac{lb}{ft^2}$

But $p_2 + \gamma_{H_2O} h - \gamma_{oil}(\frac{1}{12} ft) = 0$ where $\gamma_{oil} = 0.9\gamma_{H_2O} = 0.9(62.4\ \frac{lb}{ft^3})$
$= 56.2\ \frac{lb}{ft^3}$

Thus,

$-9.22\ \frac{lb}{ft^2} + 62.4\ \frac{lb}{ft^3}(h\ ft) - 56.2\ \frac{lb}{ft^3}(\frac{1}{12} ft) = 0$, or $h = \underline{\underline{0.223\ ft}}$

(b) $\frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} = \frac{p_3}{\gamma} + z_3 + \frac{V_3^2}{2g}$

where

$z_2 = z_3$ and $V_3 = 0$

Thus,

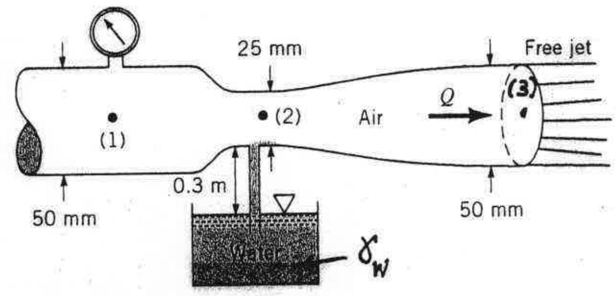
$\frac{p_2}{\gamma} + \frac{V_2^2}{2g} = \frac{p_3}{\gamma}$ or

$p_3 - p_2 = \frac{1}{2}\rho V_2^2 = \frac{1}{2}(0.00238\ \frac{slugs}{ft^3})(88\ \frac{ft}{s})^2 = \underline{\underline{9.22\ \frac{lb}{ft^2}}}$

37 br

3.75

3.75 Air flows through the device shown in Fig. P3.75 and **Video V3.10**. If the flowrate is large enough, the pressure within the constriction will be low enough to draw the water up into the tube. Determine the flowrate, Q, and the pressure needed at section (1) to draw the water into section (2). Neglect compressibility and viscous effects.



■ FIGURE P3.75

$$\frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 = \frac{p_3}{\gamma} + \frac{V_3^2}{2g} + z_3 \qquad \text{where } z_2 = z_3 \text{ , } A_2 V_2 = A_3 V_3$$

$$\text{or } V_2 = \left(\frac{D_3}{D_2}\right)^2 V_3 = \left(\frac{50\,mm}{25\,mm}\right)^2 V_3 = 4V_3$$

Thus, since $p_3 = 0$

$$\frac{p_2}{\gamma} = \frac{V_3^2}{2g} - \frac{V_2^2}{2g} = -\frac{15\,V_3^2}{2g}$$

But,

$$p_2 = -\gamma_w h \quad \text{so that} \quad \frac{p_2}{\gamma} = -\frac{\gamma_w}{\gamma} h = -\frac{9.80 \times 10^3 \frac{N}{m^3}}{12 \frac{N}{m^3}}(0.3\,m) = -245\,m$$

Thus,

$$-245\,m = -\frac{15\,V_3^2}{2\left(9.81 \frac{m}{s^2}\right)}$$

or

$$V_3 = 17.9 \frac{m}{s}$$

Thus,

$$Q = A_3 V_3 = \frac{\pi}{4}(0.050m)^2\left(17.9\frac{m}{s}\right) = \underline{\underline{0.0351 \frac{m^3}{s}}}$$

Also,

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_3}{\gamma} + \frac{V_3^2}{2g} + z_3 \qquad \text{where } V_1 = \frac{A_3}{A_1} V_3 = V_3 \text{ and } z_1 = z_3$$

Thus,

$$p_1 = p_3 + \gamma(z_3 - z_1) + \tfrac{1}{2}\rho\left(V_3^2 - V_1^2\right)$$

or

$$\underline{\underline{p_1 = 0}}$$

75 br