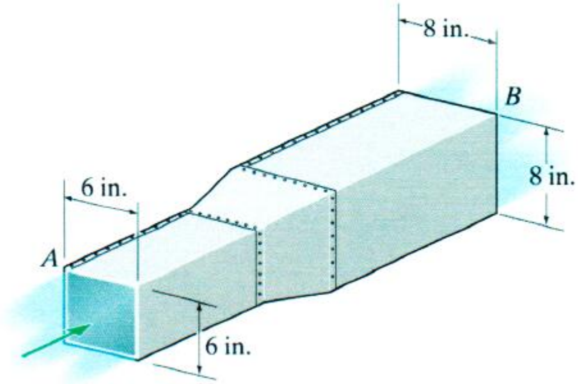
Hibbeler
Prob 5-48

Air at 100 °F flows through the square horizontal duct section at Point A at 200 ft/s under a pressure of 1.50 psi.

Determine the pressure in the square duct section at Point B.




Write Bernoulli Eqn from A to B

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + \cancel{z_A} = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + \cancel{z_B}$$

$z_A = z_B$
$P_A = 1.50$ psi
$V_A = 200$ ft/s
assume
① incompressible
② no friction

$$P_B = P_A + \frac{\gamma}{2g}\left(V_A^2 - V_B^2\right)$$

$$\boxed{P_B = P_A + \frac{\rho}{2}\left(V_A^2 - V_B^2\right)}$$

But from the contenuity eqn for incompressible flow

$$Q_A = Q_B$$

$$V_A A_A = V_B A_B \Rightarrow V_B^2 = V_A^2\left(\frac{A_A}{A_B}\right)^2$$

$$\therefore \boxed{P_B = P_A + \frac{\rho}{2}\left(1 - \frac{A_A^2}{A_B^2}\right)V_A^2}$$

$A_A^2 = (36\ in^2)^2 = 1296\ in^4$
$A_B^2 = (64\ in^2)^2 = 4096\ in^4$

Now let's insert the values

Hibbeler App A

$\rho_{air} = 0.00220\ \frac{slugs}{ft^3}$

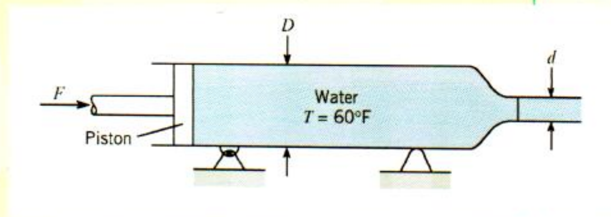
$$P_B = 1.50\ \frac{lbf}{in^2} + \left(\frac{0.00220}{2}\ \frac{slugs}{ft^3}\right)\left(1 - \frac{1296}{4096}\right)\left(200\ \frac{ft}{s}\right)^2$$

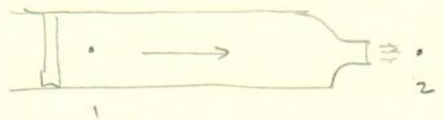
$$= 1.50\ \frac{lbf}{in^2} + 30.08\ \frac{lbf}{ft^2} \times \frac{1\ ft^2}{144\ in^2}$$

$$= 1.50 + 0.209$$

or $\boxed{P_B \simeq 1.71\ psi}$ ans

$\boxed{5.52}$ Water is forced out of the cylinder shown in the diagram. If the piston is driven at a speed of 4 ft/s, what will be the average exit velocity of the water if $d = 2$ in and $D = 4$ in? Also estimate the force that will be required to drive the piston.




Bernoulli eqn from ① to ②

free stream

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{z_1} = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + \cancel{z_2}$$

horizontal

$$\therefore \frac{P_1}{\gamma} = \frac{V_2^2 - V_1^2}{2g}$$

Continuity Eqn

$$Q_1 = Q_2$$
$$V_1 A_1 = V_2 A_2$$

$$\therefore V_2 = \frac{V_1 A_1}{A_2} = \frac{(4\ \text{ft/s})\frac{\pi}{4}(4\ \text{in})^2}{\frac{\pi}{4}(2\ \text{in})^2}$$

$$\boxed{V_2 = 16\ \text{ft/s}}$$ ans

now putting this into the Bernoulli Eqn — water 60°F

$$P_1 = \frac{\rho(V_2^2 - V_1^2)}{2} = \frac{1.94\ \frac{\text{slug}}{\text{ft}^3}}{2}(16^2 - 4^2)\ \text{ft}^2/\text{s}^2$$

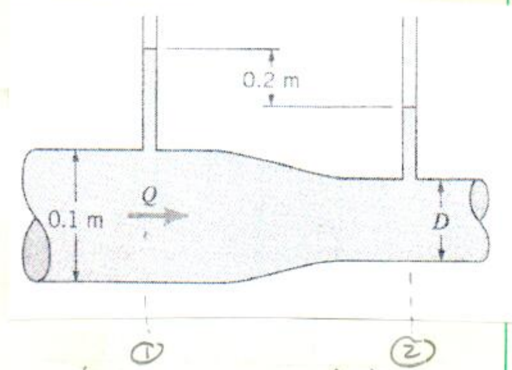
$1\ \text{lbf} = 1\ \text{slug}\ \frac{\text{ft}}{\text{s}^2}$

$$= 232.8\ \frac{\text{slugs}}{\text{ft-s}^2}\left(\frac{\text{ft}}{\text{ft}}\right) = \boxed{232.8\ \frac{\text{lbf}}{\text{ft}^2}} \ast \frac{1\ \text{ft}^2}{144\ \text{in}^2}$$

$$\boxed{P_1 = 1.62\ \text{psi}}$$

$$\therefore F_1 = P_1 A_1 = \left(1.62\ \frac{\text{lbf}}{\text{in}^2}\right)\left(\frac{\pi}{4}\right)(16\ \text{in}^2) = \boxed{20.3\ \text{lbf}}$$ ans

**3.31** Water flows through the pipe contraction as shown. For the given 0.2 m difference in the manometer level, determine the flow rate, Q, in the pipe if D = 0.05 m. Neglect viscous effects.




First identify the upstream and downstream locations of the manometer tubes as pt 1 and pt 2.

Now applying the Bernoulli eqn., we have

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \underbrace{\cancel{z_1}}_{\to 0} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \underbrace{\cancel{z_2}}_{\to 0} \quad \Big\}\text{ where } z_1 = z_2 = 0$$

thus, $$\boxed{\frac{P_1 - P_2}{\gamma} = \frac{V_2^2 - V_1^2}{2g}}$$

From the continuity eqn

$$Q_1 = Q_2$$

$$A_1 V_1 = A_2 V_2 \quad \text{or} \quad \boxed{V_2 = \frac{A_1}{A_2} V_1 = \left(\frac{D_1}{D_2}\right)^2 V_1}$$

Putting this result into the reduced Bernoulli eqn gives

$$\frac{\left[\left(\frac{D_1}{D_2}\right)^4 - 1\right] V_1^2}{2g} = \frac{P_1 - P_2}{\gamma}$$

$$\text{or} \quad \boxed{V_1 = \left[\frac{2g\,(P_1 - P_2)}{\gamma}\right]^{1/2} \left[\left(\frac{D_1}{D_2}\right)^4 - 1\right]^{-\frac{1}{2}}}$$

from the manometer $P_1 - P_2 = (0.2\text{ m})\,\gamma$

$\Big\{ P_1 = \gamma h_1$; $P_2 = \gamma h_2$; $P_1 - P_2 = \gamma(h_1 - h_2)$

from the dimension given

$$\frac{D_1}{D_2} = \frac{0.1}{0.05} = 2 \qquad \therefore \left[\left(\frac{D_1}{D_2}\right)^4 - 1\right]^{-\frac{1}{2}} = \frac{1}{\sqrt{15}} = 0.2582$$

$$\therefore V_1 = \left[2\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(0.2\text{m})\right]^{1/2} (0.2582)$$

$$\boxed{V_1 = 0.511\text{ m/s}}$$

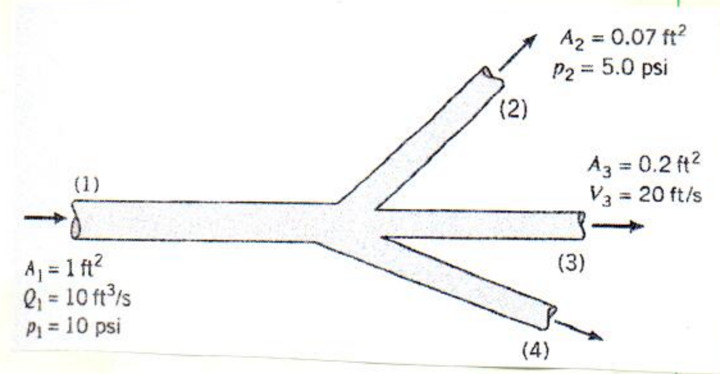
ans

$$\text{and} \quad Q = A_1 V_1 = \frac{\pi}{4}(.1\text{m})^2 (0.511\text{ m/s}) = \boxed{4.01 \times 10^{-3}\ \frac{\text{m}^3}{\text{s}}}$$

Munson 3rd Ed 4th Ed



(3.82) Water flows through the horizontal branching pipe shown at a rate of 10 ft³/s. If viscous effects are negligible, determine the water speed at section 2, the pressure at section 3, and the flow rate at section 4.




(a) Bernoulli Eqn between (1) and (2)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{z_1} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \cancel{z_2}$$

$$\frac{V_2^2}{2g} = \frac{V_1^2}{2g} + \frac{P_1 - P_2}{\gamma} \qquad V_1 = \frac{Q}{A_1} = \frac{10\ \text{ft}^3/\text{s}}{1\ \text{ft}^2} \qquad \boxed{V_1 = 10\ \text{ft/s}}$$

$$V_2 = \left[V_1^2 + \left(\frac{P_1 - P_2}{\gamma}\right)(2g)\right]^{1/2}$$

$$= \left[(10\ \text{ft/s})^2 + \frac{(10-5)\frac{\text{lbf}}{\text{in}^2} \cdot \frac{144\ \text{in}^2}{\text{ft}^2}}{\left(62.4\ \frac{\text{lbf}}{\text{ft}^3}\right)} \times 2 \times 32.2\ \text{ft/s}^2\right]^{1/2}$$

$$= \left[100 + \frac{5(144)(2)(32.2)}{62.4}\ \text{ft}^2/\text{s}^2\right]^{1/2} = [100 + 743]^{1/2}$$

$$V_2 = \boxed{29\ \text{ft/s}} \quad \text{ans}$$

also $Q_2 = V_2 A_2 = (29\ \text{ft/s})(0.07\ \text{ft}^2) = \boxed{2.03\ \text{ft}^3/\text{s}}$

(b) Bernoulli eqn between (1) and (3)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{z_1} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + \cancel{z_3}$$

water
$\gamma = \rho g = \left(1.94\ \frac{\text{slug}}{\text{ft}^3}\right)\left(32.174\ \frac{\text{ft}}{\text{s}^2}\right) = 62.4\ \text{lbf/ft}^3$

$$P_3 = P_1 + \frac{\gamma}{2g}\left(V_1^2 - V_3^2\right)$$

$$= (10)(144)\frac{\text{lbf}}{\text{ft}^2} + \frac{62.4\ \text{lbf/ft}^3}{2(32.2)\ \text{ft/s}^2}\left[(10\ \text{ft/s})^2 - (20\ \text{ft/s})^2\right]$$

$$= (1440 - 290.7)\ \text{lbf/ft}^2$$

$$P_3 = 1149.3\ \frac{\text{lbf}}{\text{ft}^2} = \boxed{7.98\ \text{psi}} \quad \text{ans}$$

also $Q_3 = V_3 A_3 = (20)(0.2) = \boxed{4\ \text{ft}^3/\text{s}}$

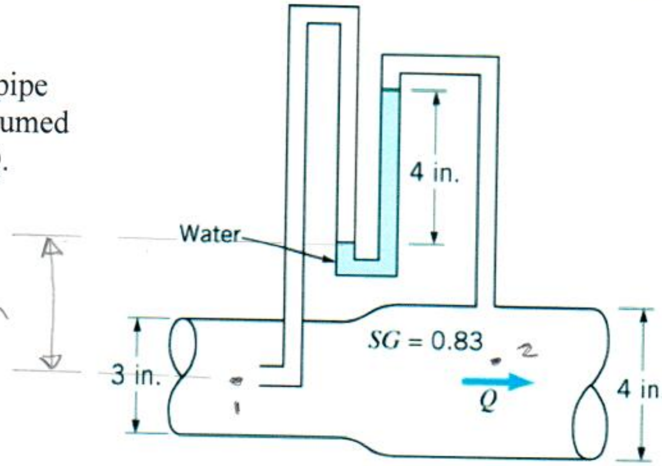
see part c on left side

(c) from continuity eqn
$Q_4 = Q_1 - Q_2 - Q_3$
$= 10 - 2.03 - 4 = \boxed{3.97\ \text{ft}^3/\text{s}}$ ans

Munson 4th Ed

Prob 3.48

Oil of specific gravity 0.83 flows in the pipe section shown. If viscous effects are assumed to be negligible, estimate the flow rate Q.




First note Pts 1 and 2 on the diagram and then write Bernoulli's eqn from ① → ②

$$\frac{P_1}{\gamma_{oil}} + \underbrace{\cancel{\frac{V_1^2}{2g}}}_{\to 0} + \cancel{z_1} = \frac{P_2}{\gamma_{oil}} + \frac{V_2^2}{2g} + \cancel{z_2}$$

$z_1 = z_2$

$V_1 = 0$ stagnation point

$$\therefore \frac{V_2^2}{2g} = \frac{P_1 - P_2}{0.83\gamma_w}$$

$$\boxed{V_2^2 = 2.410 g \frac{P_1 - P_2}{\gamma_w}}$$

Now from the manometer eqn

$$P_1 - \cancel{\gamma_{oil} h} - \gamma_w \left(\tfrac{1}{3} ft\right) + \gamma_{oil}\left(\tfrac{1}{3} ft\right) + \cancel{\gamma_{oil} h} = P_2$$

$$P_1 - P_2 = \gamma_w \left(\tfrac{1}{3} ft\right)(1 - 0.83)$$

$$\frac{P_1 - P_2}{\gamma_w} = \left(\tfrac{1}{3} ft\right)(0.17) = 0.05667\ ft$$

$$\therefore V_2 = \left[2.410 \left(32.174 \frac{ft}{s^2}\right)(0.05667\ ft)\right]^{1/2}$$

$$\boxed{V_2 = 2.096\ ft/s}$$

and finally

$$Q = V_2 A_2 = \left(2.096 \frac{ft}{s}\right) \frac{\pi}{4} \left(\tfrac{1}{3} ft\right)^2 = \boxed{0.183\ ft^3/s}$$