
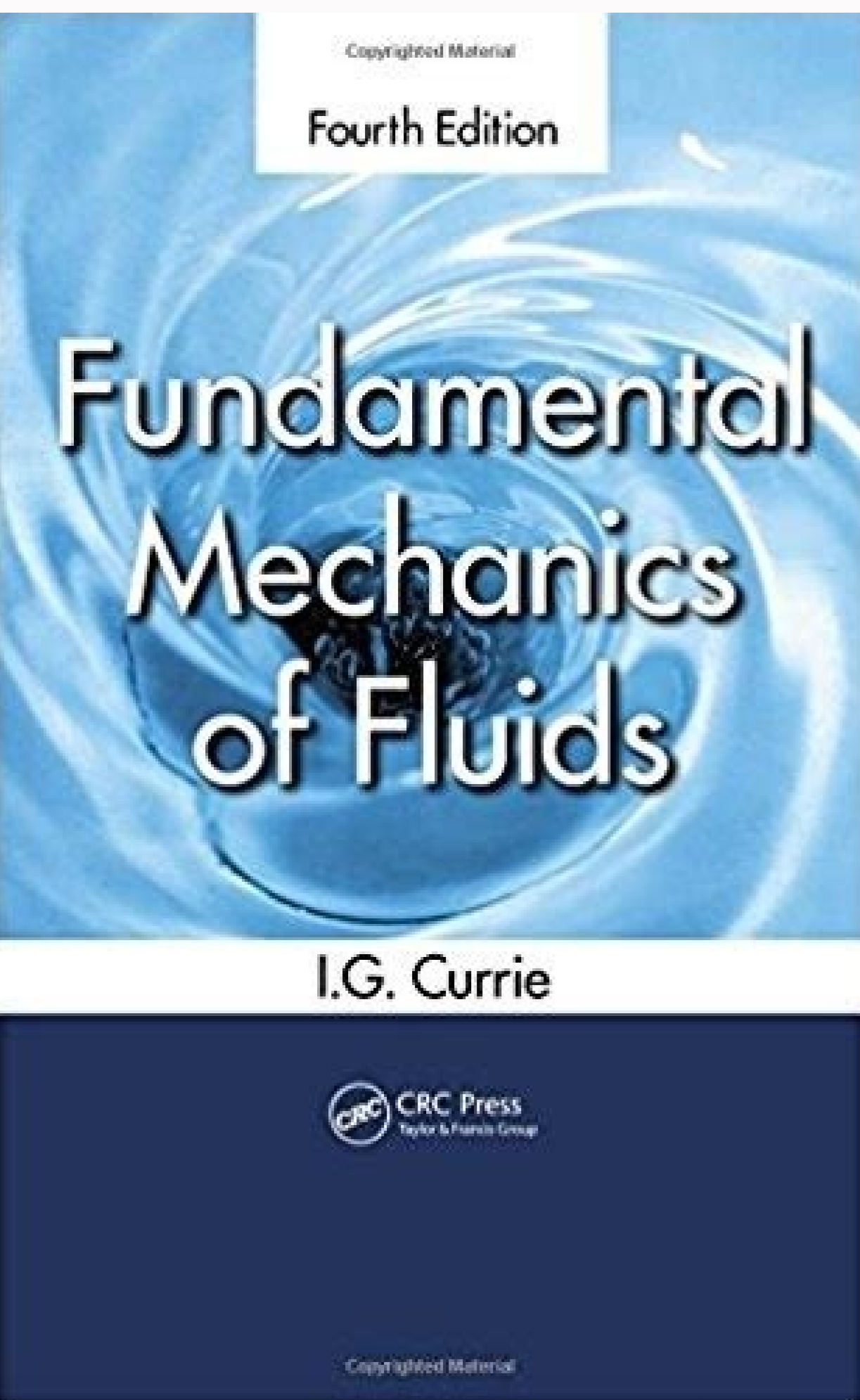
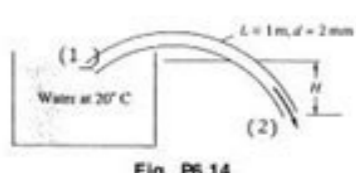


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6.14 Water at 20°C is to be siphoned through a tube 1 m long and 2 mm in diameter, as in Fig. P6.14. Is there any height H for which the flow might not be laminar? What is the flow rate if $H = 50$ cm? Neglect the tube curvature.



Solution: For water at 20°C, take $\rho = 998 \text{ kg/m}^3$ and $\mu = 0.001 \text{ kg/m}\cdot\text{s}$. Write the steady flow energy equation between points 1 and 2 above:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_L, \text{ or: } H - \frac{V^2}{2g} = h_L = \frac{32\mu L}{\rho g d^3} V \quad (1)$$

Enter data in Eq. (1): $0.5 - \frac{V^2}{2(9.81)} = \frac{32(0.001)(1.0)V}{(998)(9.81)(0.002)^3}$, solve $V = 0.590 \frac{\text{m}}{\text{s}}$

Equation (1) is quadratic in V and has only one positive root. The siphon flow rate is

$$Q_{\text{th-siphon}} = \frac{\pi}{4}(0.002)^2(0.590) = 1.85E-6 \frac{\text{m}^3}{\text{s}} = \mathbf{0.0067 \frac{\text{m}^3}{\text{h}} \text{ if } H = 50 \text{ cm. Ans.}}$$

Check: $Re = (998)(0.590)(0.002)/(0.001) = 1180$ (OK, laminar flow)

It is possible to approach $Re = 2000$ (possible transition to turbulent flow) for $H < 1 \text{ m}$, for the case of the siphon bent over nearly vertical. We obtain $Re = 2000$ at $H = \mathbf{0.87 \text{ m}}$.

6.15 Professor Gordon Holloway and his students at the University of New Brunswick went to a fast-food emporium and tried to drink chocolate shakes ($\rho = 1200 \text{ kg/m}^3$, $\mu = 6 \text{ kg/m}\cdot\text{s}$) through fat straws 8 mm in diameter and 30 cm long. (a) Verify that their human lungs, which can develop approximately 3000 Pa of vacuum pressure, would be unable to drink the milkshake through the vertical straw. (b) A student cut 15 cm from his straw and proceeded to drink happily. What rate of milkshake flow was produced by this strategy?

Solution: (a) Assume the straw is barely inserted into the milkshake. Then the energy equation predicts

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

$$= 0 + 0 + 0 = \frac{(-3000 \text{ Pa})}{(1200 \text{ kg/m}^3)(9.81 \text{ m/s}^2)} + \frac{V^2}{2g} + 0.3 \text{ m} + h_f$$

Solve for $h_f = 0.255 \text{ m} - 0.3 \text{ m} - \frac{V^2}{2g} < 0$ which is impossible. Ans. (a)

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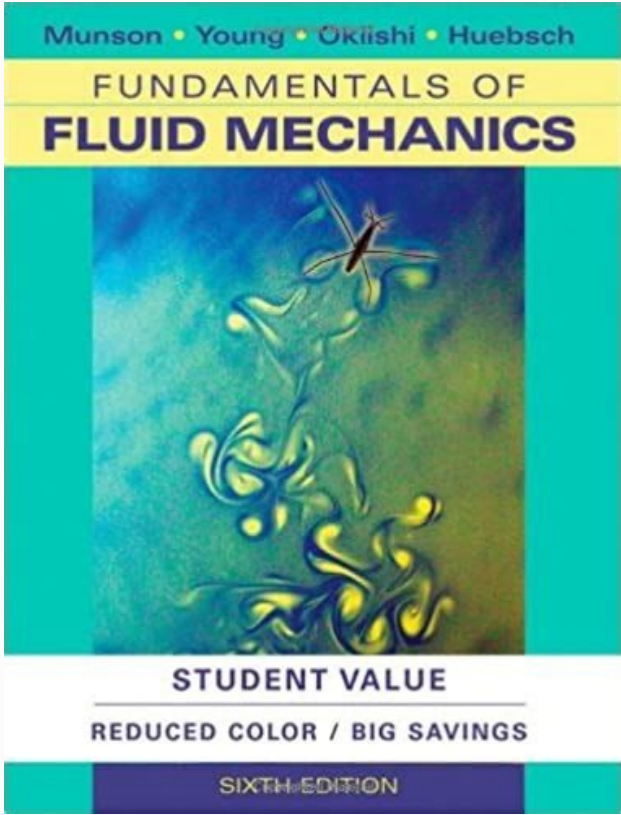
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1.6 If p is a pressure, V a velocity, and ρ a fluid density, what are the dimensions (in the MLT system) of (a) p/ρ , (b) $pV\rho$, and (c) $p/\rho V^2$?

(a) $\frac{p}{\rho} \approx \frac{ML^{-1}T^{-2}}{ML^{-3}} \approx L^2T^{-2}$

(b) $pV\rho \approx (ML^{-1}T^{-2})(LT^{-1})(ML^{-3}) \approx M^2L^{-2}T^{-3}$

(c) $\frac{p}{\rho V^2} \approx \frac{ML^{-1}T^{-2}}{(ML^{-3})(LT^{-1})^2} \approx M^0L^0T^0$ (dimensionless)



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