1.4

1.4 If P is a force and x a length, what are the dimensions (in the FLT system) of **(a)** dP/dx, **(b)** d^3P/dx^3, and **(c)** $\int P\,dx$?

(a) $\frac{dP}{dx} \doteq \frac{F}{L} \doteq \underline{\underline{FL^{-2}}}$

(b) $\frac{d^3P}{dx^3} \doteq \frac{F}{L^3} \doteq \underline{\underline{FL^{-3}}}$

(c) $\int P\,dx \doteq \underline{\underline{FL}}$

1.5

1.5 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) $\frac{p}{\rho} \doteq \frac{ML^{-1}T^{-2}}{ML^{-3}} \doteq \underline{\underline{L^2T^{-2}}}$

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

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

1.9

1.9 According to information found in an old hydraulics book, the energy loss per unit weight of fluid flowing through a nozzle connected to a hose can be estimated by the formula

$$h = (0.04 \text{ to } 0.09)(D/d)^4 V^2/2g$$

where h is the energy loss per unit weight, D the hose diameter, d the nozzle tip diameter, V the fluid velocity in the hose, and g the acceleration of gravity. Do you think this equation is valid in any system of units? Explain.

$$h = (0.04 \text{ to } 0.09)\left(\frac{D}{d}\right)^4 \frac{V^2}{2g}$$

$$\left[\frac{FL}{F}\right] \doteq \left[0.04 \text{ to } 0.09\right]\left[\frac{L^4}{L^4}\right]\left[\frac{1}{2}\right]\left[\frac{L^2}{T^2}\right]\left[\frac{T^2}{L}\right]$$

$$[L] \doteq [0.04 \text{ to } 0.09][L]$$

Since each term in the equation must have the same dimensions, the constant term (0.04 to 0.09) must be dimensionless. Thus, the equation is a general homogeneous equation that is valid in any system of units. Yes.

1.10

1.10 The pressure difference, Δp, across a partial blockage in an artery (called a *stenosis*) is approximated by the equation

$$\Delta p = K_v \frac{\mu V}{D} + K_u \left(\frac{A_0}{A_1} - 1\right)^2 \rho V^2$$

where V is the blood velocity, μ the blood viscosity ($FL^{-2}T$), ρ the blood density (ML^{-3}), D the artery diameter, A_0 the area of the unobstructed artery, and A_1 the area of the stenosis. Determine the dimensions of the constants K_v and K_u. Would this equation be valid in any system of units?

$$\Delta p = K_v \frac{\mu V}{D} + K_u\left[\frac{A_0}{A_1} - 1\right]^2 \rho V^2$$

$$[FL^{-2}] \doteq [K_v]\left[\left(\frac{FT}{L^2}\right)\left(\frac{L}{T}\right)\left(\frac{1}{L}\right)\right] + [K_u]\left[\frac{(L^2)}{(L^2)} - 1\right]^2 \left[\frac{FT^2}{L^4}\right]\left[\frac{L}{T}\right]^2$$

$$[FL^{-2}] \doteq [K_v][FL^{-2}] + [K_u][FL^{-2}]$$

Since each term must have the same dimensions, K_v and K_u are dimensionless. Thus, the equation is a general homogeneous equation that would be valid in any consistent system of units. Yes.

1,29

1.29

1.29 The information on a can of pop indicates that the can contains 355 mL. The mass of a full can of pop is 0.369 kg while an empty can weighs 0.153 N. Determine the specific weight, density, and specific gravity of the pop and compare your results with the corresponding values for water at 20 °C. Express your results in SI units.

$$\gamma = \frac{\text{weight of fluid}}{\text{volume of fluid}} \qquad (1)$$

total weight = mass x g = $(0.369\ kg)(9.81\ \frac{m}{s^2}) = 3.62\ N$

weight of can = $0.153\ N$

Volume of fluid = $(355 \times 10^{-3} L)(10^{-3} \frac{m^3}{L}) = 355 \times 10^{-6}\ m^3$

Thus, from Eq. (1)

$$\gamma = \frac{3.62\ N - 0.153\ N}{355 \times 10^{-6}\ m^3} = \underline{\underline{9770\ \frac{N}{m^3}}}$$

$$\rho = \frac{\gamma}{g} = \frac{9770\ \frac{N}{m^3}}{9.81\ \frac{m}{s^2}} = 996\ \frac{N \cdot s^2}{m^4} = \underline{\underline{996\ \frac{kg}{m^3}}}$$

$$SG = \frac{\rho}{\rho_{H_2O @ 4°C}} = \frac{996\ \frac{kg}{m^3}}{1000\ \frac{kg}{m^3}} = \underline{\underline{0.996}}$$

For water at 20°C (see Table B.2 in Appendix B)

$$\gamma_{H_2O} = 9789\ \frac{N}{m^3}\ ; \quad \rho_{H_2O} = 998.2\ \frac{kg}{m^3}\ ; \quad SG = 0.9982$$

A comparison of these values for water with those for the pop shows that the specific weight, density, and specific gravity of the pop are all slightly lower than the corresponding values for water.

Master Typing Sheet
10% Reduction
8 1/2 x 11 trim size

1.42

1.42 The viscosity of a soft drink was determined by using a capillary tube viscometer similar to that shown in Fig. P1.41 and Video V1.3. For this device the kinematic viscosity, ν, is directly proportional to the time, t, that it takes for a given amount of liquid to flow through a small capillary tube. That is, $\nu = Kt$. The following data were obtained from regular pop and diet pop. The corresponding measured specific gravities are also given. Based on these data, by what percent is the absolute viscosity, μ, of regular pop greater than that of diet pop?

	Regular pop	Diet pop
t(s)	377.8	300.3
SG	1.044	1.003

$$\% \text{ greater} = \left[\frac{\mu_{reg} - \mu_{diet}}{\mu_{diet}}\right] \times 100 = \left[\frac{\mu_{reg}}{\mu_{diet}} - 1\right] \times 100$$

Since $\nu = \mu/\rho$, $\nu = kt$, and $\rho = (SG)\rho_{H_2O @ 4°C}$

it follows that

$$\% \text{ greater} = \left[\frac{(\nu\rho)_{reg}}{(\nu\rho)_{diet}} - 1\right] \times 100$$

$$= \left[\frac{(t \times SG)_{reg}}{(t \times SG)_{diet}} - 1\right] \times 100$$

$$= \left[\frac{(377.8\ s)(1.044)}{(300.3\ s)(1.003)} - 1\right] \times 100$$

$$= \underline{\underline{31.0\%}}$$

1.57

1.57 A 25-mm-diameter shaft is pulled through a cylindrical bearing as shown in Fig. P1.57. The lubricant that fills the 0.3-mm gap between the shaft and bearing is an oil having a kinematic viscosity of 8.0×10^{-4} m²/s and a specific gravity of 0.91. Determine the force P required to pull the shaft at a velocity of 3 m/s. Assume the velocity distribution in the gap is linear.

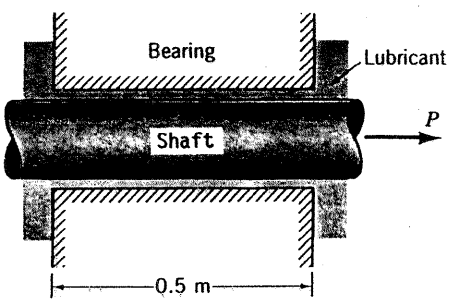
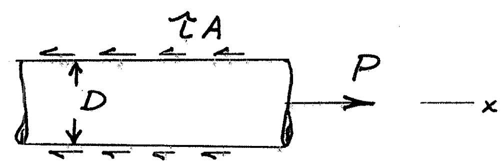


FIGURE P1.57



$\sum F_x = 0$

Thus, $P = \tau A$

where $A = \pi D \times (\text{shaft length in bearing}) = \pi D \ell$

and $\tau = \mu \dfrac{(\text{velocity of shaft})}{(\text{gap width})} = \mu \dfrac{V}{b}$

so that

$$P = \left(\mu \frac{V}{b}\right)(\pi D \ell)$$

Since $\mu = \nu \rho = \nu (SG)(\rho_{H_2O @ 4°C})$,

$$P = \frac{(8.0 \times 10^{-4} \frac{m^2}{s})(0.91 \times 10^3 \frac{kg}{m^3})(3 \frac{m}{s})(\pi)(0.025 m)(0.5 m)}{(0.0003 m)}$$

$$= \underline{\underline{286 \text{ N}}}$$

1.72

1.72 Carbon dioxide at 30 °C and 300 kPa absolute pressure expands isothermally to an absolute pressure of 165 kPa. Determine the final density of the gas.

For isothermal expansion, $\frac{p}{\rho} = \text{constant}$ so that

$$\frac{p_i}{\rho_i} = \frac{p_f}{\rho_f}$$ where $i \sim$ initial state and $f \sim$ final state.

Thus,

$$\rho_f = \frac{p_f}{p_i}\,\rho_i$$

Also,

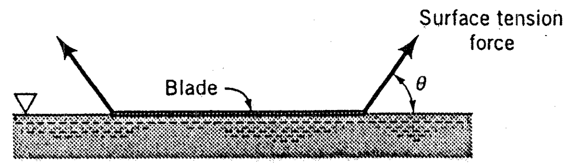
$$\rho_i = \frac{p_i}{RT_i} = \frac{300 \times 10^3 \frac{N}{m^2}}{\left(188.9 \frac{J}{kg \cdot K}\right)\left[(30°C + 273)K\right]} = 5.24 \frac{kg}{m^3}$$

so that

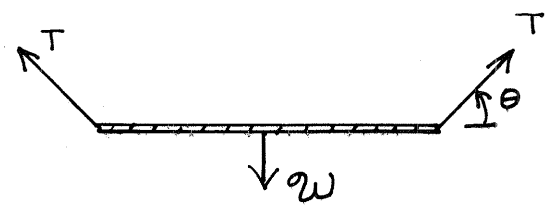
$$\rho_f = \left(\frac{165 \text{ kPa}}{300 \text{ kPa}}\right)\left(5.24 \frac{kg}{m^3}\right) = \underline{\underline{2.88 \frac{kg}{m^3}}}$$

1.84

1.84 As shown in Video V1.5, surface tension forces can be strong enough to allow a double-edge steel razor blade to "float" on water, but a single-edge blade will sink. Assume that the surface tension forces act at an angle θ relative to the water surface as shown in Fig. P1.84. (a) The mass of the double-edge blade is 0.64×10^{-3} kg, and the total length of its sides is 206 mm. Determine the value of θ required to maintain equilibrium between the blade weight and the resultant surface tension force. (b) The mass of the single-edge blade is 2.61×10^{-3} kg, and the total length of its sides is 154 mm. Explain why this blade sinks. Support your answer with the necessary calculations.



■ FIGURE P1.84



(a) $\sum F_{vertical} = 0$

$$\mathcal{W} = T \sin\theta$$

where $\mathcal{W} = m_{blade} \times g$ and $T = \sigma \times$ length of sides.

$$\therefore \left(0.64 \times 10^{-3}\,kg\right)\left(9.81\,m/s^2\right) = \left(7.34 \times 10^{-2}\,\frac{N}{m}\right)\left(0.206\,m\right)\sin\theta$$

$$\sin\theta = 0.415$$

$$\underline{\underline{\theta = 24.5^\circ}}$$

(b) For single-edge blade

$$\mathcal{W} = m_{blade} \times g = \left(2.61 \times 10^{-3}\,kg\right)\left(9.81\,m/s^2\right)$$
$$= 0.0256\ N$$

and

$$T \sin\theta = \left(\sigma \times \text{length of blade}\right)\sin\theta$$
$$= \left(7.34 \times 10^{-2}\ N/m\right)\left(0.154\,m\right)\sin\theta$$
$$= 0.0113 \sin\theta$$

In order for blade to "float" $\mathcal{W} < T\sin\theta$. Since maximum value for $\sin\theta$ is 1, it follows that $\mathcal{W} > T\sin\theta$ and single-edge blade will sink.