1.39

1.39

1.39 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 × 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)

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

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

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

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

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

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.

22-61

1.41

1.41 If 1 cup of cream having a density of 1005 kg/m³ is turned into 3 cups of whipped cream, determine the specific gravity and specific weight of the whipped cream.

Mass of cream, $m = \left(1005 \frac{kg}{m^3}\right) \times \left(\forall_{cup}\right)$

where $\forall$ ~ volume.

Since $m_{cream} = m_{\substack{whipped\\cream}}$

$$\rho_{\substack{whipped\\cream}} = \frac{m_{\substack{whipped\\cream}}}{\forall_{3\,cups}} = \frac{\left(1005 \frac{kg}{m^3}\right)\forall_{cup}}{\forall_{3\,cups}}$$

$$= \frac{1005 \frac{kg}{m^3}}{3} = 335 \frac{kg}{m^3}$$

$$SG = \frac{\rho_{\substack{whipped\\cream}}}{\rho_{H_2O\,@\,4°C}} = \frac{335 \frac{kg}{m^3}}{1000 \frac{kg}{m^3}} = \underline{\underline{0.335}}$$

$$\gamma_{\substack{whipped\\cream}} = \rho_{\substack{whipped\\cream}} \times g = \left(335 \frac{kg}{m^3}\right)\left(9.81 \frac{m}{s^2}\right)$$

$$= \underline{\underline{3290 \frac{N}{m^3}}}$$

2 @ 6r

1.44

1.44 Determine the mass of air in a 2 m³ tank if the air is at room temperature, 20 °C, and the absolute pressure within the tank is 200 kPa (abs).

$m = \rho V$ where $V = 2\,m^3$ and

$\rho = p/RT$ with $T = 20°C = (20+273)\,K = 293\,K$

and $p = 200\,kPa = 200 \times 10^3 \frac{N}{m^2}$

Thus,

$\rho = (200 \times 10^3 \frac{N}{m^2}) / [(2.869 \times 10^2 \frac{N \cdot m}{kg \cdot K})(293\,K)]$

$= 2.38 \frac{kg}{m^3}$

Hence,

$m = \rho V = 2.38 \frac{kg}{m^3} (2\,m^3) = \underline{\underline{4.76\,kg}}$

31 bi

1.45

1.45 Nitrogen is compressed to a density of 4 kg/m³ under an absolute pressure of 400 kPa. Determine the temperature in degrees Celsius.

$$T = \frac{p}{\rho R} = \frac{400 \times 10^3 \ \frac{N}{m^2}}{\left(4 \ \frac{kg}{m^3}\right)\left(296.8 \ \frac{J}{kg \cdot K}\right)} = 337 \ K$$

$$T_C = T_K - 273 = 337 \ K - 273 = \underline{\underline{64 \ ^\circ C}}$$

1.46

1.46 The temperature and pressure at the surface of Mars during a Martian spring day were determined to be −50 °C and 900 Pa, respectively. (a) Determine the density of the Martian atmosphere for these conditions if the gas constant for the Martian atmosphere is assumed to be equivalent to that of carbon dioxide. (b) Compare the answer from part (a) with the density of the earth's atmosphere during a spring day when the temperature is 18 °C and the pressure 101.6 kPa (abs).

(a) $$\rho_{Mars} = \frac{p}{RT} = \frac{900 \ \frac{N}{m^2}}{\left(188.9 \ \frac{J}{kg \cdot K}\right)\left[(-50^\circ C + 273) K\right]} = \underline{\underline{0.0214 \ \frac{kg}{m^3}}}$$

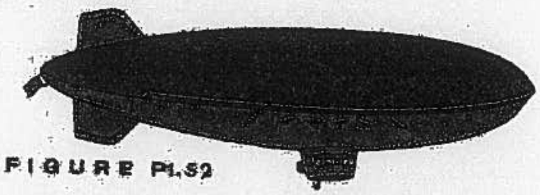
(b) $$\rho_{earth} = \frac{p}{RT} = \frac{101.6 \times 10^3 \ \frac{N}{m^2}}{\left(286.9 \ \frac{J}{kg \cdot K}\right)\left[(18^\circ C + 273) K\right]} = 1.22 \ \frac{kg}{m^3}$$

Thus,

$$\frac{\rho_{Mars}}{\rho_{earth}} = \frac{0.0214 \ \frac{kg}{m^3}}{1.22 \ \frac{kg}{m^3}} = 0.0175 = \underline{\underline{1.75\%}}$$

1.52

1.52 The helium-filled blimp shown in Fig. P1.52 is used at various athletic events. Determine the number of pounds of helium within it if its volume is 68,000 ft^3 and the temperature and pressure are 80 °F and 14.2 psia, respectively.



■ FIGURE P1.52

$\mathcal{W} = \gamma \mathcal{V}$ where $\mathcal{V} = 68{,}000\,\text{ft}^3$ and $\gamma = \rho g = (p/RT)g$

Thus,

$$\gamma = \left[14.2\,\frac{\text{lb}}{\text{in.}^2}\left(144\,\frac{\text{in.}^2}{\text{ft}^2}\right)\Big/\left(\left(1.242\times10^4\,\frac{\text{ft}\cdot\text{lb}}{\text{slug}\cdot{}^\circ\text{R}}\right)(80+460)\,{}^\circ\text{R}\right)\right]\left(32.2\,\frac{\text{ft}}{\text{s}^2}\right)$$

$$= 9.82\times10^{-3}\,\frac{\text{slug}}{\text{ft}^2\cdot\text{s}^2}\left(1\,\text{lb}/(\text{slug}\,\text{ft}/\text{s}^2)\right) = 9.82\times10^{-3}\,\frac{\text{lb}}{\text{ft}^3}$$

Hence,

$$\mathcal{W} = 9.82\times10^{-3}\,\frac{\text{lb}}{\text{ft}^3}\left(68{,}000\,\text{ft}^3\right) = \underline{\underline{668\,\text{lb}}}$$

34 bi

1.61

1.61 The viscosity of a certain fluid is 5×10^{-4} poise. Determine its viscosity in both SI and BG units.

From Appendix E, $10^{-1} \frac{N \cdot s}{m^2} = 1$ poise. Thus,

$$\mu = (5 \times 10^{-4} \text{ poise})\left(10^{-1} \frac{\frac{N \cdot s}{m^2}}{\text{poise}}\right) = \underline{\underline{5 \times 10^{-5} \frac{N \cdot s}{m^2}}}$$

and From Table 1.4

$$\mu = \left(5 \times 10^{-5} \frac{N \cdot s}{m^2}\right)\left(2.089 \times 10^{-2} \frac{\frac{lb \cdot s}{ft^2}}{\frac{N \cdot s}{m^2}}\right) = \underline{\underline{10.4 \times 10^{-7} \frac{lb \cdot s}{ft^2}}}$$

1.62

1.62 The kinematic viscosity and specific gravity of a liquid are $3.5 \times 10^{-4}\ m^2/s$ and 0.79, respectively. What is the dynamic viscosity of the liquid in SI units?

$$\mu = \nu \rho$$

$$\rho = (SG)(\rho_{H_2O @ 4°C})$$

$$\mu = \left(3.5 \times 10^{-4}\ \frac{m^2}{s}\right)\left(0.79 \times 10^3\ \frac{kg}{m^3}\right) = 0.277\ \frac{kg}{m \cdot s} = \underline{\underline{0.277\ \frac{N \cdot s}{m^2}}}$$

1.74

1.74 For a parallel plate arrangement of the type shown in Fig. 1.5 it is found that when the distance between plates is 2 mm, a shearing stress of 150 Pa develops at the upper plate when it is pulled at a velocity of 1 m/s. Determine the viscosity of the fluid between the plates. Express your answer in SI units.

$$\tau = \mu \frac{du}{dy}$$

$$\frac{du}{dy} = \frac{U}{b}$$

$$\mu = \frac{\tau}{\left(\frac{U}{b}\right)} = \frac{150 \frac{N}{m^2}}{\left(\frac{1 \frac{m}{s}}{0.002\,m}\right)} = \underline{\underline{0.300 \frac{N \cdot s}{m^2}}}$$

1.78

1.78 A 25-mm-diameter shaft is pulled through a cylindrical bearing as shown in Fig. P1.78. The lubricant that fills the 0.3-mm gap between the shaft and bearing is an oil having a kinematic viscosity of $8.0 \times 10^{-4}\ m^2/s$ 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.

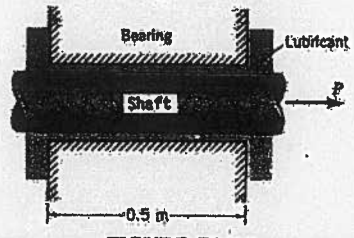
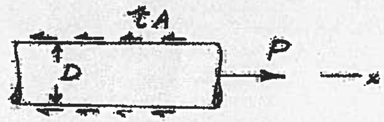


FIGURE P1.78



$$\sum F_x = 0$$

Thus,

$$P = \tau A$$

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

and

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

so that

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

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

$$P = \frac{\left(8.0\times10^{-4} \frac{m^2}{s}\right)\left(0.91\times10^{3} \frac{kg}{m^3}\right)\left(3 \frac{m}{s}\right)(\pi)(0.025 m)(0.5 m)}{(0.0003 m)}$$

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

1.80

1.80 A 10-kg block slides down a smooth inclined surface as shown in Fig. P1.80. Determine the terminal velocity of the block if the 0.1-mm gap between the block and the surface contains SAE 30 oil at 60 °F. Assume the velocity distribution in the gap is linear, and the area of the block in contact with the oil is 0.1 m².

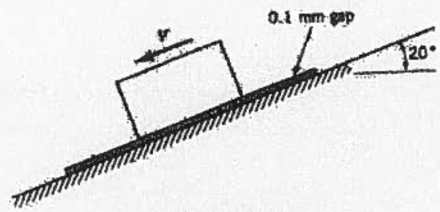
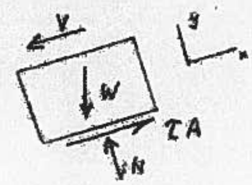


FIGURE P1.80



$$\Sigma F_x = 0$$

Thus,

$$W \sin 20° = \tau A$$

Since

$$\tau = \mu \frac{V}{b}$$, where b is film thickness,

$$W \sin 20° = \mu \frac{V}{b} A$$

Thus, (with $W = mg$)

$$V = \frac{b W \sin 20°}{\mu A} = \frac{(0.0001\,m)(10\,kg)(9.81\,\frac{m}{s^2})(\sin 20°)}{(0.38\,\frac{N \cdot s}{m^2})(0.1\,m^2)}$$

$$= \underline{0.0883\,\frac{m}{s}}$$

1.87

1.87 The viscosity of liquids can be measured through the use of a *rotating cylinder viscometer* of the type illustrated in Fig. P1.87. In this device the outer cylinder is fixed and the inner cylinder is rotated with an angular velocity, ω. The torque $\mathcal{T}$ required to develop ω is measured and the viscosity is calculated from these two measurements. **(a)** Develop an equation relating μ, ω, $\mathcal{T}$, ℓ, R_o, and R_i. Neglect end effects and assume the velocity distribution in the gap is linear. **(b)** The following torque-angular velocity data were obtained with a rotating cylinder viscometer of the type discussed in part (a).

Torque (ft · lb)	13.1	26.0	39.5	52.7	64.9	78.6
Angular velocity (rad/s)	1.0	2.0	3.0	4.0	5.0	6.0

For this viscometer $R_o = 2.50$ in., $R_i = 2.45$ in., and $\ell = 5.00$ in. Make use of these data and a standard curve-fitting program to determine the viscosity of the liquid contained in the viscometer.

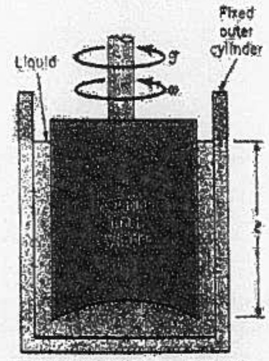


FIGURE P1.87

(a) Torque, $d\mathcal{T}$, due to shearing stress on inner cylinder is equal to

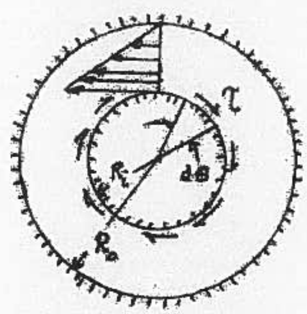
$$d\mathcal{T} = R_i \, \tau \, dA$$

where $dA = (R_i \, d\theta)\ell$. Thus,

$$d\mathcal{T} = R_i^2 \ell \, \tau \, d\theta$$

and torque required to rotate inner cylinder is

$$\mathcal{T} = R_i^2 \ell \, \tau \int_0^{2\pi} d\theta = 2\pi R_i^2 \ell \, \tau$$



top view

($\ell \sim$ cylinder length)

For a linear velocity distribution in the gap

$$\tau = \mu \frac{R_i \omega}{R_o - R_i} \quad \text{so that}$$

$$\mathcal{T} = \frac{2\pi R_i^3 \ell \mu \omega}{R_o - R_i} \qquad (1)$$

(b) Thus, for a fixed geometry and a given viscosity, Eq. (1) is of the form

$$y = b\,x \qquad (y \sim \mathcal{T} \text{ and } x \sim \omega)$$

where b is a constant equal to

(con't)

1.87 (con't)

$$b = \frac{2\pi R_i^3 \ell \mu}{R_o - R_i} \qquad (2)$$

To obtain b fit the data to a linear equation of the form $y = bx$ using a standard curve-fitting program such as found in EXCEL.

Thus, from Eq. (2)

$$\mu = \frac{(b)(R_o - R_i)}{2\pi R_i^3 \ell}$$

and with the data given, $b = 13.08\ ft \cdot lb \cdot s$, so that

$$\mu = \frac{(13.08\ ft \cdot lb \cdot s)\left(\frac{2.50 - 2.45}{12}\ ft\right)}{2\pi \left(\frac{2.45}{12}\ ft\right)^3 \left(\frac{5.00}{12}\ ft\right)} = \underline{\underline{2.45\ \frac{lb \cdot s}{ft^2}}}$$

1.96

1.96 Estimate the increase in pressure (in psi) required to decrease a unit volume of mercury by 0.1%.

$$E_V = -\frac{dp}{dV/V} \qquad (Eq.\ 1.12)$$

Thus,

$$\Delta p \approx -\frac{E_V\,\Delta V}{V} = -\left(4.14\times10^6\ \frac{lb}{in.^2}\right)(-0.001)$$

$$\Delta p \approx \underline{\underline{4.14\times10^3\ psi}}$$

1.97

1.97 A 1-m³ volume of water is contained in a rigid container. Estimate the change in the volume of the water when a piston applies a pressure of 35 MPa.

$$E_V = -\frac{dp}{dV/V} \qquad (Eq.\ 1.12)$$

Thus,

$$\Delta V \approx -\frac{V\,\Delta p}{E_V} = -\frac{(1\ m^3)(35\times10^6\ \frac{N}{m^2})}{2.15\times10^9\ \frac{N}{m^2}} = -0.0163\ m^3$$

or

$$\underline{decrease}\ \text{in volume} \approx \underline{\underline{0.0163\ m^3}}$$

1.102

1.102 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

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

1.118

1.118 When a 2-mm-diameter tube is inserted into a liquid in an open tank, the liquid is observed to rise 10 mm above the free surface of the liquid. the contact angle between the liquid and the tube is zero, and the specific weight of the liquid is 1.2×10^4 N/m³. Determine the value of the surface tension for this liquid.

$$h = \frac{2\sigma \cos\theta}{\gamma R}, \quad \text{where } \theta = 0$$

Thus,

$$\sigma = \frac{\gamma h R}{2\cos\theta} = \frac{1.2\times10^4 \frac{N}{m^3}(10\times10^{-3}\,m)(2\times10^{-3}\,m/2)}{2\cos 0}$$

$$= \underline{\underline{0.060 \frac{N}{m}}}$$

1.120

1.120 Small droplets of carbon tetrachloride at 68 °F are formed with a spray nozzle. If the average diameter of the droplets is 200 μm what is the difference in pressure between the inside and outside of the droplets?

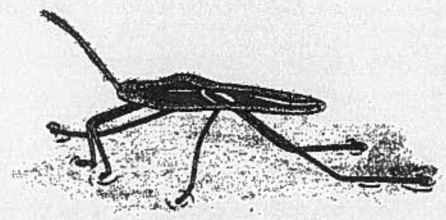
$$p = \frac{2\sigma}{R} \qquad (Eq.\ 1.21)$$

Since $\sigma = 2.69 \times 10^{-2}\ \frac{N}{m}$ at $68°F\ (=20°C)$,

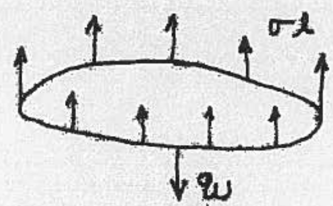
$$p = \frac{2\ (2.69 \times 10^{-2}\ \frac{N}{m})}{100 \times 10^{-6}\ m} = \underline{\underline{538\ Pa}}$$

1.131

1.131 (See Fluids in the News article titled "Walking on water," Section 1.9.) **(a)** The water strider bug shown in Fig. P1.131 is supported on the surface of a pond by surface tension acting along the interface between the water and the bug's legs. Determine the minimum length of this interface needed to support the bug. Assume the bug weighs 10^{-4} N and the surface tension force acts vertically upwards. **(b)** Repeat part (a) if surface tension were to support a person weighing 750 N.



■ FIGURE P1.131



For equilibrium,

$$\mathcal{W} = \sigma \ell$$

$\mathcal{W} \sim$ weight

$\sigma \sim$ surface tension

$\ell \sim$ length of interface

(a) $$\ell = \frac{\mathcal{W}}{\sigma} = \frac{10^{-4}\,N}{7.34 \times 10^{-2}\,\frac{N}{m}}$$

$$= 1.36 \times 10^{-3}\,m$$

$$= (1.36 \times 10^{-3}\,m)\left(10^{3}\,\frac{mm}{m}\right) = \underline{1.36\,mm}$$

(b) $$\ell = \frac{750\,N}{7.34 \times 10^{-2}\,\frac{N}{m}} = \underline{1.02 \times 10^{4}\,m} \quad (6.34\,mi\ !!)$$