Basic Principles and Calculations in Chemical Engineering 9th edition Himmelblau Solutions Manual

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Chapter 2 Solutions

2.1 Units of Measure

2.1.1

(a)	N/mm or nm (nanometer)
(b)	°C/M/s
(c)	100 kPa
(d)	273.15 K
(e)	1.50m, 45 kg
(f)	250°C
(g)	J/s
(h)	250 N

2.1.2 a. The device measures equivalent masses when it is balanced (both pans aligned horizontally).
b. The compressed spring measures the force under the influence of gravity. If this system were applied on the surface of the moon, the measurement would be much smaller.

2.2 Unit Conversions

2.2.1

(a) $\dfrac{2.5\ \cancel{\text{mi}}}{} \Big| \dfrac{1610\ \text{m}}{\cancel{\text{mi}}} = 4.0\times10^{3}\ \text{m or } 4.0\ \text{km}$

(b) $\dfrac{52.66\ \cancel{\text{Btu}}}{} \Big| \dfrac{1.055\ \text{kJ}}{\cancel{\text{Btu}}} = 55.56\ \text{kJ}$

(c) $\dfrac{5.00\ \cancel{\text{hp}}}{} \Big| \dfrac{0.7457\ \text{kW}}{\cancel{\text{hp}}} = 3.73\ \text{kW}$

(d) $\dfrac{50.\ \cancel{\text{gal}}}{\cancel{\text{min}}} \Big| \dfrac{3.875\times10^{-3}\ \text{m}^3}{\cancel{\text{gal}}} \Big| \dfrac{\cancel{\text{min}}}{60\ \text{s}} = 3.2\times10^{-3}\ \text{m}^3\ \text{s}^{-1}$

(e) $\dfrac{22.5\ \cancel{\text{lb}}_f}{\cancel{\text{in}}^2} \Big| \dfrac{6.958\ \text{kPa}}{\cancel{\text{lb}}_f/\cancel{\text{in}}^2} = 157\ \text{kPa}$

(f) $\dfrac{45.6\ \cancel{\text{slug}}}{\text{s}} \Big| \dfrac{32.174\ \cancel{\text{lb}}_m}{\cancel{\text{slug}}} \Big| \dfrac{0.4536\ \text{kg}}{\cancel{\text{lb}}_m} = 665\ \text{kg s}^{-1}$

(g) $\dfrac{17.0\ \cancel{\text{hp}}\ \cancel{\text{h}}}{} \Big| \dfrac{745.7\ \text{J}}{\cancel{\text{hp}}\ \cancel{\text{s}}} \Big| \dfrac{3600\ \cancel{\text{s}}}{\cancel{\text{h}}} = 4.56\times10^{6}\ \text{J}=4.56\times10^{3}\ \text{kJ}=4.56\ \text{MJ}$

(h) $\dfrac{35.9\ \cancel{\text{gal}}}{\text{s}\ \cancel{\text{ft}}^2} \Big| \dfrac{3.875\times10^{-3}\ \text{m}^3}{\cancel{\text{gal}}} \Big| \dfrac{\cancel{\text{ft}}^2}{0.3048^2\ \text{m}^2} = 1.50\ \text{m}^3\ \text{m}^{-2}\ \text{s}^{-1}$

(i) $357^\circ\text{F}+459.67=816.67^\circ\text{R}$ $\quad \dfrac{816.67^\circ\text{R}}{} \Big| \dfrac{5\ \text{K}}{9^\circ\text{R}} = 454\ \text{K}$

(j) $$\frac{7.6\ \cancel{lb}_m}{\cancel{ft}^3}\Bigg|\frac{0.4536\ kg}{\cancel{lb}_m}\Bigg|\frac{\cancel{ft}^3}{0.02832\ m^3} = 120\ kg\ m^{-3}$$

2.2.2

(a) $$\frac{6.000\ \cancel{ft}}{}\Bigg|\frac{0.3048\ \cancel{m}}{\cancel{ft}}\Bigg|\frac{10^6 \mu m}{\cancel{m}} = 1.829\times10^{6}\ \mu m$$

(b) $$\frac{100\ \cancel{k}m}{\cancel{h}}\Bigg|\frac{3.937\times10^{4}\ in}{\cancel{k}m}\Bigg|\frac{\cancel{h}}{3600\ \cancel{s}}\Bigg|\frac{\cancel{s}}{10^{6}\ \mu s} = 1.094\times10^{-3}\ in\ \mu s^{-1}$$

(c) $$\frac{500K}{}\Bigg|\frac{9^{o}R}{5\ K} = 900^{o}\ R \qquad 900^{o}\ R\text{-}459.67=440^{o}F$$

(d) $$\frac{1\times10^{6}\ B\cancel{t}u}{\cancel{h}}\Bigg|\frac{2.93\times10^{-4}\ kW\ \cancel{h}}{B\cancel{t}u} = 293\ kW$$

(e) $$\frac{7.5\ kg}{\cancel{m}^{-3}}\Bigg|\frac{\cancel{m}^{-3}}{28.3776\ bushel}\Bigg|\frac{2.2046\ lb_m}{kg}\Bigg|\frac{16\ oz}{lb_m} = 9.3\ oz\ bushel^{-1}$$

(f) $$\frac{15.367\ \cancel{lb}_m\ \cancel{ft}^2}{\cancel{s}^2}\Bigg|\frac{\cancel{lb}_f\ \cancel{s}^2}{32.174\ \cancel{lb}_m\ \cancel{ft}}\Bigg|\frac{1.285\times10^{-3}\ Btu}{\cancel{lb}_f\ \cancel{ft}} = 6.1374\times10^{-4}\ Btu$$

(g) $$\frac{0.2433\ \cancel{kg}}{\cancel{m}\ \cancel{s}^2}\Bigg|\frac{\cancel{N}\ \cancel{s}^2}{\cancel{kg}\ \cancel{m}}\Bigg|\frac{\cancel{Pa}\ \cancel{m}^2}{\cancel{N}}\Bigg|\frac{1.414\times10^{-4}\ psi}{\cancel{Pa}} = 3.440\times10^{-5}\ psi$$

(h) $$\frac{10.1\ \cancel{A}\ \cancel{V}}{}\Bigg|\frac{\cancel{W}}{\cancel{A}\ \cancel{V}}\Bigg|\frac{kW}{1000\ \cancel{W}} = 0.0101\ kW$$

(i) $$\frac{32.17\ \cancel{ft}}{\cancel{s}^2}\Bigg|\frac{3600^2\ \cancel{s}^2}{h^2}\Bigg|\frac{0.3048\ \cancel{m}}{\cancel{ft}}\Bigg|\frac{1000\ mm}{\cancel{m}} = 1.271\times10^{11}\ mm\ h^{-2}$$

(j) $$\frac{0.779\ \cancel{lb}_m\ \cancel{ft}}{\cancel{s}^3}\Bigg|\frac{\cancel{lb}_f\ \cancel{s}^2}{32.174\ \cancel{lb}_m\ \cancel{f}}\Bigg|\frac{3.766\times10^{-7}\ kW\ \cancel{h}}{\cancel{lb}_f\ \cancel{ft}}\Bigg|\frac{3600\ \cancel{s}}{\cancel{h}} = 3.28\times10^{-5}\ kW$$

2.2.3 Fractional reduction in miles driven = 1000/13500 = 0.07407
Gasoline saved = 0.07407(136.8) = 10.13 billion gallons

2.2.4

$$\frac{2000\ B\cancel{t}u}{\cancel{h}}\Bigg|\frac{\cancel{kW}\ \cancel{h}}{11.2\ B\cancel{t}u}\Bigg|\frac{\$0.14}{\cancel{kW}\ \cancel{h}}\Bigg|\frac{24\ \cancel{h}}{\cancel{d}}\Bigg|\frac{30\ \cancel{d}}{mo} = \$18,000\ mo^{-1}$$

2.2.5

$$\frac{4.24\ \cancel{l}y}{}\Bigg|\frac{2.99792\times10^{8}\ \cancel{m}}{\cancel{s}}\Bigg|\frac{3600\ \cancel{s}}{\cancel{h}}\Bigg|\frac{24\ \cancel{h}}{\cancel{d}}\Bigg|\frac{365\ \cancel{d}}{\cancel{l}y}\Bigg|\frac{\cancel{mi}}{1610\ \cancel{m}}\Bigg|\frac{AU}{9.29\times10^{7}\ \cancel{mi}} = 2.68\times10^{6}\ AU$$

2.2.6

$$\frac{8.6\ \cancel{l}y}{}\Bigg|\frac{2.99792\times10^{8}\ \cancel{m}}{\cancel{s}}\Bigg|\frac{3600\ \cancel{s}}{\cancel{h}}\Bigg|\frac{24\ \cancel{h}}{\cancel{d}}\Bigg|\frac{365\ \cancel{d}}{\cancel{l}y}\Bigg|\frac{pc}{3.0867\times10^{16}\ \cancel{mi}} = 2.6\ pc$$

2.2.7

$$\frac{400{,}000\ \cancel{\text{bbl}}}{\cancel{\text{d}}}\left|\frac{42\ \cancel{\text{gal}}}{\cancel{\text{bbl}}}\right|\frac{3.875\ \cancel{\text{l}}}{\cancel{\text{gal}}}\left|\frac{850\ \cancel{\text{g}}}{\cancel{\text{l}}}\right|\frac{\text{lb}_\text{m}}{454.3\ \cancel{\text{g}}}\left|\frac{\cancel{\text{d}}}{24\ \text{h}}\right. = 5.075\times10^{6}\ \text{lb}_\text{m}\ \text{h}^{-1}$$

2.2.8

$$\frac{18\times15\times8\ \cancel{\text{in}^3}}{297\ \cancel{\text{s}}}\left|\frac{2.54^3\ \cancel{\text{cm}^3}}{\cancel{\text{in}^3}}\right|\frac{\cancel{\text{l}}}{1000\ \cancel{\text{cm}^3}}\left|\frac{\text{gal}}{3.875\ \cancel{\text{l}}}\right|\frac{60\ \cancel{\text{s}}}{\text{min}} = 1.8\ \text{gal min}^{-1}$$

2.2.9

$$\frac{12\text{k}\cancel{\text{m}}}{\cancel{\text{L}}}\left|\frac{3.875\ \cancel{\text{L}}}{\text{gal}}\right|\frac{\text{mi}}{1.61\ \text{k}\cancel{\text{m}}} = 28.9\ \text{mi/gal}$$

2.2.10

$$\frac{\$1.29\ \text{CAD}}{\text{L}}\left|\frac{\$0.79\ \text{USD}}{\$1\ \text{CAD}}\right|\frac{3.875\ \text{L}}{\text{gal}} = \$3.95\ \text{USD/gal}$$

2.2.11

$$\frac{8.314\ \text{k}\cancel{\text{Pa}}\ \cancel{\text{m}}^3}{\text{k}\cancel{\text{g}}\text{mol}\ \cancel{\text{K}}}\left|\frac{\text{atm}}{101.3\ \text{k}\cancel{\text{Pa}}}\right|\frac{35.31\ \text{ft}^3}{\cancel{\text{m}}^3}\left|\frac{\text{k}\cancel{\text{g}}\text{mol}}{2.2046\ \text{lbmol}}\right|\frac{5\ \cancel{\text{K}}}{9°\ \text{R}} = 0.7303\frac{\text{atm ft}^3}{\text{lbmol° R}}$$

2.2.12

$$V = Ah = \frac{3500\ \text{f}\cancel{\text{t}}^2}{}\left|\frac{3\ \cancel{\text{in}}}{}\right|\frac{\cancel{\text{ft}}}{12\ \cancel{\text{in}}}\left|\frac{7.481\ \text{gal}}{\cancel{\text{ft}}^3}\right. = 6546\ \text{gal}$$

2.2.13 a. Basis: 1 mi^3

$$\frac{1\text{mi}^3}{}\left|\left(\frac{5280\ \text{ft}}{1\ \text{mi}}\right)^3\right|\left(\frac{12\ \text{in}}{1\ \text{ft}}\right)^3\left|\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right)^3\right|\left(\frac{1\ \text{m}}{100\ \text{cm}}\right)^3 = \boxed{4.17\times10^9\text{m}^3}$$

b. Basis: 1 ft^3/s

$$\frac{1\ \text{ft}^3}{1\ \text{s}}\left|\frac{60\ \text{s}}{1\ \text{min}}\right|\frac{7.48\ \text{gal}}{1\ \text{ft}^3} = \boxed{449\ \text{gal / min}}$$

2.2.14

a. $$\frac{0.04\ \text{g}}{(\text{min})(\text{m}^3)}\left|\frac{60\ \text{min}}{1\ \text{hr}}\right|\frac{(12\ \text{in})^3}{1\ \text{ft}^3}\left|\frac{1\ \text{lb}_m}{454\,\text{g}}\right. = \boxed{9.14\frac{\text{lb}_m}{(\text{hr})\ (\text{ft}^3)}}$$

b. $$\frac{2\text{L}}{\text{s}}\left|\frac{3600\ \text{s}}{1\ \text{hr}}\right|\frac{24\ \text{hr}}{1\ \text{day}}\left|\frac{1\ \text{ft}^3}{28.32\text{L}}\right. = \boxed{6.1\times 10^3\ \frac{\text{ft}^3}{\text{day}}}$$

c. $$\frac{6\ (\text{in.})(\text{cm}^2)}{(\text{yr})(\text{s})(\text{lb}_m)(\text{ft}^2)}\left|\frac{1\ \text{ft}^2}{(12\ \text{in})^2}\right|\frac{(1\ \text{in})^2}{(2.54\ \text{cm})^2}\left|\frac{1\ \text{yr}}{365\ \text{days}}\right|\frac{1\ \text{day}}{24\ \text{hr}}\left|\frac{1\ \text{hr}}{3600\text{s}}\right|\frac{2.2\ \text{lb}_m}{1\ \text{kg}}$$

$$\frac{1\ \text{ft}}{12\ \text{in}}\left|\frac{0.3048\ \text{m}}{1\ \text{ft}}\right. = \boxed{1.14\times 10^{-11}\frac{\text{m}}{(\text{kg})\ (\text{s}^2)}}$$

2.2.15

a. Basis: 60.0 mile/hr

$$\frac{60.0\ \text{mile}}{\text{hr}}\left|\frac{5280\ \text{ft}}{1\ \text{mile}}\right|\frac{1\ \text{hr}}{3600\ \text{sec}} = \boxed{88\ \frac{\text{ft}}{\text{sec}}}$$

b. Basis: $50.0\ \text{lb}_m/(\text{in})^2$

$$\frac{50.0/\text{lb}_m}{(\text{in})^2}\left|\frac{454\ \text{g}}{1\ \text{lb}}\right|\frac{1\ \text{kg}}{1000\ \text{g}}\left|\frac{1(\text{in})^2}{(2.54\ \text{cm})^2}\right|\frac{(100\ \text{cm})^2}{(1\ \text{m})^2} = \boxed{3.52\ \times\ 10^4\ \frac{\text{kg}}{\text{m}^2}}$$

c. Basis: $6.20\ \text{cm}/(\text{hr})^2$

$$\frac{6.20\ \text{cm}}{(\text{hr})^2}\left|\frac{1\ \text{m}}{100\ \text{cm}}\right|\frac{10^9\text{nm}}{1\ \text{m}}\left|\frac{1(\text{hr})^2}{(3600\ \text{sec})^2}\right. = \boxed{4.79\ \frac{\text{nm}}{\text{sec}^2}}$$

2.2.16

$$\frac{20\ \text{hp}}{}\left|\frac{0.7457\ \text{kW}}{1\ \text{hp}}\right. = 14.91\ \text{kW}$$

No, not enough power even at 100% efficiency; 68 kW = 91.2 hp.

2.2.17

$$\frac{1\text{ hr}}{525\text{ mile}}\left|\frac{2200\text{ gal}}{1\text{ hr}}\right|\frac{1000\text{ mile}}{} = \boxed{4190.5\text{ gal}}$$

$$\frac{1\text{ hr}}{475\text{ mile}}\left|\frac{2000\text{ gal}}{1\text{ hr}}\right|\frac{1000\text{ mile}}{} = \boxed{\frac{4210\text{ gal}}{(20\text{ gal})}}$$

None: 20 gal more are needed.

2.2.18 Let t_A be the time for A to paint one house; t_B for B
A does a house in 5 hours, or 1 house/5 hr. B does one house in 3 hours, or 1 house/3 hr.

$$\frac{1\text{ house}}{5\text{ hr}}\left|\frac{t_A\text{ hr}}{}\right. + \frac{1\text{ house}}{3\text{ hr}}\left|\frac{t_B\text{ hr}}{}\right. = 1\text{ house}$$

Also $t_A = t_B$ so that $\frac{3}{15}t_A + \frac{5}{15}t_A = 1$ or $\frac{8}{15}t_A = 1$

$t_A = \frac{15}{8}$ hr $= t_B = 1.875$ hr or $\boxed{112.5\text{ min}}$

2.2.19

$$\frac{20.0\text{g}}{(\text{m})(\text{s})}\left|\frac{1\text{ lb}_m}{453.6\text{ g}}\right|\frac{0.3048\text{m}}{1\text{ ft}}\left|\frac{3600\text{s}}{1\text{ hr}}\right|\frac{1\ (\text{lb}_f)(\text{s}^2)}{32.174(\text{lb}_m)(\text{ft})}\left|\frac{1(\text{hr})^2}{(3600)^2\text{s}^2}\right.$$

$$= \boxed{1.16\times10^{-7}\frac{(\text{lb}_f)(\text{hr})}{\text{ft}^2}}$$

2.2.20

$$\frac{1.0\text{ Btu}}{(\text{hr})(\text{ft}^2)\left(\frac{°\text{F}}{\text{ft}}\right)}\left|\frac{24\text{ hrs}}{1\text{ day}}\right|\frac{1\text{ ft}^2}{(12\text{ in})^2}\left|\frac{1\text{ in}^2}{(2.54\text{ cm}^2)}\right|\frac{(100\text{ cm})^2}{1\text{ m}^2}\left|\frac{1.8°\text{F}}{1°\text{C}}\right|\frac{2.54\text{ cm}}{\text{in}}$$

$$\frac{252\text{ cal}}{1\text{ Btu}}\left|\frac{12\text{ in}}{1\text{ ft}}\right|\frac{4.184\text{ J}}{1\text{ cal}}\left|\frac{1\text{ kJ}}{1000\text{ J}}\right. = 1.49\times10^4\frac{\text{kJ}}{(\text{day})(\text{m}^2)(°\text{C}/\text{cm})}$$

2.2.21 Basis: 1 lb H_2O

a. $$KE=\frac{1}{2}mv^2=\frac{1}{2}\left|\frac{1\ lb_m}{}\right|\left(\frac{3\ ft}{s}\right)^3\left|\frac{(s^2)(lb_f)}{32.174(ft)(lb_m)}\right.=0.14(ft)(lb_f)$$

b. Let A = area of the pipe and v = water velocity. The flow rate is

$$q=Av=\left(\frac{\pi D^2}{4}\right)(v)$$

$$\frac{\pi}{4}\left|\frac{(2\ in)^2}{}\right|\frac{(1\ ft)^2}{(12\ in)^2}\left|\frac{3\ ft}{S}\right|\frac{60\ s}{1\ min}\left|\frac{7.48\ gal}{1\ ft^3}\right.=\boxed{29.37\ gal/min}$$

2.2.22

$$PE=\frac{75\ gal}{min}\left|\frac{8.33\ lb_m}{gal}\right|\frac{32.2\ ft}{sec^2}\left|\frac{100}{ft}\right|\frac{60\ s}{hr}\left|\frac{s^2\text{-}lb_f}{32.2\ lb_m\text{-}ft}\right|\frac{Btu}{778\ ft\text{-}lb_f}=4818\ Btu/hr$$

$$\text{Pump Work}=\frac{2\ hp}{}\left|\frac{2545\ Btu}{hp\text{-}hr}\right.=5090\ Btu/hr$$

Rate of energy input for heating = PW - PE =5090 - 4818 = 272 Btu/hr

2.2.23 The object has a mass of 21.3 kg (within a precision of ± .1 kg). The weight is the force used to support the mass.

2.2.24 In American Engineering System

Power = FV

$$=\frac{800\ lb_f}{1}\left|\frac{300\ ft}{min}\right.=\boxed{2.4\times10^5\frac{(lb_f)(ft)}{min}}\text{ or 7.27 hp}$$

In SI

$$\text{Power}=\frac{4000\ N}{1}\left|\frac{1.5\ m}{s}\right|\frac{1\ (watt)(s)}{1(N)(m)}$$

$$=\boxed{6000\ watts}$$

2.2.25

$$KE = \frac{1}{2} m v^2$$

$$= \frac{1}{2}\left|\frac{2300\ \text{kg}}{}\right|\frac{1\ \text{lb}_m}{0.454\ \text{kg}}\left|\left(\frac{10.0\ \text{ft}}{\text{s}}\right)^2\right|\frac{1}{\frac{32.2\ \text{lb}_m}{\text{lb}_f}\left|\frac{\text{ft}}{\text{sec}^2}\right.}\left|\frac{1\ \text{Btu}}{778.2(\text{ft})(\text{lb}_f)}\right.$$

$$= \boxed{10.11\ \text{Btu}}$$

2.2.26 Basis: 10 tons at 6 ft/s

$$KE = \frac{1}{2} m v^2 = \frac{1}{2}\left|\frac{20{,}000\ \text{lb}_m}{}\right|\left(\frac{6\ \text{ft}}{\text{s}}\right)^2\left|\frac{1(\text{s}^2)(\text{lb}_f)}{32.2(\text{ft})(\text{lb}_m)}\right. = \boxed{11{,}200(\text{ft})(\text{lb}_f)}$$

2.2.27 Basis: 1 mRNA

$$\frac{1\ \text{nRNA}}{}\left|\frac{3x\ \text{ribonucleotides}}{\text{nRNA}}\right|\frac{1\ \text{active ribosome}}{264\ \text{ribonucleotides}}\left|\frac{1200\ \text{amino acids}}{\text{min-active ribosome}}\right|\frac{\text{protein}}{x\ \text{amino acids}} =$$

13.6 protein molecules formed per min per nRNA

Section 2.2.1 Temperature

2.2.28

$T_K = -10 + 273 = 263\text{K}$

$T_{°F} = -10\ (1.8) + 32 = 14°\text{F}$

$T_{°R} = 14 + 460 = 474°\text{R}$

2.2.29 Yes, if the temperature scale is a linear relative one (°C, °F), or a logarithmic scale (ln 1° is zero). No, if the scale is absolute, but read J. Wisniak, *J. Chem. Educ*., **77**, 518-522 (2000) for a different conclusion.

2.2.30

$$C_p = 8.41 + \underbrace{2.4346 \times 10^{-5} T_K}_{\left(2.4346\times10^{-5}\frac{J}{(\text{gmol})(K)^2}\right)(T_K)}$$

Substitute 1.8 TK = T°R

$$Cp = 8.41 + 2.4346 \times 10^{-5} \frac{J}{(gmol)(K)^2}\left(\frac{T_{\circ R}}{1.8}\right)$$

$$= \boxed{8.41 + 1.353 \times 10^{-5} T_{\circ R}}$$

2.2.31

a) $$\frac{10°C}{}\left|\frac{1.8°F}{1.0°C}\right| + 32 = \boxed{50°F}$$

b) $$\frac{10°C}{}\left|\frac{1.8°F}{1.0°C}\right| + 32 + 460°R = \boxed{510°R}$$

c) $$\frac{-25°F - 32°F}{1.8}\left|\frac{1.0°C}{1.8°F}\right| + 273K = \boxed{241.3K}$$

d) $$\frac{150K}{}\left|\frac{1.8°R}{1.0K}\right| = \boxed{270°R}$$

2.2.32 First multiply the RHS of the equation so that

Btu	1054.8J	1 lb mol	1.8°F	1°C
(lbmol)(°F)	1 Btu	454 gmol	1.0°C	1K

$$= 4.182 \frac{J}{(gmol)(K)}$$

and substitute $T_{°F} = 1.8T_{°C} + 32$

$$C_p = [8.488 + 0.5757\times10^{-2}(1.8T_{°C} + 32) - 0.2159\times10^{-5}(1.8T_{°C} + 32)^2 + 0.3059\times10^{-9}(1.8T_{°C} + 32)^3]4.182\frac{J}{(gmol)(K)}$$

Simplifying,

$$C_p = 36.05 + 0.0447T - 0.2874 \times 10^{-4} T^2 + 0.7424 \times 10^{-8} T^3$$

Section 2.3 Equations and Units

2.3.1

Solving for the constant term in the equation, $4.8 = \frac{Q}{Wh^{1.5}} = \frac{gpm}{}\left|\frac{}{in}\right|\frac{}{in^{1.5}} = gpm\ in^{-2.5}$

2.3.2

From the back inside cover, $R = \dfrac{10.73 \text{ psia } \cancel{\text{ft}}^3}{\text{lb}\cancel{\text{mol}}\ ^\circ\cancel{\text{R}}}\left|\dfrac{7.481 \text{ gal}}{\cancel{\text{ft}}^3}\right|\dfrac{\text{lb}\cancel{\text{mol}}}{454.3 \text{ gmol}}\left|\dfrac{9^\circ \cancel{\text{R}}}{5\text{K}}\right. = 0.3180 \text{ psia gal gmol}^{-1}\ \text{K}^{-1}$

2.3.3

Solving for M the constant term in the equation recognizing that a radian is dimensionless,

$$M = \frac{TL}{\theta S} = \frac{\cancel{\text{N}}\text{ m}}{}\left|\frac{\text{m}}{}\right|\frac{\text{m}^2}{\cancel{\text{N}}} = \text{m}^4$$

2.3.4

$P = \dot{m}gh =$

$$\frac{4.3\times10^6 \text{ } \cancel{\text{gal}}}{\cancel{\text{min}}}\left|\frac{9.801 \text{ } \cancel{\text{m}}}{\cancel{\text{s}}^2}\right|\frac{180 \text{ } \cancel{\text{m}}}{}\left|\frac{3.875\times10^{-3} \text{ } \cancel{\text{m}}^3}{\cancel{\text{gal}}}\right|\frac{1000 \text{ } \cancel{\text{kg}}}{\cancel{\text{m}}^3}\left|\frac{\cancel{\text{J}}\ \cancel{\text{s}}^2}{\cancel{\text{kg}}\ \cancel{\text{m}}^2}\right|\frac{\cancel{\text{W}}\ \cancel{\text{s}}}{\cancel{\text{J}}}\left|\frac{\text{h}}{3600 \text{ } \cancel{\text{s}}}\right|\frac{\text{TW}}{10^{12} \text{ } \cancel{\text{W}}}\left|\frac{60 \text{ } \cancel{\text{min}}}{\cancel{\text{h}}}\right|\frac{24 \text{ } \cancel{\text{h}}}{\cancel{\text{d}}}\left|\frac{365 \text{ } \cancel{\text{d}}}{y}\right.$$

$= 4.3 \text{ TW h y}^{-1}$

2.3.5

$$\frac{\pi 15^2 \text{ } \cancel{\text{ft}}^2}{4}\left|\frac{30 \text{ } \cancel{\text{ft}}}{}\right|\frac{7.481 \text{ } \cancel{\text{gal}}}{\cancel{\text{ft}}^3}\left|\frac{\text{car}}{15 \text{ } \cancel{\text{gal}}}\right. = 2600 \text{ cars}$$

2.3.6

$C_D = \dfrac{2F}{\rho v^2 A} = \dfrac{\text{lb}_f}{}\left|\dfrac{\cancel{\text{ft}}^3}{\text{lb}_m}\right|\dfrac{\text{s}^2}{\cancel{\text{ft}}^2}\left|\dfrac{}{\text{ft}^2}\right. = \text{lb}_f\ \text{s}^2\ \text{lb}_m^{-1}\ \text{ft}^{-1}$ Note that if the right hand side is multiplied by g_c C_D becomes dimensionless.

2.3.7

$$G = F\frac{r^2}{Mm} = \frac{\text{N}}{}\left|\frac{\text{m}^2}{}\right|\frac{}{\text{kg}}\left|\frac{}{\text{kg}}\right. = \text{N m}^2\ \text{kg}^{-2}$$

2.3.8

a₁. A is in g/cm^3
a₂. B is in $g/(cm^3)(°C)$
a₃. Since the exponent of e must be dimensionless
C is in atm^{-1}

b_1 $$A = \frac{1.096\ g}{cm^3}\left|\frac{(30.48)^3 cm^3}{ft^3}\right|\frac{1\ lb_m}{454 g} = \boxed{68.4\ \frac{lb_m}{ft^3}}$$

b_2 $$B = \frac{0.00086\ g}{(cm^3)(^\circ C)}\left|\frac{(30.48)^3 cm^3}{ft^3}\right|\frac{1\ lbm}{454\ g}\left|\frac{1^\circ C}{1.8^\circ R}\right. = \boxed{0.0298\ \frac{lb_m}{(ft^3)(^\circ R)}}$$

b_3 $$C = \frac{0.000953}{atm}\left|\frac{1\ atm}{14.7\ lb_f/in^2}\right. = \boxed{0.0000648\ \frac{1}{lb_f/in^2}}$$

2.3.9 Introduce the units. The net units are the same on both sides of the equation.

$$\mathbf{(ft)(ft)^{1.5}\left(\frac{ft}{s^2}\right)^{1/2} = \frac{ft^3}{s}}$$

2.3.10

No. $$q = 0.6(2m^2)\left[\frac{(2)}{}\left|\frac{9.8m}{s^2}\right|\frac{10^{-3}m}{kg}\left|\frac{50\times10^3(kg)(m)}{(s^2)(m^2)}\right|\frac{1}{1-\left(\frac{2}{5}\right)^2}\right]^{1/2}$$

The net units on the right-hand side of the equation are

$$m^2\left[\frac{m^3}{s^4}\right]^{1/2} \neq \frac{m^3}{s}$$

Consequently, the formula will not yield 80.8 m^3/s; presumably in the formula the g should be g_c for use in the AE system.

2.3.11 $Q = 0.61S\sqrt{(2\Delta p)/\rho}$ Assume hole is open to atmosphere.

$$\Delta p = \frac{144\ in^2}{1\ ft^2}\left[\frac{23\ lb_f}{in^2} + \frac{73\ in\ gas.}{}\left|\frac{0.703\ H_2O}{1\ gas}\right|\frac{1\ ft}{12\ in}\left|\frac{14.7\ \frac{lb_f}{in^2}}{33.91\ ft\ H_2O}\right.\right]$$

$= 3{,}579\ lb_f/ft^2$

$$\rho = \frac{0.703\frac{lb}{ft^3}}{1\ lb/ft^3 H_2O}\left|\frac{14.7}{62.4}\frac{l-bH_2O}{ft^3 H_2O}\right. = 43.87\frac{lb_m}{ft^3}\ N$$

$$S = \pi\left(\frac{1}{(4)12}\right)^2 = 3.41\times10^{-4} ft^2$$

$$Q = (3600)(0.61)(3.41\times10^{-4})\sqrt{(2)(3579)g_c / 43.87} = \boxed{54\frac{ft^3}{hr}}$$

2.3.12 a. $Z = 1 + \rho B + \rho^2 C + \rho^3 D$

	Units
B	cm^3 / g mol
C	$(cm^3/\text{ g mol})^2$
D	$(cm^3/\text{ g mol})^3$

b. $Z = 1 + \rho^* B^* + (\rho^*)^2 C^* + (\rho^*)^3 D^*$

	Units
B*	ft^3 / lb_m
C*	$(ft^3/ lb_m)^2$
D*	$(ft^3/ lb_m)^3$

If B is the original coefficient, B* is obtained by multiplying B by conversion factors. Let MW be the molecular weight of the compound.

$$B^* \frac{ft^3}{lb_m} = \frac{B\ cm^3}{g\ mol}\left|\left(\frac{1\ ft}{30.48\ cm}\right)^3\right|\frac{1\ g\ mol}{MW\ g}\left|\frac{454\ g}{1\ lb_m}\right. = \boxed{B\ \frac{0.016}{MW}}$$

$$C^*\left(\frac{ft^3}{lb_m}\right)^2 = C\left(\frac{cm^3}{g\ mol}\right)^2\left|\left(\frac{1\ ft}{30.48\ cm}\right)^6\right|\left(\frac{1\ g\ mol}{MWg}\right)^2\left|\left(\frac{454g}{1\ lb_m}\right)^2\right. = \boxed{C\ \frac{2.57\times10^{-4}}{MW^2}}$$

$$D^*\left(\frac{ft^3}{lb_m}\right)^3 = \boxed{D\ \frac{4.096\times10^{-6}}{MW^3}}$$

2.3.13

$$u\left[\frac{m}{s}\right] = k[1]\left[\left(\frac{\tau}{\rho}\right)^{1/2}\left(\frac{N}{m^2}\right)^{1/2}\left(\frac{m^3}{kg}\right)^{1/2}\right]$$

To get u in ft/s, substitute for τ and for ρ, and multiply both sides of the equation by 3.281 ft/1 m (k is dimensionless).

$$\tau\frac{N}{m^2} = \frac{\tau' lb_f}{ft^2}\left|\left(\frac{3.281\ ft}{1\ m}\right)^2\right|\frac{1\ N}{0.2248\ lb_f}$$

$$\rho\frac{kg}{m^3} = \frac{\rho'\ lb_m}{ft^3}\left|\left(\frac{3.281\ ft}{1\ m}\right)^3\right|\frac{1\ kg}{0.454\ lb_m}$$

$$\boxed{u' = 2.57\ k\left(\frac{\tau'}{\rho'}\right)}$$

2.3.14 Place units for the symbols in the given equation, and equate the units on the left- and right-hand sides of the equation by assigning appropriate units to the coefficient 0.943.

LHS RHS

$$\frac{Btu}{(hr)(ft^2)(\Delta°F)} \stackrel{?}{=} \left[\left(\frac{Btu}{(hr)(ft)(\Delta°F)}\right)^3\left|\left(\frac{lb_m}{ft^3}\right)^2\right|\frac{ft}{(hr)^2}\left|\frac{Btu}{lb_m}\right|\frac{}{ft}\left|\frac{(hr)(ft)}{lb_m}\right|\frac{}{\Delta°F}\right]^{1/4}$$

The units are the same on the right and left so that 0.943 has no units associated with it.

2.3.15

$$\eta = \frac{\text{numerator}}{\text{denominator}}$$

$$\text{Numerator} = Y^c_{x/s}\ \gamma_b\ \Delta H^c_{b/e^-}$$

$$= \left(\frac{\text{mol cell C}}{\text{mole substrate C}}\right)\left(\frac{e^-\ \text{equiv.}}{\text{mol cell C}}\right)\left(\frac{\text{energy}}{\text{mol } e^-\ \text{equiv.}}\right)$$

$$= \frac{\text{energy}}{\text{mol substrate C}} \qquad (1)$$

$$\text{Denominator} = \Delta H^{c}_{cat}$$

$$= \frac{\text{energy}}{\text{mol substrate C}} \qquad (2)$$

$$\eta = \frac{(1)}{(2)} = \frac{\text{energy}}{\text{energy}}$$

There is no missing conversion factor.
What the author claimed about the units is correct.

2.3.16 For dimensional consistency:
B – absolute temperature in either °R or K
C – absolute temperature in either °R or K
A – dimensionless

In most cases, the argument of a logarithm function should be dimensionless, but in this case it will not be. Therefore, the numerical values of A, B, and C will depend upon the units used for temperature and the units used for *p**.

2.3.17 The equation is

$$\Delta p = 4 f \rho \left[(v^2 / 2g)\ (L/D) \right]$$

The units on the right-hand side (with f dimensionless) in SI are

$$\rho \frac{\text{kg}}{\text{m}^3} \left(\frac{\frac{\text{m}^2}{\text{s}^2}}{\frac{(\text{kg})(\text{m})}{\text{s}^2}} \left| \frac{\text{m}}{\text{m}} \right. \right) \rightarrow \frac{1}{\text{m}^2}$$

Hence, the equation is not dimensionally consistent because Δp has the units of N/m^2. If g is replaced with g, the units would be correct.

2.3.18 First multiply the RHS of the equation so that

Btu	1054.8J	1 lb mol	1.8°F	1°C
(lbmol)(°F)	1 Btu	454 gmol	1.0°C	1K

$$= 4.182 \frac{J}{(gmol)(K)}$$

and substitute $T_{°F} = 1.8T_{°C} + 32$

$$C_p = [8.488 + 0.5757\times10^{-2}(1.8T_{°C} + 32) - 0.2159\times10^{-5}(1.8T_{°C} + 32)^2 + 0.3059\times10^{-9}(1.8T_{°C} + 32)^3]4.182\frac{J}{(gmol)(K)}$$

Simplifying,

$$C_p = 36.05 + 0.0447T - 0.2874 \times 10^{-4} T^2 + 0.7424 \times 10^{-8} T^3$$

2.3 Measurement Errors and Significant Figures

2.4.1

(a) 1.24×10^{1}: 3 significant figures
(b) 2.3×10^{-3}: 2 significant figures
(c) $1.\ \times10^{2}$: 1 significant figure
Or 1.0×10^{2}: 2 significant figures
Or 1.00×10^{2}: 3 significant figures
(d) 2.234×10^{4}: 4 significant figures
Or 2.2340×10^{4}: 5 significant figures
(e) 2.0001×10^{-1}: 5 significant figures
(f) 2.000×10^{3}: 4 significant figures
(g) $9.\times10^{-3}$: 1 significant figure
(h) 2.30×10^{-3}: 3 significant figures
(i) 7.78×10^{2}: 3 significant figures
(j) 7.780×10^{2}: 4 significant figures

2.4.2

(a) 3 significant figures: $\pm$ 0.1%
(b) 2 significant figures: $\pm$ 1%
(c) 1 significant figure: $\pm$ 10%
Or 2 significant figures: $\pm$ 1%
Or 3 significant figures: $\pm$ 0.1%
(d) 4 significant figures: $\pm$ 0.01%
Or 5 significant figures: $\pm$ 0.001%
(e) 5 significant figures: $\pm$ 0.001%
(f) 4 significant figures: $\pm$ 0.01%
(g) 1 significant figure: $\pm$ 10%
(h) 3 significant figures: $\pm$ 0.1%
(i) 3 significant figures: $\pm$ 0.1%
(j) 4 significant figures: $\pm$ 0.01%

2.4.3

(a) $1.1\ \times10^{-3}$: 2 significant figures
(b) $5.\ \times10^{3}$: 1 significant figure
Or 5.0×10^{3}: 2 significant figures
(f) 4.354×10^{5}: 4 significant figures
Or 4.3540×10^{5}: 5 significant figures
Or 4.35400×10^{5}: 6 significant figures
(g) 1.0010×10^{2}: 5 significant figure

Or 5.00×10^{3}: 3 significant figures
Or 5.000×10^{3}: 4 significant figures
(c) 2.3001×10^{0}: 5 significant figures
(d) 8.877×10^{5}: 4 significant figures
Or 8.8770×10^{5}: 5 significant figures
(e) 8.87700×10^{5}: 6 significant figures

(h) $5.61\times10^{-}$: 3 significant figures
(i) 1.000×10^{0}: 4 significant figures
(j) $1.\times10^{1}$: 1 significant figures
Or 1.0×10^{1}: 2 significant figures

2.4.4

(a) 2 significant figures: $\pm 1\%$
(b) 1 significant figure: $\pm 10\%$
Or 2 significant figures: $\pm 1\%$
Or 3 significant figures: $\pm 0.1\%$
Or 4 significant figures $\pm 0.01\%$
(c) 5 significant figures: $\pm 0.001\%$
(d) 4 significant figures: $\pm 0.01\%$
Or 5 significant figures: $\pm 0.001\%$
(e) 6 significant figures: $\pm 0.0001\%$

(f) 4 significant figures : $\pm 0.01\%$
Or 5 significant figures: $\pm 0.001\%$
Or 6 significant figures: $\pm 0.0001\%$
(g) 5 significant figures: $\pm 0.001\%$
(h) 3 significant figures: $\pm 0.1\%$
(i) 4 significant figures: $\pm 0.01\%$
(j) 1 significant figures: $\pm 10\%$
Or 2 significant figures: $\pm 1\%$

2.4.5 Two because any numbers added to the right-hand side of the decimal point in 10 are irrelevant.

2.4.6 The sum is 1287.1430. Because 1234 has only 4 significant figures to the left of an implied decimal point, the answer should be 1287 (no decimal point).

2.4.7	The number of significant figures to the right of the decimal point is 1 (from 210.0m); hence, the sum of 215.110 m should be rounded to 215.1 m.
2.4.8	A calculator gives 569.8269 000, but you should truncate to 4 significant figures, or 569.8 cm^2.
2.4.9	Two significant figures (based on 6.3). Use 4.8×10^3.
2.4.10	Step 1: The product 1.3824 is rounded off to 1.4. Step 2: Calculate errors. For absolute error, the product 1.4 means 1.4 ± 0.05. Thus $\frac{0.05}{1.4} \times 100\% = 3.6\%$ error Similarly, 3.84 has $\frac{0.005}{3.84} \times 100\% = 0.13\%$ error and 0.36 has $\frac{0.005}{0.36} \times 100\% = 1.4\%$ error Total 2.7% error

2.5 Validating Solutions

2.5.1

a. $6 \times 4 / 3 = 8$ Exact solution = 7.704

b. 1.45 The second term is much smaller than the first term. Exact solution = 1.423

c. $3 \times 4 \times 2^8 / 3 = 4 \times 8 = 32$ Exact solution = 31.54

d. $8 \times 3 \times (16 \times 50 - 25) / 3 = 8(800 - 25) = 6400 - 200 = 6200$ Exact solution = 6767

e. $88.8 \times (1 + 1) / 2 = 88.8$ Exact solution = 87.47

2.6 Mass, Moles, and Density

2.6.1 Choosing a Basis

2.6.1	(a) A gas requires a convenient basis of 1 or 100 g moles or kg moles (if using SI units). (b) A gas requires a convenient basis of 1 or 100 lb moles (if using AE units).

(c) Use 1 or 100 kg of coal, or 1 or 100 lb of coal because the coal is a solid and mass is a convenient basis.

(d) Use 1 or 100 moles (SI or AE) as a convenient basis as you have a gas.

(e) Use 1 or 100 moles (SI or AE) as a convenient basis as you have a gas.

2.6.2 Since the mixture is a gas, use 1 or 100 moles (SI or AE) as the basis.

2.6.3 Pick one day as a basis that is equivalent to what is given—two numbers:

(a) 134.2 lb C1 (b) 10.7×10^6 gal water.

2.6.2 The Mole and Molecular Weight

2.6.4

a) $$\frac{4 \text{ g mol mg } Cl_2}{} \left| \frac{(95.23) \text{g } MgCl_2}{\text{gmol } MgCl_2} \right. = \boxed{380.9 \text{ g}}$$

b) $$\frac{2 \text{ lb mol } C_3H_8}{} \left| \frac{(44.09) \text{lb } C_3H_8}{\text{lb mol } C_3H_8} \right| \frac{454 \text{g } C_3H_8}{1 \text{ lb } C_3H_8} = \boxed{4 \times 10^4 \text{g } C_3H_8}$$

c) $$\frac{16 \text{ g } N_2}{} \left| \frac{\text{gmol } N_2}{(28.02) \text{g } N_2} \right| \frac{1 \text{ lb mol } N_2}{454 \text{ gmol } N_2} = \boxed{1.26 \times 10^{-3} \text{ lb mol } N_2}$$

(d) $$\frac{3 \text{ lb } C_2H_6O}{} \left| \frac{1 \text{ lb mol } C_2H_6O}{(46.07) \text{ lb } C_2H_6O} \right| \frac{454 \text{ g mol}}{1 \text{ lb mol}} = \boxed{29.56 \text{ g mol } C_2H_6O}$$

2.6.5

(a) $\dfrac{16.1 \text{ lb mol HCl}}{} \left| \dfrac{36.5 \text{ lb HCl}}{1 \text{ lb mol HCl}} \right. = \boxed{588 \text{ lb HCl}}$

(b) $\dfrac{19.4 \text{ lb mol KCl}}{} \left| \dfrac{74.55 \text{ lb KCl}}{1 \text{ lb mol KCl}} \right. = \boxed{1466 \text{ lb KCl}}$

(c) $\dfrac{11.9 \text{ g mol NaNO}_3}{} \left| \dfrac{85 \text{ g NaNO}_3}{1 \text{ g mol NaNO}_3} \right| \dfrac{2.20 \times 10^{-3} \text{lb}}{1 \text{ g}} = \boxed{2.23 \text{ lb NaNO}_3}$

(d) $\dfrac{164 \text{ g mol SiO}_2}{} \left| \dfrac{60.1 \text{ g SiO}_2}{1 \text{ g mol SiO}_2} \right| \dfrac{2.20 \times 10^{-3} \text{lb}}{1 \text{ g}} = \boxed{21.7 \text{ lb SiO}_2}$

2.6.6

Basis: 100 g of the compound

comp.	g	MW	g mol	Ratio of Atoms
C	42.11	12	3.51	1.09
O	51.46	16	3.22	1
H	6.43	1.008	6.38	2
			13.11	

Multiply by 11 to convert the ratios into integers

The formula becomes $C_{12}O_{11}H_{22}$.

Checking MW: 12(12) + 11(16) + 22(1.008) = 342 (close enough)

2.6.7 Vitamin A, $C_{20}OH_{30}$, Mol Wt.: 286 Vitamin C, $C_6H_8O_6$, mol. wt: 176

a. $$\text{Vitamin A} = \frac{2.00 \text{ g mol}}{} \left| \frac{286 \text{ g}}{1 \text{ g mol}} \right| \frac{1 \text{ lb}}{454 \text{ g}} = \boxed{1.26 \text{ lb}}$$

$$\frac{16 \text{ g}}{} \left| \frac{1 \text{ lb}}{454 \text{ g}} \right. = 0.0352 \text{ lb}$$

$$\text{Vitamin C} = \frac{2.00 \text{ g mol}}{} \left| \frac{176 \text{ g}}{\text{g mol}} \right| \frac{1 \text{ lb}}{454 \text{ g}} = \boxed{0.775 \text{ lb}}$$

$$\frac{16 \text{ g}}{} \left| \frac{1 \text{ lb}}{454 \text{ g}} \right. = \boxed{0.0352 \text{ lb}}$$

b. $$\text{Vitamin A} = \frac{1.00 \text{ lb mol}}{} \left| \frac{286 \text{ lb}}{1 \text{ lb mol}} \right| \frac{454 \text{ g}}{1 \text{ lb}} = \boxed{130{,}000 \text{ g}}$$

$$\text{Vitamin C} = \frac{1.00 \text{ lb mol}}{} \left| \frac{176 \text{ lb}}{1 \text{ lb mol}} \right| \frac{454 \text{ g}}{1 \text{ lb}} = \boxed{79{,}900 \text{ g}}$$

For both $$\frac{12 \text{ lb}}{} \left| \frac{454 \text{ g}}{1 \text{ lb}} \right. = \boxed{5450 \text{ g}}$$

2.6.8 $$\frac{1 \text{ kg}}{5.2 \text{ m}^3} \left| \frac{1160 \text{ m}^3}{\text{kg mol}} \right. = 223.1 \text{ kg/kg mol}$$

2.6.9 Mass fraction to mole fraction:

$$x_1 = \frac{\dfrac{\omega_1}{MW_1}}{\dfrac{\omega_1}{MW_1} + \dfrac{(1-\omega_1)}{MW_2}}$$

Mole fraction to mass fraction

$$\omega_1 = \frac{x_1 MW_1}{(x_1)(MW_1) + (1 - x_1)(MW_2)}$$

2.610 Basis: 100 kg mol gas

Comp.	Mol % = mol	MW	kg
CH_4	30	16	480
H_2	10	2	20
N_2	60	28	1680
Total	100		2180

$$\boxed{\frac{21.8\text{ kg}}{\text{kg mol}}}$$

2.6.11 Basis: 100 g mol gas

Comp.	mol = %	MW	g
CO_2	19.3	44	849.2
N_2	72.1	28	2018.8
O_2	6.5	32	208.0
H_2O	2.1	18	37.8
	100.0		3113.8

$$\text{Avg. mol. wt} = \frac{3113.8}{100.0} = \boxed{31.138}$$

2.6.12 Basis: 100 lb mol

Comp.	% = mol	MW	lb
CO_2	16	44	2640
CO	10	28	280
N_2	30	28	840
			3760

Avg. MW = 37.6 lb/lb mol

2.6.13

(a) $10\times1000\times6.022\times10^{23} = 6.022\times10^{27}$ molecules of Bz
(b) $10\times2.2046=22.046$ lb mol Bz
(c) $78\times22.046=1719.6$ lb Bz
(d) 10,000 gmol Bz
(e) 60,000 gmol H
(f) 60,000 gmol C

Section 2.6.3 Density and Specific Gravity

2.6.14

$$\frac{100\ \text{lb}_m}{} \left| \frac{\text{ft}^3}{62.4 \times 5.25\ \text{lb}_m} \right. = 0.0305\ \text{ft}^3$$

2.6.15 Basis: 1000 lb oil

$$\frac{0.926 \dfrac{\text{lb oil}}{\text{ft}^3}}{1.00 \dfrac{\text{lb } H_2O}{\text{ft}^3}} \left| \frac{62.4 \dfrac{\text{lb } H_2O}{\text{ft}^3}}{} \right. = 57.78 \frac{\text{lb oil}}{\text{ft}^3 \text{ oil}}$$

$$\frac{1000\ \text{lb oil}}{} \left| \frac{1\ \text{ft}^3\ \text{oil}}{57.78\ \text{lb oil}} \right| \frac{7.48\ \text{gal}}{1\ \text{ft}^3} = 129.5\ \text{gal}$$

2.6.16 Basis: 10,010 lb

$$\frac{10{,}010\ \text{lb}}{} \left| \frac{1\ \text{gal}}{8.80\ \text{lb}} \right| \frac{0.134\ \text{ft}^3}{\text{gal}} = \boxed{152\ \text{ft}^3}$$

2.6.17 Basis: 1 g mol each compound

	g mol	mw	g	ρ (g/cm^3)	V (cm^3)
Pb	1	207.21	207.21	11.33	18.3
Zn	1	65.38	65.38	7.14	9.16
C	1	12.01	12.01	2.26	5.31

$$\hat{V} = \frac{\text{mass (g)}}{\text{density (g/cm}^3)}$$

Set 2 is the correct one.

Section 2.7.2 Pressure and Hydrostatic Head

2.7.1

Basis: $15 cm^3$ water

a. $$m = \rho V = \frac{1000\ \text{kg}}{m^3}\left|\frac{10\ \text{m}}{}\right|\frac{10\ \text{m}}{}\left|\frac{0.15\ \text{m}}{}\right. = \boxed{15{,}000\ \text{kg}}$$

b. $$\frac{F}{A} = \frac{m\,g}{A} = \frac{15{,}000\ \text{kg}}{}\left|\frac{9.80\ \text{m}}{s^2}\right|\frac{}{10\ \text{m}}\left|\frac{}{10\ \text{m}}\right|\frac{1\ \text{N}}{1\frac{(\text{kg})(\text{m})}{s^2}}\left|\frac{1\ \text{Pa}}{\frac{\text{N}}{m^2}}\right. = 1470\ \text{Pa}$$

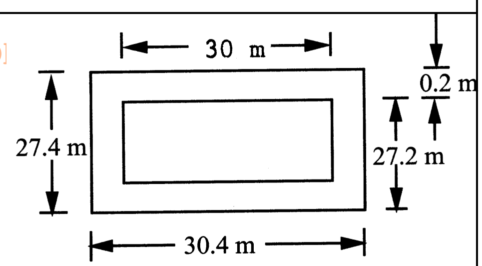
$$= \boxed{1.47\ \text{kPa}}$$

$$\frac{1.470\ \text{kPa}}{}\left|\frac{1\ \text{atm}}{101.3\ \text{kPa}}\right|\frac{14.7\ \text{psi}}{\text{atm}} = \boxed{0.21\ \text{psi}}$$

or $$\frac{15\ \text{cm}\ H_2O}{}\left|\frac{1\ \text{in.}}{2.54\ \text{cm}}\right|\frac{1\ \text{ft}}{12\ \text{in.}}\left|\frac{14.696\ \text{psi}}{33.91\ \text{ft}\ H_2O}\right. = 0.21$$

2.7.2

$$\rho_{concrete} = 2080\ kg/m^3$$
$$\rho_{water} = 1000\ kg/m^3$$



Volume of concrete:

Sides

$$V_s = \frac{5\ \text{m}}{}\left|\frac{30.2\ \text{m}}{}\right|\frac{200\ \text{mm}}{}\left|\frac{1\ \text{m}}{1000\ \text{mm}}\right|\frac{2\ \text{sides}}{} = 60.4\ m^3$$

Ends

$$V_e = \frac{5\ \text{m}}{}\left|\frac{27.2\ \text{m}}{}\right|\frac{200\ \text{mm}}{}\left|\frac{1\ \text{m}}{1000\ \text{mm}}\right|\frac{2\ \text{ends}}{} = 54.4\ m^3$$

Floor

$$V_f = \frac{27.4\ \text{m}}{}\left|\frac{30.4\ \text{m}}{}\right|\frac{200\ \text{mm}}{}\left|\frac{1\ \text{m}}{1000\ \text{mm}}\right. = 166.592\ m^3$$

Total volume = 281.392 m^3

Mass of concrete = $\dfrac{281.392\ m^3}{} \left| \dfrac{2080\ kg}{m^3} \right. = 585{,}295$

Volume of displaced water required to float:

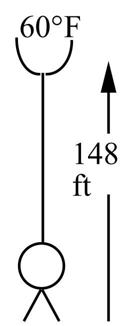
$$\frac{586{,}543.36\ \text{kg}}{} \left| \frac{1\ \text{m}^3\ H_2O}{1000\ \text{kg}\ H_2O} \right. = 586.543\ \text{m}^3$$

$$V = LWh \rightarrow h = \frac{V}{LW}$$

$$h = \frac{586.54\ \text{m}^3}{} \left| \frac{}{27.4\text{m}} \right| \frac{}{30.4\ \text{m}} = \boxed{0.703\ \text{m}}$$

2.7.3 The pressure is a gauge pressure.

Basis: 50.0 psig



a.

$$\frac{50.0\ \text{psig}}{} \left| \frac{33.91\ \text{ft}\ H_2O}{14.7\ \text{psia}} \right. = \boxed{115\ \text{ft}}$$

(difference)

b. No. Insufficient height.

Alternate solutions can be applying $\Delta p = \rho \Delta hg$.

2.7.4 $\dfrac{lb_f}{in.^2} \left| \dfrac{in.^2}{} \right. = lb_f \rightarrow lb_m$ in the AE system

so the procedure is ok, although the unit conversion is ignored.

2.7.5 Basis: Dept = 1000 m $\quad p = p_o + \rho g h$

$$p = 1\text{ atm} + \frac{1000\text{ m}}{}\left|\frac{1.024\text{ g}}{\text{cm}^3}\right|\frac{9.8\text{ m}}{\text{s}^2}\left|\frac{1\text{ kg}}{10^3\text{ g}}\right|\left(\frac{100\text{ cm}}{1\text{ m}}\right)^3\left|\frac{1\text{ N}}{\frac{(\text{kg})(\text{m})}{\text{s}^2}}\right|\frac{1\text{ kPa}}{\frac{1\text{N}}{\frac{(\text{kg})(\text{m})}{\text{s}^2}}}\left|\frac{1\text{ atm}}{1.013\times10^5\text{ N/m}^2}\right.$$

$$= \frac{100.1\text{ atm}}{}\left|\frac{101.3\text{ kPa}}{1\text{ atm}}\right. = \boxed{1.014\times10^4\text{kPa}}$$

Alternative solution:

$A_{Top} = 730.62\,\text{m}^2\text{ kPa}$

2.7.6 (a) $p_{ABS} = p_{Gauge} + p_{atm}$

$$\left(\frac{22.4\text{ lb}_f}{1\text{ in.}^2}\left|\frac{144\text{ in.}^2}{1\text{ ft}^2}\right.\right)+\left(\frac{28.6\text{ in. Hg}}{1}\left|\frac{14.7\text{ psia}}{29.92\text{ in. Hg}}\right|\frac{144\text{ in.}^2}{1\text{ ft}^2}\right)=\boxed{5250\text{ lb}_f/\text{ft}^2}$$

(b) $$\left(\frac{22.4\text{ psig}}{}\left|\frac{29.92\text{ in. Hg}}{14.7\text{ psia}}\right.\right)+28.6\text{ in. Hg}=\boxed{74.2\text{ in. Hg}}$$

(c) $$\left(\frac{22.4\text{ psig}}{1}\left|\frac{1.013\times10^5\text{N/m}^2}{14.7\text{ psia}}\right.\right)+\left(\frac{28.6\text{ in. Hg}}{1}\left|\frac{1.013\times10^5\text{N/m}^2}{27.92\text{ in. Hg}}\right.\right)=\boxed{2.51\times10^5\text{N/m}^2}$$

(d) $$\left(\frac{22.4\text{ psig}}{1}\left|\frac{33.91\text{ ft H}_2\text{O}}{14.7\text{ psia}}\right.\right)+\left(\frac{28.6\text{ in. Hg}}{1}\left|\frac{33.91\text{ ft H}_2\text{O}}{29.92\text{ in. Hg}}\right.\right)=\boxed{84.1\text{ ft H}_2\text{O}}$$

2.7.7 Neither John is necessarily right. The pressure at the top of Pikes Peak is continually changing.

2.7.8 $\Delta p = \rho g h$

a. $$= \frac{1 \text{ g}}{\text{cm}^3}\left|\frac{9.8 \text{ m}}{\text{s}^2}\right|\frac{13.1 \text{ m}}{}\left|\frac{1 \text{ kg}}{1000 \text{ g}}\right|\frac{(100 \text{ cm})^3}{\text{m}^3}\left|\frac{\text{Pa}}{\frac{1 \text{ kg}}{\text{m s}^2}}\right|\frac{1 \text{ kPa}}{1000 \text{ Pa}}$$

$$= 128.4 \text{ kPa}$$

b. $$\frac{F}{A} = \frac{mg}{A_{Bottom}} = \frac{\rho V g}{A_{Bottom}} = \frac{\rho (S.A.)(t) g}{A_{Bottom}}$$

$$A_{Bottom} = \frac{\pi}{4} D^2 = \frac{\pi}{4}\left|\frac{(30.5 \text{ m})^2}{}\right. = 730.62 \text{ m}^2$$

$$A_{TOP} = 730.62 \text{ m}^2$$

$$A_{side} = \pi D h = \pi (30.5 \text{ m})(13.1 \text{m}) = 1255.2 \text{ m}^2$$

$$S.A. = A_{Top} + A_{Bottom} + A_{Side}$$

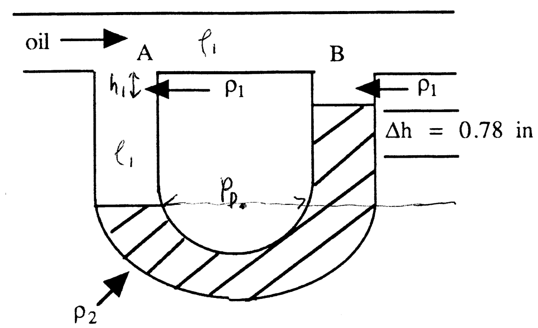
$$= (730.62 + 730.62 + 1255.22) \text{ m}^2 = 2716.46 \text{ m}^2$$

$$\frac{\rho (S.A.)(t) g}{A} =$$

$$\frac{7.86 \text{ g}}{\text{cm}^3}\left|\frac{(100 \text{ cm}^3)}{\text{m}^3}\right|\frac{2{,}716.46 \text{ m}^2}{}\left|\frac{9.35 \times 10^{-3} \text{m}}{}\right|\frac{}{730.6 \text{ m}^2}\left|\frac{9.8 \text{ m}}{\text{s}^2}\right|$$

$$\frac{1 \text{ kg}}{1000 \text{ g}}\left|\frac{1 \text{ Pa}}{1 \text{ kg / ms}^2}\right|\frac{1 \text{ kPa}}{1000 \text{ Pa}} = \boxed{2.68 \text{ kPa}}$$

2.7.9



$$p_A + \rho_1 g h_1 + \rho_2 g \Delta h = P_D$$
$$p_B + \rho_1 g h_1 + \rho_2 g \Delta h = P_D$$

$$p_A - p_B = \rho_1 g h_1 + \rho_2 g \Delta h - \rho_1 g h_1 - \rho_1 g \Delta h$$

$$= \rho_2 g \Delta h - \rho_1 g \Delta h = g\Delta h(\rho_2 - \rho_1)$$

$$= \frac{9.8\,\text{m}}{\text{s}^2}\left|\frac{0.78\,\text{in}}{}\right|\frac{1\,\text{m}}{3.28\,\text{ft}}\left|\frac{13.546-0.91\,\text{g}}{\text{cm}^3}\right|\frac{1\,\text{kg}}{1000\,\text{g}}$$

$$\frac{1\ \text{ft}}{12\ \text{in}}\left|\left(\frac{100\ \text{cm}}{1\ \text{m}}\right)^3\right|\frac{\frac{1\ \text{N}}{\text{m}^2}}{\frac{1\ \text{kg}}{(\text{m})(\text{s})^2}}\left|\frac{1\ \text{Pa}}{\frac{1\ \text{N}}{\text{m}^2}}\right|\frac{760\ \text{mm}\ \text{H}_2}{101.3\times10^3\text{Pa}}$$

$$\boxed{=18.4\ \text{mm Hg}}$$

The pressure at A is higher than the pressure at B.

Alternate solution:

$$\Delta p = \frac{(0.78\ \text{in.})}{}\left|\frac{(13.546-0.91)}{13.546}\right|\frac{760\ \text{mm Hg}}{29.92\ \text{in. Hg}} = 18.5\ \text{mm Hg}$$

Section 2.7.4 Flow rate

2.7.10

2.7.11

2.7.12

2.7.13

Section 2.7.5 Concentration

2.7.14

Component	g mol	mol fraction	MW	g	mass fraction
Na	1	0.20	23	23	0.22
C1	1	0.20	35.45	35.45	0.33
O	3	0.60	16	48	0.45
	5			106.45	1.00

2.7.15 Basis: 1 gal of solution.

Mass of solution:

$$\frac{\dfrac{1.0824\ \text{lb soln}}{\text{ft}^3\ H_2O}}{1.00\dfrac{\text{lb}\ H_2O}{\text{ft}^3 H_2O}} \left| \frac{62.4\dfrac{\text{lb}\ H_2O}{\text{ft}^3 H_2O}}{} \right| \frac{1\ \text{ft}^3}{7.481\ \text{gal}} \left| \frac{1\ \text{gal}}{} \right. = \boxed{9.03\ \text{lb soln}}.$$

$$\text{Mass fraction KOH} = \frac{0.813\ \text{lb}}{9.03\ \text{lb}} = \boxed{0.09}$$

$$\text{Mass fraction } H_2O = 1 - 0.09 = \boxed{\begin{array}{l} 0.91 \\ \hline 1.00\ \text{Total} \end{array}}$$

2.7.16 Basis: 30 lb gas

Comp.	lb	MW	lb mol	mol fr.
CO_2	20	44	0.455	0.56
N_2	10	28	0.357	0.44
	30		0.812	1.00

2.7.17 a) $\boxed{1000}$

b) $\boxed{\text{No}}$

c) Yes, because for solids and liquids the ratio in ppb is mass, whereas for gases the ratio is in moles.

2.7.18 On a paper-free basis, the total ppm are:

Brand A: 6060 ppm Brand B: 405 ppm

The respective mass fractions are:

The other entries are similar

	Fe	Cu	Pb
Brand A:	$\frac{1310}{6060} = 0.216$	$\frac{2000}{6060} = 0.330$	$\frac{2750}{6060} = 0.454$
Brand B:	$\frac{350}{405} = 0.864$	$\frac{50}{405} = 0.123$	$\frac{5}{405} = 0.0123$

$$V_s = \frac{5\text{ m}}{} \left| \frac{30.2\text{ m}}{} \right| \frac{200\text{ mm}}{} \left| \frac{1\text{ m}}{1000\text{ mm}} \right| \frac{2\text{ sides}}{} = 60.4\ \text{m}^3$$

Ends

$$V_e = \frac{5\text{ m}}{} \left| \frac{27.2\text{ m}}{} \right| \frac{200\text{ mm}}{} \left| \frac{1\text{ m}}{1000\text{ mm}} \right| \frac{2\text{ ends}}{} = 54.4\ \text{m}^3$$

Floor

$$V_f = \frac{27.4\text{ m}}{}\Bigg|\frac{30.4\text{ m}}{}\Bigg|\frac{200\text{ mm}}{}\Bigg|\frac{1\text{ m}}{1000\text{ mm}} \qquad = 166.592\ \text{m}^3$$

Total volume = 281.392 m^3

$$\text{Mass of concrete} = \frac{281.392\text{ m}^3}{}\Bigg|\frac{2080\text{ kg}}{\text{m}^3} = 585{,}295\text{ kg}$$

Volume of displaced water required to float:

$$\frac{586{,}543.36\ \text{kg}}{}\Bigg|\frac{1\ \text{m}^3\ \ H_2O}{1000\ \text{kg}\ \ H_2O} = 586.543\ \text{m}^3$$

$$V = LWh \rightarrow h = \frac{V}{LW}$$

$$h = \frac{586.54\ \text{m}^3}{}\Bigg|\frac{}{27.4\text{m}}\Bigg|\frac{}{30.4\ \text{m}} = \boxed{0.703\text{ m}}$$

2.7.19 Basis: 190,000 ppm

$$\frac{190{,}000\ \text{g}\ \ \text{PCB}}{10^6} \times 100 = \boxed{19\%}$$

2.7.20

Basis: 100 g of the sample

The biomass sample is

	g = % dry weight of cells
C	50.2
O	20.1
H	8.2
P	3.0
	95.5
other	4.5
Total	100.0

$$\frac{10.5 \text{ g cells}}{\text{g mol ATP}}\left|\frac{50.2 \text{ g C}}{100 \text{ g cells}}\right|\frac{1 \text{ g mol C}}{12 \text{ g C}} = 0.439 \text{ g mol C/g mol ATP}$$

2.7.21

$$\text{MMM(s)} \rightarrow \text{NN(s)} + 3\text{CO}_2\text{(g)}$$

a. $$\frac{2\times10^7 \text{disintegrations}}{\text{min}}\left|\frac{1 \text{ min}}{60}\right|\frac{1 \text{ curie}}{3\times10^{10} \text{disintegrations/s}}\left|\frac{10^6 \mu \text{ curie}}{1 \text{ curie}}\right. = 11\mu \text{ curie}$$

b. $$\frac{2\times10^7 \text{ disintegrations}}{\text{min}}\left|\frac{0.80}{}\right. = \boxed{1.6\times10^7 \text{cpm}}$$

2.7.22

The relation to use is

$$t_{1/2} = \ell n(2)/(k)(OH^-)T$$

with $(OH^-) = 1.5\times10^6$

	k	$t_{1/2}$ = (seconds)
Methanol	0.15×10^{-12}	30.8×10^5
Ethanol	1×10^{-12}	4.6×10^5
MTBE	0.60×10^{-12}	7.7×10^5

The order is in increasing persistence ethanol, MTBE, and methanol.

2.7.23 Yes. Bases are first entries.

$$\frac{4800 \text{ g mol } CCl_4}{10^9 \text{ g mol air}}\left|\frac{10^3 \text{ g mol air}}{\text{kg mol air}}\right|\frac{\text{kg mol air}}{22.8 \text{ m}^3}\left|\frac{154 \text{ g } CCl_4}{\text{g mol } CCl_4}\right|\frac{10^3 \text{ mg } CCl_4}{\text{g } CCl_4} =$$

32.4 mg CCl_4/m^3 which exceeds the NIOSH standards

2.7.24

a. $$\frac{25{,}600 \text{ ton P}}{\text{yr}}\left|\frac{2.6 \text{ yr}}{}\right|\frac{1}{1.2\times10^{14}\text{ gal}}\left|\frac{1 \text{ gal}}{3.785 \text{ L}}\right|\frac{2000 \text{ lb}}{1 \text{ ton}}\left|\frac{454 \text{ g}}{1 \text{ lb}}\right|\frac{10^6 \mu\text{ g}}{1 \text{ g}}$$

$= 133.1\ \mu g/L$

b. $$\frac{19{,}090 \text{ lb(P)municipal}}{30{,}100 \text{ lb(P)total}} = \boxed{63.4\%}$$

c. $$\frac{19{,}090 \text{ lb(P)municipal}}{30{,}100 \text{ lb(P)total}}\left|\frac{0.70 \text{ lb(P)det.}}{1 \text{ lb(P)municipal}}\right|\frac{100 \text{ lb(P)}_{total}}{30{,}100 \text{ lb(P)}_{total}} = \boxed{44.4\%}$$

For d. and e. assume that (P)outflow remains unchanged.

d. P retained/yr = 2,240 + 6,740 + 0.7 × 19,090 – 4,500 = 17,843 ton/yr.

P conc. in ppb =

$$\frac{17{,}843 \text{ ton}}{\text{yr}}\left|\frac{2.6 \text{ yr}}{}\right|\frac{1}{1.2\times10^{14}\text{ gal}}\left|\frac{2000 \text{ lb}}{\text{ton}}\right|\frac{1 \text{ g/cm}^3}{8.345 \text{ lb/gal}}\left|\frac{10^9 \text{ g}}{1\text{billion g}}\right. = 92.6 \text{ ppb}$$

This is greater than 10 ppb. $\boxed{\text{Eutrophication will not be reduced.}}$

e. P retained/yr = 2,240 + 6,740 + 0.3 × 19,090 – 4,500 = 10,207 $\frac{\text{ton}}{\text{yr}}$

P conc. in ppb =

$$\frac{10{,}207 \text{ ton}}{\text{yr}}\left|\frac{2.6 \text{ yr}}{}\right|\frac{}{1.2\times10^{14}\text{ gal}}\left|\frac{2000 \text{ lb}}{\text{ton}}\right|\frac{1 \text{ g/cc}}{8.345 \text{ lb/gal}}\left|\frac{10^9 \text{ g}}{1 \text{ billion g}}\right. = 53.2 \text{ ppb}$$

$\boxed{\text{This will not help.}}$

2.7.25 Basis: 10^6 g mol gas

$$\frac{350 \text{ g mol } H_2S}{10^6 \text{g mol gas}}\left|\frac{1 \text{ g mol gas}}{1 \text{ g mol } CO_2}\right|\frac{34 \text{g } H_2S}{1 \text{ g mol } H_2O}\left|\frac{1 \text{ g mol } CO_2}{44 \text{ g } CO_2}\right.$$

$$= \frac{270}{10^6}\;\frac{\text{g } H_2S}{\text{g } CO_2} = \frac{270}{10^6}\;\frac{\text{g } H_2S}{\text{g total liquid}}$$

mass fraction H_2S = $\boxed{2.70 \times 10^{-4}}$

2.7.26 (a) $$\frac{1 \text{ mol } O_2}{100 \text{ mol gas}} \Rightarrow \frac{10^4 \text{mol } O_2}{10^6 \text{ mol gas}} \text{ or } 10^4 \text{ ppm}$$

(b) Basis: 100 mol gas

Comp.	% = mol	mol fr.	answer or mol %
SO_3	55	0.932	93.2
SO_2	3	0.051	5.1
O_2	1	0.017	1.7
Total	59	1.000	100.0

2.7.27 MW $CaCO_3$: 100.06

Ca	40.05
Mg	24.3
C	12.01
O	16.00

$$\frac{100.06 \text{ g } CaCO_3}{\text{g mol Ca } CO_3}\left|\frac{1 \text{ g mol } CaCO_3}{1 \text{ g mol Ca}}\right|\frac{1 \text{ g mol Ca}}{40.05 \text{ g Ca}} = 2.50\;\frac{\text{g } CaCO_3}{\text{g Ca}}$$

Similarly $$\frac{\text{g } CaCO_3}{\text{g Mg}} = 4.118\;\frac{\text{g } CaCO_3}{\text{g Mg}}$$

Total alkalinity = 2.50 (56.4) + 4.118 (8.8) = $\boxed{177\;\frac{\text{mg } CaCO_3}{\text{L}}}$

2.7.28	No.	1 molecule in 10^{23} or more is not 13-20 ppb
2.7.29		On a mol basis, the carbon dioxide concentration in air is about 350 parts per million (ppm), while that of oxygen is about 209,500 ppm. If the atmospheric concentration of carbon dioxide is increasing at about 1% per year (i.e., from 350 ppm this year to 353.5 ppm next year), and not to 1%, the 3.5-ppm change in dioxide concentration causes the oxygen concentration to fall from 209,500 to about 209,497 ppm, which is less than a 0.002% decrease. So, there is no need to worry about an oxygen deficit at present.