1

Physics and Measurement

CHAPTER OUTLINE

1.1 Standards of Length, Mass, and Time
1.2 Matter and Model-Building
1.3 Density and Atomic Mass
1.4 Dimensional Analysis
1.5 Conversion of Units
1.6 Estimates and Order-of-Magnitude Calculations
1.7 Significant Figures

ANSWERS TO QUESTIONS

Q1.1 Atomic clocks are based on electromagnetic waves which atoms emit. Also, pulsars are highly regular astronomical clocks.

Q1.2 Density varies with temperature and pressure. It would be necessary to measure both mass and volume very accurately in order to use the density of water as a standard.

Q1.3 People have different size hands. Defining the unit precisely would be cumbersome.

Q1.4 (a) 0.3 millimeters (b) 50 microseconds (c) 7.2 kilograms

Q1.5 (b) and (d). You cannot add or subtract quantities of different dimension.

Q1.6 A dimensionally correct equation need not be true. Example: 1 chimpanzee = 2 chimpanzee is dimensionally correct. If an equation is not dimensionally correct, it cannot be correct.

Q1.7 If I were a runner, I might walk or run 10^1 miles per day. Since I am a college professor, I walk about 10^0 miles per day. I drive about 40 miles per day on workdays and up to 200 miles per day on vacation.

Q1.8 On February 7, 2001, I am 55 years and 39 days old.

$$55\text{ yr}\left(\frac{365.25\text{ d}}{1\text{ yr}}\right)+39\text{ d}=20\,128\text{ d}\left(\frac{86\,400\text{ s}}{1\text{ d}}\right)=1.74\times10^9\text{ s}\sim10^9\text{ s}.$$

Many college students are just approaching 1 Gs.

Q1.9 Zero digits. An order-of-magnitude calculation is accurate only within a factor of 10.

Q1.10 The mass of the forty-six chapter textbook is on the order of 10^0 kg .

Q1.11 With one datum known to one significant digit, we have 80 million yr + 24 yr = 80 million yr.

SOLUTIONS TO PROBLEMS

Section 1.1 Standards of Length, Mass, and Time

No problems in this section

Section 1.2 Matter and Model-Building

P1.1 From the figure, we may see that the spacing between diagonal planes is half the distance between diagonally adjacent atoms on a flat plane. This diagonal distance may be obtained from the Pythagorean theorem, $L_{\text{diag}} = \sqrt{L^2 + L^2}$. Thus, since the atoms are separated by a distance $L = 0.200 \text{ nm}$, the diagonal planes are separated by $\frac{1}{2}\sqrt{L^2 + L^2} = \boxed{0.141 \text{ nm}}$.

Section 1.3 Density and Atomic Mass

***P1.2** Modeling the Earth as a sphere, we find its volume as $\frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(6.37\times 10^6 \text{ m}\right)^3 = 1.08\times 10^{21} \text{ m}^3$. Its density is then $\rho = \frac{m}{V} = \frac{5.98\times 10^{24} \text{ kg}}{1.08\times 10^{21} \text{ m}^3} = \boxed{5.52\times 10^3 \text{ kg/m}^3}$. This value is intermediate between the tabulated densities of aluminum and iron. Typical rocks have densities around 2 000 to $3\,000 \text{ kg/m}^3$. The average density of the Earth is significantly higher, so higher-density material must be down below the surface.

P1.3 With $V = (\text{base area})(\text{height})$ $V = \left(\pi r^2\right)h$ and $\rho = \frac{m}{V}$, we have

$$\rho = \frac{m}{\pi r^2 h} = \frac{1 \text{ kg}}{\pi (19.5 \text{ mm})^2 (39.0 \text{ mm})}\left(\frac{10^9 \text{ mm}^3}{1 \text{ m}^3}\right)$$
$$\rho = \boxed{2.15\times 10^4 \text{ kg/m}^3}.$$

***P1.4** Let V represent the volume of the model, the same in $\rho = \frac{m}{V}$ for both. Then $\rho_{\text{iron}} = 9.35 \text{ kg}/V$ and $\rho_{\text{gold}} = \frac{m_{\text{gold}}}{V}$. Next, $\frac{\rho_{\text{gold}}}{\rho_{\text{iron}}} = \frac{m_{\text{gold}}}{9.35 \text{ kg}}$ and $m_{\text{gold}} = 9.35 \text{ kg}\left(\frac{19.3\times 10^3 \text{ kg/m}^3}{7.86\times 10^3 \text{ kg/m}^3}\right) = \boxed{23.0 \text{ kg}}$.

P1.5 $V = V_o - V_i = \frac{4}{3}\pi\left(r_2^3 - r_1^3\right)$

$\rho = \frac{m}{V}$, so $m = \rho V = \rho\left(\frac{4}{3}\pi\right)\left(r_2^3 - r_1^3\right) = \boxed{\frac{4\pi\rho\left(r_2^3 - r_1^3\right)}{3}}$.

P1.6 For either sphere the volume is $V = \frac{4}{3}\pi r^3$ and the mass is $m = \rho V = \rho \frac{4}{3}\pi r^3$. We divide this equation for the larger sphere by the same equation for the smaller:

$$\frac{m_\ell}{m_s} = \frac{\rho 4\pi r_\ell^3 3}{\rho 4\pi r_s^3 3} = \frac{r_\ell^3}{r_s^3} = 5.$$

Then $r_\ell = r_s \sqrt[3]{5} = 4.50\text{ cm}(1.71) = \boxed{7.69\text{ cm}}$.

P1.7 Use $1\text{ u} = 1.66 \times 10^{-24}\text{ g}$.

(a) For He, $m_0 = 4.00\text{ u}\left(\frac{1.66 \times 10^{-24}\text{ g}}{1\text{ u}}\right) = \boxed{6.64 \times 10^{-24}\text{ g}}$.

(b) For Fe, $m_0 = 55.9\text{ u}\left(\frac{1.66 \times 10^{-24}\text{ g}}{1\text{ u}}\right) = \boxed{9.29 \times 10^{-23}\text{ g}}$.

(c) For Pb, $m_0 = 207\text{ u}\left(\frac{1.66 \times 10^{-24}\text{ g}}{1\text{ u}}\right) = \boxed{3.44 \times 10^{-22}\text{ g}}$.

***P1.8** (a) The mass of any sample is the number of atoms in the sample times the mass m_0 of one atom: $m = Nm_0$. The first assertion is that the mass of one aluminum atom is

$$m_0 = 27.0\text{ u} = 27.0\text{ u} \times 1.66 \times 10^{-27}\text{ kg/1 u} = 4.48 \times 10^{-26}\text{ kg}.$$

Then the mass of 6.02×10^{23} atoms is

$$m = Nm_0 = 6.02 \times 10^{23} \times 4.48 \times 10^{-26}\text{ kg} = 0.027\,0\text{ kg} = 27.0\text{ g}.$$

Thus the first assertion implies the second. Reasoning in reverse, the second assertion can be written $m = Nm_0$.

$$0.027\,0\text{ kg} = 6.02 \times 10^{23} m_0,\text{ so } m_0 = \frac{0.027\text{ kg}}{6.02 \times 10^{23}} = 4.48 \times 10^{-26}\text{ kg},$$

in agreement with the first assertion.

(b) The general equation $m = Nm_0$ applied to one mole of any substance gives $M\text{ g} = NM\text{ u}$, where M is the numerical value of the atomic mass. It divides out exactly for all substances, giving $1.000\,000\,0 \times 10^{-3}\text{ kg} = N1.660\,540\,2 \times 10^{-27}\text{ kg}$. With eight-digit data, we can be quite sure of the result to seven digits. For one mole the number of atoms is

$$N = \left(\frac{1}{1.660\,540\,2}\right)10^{-3+27} = \boxed{6.022\,137 \times 10^{23}}.$$

(c) The atomic mass of hydrogen is 1.008 0 u and that of oxygen is 15.999 u. The mass of one molecule of H_2O is $2(1.008\,0) + 15.999\text{ u} = 18.0\text{ u}$. Then the molar mass is $\boxed{18.0\text{ g}}$.

(d) For CO_2 we have $12.011\text{ g} + 2(15.999\text{ g}) = \boxed{44.0\text{ g}}$ as the mass of one mole.

P1.9 Mass of gold abraded: $|\Delta m| = 3.80 \text{ g} - 3.35 \text{ g} = 0.45 \text{ g} = (0.45 \text{ g})\left(\frac{1 \text{ kg}}{10^3 \text{ g}}\right) = 4.5 \times 10^{-4} \text{ kg}$.

Each atom has mass $m_0 = 197 \text{ u} = 197 \text{ u}\left(\frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{ u}}\right) = 3.27 \times 10^{-25} \text{ kg}$.

Now, $|\Delta m| = |\Delta N| m_0$, and the number of atoms missing is

$$|\Delta N| = \frac{|\Delta m|}{m_0} = \frac{4.5 \times 10^{-4} \text{ kg}}{3.27 \times 10^{-25} \text{ kg}} = 1.38 \times 10^{21} \text{ atoms}.$$

The rate of loss is

$$\frac{|\Delta N|}{\Delta t} = \frac{1.38 \times 10^{21} \text{ atoms}}{50 \text{ yr}}\left(\frac{1 \text{ yr}}{365.25 \text{ d}}\right)\left(\frac{1 \text{ d}}{24 \text{ h}}\right)\left(\frac{1 \text{ h}}{60 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$

$$\frac{|\Delta N|}{\Delta t} = \boxed{8.72 \times 10^{11} \text{ atoms/s}}.$$

P1.10 (a) $m = \rho L^3 = (7.86 \text{ g/cm}^3)(5.00 \times 10^{-6} \text{ cm})^3 = \boxed{9.83 \times 10^{-16} \text{ g}} = 9.83 \times 10^{-19} \text{ kg}$

(b) $N = \frac{m}{m_0} = \frac{9.83 \times 10^{-19} \text{ kg}}{55.9 \text{ u}(1.66 \times 10^{-27} \text{ kg/1 u})} = \boxed{1.06 \times 10^7 \text{ atoms}}$

P1.11 (a) The cross-sectional area is

$$A = 2(0.150 \text{ m})(0.010 \text{ m}) + (0.340 \text{ m})(0.010 \text{ m})$$
$$= 6.40 \times 10^{-3} \text{ m}^2.$$

The volume of the beam is

$$V = AL = (6.40 \times 10^{-3} \text{ m}^2)(1.50 \text{ m}) = 9.60 \times 10^{-3} \text{ m}^3.$$

Thus, its mass is

$$m = \rho V = (7.56 \times 10^3 \text{ kg/m}^3)(9.60 \times 10^{-3} \text{ m}^3) = \boxed{72.6 \text{ kg}}.$$

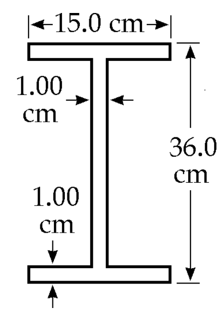

FIG. P1.11

(b) The mass of one typical atom is $m_0 = (55.9 \text{ u})\left(\frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{ u}}\right) = 9.28 \times 10^{-26} \text{ kg}$. Now $m = Nm_0$ and the number of atoms is $N = \frac{m}{m_0} = \frac{72.6 \text{ kg}}{9.28 \times 10^{-26} \text{ kg}} = \boxed{7.82 \times 10^{26} \text{ atoms}}$.

P1.12 (a) The mass of one molecule is $m_0 = 18.0\text{ u}\left(\frac{1.66\times 10^{-27}\text{ kg}}{1\text{ u}}\right) = 2.99\times 10^{-26}\text{ kg}$. The number of molecules in the pail is

$$N_{\text{pail}} = \frac{m}{m_0} = \frac{1.20\text{ kg}}{2.99\times 10^{-26}\text{ kg}} = \boxed{4.02\times 10^{25}\text{ molecules}}.$$

(b) Suppose that enough time has elapsed for thorough mixing of the hydrosphere.

$$N_{\text{both}} = N_{\text{pail}}\left(\frac{m_{\text{pail}}}{M_{\text{total}}}\right) = (4.02\times 10^{25}\text{ molecules})\left(\frac{1.20\text{ kg}}{1.32\times 10^{21}\text{ kg}}\right),$$

or

$$N_{\text{both}} = \boxed{3.65\times 10^{4}\text{ molecules}}.$$

Section 1.4 **Dimensional Analysis**

P1.13 The term x has dimensions of L, a has dimensions of LT^{-2}, and t has dimensions of T. Therefore, the equation $x = ka^m t^n$ has dimensions of

$$\text{L} = \left(\text{LT}^{-2}\right)^m (\text{T})^n \text{ or } \text{L}^1\text{T}^0 = \text{L}^m\text{T}^{n-2m}.$$

The powers of L and T must be the same on each side of the equation. Therefore,

$$\text{L}^1 = \text{L}^m \text{ and } \boxed{m = 1}.$$

Likewise, equating terms in T, we see that $n - 2m$ must equal 0. Thus, $\boxed{n = 2}$. The value of k, a dimensionless constant, $\boxed{\text{cannot be obtained by dimensional analysis}}$.

***P1.14** (a) Circumference has dimensions of L.

(b) Volume has dimensions of L^3.

(c) Area has dimensions of L^2.

Expression (i) has dimension $\text{L}\left(\text{L}^2\right)^{1/2} = \text{L}^2$, so this must be area (c).
Expression (ii) has dimension L, so it is (a).
Expression (iii) has dimension $\text{L}\left(\text{L}^2\right) = \text{L}^3$, so it is (b). Thus, $\boxed{\text{(a)} = \text{ii}; \quad \text{(b)} = \text{iii}, \ \text{(c)} = \text{i}}$.

P1.15 (a) $\boxed{\text{This is incorrect}}$ since the units of $[ax]$ are $\mathrm{m^2/s^2}$, while the units of $[v]$ are m/s.

(b) $\boxed{\text{This is correct}}$ since the units of $[y]$ are m, and $\cos(kx)$ is dimensionless if $[k]$ is in $\mathrm{m^{-1}}$.

***P1.16** (a) $a \propto \frac{\sum F}{m}$ or $a = k\frac{\sum F}{m}$ represents the proportionality of acceleration to resultant force and the inverse proportionality of acceleration to mass. If k has no dimensions, we have

$$[a] = [k]\frac{[F]}{[m]},\ \frac{\mathrm{L}}{\mathrm{T}^2} = 1\frac{[\mathrm{F}]}{\mathrm{M}},\ [\mathrm{F}] = \boxed{\frac{\mathrm{M \cdot L}}{\mathrm{T}^2}}.$$

(b) In units, $\frac{\mathrm{M \cdot L}}{\mathrm{T}^2} = \frac{\mathrm{kg \cdot m}}{\mathrm{s}^2}$, so $\boxed{1\ \text{newton} = 1\ \mathrm{kg \cdot m/s^2}}$.

P1.17 Inserting the proper units for everything except G,

$$\left[\frac{\text{kg m}}{\mathrm{s}^2}\right] = \frac{G[\text{kg}]^2}{[\text{m}]^2}.$$

Multiply both sides by $[\text{m}]^2$ and divide by $[\text{kg}]^2$; the units of G are $\boxed{\frac{\mathrm{m}^3}{\mathrm{kg \cdot s^2}}}$.

Section 1.5 **Conversion of Units**

***P1.18** Each of the four walls has area $(8.00\ \text{ft})(12.0\ \text{ft}) = 96.0\ \text{ft}^2$. Together, they have area $4\left(96.0\ \text{ft}^2\right)\left(\frac{1\ \text{m}}{3.28\ \text{ft}}\right)^2 = \boxed{35.7\ \text{m}^2}$.

P1.19 Apply the following conversion factors:

$$1\ \text{in} = 2.54\ \text{cm},\ 1\ \text{d} = 86\ 400\ \text{s},\ 100\ \text{cm} = 1\ \text{m},\ \text{and}\ 10^9\ \text{nm} = 1\ \text{m}$$

$$\left(\frac{1}{32}\ \text{in/day}\right)\frac{(2.54\ \text{cm/in})\left(10^{-2}\ \text{m/cm}\right)\left(10^9\ \text{nm/m}\right)}{86\ 400\ \text{s/day}} = \boxed{9.19\ \text{nm/s}}.$$

This means the proteins are assembled at a rate of many layers of atoms each second!

***P1.20** $8.50\ \text{in}^3 = 8.50\ \text{in}^3\left(\frac{0.025\ 4\ \text{m}}{1\ \text{in}}\right)^3 = \boxed{1.39 \times 10^{-4}\ \text{m}^3}$

P1.21 *Conceptualize*: We must calculate the area and convert units. Since a meter is about 3 feet, we should expect the area to be about $A \approx (30\text{ m})(50\text{ m}) = 1\,500\text{ m}^2$.

Categorize: We model the lot as a perfect rectangle to use Area = Length × Width. Use the conversion: $1\text{ m} = 3.281\text{ ft}$.

Analyze: $A = LW = (100\text{ ft})\left(\dfrac{1\text{ m}}{3.281\text{ ft}}\right)(150\text{ ft})\left(\dfrac{1\text{ m}}{3.281\text{ ft}}\right) = 1\,390\text{ m}^2 = \boxed{1.39\times10^3\text{ m}^2}$.

Finalize: Our calculated result agrees reasonably well with our initial estimate and has the proper units of m^2. Unit conversion is a common technique that is applied to many problems.

P1.22 (a) $V = (40.0\text{ m})(20.0\text{ m})(12.0\text{ m}) = 9.60\times10^3\text{ m}^3$

$V = 9.60\times10^3\text{ m}^3(3.28\text{ ft}/1\text{ m})^3 = \boxed{3.39\times10^5\text{ ft}^3}$

(b) The mass of the air is

$$m = \rho_{\text{air}}V = (1.20\text{ kg/m}^3)(9.60\times10^3\text{ m}^3) = 1.15\times10^4\text{ kg}.$$

The student must look up weight in the index to find

$$F_g = mg = (1.15\times10^4\text{ kg})(9.80\text{ m/s}^2) = 1.13\times10^5\text{ N}.$$

Converting to pounds,

$$F_g = (1.13\times10^5\text{ N})(1\text{ lb}/4.45\text{ N}) = \boxed{2.54\times10^4\text{ lb}}.$$

P1.23 (a) Seven minutes is 420 seconds, so the rate is

$$r = \frac{30.0\text{ gal}}{420\text{ s}} = \boxed{7.14\times10^{-2}\text{ gal/s}}.$$

(b) Converting gallons first to liters, then to m^3,

$$r = (7.14\times10^{-2}\text{ gal/s})\left(\frac{3.786\text{ L}}{1\text{ gal}}\right)\left(\frac{10^{-3}\text{ m}^3}{1\text{ L}}\right)$$

$$r = \boxed{2.70\times10^{-4}\text{ m}^3/\text{s}}.$$

(c) At that rate, to fill a 1-m^3 tank would take

$$t = \left(\frac{1\text{ m}^3}{2.70\times10^{-4}\text{ m}^3/\text{s}}\right)\left(\frac{1\text{ h}}{3\,600}\right) = \boxed{1.03\text{ h}}.$$

***P1.24** (a) Length of Mammoth Cave $= 348\text{ mi}\left(\frac{1.609\text{ km}}{1\text{ mi}}\right) = \boxed{560\text{ km} = 5.60\times10^5\text{ m} = 5.60\times10^7\text{ cm}}$.

(b) Height of Ribbon Falls $= 1\,612\text{ ft}\left(\frac{0.304\,8\text{ m}}{1\text{ ft}}\right) = \boxed{491\text{ m} = 0.491\text{ km} = 4.91\times10^4\text{ cm}}$.

(c) Height of Denali $= 20\,320\text{ ft}\left(\frac{0.304\,8\text{ m}}{1\text{ ft}}\right) = \boxed{6.19\text{ km} = 6.19\times10^3\text{ m} = 6.19\times10^5\text{ cm}}$.

(d) Depth of King's Canyon $= 8\,200\text{ ft}\left(\frac{0.304\,8\text{ m}}{1\text{ ft}}\right) = \boxed{2.50\text{ km} = 2.50\times10^3\text{ m} = 2.50\times10^5\text{ cm}}$.

P1.25 From Table 1.5, the density of lead is $1.13\times10^4\text{ kg/m}^3$, so we should expect our calculated value to be close to this number. This density value tells us that lead is about 11 times denser than water, which agrees with our experience that lead sinks.

Density is defined as mass per volume, in $\rho = \frac{m}{V}$. We must convert to SI units in the calculation.

$$\rho = \frac{23.94\text{ g}}{2.10\text{ cm}^3}\left(\frac{1\text{ kg}}{1\,000\text{ g}}\right)\left(\frac{100\text{ cm}}{1\text{ m}}\right)^3 = \boxed{1.14\times10^4\text{ kg/m}^3}$$

At one step in the calculation, we note that *one million* cubic centimeters make one cubic meter. Our result is indeed close to the expected value. Since the last reported significant digit is not certain, the difference in the two values is probably due to measurement uncertainty and should not be a concern. One important common-sense check on density values is that objects which sink in water must have a density greater than 1 g/cm^3, and objects that float must be less dense than water.

P1.26 It is often useful to remember that the 1 600-m race at track and field events is approximately 1 mile in length. To be precise, there are 1 609 meters in a mile. Thus, 1 acre is equal in area to

$$(1\text{ acre})\left(\frac{1\text{ mi}^2}{640\text{ acres}}\right)\left(\frac{1\,609\text{ m}}{\text{mi}}\right)^2 = \boxed{4.05\times10^3\text{ m}^2}.$$

***P1.27** The weight flow rate is $1\,200\ \frac{\text{ton}}{\text{h}}\left(\frac{2\,000\text{ lb}}{\text{ton}}\right)\left(\frac{1\text{ h}}{60\text{ min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = \boxed{667\text{ lb/s}}$.

P1.28 $1\text{ mi} = 1\,609\text{ m} = 1.609\text{ km}$; thus, to go from mph to km/h, multiply by 1.609.

(a) $1\text{ mi/h} = \boxed{1.609\text{ km/h}}$

(b) $55\text{ mi/h} = \boxed{88.5\text{ km/h}}$

(c) $65\text{ mi/h} = 104.6\text{ km/h}$. Thus, $\Delta v = \boxed{16.1\text{ km/h}}$.

P1.29 (a) $$\left(\frac{6\times 10^{12}\ \$}{1\,000\ \$/\text{s}}\right)\left(\frac{1\ \text{h}}{3\,600\ \text{s}}\right)\left(\frac{1\ \text{day}}{24\ \text{h}}\right)\left(\frac{1\ \text{yr}}{365\ \text{days}}\right)=\boxed{190\ \text{years}}$$

(b) The circumference of the Earth at the equator is $2\pi\left(6.378\times 10^{3}\ \text{m}\right)=4.01\times 10^{7}\ \text{m}$. The length of one dollar bill is 0.155 m so that the length of 6 trillion bills is $9.30\times 10^{11}\ \text{m}$. Thus, the 6 trillion dollars would encircle the Earth

$$\frac{9.30\times 10^{11}\ \text{m}}{4.01\times 0^{7}\ \text{m}}=\boxed{2.32\times 10^{4}\ \text{times}}.$$

P1.30 $$N_{\text{atoms}}=\frac{m_{\text{Sun}}}{m_{\text{atom}}}=\frac{1.99\times 10^{30}\ \text{kg}}{1.67\times 10^{-27}\ \text{kg}}=\boxed{1.19\times 10^{57}\ \text{atoms}}$$

P1.31 $$V=At\ \text{so}\ t=\frac{V}{A}=\frac{3.78\times 10^{-3}\ \text{m}^3}{25.0\ \text{m}^2}=\boxed{1.51\times 10^{-4}\ \text{m (or 151}\ \mu\text{m)}}$$

P1.32 $$V=\frac{1}{3}Bh=\frac{\left[(13.0\ \text{acres})\left(43\,560\ \text{ft}^2/\text{acre}\right)\right]}{3}(481\ \text{ft})$$
$$=9.08\times 10^{7}\ \text{ft}^3,$$

or

$$V=\left(9.08\times 10^{7}\ \text{ft}^3\right)\left(\frac{2.83\times 10^{-2}\ \text{m}^3}{1\ \text{ft}^3}\right)$$
$$=\boxed{2.57\times 10^{6}\ \text{m}^3}$$

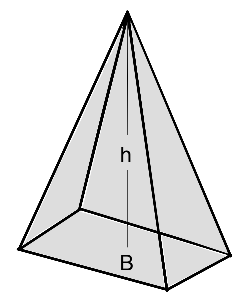

FIG. P1.32

P1.33 $$F_g=(2.50\ \text{tons/block})\left(2.00\times 10^{6}\ \text{blocks}\right)(2\,000\ \text{lb/ton})=\boxed{1.00\times 10^{10}\ \text{lbs}}$$

***P1.34** The area covered by water is

$$A_w=0.70A_{\text{Earth}}=(0.70)\left(4\pi R_{\text{Earth}}^2\right)=(0.70)(4\pi)\left(6.37\times 10^{6}\ \text{m}\right)^2=3.6\times 10^{14}\ \text{m}^2.$$

The average depth of the water is

$$d=(2.3\ \text{miles})(1\,609\ \text{m/1 mile})=3.7\times 10^{3}\ \text{m}.$$

The volume of the water is

$$V=A_w d=\left(3.6\times 10^{14}\ \text{m}^2\right)\left(3.7\times 10^{3}\ \text{m}\right)=1.3\times 10^{18}\ \text{m}^3$$

and the mass is

$$m=\rho V=\left(1\,000\ \text{kg/m}^3\right)\left(1.3\times 10^{18}\ \text{m}^3\right)=\boxed{1.3\times 10^{21}\ \text{kg}}.$$

P1.35 (a) $$d_{\text{nucleus, scale}} = d_{\text{nucleus, real}}\left(\frac{d_{\text{atom, scale}}}{d_{\text{atom, real}}}\right) = \left(2.40\times10^{-15}\ \text{m}\right)\left(\frac{300\ \text{ft}}{1.06\times10^{-10}\ \text{m}}\right) = 6.79\times10^{-3}\ \text{ft, or}$$

$$d_{\text{nucleus, scale}} = \left(6.79\times10^{-3}\ \text{ft}\right)\left(304.8\ \text{mm/1 ft}\right) = \boxed{2.07\ \text{mm}}$$

(b) $$\frac{V_{\text{atom}}}{V_{\text{nucleus}}} = \frac{\frac{4\pi r_{\text{atom}}^3}{3}}{\frac{4\pi r_{\text{nucleus}}^3}{3}} = \left(\frac{r_{\text{atom}}}{r_{\text{nucleus}}}\right)^3 = \left(\frac{d_{\text{atom}}}{d_{\text{nucleus}}}\right)^3 = \left(\frac{1.06\times10^{-10}\ \text{m}}{2.40\times10^{-15}\ \text{m}}\right)^3$$

$$= \boxed{8.62\times10^{13}\ \text{times as large}}$$

***P1.36** $$\begin{array}{c}\text{scale distance}\\ \text{between}\end{array} = \left(\begin{array}{c}\text{real}\\ \text{distance}\end{array}\right)\left(\begin{array}{c}\text{scale}\\ \text{factor}\end{array}\right) = \left(4.0\times10^{13}\ \text{km}\right)\left(\frac{7.0\times10^{-3}\ \text{m}}{1.4\times10^{9}\ \text{m}}\right) = \boxed{200\ \text{km}}$$

P1.37 The scale factor used in the "dinner plate" model is

$$S = \frac{0.25\ \text{m}}{1.0\times10^{5}\ \text{lightyears}} = 2.5\times10^{-6}\ \text{m/lightyears}.$$

The distance to Andromeda in the scale model will be

$$D_{\text{scale}} = D_{\text{actual}}S = \left(2.0\times10^{6}\ \text{lightyears}\right)\left(2.5\times10^{-6}\ \text{m/lightyears}\right) = \boxed{5.0\ \text{m}}.$$

P1.38 (a) $$\frac{A_{\text{Earth}}}{A_{\text{Moon}}} = \frac{4\pi r_{\text{Earth}}^2}{4\pi r_{\text{Moon}}^2} = \left(\frac{r_{\text{Earth}}}{r_{\text{Moon}}}\right)^2 = \left(\frac{\left(6.37\times10^{6}\ \text{m}\right)\left(100\ \text{cm/m}\right)}{1.74\times10^{8}\ \text{cm}}\right)^2 = \boxed{13.4}$$

(b) $$\frac{V_{\text{Earth}}}{V_{\text{Moon}}} = \frac{\frac{4\pi r_{\text{Earth}}^3}{3}}{\frac{4\pi r_{\text{Moon}}^3}{3}} = \left(\frac{r_{\text{Earth}}}{r_{\text{Moon}}}\right)^3 = \left(\frac{\left(6.37\times10^{6}\ \text{m}\right)\left(100\ \text{cm/m}\right)}{1.74\times10^{8}\ \text{cm}}\right)^3 = \boxed{49.1}$$

P1.39 To balance, $m_{\text{Fe}} = m_{\text{Al}}$ or $\rho_{\text{Fe}}V_{\text{Fe}} = \rho_{\text{Al}}V_{\text{Al}}$

$$\rho_{\text{Fe}}\left(\frac{4}{3}\right)\pi r_{\text{Fe}}{}^3 = \rho_{\text{Al}}\left(\frac{4}{3}\right)\pi r_{\text{Al}}{}^3$$

$$r_{\text{Al}} = r_{\text{Fe}}\left(\frac{\rho_{\text{Fe}}}{\rho_{\text{Al}}}\right)^{1/3} = (2.00\ \text{cm})\left(\frac{7.86}{2.70}\right)^{1/3} = \boxed{2.86\ \text{cm}}.$$

P1.40 The mass of each sphere is

$$m_{\text{Al}} = \rho_{\text{Al}} V_{\text{Al}} = \frac{4\pi \rho_{\text{Al}} r_{\text{Al}}^3}{3}$$

and

$$m_{\text{Fe}} = \rho_{\text{Fe}} V_{\text{Fe}} = \frac{4\pi \rho_{\text{Fe}} r_{\text{Fe}}^3}{3}.$$

Setting these masses equal,

$$\frac{4\pi \rho_{\text{Al}} r_{\text{Al}}^3}{3} = \frac{4\pi \rho_{\text{Fe}} r_{\text{Fe}}^3}{3} \text{ and } \boxed{r_{\text{Al}} = r_{\text{Fe}} \sqrt[3]{\frac{\rho_{\text{Fe}}}{\rho_{\text{Al}}}}}.$$

Section 1.6 **Estimates and Order-of-Magnitude Calculations**

P1.41 Model the room as a rectangular solid with dimensions 4 m by 4 m by 3 m, and each ping-pong ball as a sphere of diameter 0.038 m. The volume of the room is $4 \times 4 \times 3 = 48 \text{ m}^3$, while the volume of one ball is

$$\frac{4\pi}{3}\left(\frac{0.038 \text{ m}}{2}\right)^3 = 2.87 \times 10^{-5} \text{ m}^3.$$

Therefore, one can fit about $\dfrac{48}{2.87 \times 10^{-5}} \sim \boxed{10^6}$ ping-pong balls in the room.

As an aside, the actual number is smaller than this because there will be a lot of space in the room that cannot be covered by balls. In fact, even in the best arrangement, the so-called "best packing fraction" is $\frac{1}{6}\pi\sqrt{2} = 0.74$ so that at least 26% of the space will be empty. Therefore, the above estimate reduces to $1.67 \times 10^6 \times 0.740 \sim 10^6$.

P1.42 A reasonable guess for the diameter of a tire might be 2.5 ft, with a circumference of about 8 ft. Thus, the tire would make $(50\,000 \text{ mi})(5\,280 \text{ ft/mi})(1 \text{ rev/8 ft}) = 3 \times 10^7 \text{ rev} \sim \boxed{10^7 \text{ rev}}$.

P1.43 In order to reasonably carry on photosynthesis, we might expect a blade of grass to require at least $\frac{1}{16} \text{ in}^2 = 43 \times 10^{-5} \text{ ft}^2$. Since $1 \text{ acre} = 43\,560 \text{ ft}^2$, the number of blades of grass to be expected on a quarter-acre plot of land is about

$$n = \frac{\text{total area}}{\text{area per blade}} = \frac{(0.25 \text{ acre})\left(43\,560 \text{ ft}^2/\text{acre}\right)}{43 \times 10^{-5} \text{ ft}^2/\text{blade}} = 2.5 \times 10^7 \text{ blades} \sim \boxed{10^7 \text{ blades}}.$$

P1.44 A typical raindrop is spherical and might have a radius of about 0.1 inch. Its volume is then approximately 4×10^{-3} in^3. Since 1 acre = 43 560 ft^2, the volume of water required to cover it to a depth of 1 inch is

$$(1 \text{ acre})(1 \text{ inch}) = (1 \text{ acre} \cdot \text{in})\left(\frac{43\,560 \text{ ft}^2}{1 \text{ acre}}\right)\left(\frac{144 \text{ in}^2}{1 \text{ ft}^2}\right) \approx 6.3 \times 10^6 \text{ in}^3.$$

The number of raindrops required is

$$n = \frac{\text{volume of water required}}{\text{volume of a single drop}} = \frac{6.3 \times 10^6 \text{ in}^3}{4 \times 10^{-3} \text{ in}^3} = 1.6 \times 10^9 \sim \boxed{10^9}.$$

***P1.45** Assume the tub measures 1.3 m by 0.5 m by 0.3 m. One-half of its volume is then

$$V = (0.5)(1.3 \text{ m})(0.5 \text{ m})(0.3 \text{ m}) = 0.10 \text{ m}^3.$$

The mass of this volume of water is

$$m_{\text{water}} = \rho_{\text{water}} V = \left(1\,000 \text{ kg/m}^3\right)\left(0.10 \text{ m}^3\right) = 100 \text{ kg} \boxed{\sim 10^2 \text{ kg}}.$$

Pennies are now mostly zinc, but consider copper pennies filling 50% of the volume of the tub. The mass of copper required is

$$m_{\text{copper}} = \rho_{\text{copper}} V = \left(8\,920 \text{ kg/m}^3\right)\left(0.10 \text{ m}^3\right) = 892 \text{ kg} \boxed{\sim 10^3 \text{ kg}}.$$

P1.46 The typical person probably drinks 2 to 3 soft drinks daily. Perhaps half of these were in aluminum cans. Thus, we will estimate 1 aluminum can disposal per person per day. In the U.S. there are ~250 million people, and 365 days in a year, so

$$\left(250 \times 10^6 \text{ cans/day}\right)(365 \text{ days/year}) \cong \boxed{10^{11} \text{ cans}}$$

are thrown away or recycled each year. Guessing that each can weighs around $1/10$ of an ounce, we estimate this represents

$$\left(10^{11} \text{ cans}\right)(0.1 \text{ oz/can})(1 \text{ lb/16 oz})(1 \text{ ton/2\,000 lb}) \approx 3.1 \times 10^5 \text{ tons/year}. \boxed{\sim 10^5 \text{ tons}}$$

P1.47 Assume: Total population $= 10^7$; one out of every 100 people has a piano; one tuner can serve about 1 000 pianos (about 4 per day for 250 weekdays, assuming each piano is tuned once per year). Therefore,

$$\#\ \text{tuners} \sim \left(\frac{1 \text{ tuner}}{1\,000 \text{ pianos}}\right)\left(\frac{1 \text{ piano}}{100 \text{ people}}\right)(10^7 \text{ people}) = \boxed{100}.$$

Section 1.7 **Significant Figures**

***P1.48** METHOD ONE

We treat the best value with its uncertainty as a binomial (21.3 ± 0.2) cm (9.8 ± 0.1) cm,

$$A = \left[21.3(9.8) \pm 21.3(0.1) \pm 0.2(9.8) \pm (0.2)(0.1)\right] \text{ cm}^2 .$$

The first term gives the best value of the area. The cross terms add together to give the uncertainty and the fourth term is negligible.

$$A = \boxed{209 \text{ cm}^2 \pm 4 \text{ cm}^2} .$$

METHOD TWO

We add the fractional uncertainties in the data.

$$A = (21.3 \text{ cm})(9.8 \text{ cm}) \pm \left(\frac{0.2}{21.3} + \frac{0.1}{9.8}\right) = 209 \text{ cm}^2 \pm 2\% = 209 \text{ cm}^2 \pm 4 \text{ cm}^2$$

P1.49 (a)

$$\begin{aligned} \pi r^2 &= \pi(10.5 \text{ m} \pm 0.2 \text{ m})^2 \\ &= \pi\left[(10.5 \text{ m})^2 \pm 2(10.5 \text{ m})(0.2 \text{ m}) + (0.2 \text{ m})^2\right] \\ &= \boxed{346 \text{ m}^2 \pm 13 \text{ m}^2} \end{aligned}$$

(b)

$$2\pi r = 2\pi(10.5 \text{ m} \pm 0.2 \text{ m}) = \boxed{66.0 \text{ m} \pm 1.3 \text{ m}}$$

P1.50 (a) $\boxed{3}$ (b) $\boxed{4}$ (c) $\boxed{3}$ (d) $\boxed{2}$

P1.51

$$r = (6.50 \pm 0.20) \text{ cm} = (6.50 \pm 0.20) \times 10^{-2} \text{ m}$$

$$m = (1.85 \pm 0.02) \text{ kg}$$

$$\rho = \frac{m}{\left(\frac{4}{3}\right)\pi r^3}$$

also,

$$\frac{\delta\rho}{\rho} = \frac{\delta m}{m} + \frac{3\delta r}{r} .$$

In other words, the percentages of uncertainty are cumulative. Therefore,

$$\frac{\delta\rho}{\rho} = \frac{0.02}{1.85} + \frac{3(0.20)}{6.50} = 0.103 ,$$

$$\rho = \frac{1.85}{\left(\frac{4}{3}\right)\pi\left(6.5 \times 10^{-2} \text{ m}\right)^3} = \boxed{1.61 \times 10^3 \text{ kg/m}^3}$$

and

$$\rho \pm \delta\rho = \boxed{(1.61 \pm 0.17) \times 10^3 \text{ kg/m}^3} = (1.6 \pm 0.2) \times 10^3 \text{ kg/m}^3 .$$

P1.52 (a)

$$\begin{array}{r} 756.?? \\ 37.2? \\ 0.83 \\ \underline{+\ 2.5?} \\ 796.53 \end{array} = \boxed{797}$$

(b) $0.003\ 2(2\ \text{s.f.}) \times 356.3(4\ \text{s.f.}) = 1.140\ 16 = (2\ \text{s.f.})\ \boxed{1.1}$

(c) $5.620(4\ \text{s.f.}) \times \pi(>4\ \text{s.f.}) = 17.656 = (4\ \text{s.f.})\ \boxed{17.66}$

***P1.53** We work to nine significant digits:

$$1\ \text{yr} = 1\ \text{yr}\left(\frac{365.242\ 199\ \text{d}}{1\ \text{yr}}\right)\left(\frac{24\ \text{h}}{1\ \text{d}}\right)\left(\frac{60\ \text{min}}{1\ \text{h}}\right)\left(\frac{60\ \text{s}}{1\ \text{min}}\right) = \boxed{31\ 556\ 926.0\ \text{s}}.$$

P1.54 The distance around is $38.44\ \text{m} + 19.5\ \text{m} + 38.44\ \text{m} + 19.5\ \text{m} = 115.88\ \text{m}$, but this answer must be rounded to 115.9 m because the distance 19.5 m carries information to only one place past the decimal. $\boxed{115.9\ \text{m}}$

P1.55

$$V = 2V_1 + 2V_2 = 2(V_1 + V_2)$$

$$V_1 = (17.0\ \text{m} + 1.0\ \text{m} + 1.0\ \text{m})(1.0\ \text{m})(0.09\ \text{m}) = 1.70\ \text{m}^3$$

$$V_2 = (10.0\ \text{m})(1.0\ \text{m})(0.090\ \text{m}) = 0.900\ \text{m}^3$$

$$V = 2\left(1.70\ \text{m}^3 + 0.900\ \text{m}^3\right) = \boxed{5.2\ \text{m}^3}$$

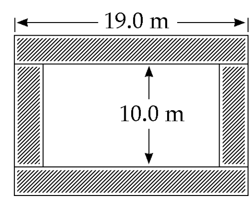

FIG. P1.55

$$\left.\begin{array}{l} \dfrac{\delta \ell_1}{\ell_1} = \dfrac{0.12\ \text{m}}{19.0\ \text{m}} = 0.0063 \\ \dfrac{\delta w_1}{w_1} = \dfrac{0.01\ \text{m}}{1.0\ \text{m}} = 0.010 \\ \dfrac{\delta t_1}{t_1} = \dfrac{0.1\ \text{cm}}{9.0\ \text{cm}} = 0.011 \end{array}\right\} \frac{\delta V}{V} = 0.006 + 0.010 + 0.011 = 0.027 = \boxed{3\%}$$

Additional Problems

P1.56 It is desired to find the distance x such that

$$\frac{x}{100\ \text{m}} = \frac{1\ 000\ \text{m}}{x}$$

(i.e., such that x is the same multiple of 100 m as the multiple that 1 000 m is of x). Thus, it is seen that

$$x^2 = (100\ \text{m})(1\ 000\ \text{m}) = 1.00 \times 10^5\ \text{m}^2$$

and therefore

$$x = \sqrt{1.00 \times 10^5\ \text{m}^2} = \boxed{316\ \text{m}}.$$

***P1.57** Consider one cubic meter of gold. Its mass from Table 1.5 is 19 300 kg. One atom of gold has mass

$$m_0 = (197\ \text{u})\left(\frac{1.66\times10^{-27}\ \text{kg}}{1\ \text{u}}\right) = 3.27\times10^{-25}\ \text{kg}.$$

So, the number of atoms in the cube is

$$N = \frac{19\,300\ \text{kg}}{3.27\times10^{-25}\ \text{kg}} = 5.90\times10^{28}.$$

The imagined cubical volume of each atom is

$$d^3 = \frac{1\ \text{m}^3}{5.90\times10^{28}} = 1.69\times10^{-29}\ \text{m}^3.$$

So

$$d = \boxed{2.57\times10^{-10}\ \text{m}}.$$

P1.58 $A_{\text{total}} = (N)(A_{\text{drop}}) = \left(\frac{V_{\text{total}}}{V_{\text{drop}}}\right)(A_{\text{drop}}) = \left(\frac{V_{\text{total}}}{\frac{4\pi r^3}{3}}\right)(4\pi r^2)$

$A_{\text{total}} = \left(\frac{3V_{\text{total}}}{r}\right) = 3\left(\frac{30.0\times10^{-6}\ \text{m}^3}{2.00\times10^{-5}\ \text{m}}\right) = \boxed{4.50\ \text{m}^2}$

P1.59 One month is

$$1\ \text{mo} = (30\ \text{day})(24\ \text{h/day})(3\,600\ \text{s/h}) = 2.592\times10^6\ \text{s}.$$

Applying units to the equation,

$$V = \left(1.50\ \text{Mft}^3/\text{mo}\right)t + \left(0.008\,00\ \text{Mft}^3/\text{mo}^2\right)t^2.$$

Since $1\ \text{Mft}^3 = 10^6\ \text{ft}^3$,

$$V = \left(1.50\times10^6\ \text{ft}^3/\text{mo}\right)t + \left(0.008\,00\times10^6\ \text{ft}^3/\text{mo}^2\right)t^2.$$

Converting months to seconds,

$$V = \frac{1.50\times10^6\ \text{ft}^3/\text{mo}}{2.592\times10^6\ \text{s/mo}}t + \frac{0.008\,00\times10^6\ \text{ft}^3/\text{mo}^2}{\left(2.592\times10^6\ \text{s/mo}\right)^2}t^2.$$

Thus, $\boxed{V\,[\text{ft}^3] = \left(0.579\ \text{ft}^3/\text{s}\right)t + \left(1.19\times10^{-9}\ \text{ft}^3/\text{s}^2\right)t^2}$.

P1.60

α'(deg)	α(rad)	$\tan(\alpha)$	$\sin(\alpha)$	difference
15.0	0.262	0.268	0.259	3.47%
20.0	0.349	0.364	0.342	6.43%
25.0	0.436	0.466	0.423	10.2%
24.0	0.419	0.445	0.407	9.34%
24.4	0.426	0.454	0.413	9.81%
24.5	0.428	0.456	0.415	9.87%
24.6	0.429	0.458	0.416	9.98%
24.7	0.431	0.460	0.418	10.1%

$\boxed{24.6°}$

P1.61

$$2\pi r = 15.0 \text{ m}$$
$$r = 2.39 \text{ m}$$
$$\frac{h}{r} = \tan 55.0°$$
$$h = (2.39 \text{ m})\tan(55.0°) = \boxed{3.41 \text{ m}}$$

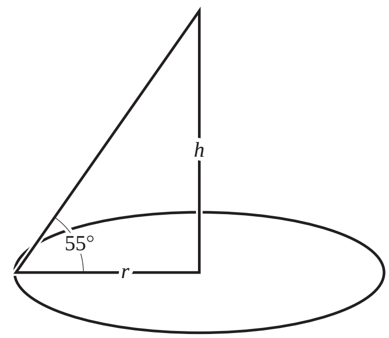

FIG. P1.61

***P1.62** Let *d* represent the diameter of the coin and *h* its thickness. The mass of the gold is

$$m = \rho V = \rho A t = \rho\left(\frac{2\pi d^2}{4} + \pi d h\right)t$$

where *t* is the thickness of the plating.

$$m = 19.3\left[2\pi\frac{(2.41)^2}{4} + \pi(2.41)(0.178)\right]\left(0.18 \times 10^{-4}\right)$$
$$= 0.003\,64 \text{ grams}$$
$$\text{cost} = 0.003\,64 \text{ grams} \times \$10/\text{gram} = \$0.036\,4 = \boxed{3.64 \text{ cents}}$$

This is negligible compared to \$4.98.

P1.63 The actual number of seconds in a year is

$$(86\,400 \text{ s/day})(365.25 \text{ day/yr}) = 31\,557\,600 \text{ s/yr}.$$

The percent error in the approximation is

$$\frac{\left|\left(\pi \times 10^7 \text{ s/yr}\right) - \left(31\,557\,600 \text{ s/yr}\right)\right|}{31\,557\,600 \text{ s/yr}} \times 100\% = \boxed{0.449\%}.$$

P1.64 (a) $[V] = \mathrm{L}^3$, $[A] = \mathrm{L}^2$, $[h] = \mathrm{L}$

$$[V] = [A][h]$$

$\mathrm{L}^3 = \mathrm{L}^2\mathrm{L} = \mathrm{L}^3$. Thus, the equation is dimensionally correct.

(b) $V_{\text{cylinder}} = \pi R^2 h = \left(\pi R^2\right)h = Ah$, where $\boxed{A = \pi R^2}$

$V_{\text{rectangular object}} = \ell w h = (\ell w)h = Ah$, where $\boxed{A = \ell w}$

P1.65 (a) The speed of rise may be found from

$$v = \frac{(\text{Vol rate of flow})}{(\text{Area: } \frac{\pi D^2}{4})} = \frac{16.5\ \text{cm}^3/\text{s}}{\frac{\pi(6.30\ \text{cm})^2}{4}} = \boxed{0.529\ \text{cm/s}}.$$

(b) Likewise, at a 1.35 cm diameter,

$$v = \frac{16.5\ \text{cm}^3/\text{s}}{\frac{\pi(1.35\ \text{cm})^2}{4}} = \boxed{11.5\ \text{cm/s}}.$$

P1.66 (a) 1 cubic meter of water has a mass

$$m = \rho V = \left(1.00\times10^{-3}\ \text{kg/cm}^3\right)\left(1.00\ \text{m}^3\right)\left(10^2\ \text{cm/m}\right)^3 = \boxed{1\,000\ \text{kg}}$$

(b) As a rough calculation, we treat each item as if it were 100% water.

cell: $m = \rho V = \rho\left(\frac{4}{3}\pi R^3\right) = \rho\left(\frac{1}{6}\pi D^3\right) = \left(1\,000\ \text{kg/m}^3\right)\left(\frac{1}{6}\pi\right)\left(1.0\times10^{-6}\ \text{m}\right)^3$

$= \boxed{5.2\times10^{-16}\ \text{kg}}$

kidney: $m = \rho V = \rho\left(\frac{4}{3}\pi R^3\right) = \left(1.00\times10^{-3}\ \text{kg/cm}^3\right)\left(\frac{4}{3}\pi\right)(4.0\ \text{cm})^3$

$= \boxed{0.27\ \text{kg}}$

fly: $m = \rho\left(\frac{\pi}{4}D^2h\right) = \left(1\times10^{-3}\ \text{kg/cm}^3\right)\left(\frac{\pi}{4}\right)(2.0\ \text{mm})^2(4.0\ \text{mm})\left(10^{-1}\ \text{cm/mm}\right)^3$

$= \boxed{1.3\times10^{-5}\ \text{kg}}$

P1.67 $V_{20\ \text{mpg}} = \dfrac{(10^8\ \text{cars})(10^4\ \text{mi/yr})}{20\ \text{mi/gal}} = 5.0\times10^{10}\ \text{gal/yr}$

$V_{25\ \text{mpg}} = \dfrac{(10^8\ \text{cars})(10^4\ \text{mi/yr})}{25\ \text{mi/gal}} = 4.0\times10^{10}\ \text{gal/yr}$

Fuel saved $= V_{25\ \text{mpg}} - V_{20\ \text{mpg}} = \boxed{1.0\times10^{10}\ \text{gal/yr}}$

P1.68 $v = \left(5.00\dfrac{\text{furlongs}}{\text{fortnight}}\right)\left(\dfrac{220\text{ yd}}{1\text{ furlong}}\right)\left(\dfrac{0.914\,4\text{ m}}{1\text{ yd}}\right)\left(\dfrac{1\text{ fortnight}}{14\text{ days}}\right)\left(\dfrac{1\text{ day}}{24\text{ hrs}}\right)\left(\dfrac{1\text{ hr}}{3\,600\text{ s}}\right) = \boxed{8.32\times10^{-4}\text{ m/s}}$

This speed is almost 1 mm/s; so we might guess the creature was a snail, or perhaps a sloth.

P1.69 The volume of the galaxy is

$$\pi r^2 t = \pi\left(10^{21}\text{ m}\right)^2\left(10^{19}\text{ m}\right) \sim 10^{61}\text{ m}^3.$$

If the distance between stars is 4×10^{16} m, then there is one star in a volume on the order of

$$\left(4\times10^{16}\text{ m}\right)^3 \sim 10^{50}\text{ m}^3.$$

The number of stars is about $\dfrac{10^{61}\text{ m}^3}{10^{50}\text{ m}^3/\text{star}} \sim \boxed{10^{11}\text{ stars}}$.

P1.70 The density of each material is $\rho = \dfrac{m}{V} = \dfrac{m}{\pi r^2 h} = \dfrac{4m}{\pi D^2 h}$.

Al: $\rho = \dfrac{4(51.5\text{ g})}{\pi(2.52\text{ cm})^2(3.75\text{ cm})} = \boxed{2.75\dfrac{\text{g}}{\text{cm}^3}}$ The tabulated value $\left(2.70\dfrac{\text{g}}{\text{cm}^3}\right)$ is $\boxed{2\%}$ smaller.

Cu: $\rho = \dfrac{4(56.3\text{ g})}{\pi(1.23\text{ cm})^2(5.06\text{ cm})} = \boxed{9.36\dfrac{\text{g}}{\text{cm}^3}}$ The tabulated value $\left(8.92\dfrac{\text{g}}{\text{cm}^3}\right)$ is $\boxed{5\%}$ smaller.

Brass: $\rho = \dfrac{4(94.4\text{ g})}{\pi(1.54\text{ cm})^2(5.69\text{ cm})} = \boxed{8.91\dfrac{\text{g}}{\text{cm}^3}}$

Sn: $\rho = \dfrac{4(69.1\text{ g})}{\pi(1.75\text{ cm})^2(3.74\text{ cm})} = \boxed{7.68\dfrac{\text{g}}{\text{cm}^3}}$

Fe: $\rho = \dfrac{4(216.1\text{ g})}{\pi(1.89\text{ cm})^2(9.77\text{ cm})} = \boxed{7.88\dfrac{\text{g}}{\text{cm}^3}}$ The tabulated value $\left(7.86\dfrac{\text{g}}{\text{cm}^3}\right)$ is $\boxed{0.3\%}$ smaller.

P1.71 (a) $(3\,600\text{ s/hr})(24\text{ hr/day})(365.25\text{ days/yr}) = \boxed{3.16\times10^{7}\text{ s/yr}}$

(b) $V_{\text{mm}} = \dfrac{4}{3}\pi r^3 = \dfrac{4}{3}\pi\left(5.00\times10^{-7}\text{ m}\right)^3 = 5.24\times10^{-19}\text{ m}^3$

$\dfrac{V_{\text{cube}}}{V_{\text{mm}}} = \dfrac{1\text{ m}^3}{5.24\times10^{-19}\text{ m}^3} = 1.91\times10^{18}\text{ micrometeorites}$

This would take $\dfrac{1.91\times10^{18}\text{ micrometeorites}}{3.16\times10^{7}\text{ micrometeorites/yr}} = \boxed{6.05\times10^{10}\text{ yr}}$.

ANSWERS TO EVEN PROBLEMS

P1.2 $5.52 \times 10^3 \text{ kg/m}^3$, between the densities of aluminum and iron, and greater than the densities of surface rocks.

P1.4 23.0 kg

P1.6 7.69 cm

P1.8 (a) and (b) see the solution, $N_A = 6.022\,137 \times 10^{23}$; (c) 18.0 g; (d) 44.0 g

P1.10 (a) 9.83×10^{-16} g; (b) 1.06×10^7 atoms

P1.12 (a) 4.02×10^{25} molecules; (b) 3.65×10^4 molecules

P1.14 (a) ii; (b) iii; (c) i

P1.16 (a) $\frac{\text{M} \cdot \text{L}}{\text{T}^2}$; (b) $1 \text{ newton} = 1 \text{ kg} \cdot \text{m/s}^2$

P1.18 35.7 m^2

P1.20 $1.39 \times 10^{-4} \text{ m}^3$

P1.22 (a) $3.39 \times 10^5 \text{ ft}^3$; (b) 2.54×10^4 lb

P1.24 (a) $560 \text{ km} = 5.60 \times 10^5 \text{ m} = 5.60 \times 10^7 \text{ cm}$; (b) $491 \text{ m} = 0.491 \text{ km} = 4.91 \times 10^4 \text{ cm}$; (c) $6.19 \text{ km} = 6.19 \times 10^3 \text{ m} = 6.19 \times 10^5 \text{ cm}$; (d) $2.50 \text{ km} = 2.50 \times 10^3 \text{ m} = 2.50 \times 10^5 \text{ cm}$

P1.26 $4.05 \times 10^3 \text{ m}^2$

P1.28 (a) $1 \text{ mi/h} = 1.609 \text{ km/h}$; (b) 88.5 km/h; (c) 16.1 km/h

P1.30 1.19×10^{57} atoms

P1.32 $2.57 \times 10^6 \text{ m}^3$

P1.34 1.3×10^{21} kg

P1.36 200 km

P1.38 (a) 13.4; (b) 49.1

P1.40 $r_{\text{Al}} = r_{\text{Fe}} \left(\frac{\rho_{\text{Fe}}}{\rho_{\text{Al}}} \right)^{1/3}$

P1.42 $\sim 10^7$ rev

P1.44 $\sim 10^9$ raindrops

P1.46 $\sim 10^{11}$ cans; $\sim 10^5$ tons

P1.48 $(209 \pm 4) \text{ cm}^2$

P1.50 (a) 3; (b) 4; (c) 3; (d) 2

P1.52 (a) 797; (b) 1.1; (c) 17.66

P1.54 115.9 m

P1.56 316 m

P1.58 4.50 m^2

P1.60 see the solution; 24.6°

P1.62 3.64 cents; no

P1.64 see the solution

P1.66 (a) 1 000 kg; (b) 5.2×10^{-16} kg; 0.27 kg; 1.3×10^{-5} kg

P1.68 8.32×10^{-4} m/s; a snail

P1.70 see the solution