Chapter 1

1. The metric prefixes (micro, pico, nano, ...) are given for ready reference on the inside front cover of the textbook (see also Table 1-2).

   (a) Since $1\,\text{km} = 1 \times 10^3\,\text{m}$ and $1\,\text{m} = 1 \times 10^6\,\mu\text{m}$,

   $$1\,\text{km} = 10^3\,\text{m} = (10^3\,\text{m})(10^6\,\mu\text{m/m}) = 10^9\,\mu\text{m}\,.$$

   The given measurement is 1.0 km (two significant figures), which implies our result should be written as $1.0 \times 10^9\ \mu$m.

   (b) We calculate the number of microns in 1 centimeter. Since $1\,\text{cm} = 10^{-2}\,\text{m}$,

   $$1\,\text{cm} = 10^{-2}\,\text{m} = (10^{-2}\,\text{m})(10^6\,\mu\text{m/m}) = 10^4\,\mu\text{m}\,.$$

   We conclude that the fraction of one centimeter equal to $1.0\,\mu$m is 1.0×10^{-4}.

   (c) Since $1\,\text{yd} = (3\,\text{ft})(0.3048\,\text{m/ft}) = 0.9144\,\text{m}$,

   $$1.0\,\text{yd} = (0.91\,\text{m})(10^6\,\mu\text{m/m}) = 9.1 \times 10^5\,\mu\text{m}\,.$$

2. The customer expects $20 \times 7056\ \text{in}^3$ and receives $20 \times 5826\ \text{in}^3$, the difference being 24600 cubic inches, or

   $$\left(24600\ \text{in}^3\right)\left(\frac{2.54\ \text{cm}}{1\ \text{inch}}\right)^3\left(\frac{1\ \text{L}}{1000\ \text{cm}^3}\right) = 403\ \text{L}$$

   where Appendix D has been used (see also Sample Problem 1-2).

3. Using the given conversion factors, we find

   (a) the distance d *in rods* to be

   $$d = 4.0\,\text{furlongs} = \frac{(4.0\,\text{furlongs})(201.168\,\text{m/furlong})}{5.0292\,\text{m/rod}} = 160\,\text{rods}\,,$$

   (b) and that distance *in chains* to be

   $$d = \frac{(4.0\,\text{furlongs})(201.168\,\text{m/furlong})}{20.117\,\text{m/chain}} = 40\,\text{chains}\ .$$

4. (a) Recalling that 2.54 cm equals 1 inch (exactly), we obtain

   $$(0.80\ \text{cm})\left(\frac{1\ \text{inch}}{2.54\ \text{cm}}\right)\left(\frac{6\ \text{picas}}{1\ \text{inch}}\right)\left(\frac{12\ \text{points}}{1\ \text{pica}}\right) \approx 23\ \text{points}\ ,$$

   (b) and

   $$(0.80\ \text{cm})\left(\frac{1\ \text{inch}}{2.54\ \text{cm}}\right)\left(\frac{6\ \text{picas}}{1\ \text{inch}}\right) \approx 1.9\ \text{picas}\ .$$

5. Various geometric formulas are given in Appendix E.

   (a) Substituting
   $$R = \left(6.37 \times 10^6\,\text{m}\right)\left(10^{-3}\,\text{km/m}\right) = 6.37 \times 10^3\,\text{km}$$
   into *circumference* $= 2\pi R$, we obtain 4.00×10^4 km.

   (b) The surface area of Earth is
   $$4\pi R^2 = 4\pi\left(6.37 \times 10^3\,\text{km}\right)^2 = 5.10 \times 10^8\ \text{km}^2\ .$$

   (c) The volume of Earth is
   $$\frac{4\pi}{3}R^3 = \frac{4\pi}{3}\left(6.37 \times 10^3\,\text{km}\right)^3 = 1.08 \times 10^{12}\ \text{km}^3\ .$$

6. (a) Using the fact that the area A of a rectangle is width×length, we find
   $$\begin{aligned} A_{\text{total}} &= (3.00\text{ acre}) + (25.0\,\text{perch})(4.00\,\text{perch}) \\ &= (3.00\,\text{acre})\left(\frac{(40\,\text{perch})(4\,\text{perch})}{1\text{ acre}}\right) + 100\,\text{perch}^2 \\ &= 580\text{ perch}^2\ . \end{aligned}$$
   We multiply this by the perch^2 $\rightarrow$ rood conversion factor $(1\,\text{rood}/40\,\text{perch}^2)$ to obtain the answer: $A_{\text{total}} = 14.5$ roods.

   (b) We convert our intermediate result in part (a):
   $$A_{\text{total}} = (580\text{ perch}^2)\left(\frac{16.5\text{ ft}}{1\text{ perch}}\right)^2 = 1.58 \times 10^5\ \text{ft}^2\ .$$
   Now, we use the feet $\rightarrow$ meters conversion given in Appendix D to obtain
   $$A_{\text{total}} = \left(1.58 \times 10^5\ \text{ft}^2\right)\left(\frac{1\text{ m}}{3.281\text{ ft}}\right)^2 = 1.47 \times 10^4\ \text{m}^2\ .$$

7. The volume of ice is given by the product of the semicircular surface area and the thickness. The semicircle area is $A = \pi r^2/2$, where r is the radius. Therefore, the volume is
   $$V = \frac{\pi}{2}r^2 z$$
   where z is the ice thickness. Since there are 10^3 m in 1 km and 10^2 cm in 1 m, we have
   $$r = (2000\,\text{km})\left(\frac{10^3\,\text{m}}{1\,\text{km}}\right)\left(\frac{10^2\,\text{cm}}{1\,\text{m}}\right) = 2000 \times 10^5\ \text{cm}\ .$$
   In these units, the thickness becomes
   $$z = (3000\,\text{m})\left(\frac{10^2\,\text{cm}}{1\,\text{m}}\right) = 3000 \times 10^2\,\text{cm}\ .$$
   Therefore,
   $$V = \frac{\pi}{2}\left(2000 \times 10^5\,\text{cm}\right)^2\left(3000 \times 10^2\,\text{cm}\right) = 1.9 \times 10^{22}\,\text{cm}^3\ .$$

8. The total volume V of the real house is that of a triangular prism (of height $h = 3.0$ m and base area $A = 20 \times 12 = 240$ m^2) in addition to a rectangular box (height $h' = 6.0$ m and same base). Therefore,
   $$V = \frac{1}{2}hA + h'A = \left(\frac{h}{2} + h'\right)A = 1800\ \text{m}^3\ .$$

(a) Each dimension is reduced by a factor of 1/12, and we find

$$V_{\text{doll}} = \left(1800 \text{ m}^3\right)\left(\frac{1}{12}\right)^3 \approx 1.0 \text{ m}^3 \ .$$

(b) In this case, each dimension (relative to the real house) is reduced by a factor of 1/144. Therefore,

$$V_{\text{miniature}} = \left(1800 \text{ m}^3\right)\left(\frac{1}{144}\right)^3 \approx 6.0 \times 10^{-4} \text{ m}^3 \ .$$

9. We use the conversion factors found in Appendix D.

$$1 \,\text{acre} \cdot \text{ft} = (43,560 \,\text{ft}^2) \cdot \text{ft} = 43,560 \,\text{ft}^3 \,.$$

Since 2 in. = (1/6) ft, the volume of water that fell during the storm is

$$V = (26 \,\text{km}^2)(1/6 \,\text{ft}) = (26 \,\text{km}^2)(3281 \,\text{ft/km})^2(1/6 \,\text{ft}) = 4.66 \times 10^7 \,\text{ft}^3 \,.$$

Thus,

$$V = \frac{4.66 \times 10^7 \,\text{ft}^3}{4.3560 \times 10^4 \,\text{ft}^3/\text{acre} \cdot \text{ft}} = 1.1 \times 10^3 \,\text{acre} \cdot \text{ft} \,.$$

10. The metric prefixes (micro (μ), pico, nano, ...) are given for ready reference on the inside front cover of the textbook (also, Table 1-2).

$$\begin{aligned} 1 \,\mu\text{century} &= \left(10^{-6} \,\text{century}\right)\left(\frac{100 \,\text{y}}{1 \,\text{century}}\right)\left(\frac{365 \,\text{day}}{1 \,\text{y}}\right)\left(\frac{24 \,\text{h}}{1 \,\text{day}}\right)\left(\frac{60 \,\text{min}}{1 \,\text{h}}\right) \\ &= 52.6 \,\text{min} \ . \end{aligned}$$

The percent difference is therefore

$$\frac{52.6 \,\text{min} - 50 \,\text{min}}{50 \,\text{min}} = 5.2\% \,.$$

11. We use the conversion factors given in Appendix D and the definitions of the SI prefixes given in Table 1-2 (also listed on the inside front cover of the textbook). Here, "ns" represents the nanosecond unit, "ps" represents the picosecond unit, and so on.

(a) $1 \,\text{m} = 3.281 \,\text{ft}$ and $1 \,\text{s} = 10^9 \,\text{ns}$. Thus,

$$3.0 \times 10^8 \,\text{m/s} = \left(\frac{3.0 \times 10^8 \,\text{m}}{\text{s}}\right)\left(\frac{3.281 \,\text{ft}}{\text{m}}\right)\left(\frac{\text{s}}{10^9 \,\text{ns}}\right) = 0.98 \,\text{ft/ns} \,.$$

(b) Using $1 \,\text{m} = 10^3 \,\text{mm}$ and $1 \,\text{s} = 10^{12} \,\text{ps}$, we find

$$\begin{aligned} 3.0 \times 10^8 \,\text{m/s} &= \left(\frac{3.0 \times 10^8 \,\text{m}}{\text{s}}\right)\left(\frac{10^3 \,\text{mm}}{\text{m}}\right)\left(\frac{\text{s}}{10^{12} \,\text{ps}}\right) \\ &= 0.30 \ \text{mm/ps} \ . \end{aligned}$$

12. The number of seconds in a year is 3.156×10^7. This is listed in Appendix D and results from the product

$$(365.25 \,\text{day/y})(24 \,\text{h/day})(60 \,\text{min/h})(60 \,\text{s/min}) \ .$$

(a) The number of shakes in a second is 10^8; therefore, there are indeed more shakes per second than there are seconds per year.

(b) Denoting the age of the universe as 1 u-day (or 86400 u-sec), then the time during which humans have existed is given by

$$\frac{10^6}{10^{10}} = 10^{-4} \text{ u-day} ,$$

which we may also express as

$$\left(10^{-4} \text{ u-day}\right)\left(\frac{86400 \text{ u-sec}}{1 \text{ u-day}}\right) = 8.6 \text{ u-sec} .$$

13. None of the clocks advance by exactly 24 h in a 24-h period but this is not the most important criterion for judging their quality for measuring time intervals. What is important is that the clock advance by the same amount in each 24-h period. The clock reading can then easily be adjusted to give the correct interval. If the clock reading jumps around from one 24-h period to another, it cannot be corrected since it would impossible to tell what the correction should be. The following gives the corrections (in seconds) that must be applied to the reading on each clock for each 24-h period. The entries were determined by subtracting the clock reading at the end of the interval from the clock reading at the beginning.

CLOCK	Sun. -Mon.	Mon. -Tues.	Tues. -Wed.	Wed. -Thurs.	Thurs. -Fri.	Fri. -Sat
A	−16	−16	−15	−17	−15	−15
B	−3	+5	−10	+5	+6	−7
C	−58	−58	−58	−58	−58	−58
D	+67	+67	+67	+67	+67	+67
E	+70	+55	+2	+20	+10	+10

Clocks C and D are both good timekeepers in the sense that each is consistent in its daily drift (relative to WWF time); thus, C and D are easily made "perfect" with simple and predictable corrections. The correction for clock C is less than the correction for clock D, so we judge clock C to be the best and clock D to be the next best. The correction that must be applied to clock A is in the range from 15 s to 17s. For clock B it is the range from −5 s to +10 s, for clock E it is in the range from −70 s to −2 s. After C and D, A has the smallest range of correction, B has the next smallest range, and E has the greatest range. From best the worst, the ranking of the clocks is C, D, A, B, E.

14. The time on any of these clocks is a straight-line function of that on another, with slopes $\neq$ 1 and y-intercepts $\neq 0$. From the data in the figure we deduce

$$\begin{aligned} t_C &= \frac{2}{7}t_B + \frac{594}{7} \\ t_B &= \frac{33}{40}t_A - \frac{662}{5} . \end{aligned}$$

These are used in obtaining the following results.

(a) We find

$$t'_B - t_B = \frac{33}{40}\left(t'_A - t_A\right) = 495 \text{ s}$$

when $t'_A - t_A = 600$ s.

(b) We obtain

$$t'_C - t_C = \frac{2}{7}\left(t'_B - t_B\right) = \frac{2}{7}(495) = 141 \text{ s} .$$

(c) Clock B reads $t_B = (33/40)(400) - (662/5) \approx 198$ s when clock A reads $t_A = 400$ s.

(d) From $t_C = 15 = (2/7)t_B + (594/7)$, we get $t_B \approx -245$ s.

15. We convert meters to astronomical units, and seconds to minutes, using

$$\begin{aligned} 1000\,\text{m} &= 1\,\text{km} \\ 1\,\text{AU} &= 1.50\times10^8\,\text{km} \\ 60\,\text{s} &= 1\,\text{min}\,. \end{aligned}$$

Thus, 3.0×10^8 m/s becomes

$$\left(\frac{3.0\times10^8\,\text{m}}{\text{s}}\right)\left(\frac{1\,\text{km}}{1000\,\text{m}}\right)\left(\frac{\text{AU}}{1.50\times10^8\,\text{km}}\right)\left(\frac{60\,\text{s}}{\text{min}}\right) = 0.12\,\text{AU/min}\,.$$

16. Since a change of longitude equal to 360° corresponds to a 24 hour change, then one expects to change longitude by $360^\circ/24 = 15^\circ$ before resetting one's watch by 1.0 h.

17. The last day of the 20 centuries is longer than the first day by

$$(20\,\text{century})(0.001\,\text{s/century}) = 0.02\,\text{s}\,.$$

The average day during the 20 centuries is $(0+0.02)/2 = 0.01$ s longer than the first day. Since the increase occurs uniformly, the cumulative effect T is

$$\begin{aligned} T &= (\text{average increase in length of a day})(\text{number of days}) \\ &= \left(\frac{0.01\,\text{s}}{\text{day}}\right)\left(\frac{365.25\,\text{day}}{\text{y}}\right)(2000\,\text{y}) \\ &= 7305\ \text{s} \end{aligned}$$

or roughly two hours.

18. We denote the pulsar rotation rate f (for frequency).

$$f = \frac{1\ \text{rotation}}{1.55780644887275\times10^{-3}\,\text{s}}$$

(a) Multiplying f by the time-interval $t = 7.00$ days (which is equivalent to 604800 s, if we ignore *significant figure* considerations for a moment), we obtain the number of rotations:

$$N = \left(\frac{1\,\text{rotation}}{1.55780644887275\times10^{-3}\,\text{s}}\right)(604800\,\text{s}) = 388238218.4$$

which should now be rounded to 3.88×10^8 rotations since the time-interval was specified in the problem to three significant figures.

(b) We note that the problem specifies the *exact* number of pulsar revolutions (one million). In this case, our unknown is t, and an equation similar to the one we set up in part (a) takes the form

$$\begin{aligned} N &= ft \\ 1\times10^6 &= \left(\frac{1\ \text{rotation}}{1.55780644887275\times10^{-3}\,\text{s}}\right)t \end{aligned}$$

which yields the result $t = 1557.80644887275$ s (though students who do this calculation on their calculator might not obtain those last several digits).

(c) Careful reading of the problem shows that the time-uncertainty *per revolution* is $\pm3\times10^{-17}$ s. We therefore expect that as a result of one million revolutions, the uncertainty should be $(\pm3\times10^{-17})(1\times10^6) = \pm3\times10^{-11}$ s.

19. If M_E is the mass of Earth, m is the average mass of an atom in Earth, and N is the number of atoms, then $M_E = Nm$ or $N = M_E/m$. We convert mass m to kilograms using Appendix D ($1\,\mathrm{u} = 1.661 \times 10^{-27}\,\mathrm{kg}$). Thus,

$$N = \frac{M_E}{m} = \frac{5.98 \times 10^{24}\,\mathrm{kg}}{(40\,\mathrm{u})(1.661 \times 10^{-27}\,\mathrm{kg/u})} = 9.0 \times 10^{49} \ .$$

20. To organize the calculation, we introduce the notion of density (which the students have probably seen in other courses):

$$\rho = \frac{m}{V} \ .$$

(a) We take the volume of the leaf to be its area A multiplied by its thickness z. With density $\rho = 19.32\ \mathrm{g/cm^3}$ and mass $m = 27.63$ g, the volume of the leaf is found to be

$$V = \frac{m}{\rho} = 1.430\ \mathrm{cm^3} \ .$$

We convert the volume to SI units:

$$(1.430\ \mathrm{cm^3})\left(\frac{1\ \mathrm{m}}{100\ \mathrm{cm}}\right)^3 = 1.430 \times 10^{-6}\ \mathrm{m^3} \ .$$

And since $V = A\,z$ where $z = 1 \times 10^{-6}$ m (metric prefixes can be found in Table 1-2), we obtain

$$A = \frac{1.430 \times 10^{-6}\,\mathrm{m^3}}{1 \times 10^{-6}\,\mathrm{m}} = 1.430\ \mathrm{m^2} \ .$$

(b) The volume of a cylinder of length ℓ is $V = A\ell$ where the cross-section area is that of a circle: $A = \pi r^2$. Therefore, with $r = 2.500 \times 10^{-6}$ m and $V = 1.430 \times 10^{-6}\,\mathrm{m^3}$, we obtain

$$\ell = \frac{V}{\pi r^2} = 7.284 \times 10^4\ \mathrm{m} \ .$$

21. We introduce the notion of density (which the students have probably seen in other courses):

$$\rho = \frac{m}{V}$$

and convert to SI units: $1\,\mathrm{g} = 1 \times 10^{-3}\,\mathrm{kg}$.

(a) For volume conversion, we find $1\,\mathrm{cm^3} = (1 \times 10^{-2}\,\mathrm{m})^3 = 1 \times 10^{-6}\,\mathrm{m^3}$. Thus, the density in $\mathrm{kg/m^3}$ is

$$1\,\mathrm{g/cm^3} = \left(\frac{1\,\mathrm{g}}{\mathrm{cm^3}}\right)\left(\frac{10^{-3}\,\mathrm{kg}}{\mathrm{g}}\right)\left(\frac{\mathrm{cm^3}}{10^{-6}\,\mathrm{m^3}}\right) = 1 \times 10^3\ \mathrm{kg/m^3} \ .$$

Thus, the mass of a cubic meter of water is 1000 kg.

(b) We divide the mass of the water by the time taken to drain it. The mass is found from $M = \rho V$ (the product of the volume of water and its density):

$$M = (5700\,\mathrm{m^3})(1 \times 10^3\,\mathrm{kg/m^3}) = 5.70 \times 10^6\ \mathrm{kg} \ .$$

The time is $t = (10\,\mathrm{h})(3600\,\mathrm{s/h}) = 3.6 \times 10^4\,\mathrm{s}$, so the *mass flow rate* R is

$$R = \frac{M}{t} = \frac{5.70 \times 10^6\,\mathrm{kg}}{3.6 \times 10^4\,\mathrm{s}} = 158\ \mathrm{kg/s} \ .$$

22. The volume of the water that fell is

$$\begin{aligned} V &= (26\,\mathrm{km}^2)(2.0\,\mathrm{in.}) \\ &= (26\,\mathrm{km}^2)\left(\frac{1000\,\mathrm{m}}{1\,\mathrm{km}}\right)^2 (2.0\,\mathrm{in.})\left(\frac{0.0254\,\mathrm{m}}{1\,\mathrm{in.}}\right) \\ &= (26\times 10^6\,\mathrm{m}^2)(0.0508\,\mathrm{m}) \\ &= 1.3\times 10^6\ \mathrm{m}^3\ . \end{aligned}$$

We write the mass-per-unit-volume (density) of the water as:

$$\rho = \frac{m}{V} = 1\times 10^3\ \mathrm{kg/m}^3\ .$$

The mass of the water that fell is therefore given by $m = \rho V$:

$$\begin{aligned} m &= \left(1\times 10^3\,\mathrm{kg/m}^3\right)\left(1.3\times 10^6\,\mathrm{m}^3\right) \\ &= 1.3\times 10^9\ \mathrm{kg}\ . \end{aligned}$$

23. We introduce the notion of density (which the students have probably seen in other courses):

$$\rho = \frac{m}{V}$$

and convert to SI units: $1000\,\mathrm{g} = 1\,\mathrm{kg}$, and $100\,\mathrm{cm} = 1$ m.

(a) The density ρ of a sample of iron is therefore

$$\rho = \left(7.87\,\mathrm{g/cm}^3\right)\left(\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}}\right)\left(\frac{100\,\mathrm{cm}}{1\,\mathrm{m}}\right)^3$$

which yields $\rho = 7870\ \mathrm{kg/m}^3$. If we ignore the empty spaces between the close-packed spheres, then the density of an individual iron atom will be the same as the density of any iron sample. That is, if M is the mass and V is the volume of an atom, then

$$V = \frac{M}{\rho} = \frac{9.27\times 10^{-26}\,\mathrm{kg}}{7.87\times 10^3\,\mathrm{kg/m}^3} = 1.18\times 10^{-29}\ \mathrm{m}^3\ .$$

(b) We set $V = 4\pi R^3/3$, where R is the radius of an atom (Appendix E contains several geometry formulas). Solving for R, we find

$$R = \left(\frac{3V}{4\pi}\right)^{1/3} = \left(\frac{3(1.18\times 10^{-29}\,\mathrm{m}^3)}{4\pi}\right)^{1/3} = 1.41\times 10^{-10}\,\mathrm{m}\,.$$

The center-to-center distance between atoms is twice the radius, or 2.82×10^{-10} m.

24. The metric prefixes (micro (μ), pico, nano, ...) are given for ready reference on the inside front cover of the textbook (see also Table 1-2). The surface area A of each grain of sand of radius $r = 50\,\mu\mathrm{m} = 50\times 10^{-6}$ m is given by $A = 4\pi(50\times 10^{-6})^2 = 3.14\times 10^{-8}\ \mathrm{m}^2$ (Appendix E contains a variety of geometry formulas). We introduce the notion of density (which the students have probably seen in other courses):

$$\rho = \frac{m}{V}$$

so that the mass can be found from $m = \rho V$, where $\rho = 2600\ \mathrm{kg/m}^3$. Thus, using $V = 4\pi r^3/3$, the mass of each grain is

$$m = \left(\frac{4\pi\left(50\times 10^{-6}\,\mathrm{m}\right)^3}{3}\right)\left(2600\,\frac{\mathrm{kg}}{\mathrm{m}^3}\right) = 1.36\times 10^{-9}\ \mathrm{kg}\ .$$

We observe that (because a cube has six equal faces) the indicated surface area is 6 m^2. The number of spheres (the grains of sand) N which have a total surface area of 6 m^2 is given by

$$N = \frac{6\,\mathrm{m}^2}{3.14 \times 10^{-8}\,\mathrm{m}^2} = 1.91 \times 10^8 \ .$$

Therefore, the total mass M is given by

$$M = Nm = \left(1.91 \times 10^8\right)\left(1.36 \times 10^{-9}\ \mathrm{kg}\right) = 0.260\,\mathrm{kg} \ .$$

25. From the Figure we see that, regarding differences in positions Δx, 212 S is equivalent to 258 W and 180 S is equivalent to 156 Z. Whether or not the origin of the Zelda path coincides with the origins of the other paths is immaterial to consideration of Δx.

    (a)

$$\Delta x = (50.0\ \mathrm{S})\left(\frac{258\ \mathrm{W}}{212\ \mathrm{S}}\right) = 60.8\ \mathrm{W}$$

    (b)

$$\Delta x = (50.0\ \mathrm{S})\left(\frac{156\ \mathrm{Z}}{180\ \mathrm{S}}\right) = 43.3\ \mathrm{Z}$$

26. The first two conversions are easy enough that a *formal* conversion is not especially called for, but in the interest of *practice makes perfect* we go ahead and proceed formally:

    (a)

$$(11\ \text{tuffet})\left(\frac{2\ \text{peck}}{1\ \text{tuffet}}\right) = 22\ \text{peck}$$

    (b)

$$(11\ \text{tuffet})\left(\frac{0.50\ \text{bushel}}{1\ \text{tuffet}}\right) = 5.5\ \text{bushel}$$

    (c)

$$(5.5\ \text{bushel})\left(\frac{36.3687\ \mathrm{L}}{1\ \text{bushel}}\right) \approx 200\ \mathrm{L}$$

27. We make the assumption that the clouds are directly overhead, so that Figure 1-3 (and the calculations that accompany it) apply. Following the steps in Sample Problem 1-4, we have

$$\frac{\theta}{360^\circ} = \frac{t}{24\ \mathrm{h}}$$

which, for $t = 38$ min $= 38/60$ h yields $\theta = 9.5^\circ$. We obtain the altitude h from the relation

$$d^2 = r^2 \tan^2\theta = 2rh$$

which is discussed in that Sample Problem, where $r = 6.37 \times 10^6$ m is the radius of the earth. Therefore, $h = 8.9 \times 10^4$ m.

28. In the simplest approach, we set up a ratio for the total increase in *horizontal depth* x (where $\Delta x = 0.05$ m is the increase in horizontal depth per step)

$$x = N_{\text{steps}} \Delta x = \left(\frac{4.57}{0.19}\right)(0.05) = 1.2 \text{ m} .$$

However, we can approach this more carefully by noting that if there are $N = 4.57/.19 \approx 24$ rises then under normal circumstances we would expect $N - 1 = 23$ runs (horizontal pieces) in that staircase. This would yield $(23)(0.05) = 1.15$ m, which – to two significant figures – agrees with our first result.

29. Abbreviating wapentake as "wp" and assuming a hide to be 110 acres, we set up the ratio 25 wp/11 barn along with appropriate conversion factors:

$$\frac{(25\,\text{wp})\left(\frac{100\,\text{hide}}{1\,\text{wp}}\right)\left(\frac{110\,\text{acre}}{1\,\text{hide}}\right)\left(\frac{4047\,\text{m}^2}{1\,\text{acre}}\right)}{(11\,\text{barn})\left(\frac{1\times10^{-28}\,\text{m}^2}{1\,\text{barn}}\right)} \approx 1 \times 10^{36} .$$

30. It is straightforward to compute how many seconds in a year (about 3×10^7). Now, if we estimate roughly one breath per second (or every two seconds, or three seconds – it won't affect the result) then to within an order of magnitude, a person takes 10^7 breaths in a year.

31. A day is equivalent to 86400 seconds and a meter is equivalent to a million micrometers, so

$$\frac{(3.7\,\text{m})(10^6\,\mu\text{m/m})}{(14\,\text{day})(86400\,\text{s/day})} = 3.1\ \mu\text{m/s} .$$

32. The mass in kilograms is

$$(28.9\,\text{piculs})\left(\frac{100\,\text{gin}}{1\,\text{picul}}\right)\left(\frac{16\,\text{tahil}}{1\,\text{gin}}\right)\left(\frac{10\,\text{chee}}{1\,\text{tahil}}\right)\left(\frac{10\,\text{hoon}}{1\,\text{chee}}\right)\left(\frac{0.3779\,\text{g}}{1\,\text{hoon}}\right)$$

which yields 1.747×10^6 g or roughly 1750 kg.

33. (a) In atomic mass units, the mass of one molecule is $16 + 1 + 1 = 18$ u. Using Eq. 1-9, we find

$$(18\,\text{u})\left(\frac{1.6605402 \times 10^{-27}\,\text{kg}}{1\,\text{u}}\right) = 3.0 \times 10^{-26}\ \text{kg} .$$

(b) We divide the total mass by the mass of each molecule and obtain the (approximate) number of water molecules:

$$\frac{1.4 \times 10^{21}}{3.0 \times 10^{-26}} \approx 5 \times 10^{46} .$$

34. (a) We find the volume in cubic centimeters

$$(193\,\text{gal})\left(\frac{231\,\text{in}^3}{1\,\text{gal}}\right)\left(\frac{2.54\,\text{cm}}{1\,\text{in}}\right)^3 = 7.31 \times 10^5\ \text{cm}^3$$

and subtract this from 1×10^6 cm^3 to obtain 2.69×10^5 cm^3. The conversion gal $\rightarrow$ in^3 is given in Appendix D (immediately below the table of Volume conversions).

(b) The volume found in part (a) is converted (by dividing by $(100\,\text{cm/m})^3$) to 0.731 m^3, which corresponds to a mass of

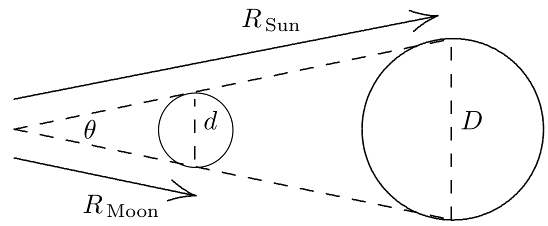
$$\left(1000\,\text{kg/m}^3\right)\left(0.731\,\text{m}^2\right) = 731\ \text{kg}$$

using the density given in the problem statement. At a rate of 0.0018 kg/min, this can be filled in

$$\frac{731\,\text{kg}}{0.0018\,\text{kg/min}} = 4.06 \times 10^5\ \text{min}$$

which we convert to 0.77 y, by dividing by the number of minutes in a year (365 days)(24 h/day)(60 min/h).

35. (a) When θ is measured in radians, it is equal to the arclength divided by the radius. For very large radius circles and small values of θ, such as we deal with in this problem, the arcs may be approximated as straight lines – which for our purposes correspond to the diameters d and D of the Moon and Sun, respectively. Thus,



$$\theta = \frac{d}{R_{\text{Moon}}} = \frac{D}{R_{\text{Sun}}} \implies \frac{R_{\text{Sun}}}{R_{\text{Moon}}} = \frac{D}{d}$$

which yields $D/d = 400$.

(b) Various geometric formulas are given in Appendix E. Using r_s and r_m for the radius of the Sun and Moon, respectively (noting that their ratio is the same as D/d), then the Sun's volume divided by that of the Moon is

$$\frac{\frac{4}{3}\pi r_s^3}{\frac{4}{3}\pi r_m^3} = \left(\frac{r_s}{r_m}\right)^3 = 400^3 = 6.4 \times 10^7 \ .$$

(c) The angle should turn out to be roughly 0.009 rad (or about half a degree). Putting this into the equation above, we get

$$d = \theta R_{\text{Moon}} = (0.009)\left(3.8 \times 10^5\right) \approx 3.4 \times 10^3 \text{ km} \ .$$

36. (a) For the minimum (43 cm) case, 9 cubit converts as follows:

$$(9\,\text{cubit})\left(\frac{0.43\,\text{m}}{1\,\text{cubit}}\right) = 3.9 \text{ m} \ .$$

And for the maximum (43 cm) case we obtain

$$(9\,\text{cubit})\left(\frac{0.53\text{ m}}{1\,\text{cubit}}\right) = 4.8 \text{ m} \ .$$

(b) Similarly, with $0.43\,\text{m} \rightarrow 430\,\text{mm}$ and $0.53\,\text{m} \rightarrow 530\,\text{mm}$, we find 3.9×10^3 mm and 4.8×10^3 mm, respectively.

(c) We can convert length and diameter first and then compute the volume, or first compute the volume and then convert. We proceed using the latter approach (where d is diameter and ℓ is length).

$$\begin{aligned} V_{\text{cylinder, min}} &= \frac{\pi}{4}\,\ell\, d^2 = 28 \text{ cubit}^3 \\ &= \left(28\,\text{cubit}^3\right)\left(\frac{0.43\,\text{m}}{1\,\text{cubit}}\right)^3 \\ &= 2.2 \text{ m}^3 \ . \end{aligned}$$

Similarly, with 0.43 m replaced by 0.53 m, we obtain $V_{\text{cylinder, max}} = 4.2\,\text{m}^3$.

37. (a) Squaring the relation $1\,\text{ken} = 1.97\,\text{m}$, and setting up the ratio, we obtain

$$\frac{1\,\text{ken}^2}{1\,\text{m}^2} = \frac{1.97^2\,\text{m}^2}{1\,\text{m}^2} = 3.88 \ .$$

(b) Similarly, we find

$$\frac{1\,\text{ken}^3}{1\,\text{m}^3} = \frac{1.97^3\,\text{m}^3}{1\,\text{m}^3} = 7.65\ .$$

(c) The volume of a cylinder is the circular area of its base multiplied by its height. Thus,

$$\pi r^2 h = \pi (3.00)^2 (5.50) = 155.5\ \text{ken}^3\ .$$

(d) If we multiply this by the result of part (b), we determine the volume in cubic meters: $(155.5)(7.65) = 1.19 \times 10^3\ \text{m}^3$.

38. Although we can look up the distance from Cleveland to Los Angeles, we can just as well (for an order of magnitude calculation) assume it's some relatively small fraction of the circumference of Earth – which suggests that (again, for an order of magnitude calculation) we can estimate the distance to be roughly r, where $r \approx 6 \times 10^6$ m is the radius of Earth. If we take each toilet paper sheet to be roughly 10 cm (0.1 m) then the number of sheets needed is roughly $6 \times 10^6/0.1 = 6 \times 10^7 \approx 10^8$.

39. Using the (exact) conversion $2.54\,\text{cm} = 1\,\text{in.}$ we find that $1\ \text{ft} = (12)(2.54)/100 = 0.3048$ m (which also can be found in Appendix D). The volume of a cord of wood is $8 \times 4 \times 4 = 128\ \text{ft}^3$, which we convert (multiplying by 0.3048^3) to $3.6\ \text{m}^3$. Therefore, one cubic meter of wood corresponds to $1/3.6 \approx 0.3$ cord.

40. (a) When θ is measured in radians, it is equal to the arclength s divided by the radius R. For a very large radius circle and small value of θ, such as we deal with in Fig. 1-9, the arc may be approximated as the straight line-segment of length 1 AU. First, we convert $\theta = 1$ arcsecond to radians:

$$(1\,\text{arcsecond}) \left(\frac{1\,\text{arcminute}}{60\,\text{arcsecond}}\right) \left(\frac{1^\circ}{60\,\text{arcminute}}\right) \left(\frac{2\pi\,\text{radian}}{360^\circ}\right)$$

which yields $\theta = 4.85 \times 10^{-6}$ rad. Therefore, one parsec is

$$R_\text{o} = \frac{s}{\theta} = \frac{1\ \text{AU}}{4.85 \times 10^{-6}} = 2.06\ \times 10^5\ \text{AU}\ .$$

Now we use this to convert $R = 1$ AU to parsecs:

$$R = (1\,\text{AU}) \left(\frac{1\,\text{pc}}{2.06\ \times 10^5\,\text{AU}}\right) = 4.9 \times 10^{-6}\,\text{pc}\ .$$

(b) Also, since it is straightforward to figure the number of seconds in a year (about 3.16×10^7 s), and (for constant speeds) distance = speed×time, we have

$$1\,\text{ly} = (186,000\,\text{mi/s})\left(3.16 \times 10^7\,\text{s}\right) 5.9 \times 10^{12}\ \text{mi}$$

which we convert to AU by dividing by 92.6×10^6 (given in the problem statement), obtaining 6.3×10^4 AU. Inverting, the result is $1\,\text{AU} = 1/6.3 \times 10^4 = 1.6 \times 10^{-5}$ ly.

(c) As found in the previous part, $1\,\text{ly} = 5.9 \times 10^{12}\,\text{mi}$.

(d) We now know what one parsec is in AU (denoted above as R_o), and we also know how many miles are in an AU. Thus, one parsec is equivalent to

$$\left(92.9 \times 10^6\,\text{mi/AU}\right)\left(2.06\ \times 10^5\,\text{AU}\right) = 1.9 \times 10^{13}\ \text{mi}\ .$$

41. We reduce the stock amount to British teaspoons:

$$\begin{aligned} 1\ \text{breakfastcup} &= 2 \times 8 \times 2 \times 2 = 64\ \text{teaspoons} \\ 1\ \text{teacup} &= 8 \times 2 \times 2 = 32\ \text{teaspoons} \\ 6\ \text{tablespoons} &= 6 \times 2 \times 2 = 24\ \text{teaspoons} \\ 1\ \text{dessertspoon} &= 2\ \text{teaspoons} \end{aligned}$$

which totals to 122 teaspoons – which corresponds (since liquid measure is being used) to 122 U.S. teaspoons. Since each U.S cup is 48 teaspoons, then upon dividing $122/48 \approx 2.54$, we find this amount corresponds to two-and-a-half U.S. cups plus a remainder of precisely 2 teaspoons. For the nettle tops, one-half quart is still one-half quart. For the rice, one British tablespoon is 4 British teaspoons which (since dry-goods measure is being used) corresponds to 2 U.S. teaspoons. Finally, a British saltspoon is $\frac{1}{2}$ British teaspoon which corresponds (since dry-goods measure is again being used) to 1 U.S. teaspoon.

42. (a) *Mega*phone.
    (b) *micro*phone.
    (c) *deka*card ("deck of cards").
    (d) *Giga*low ("gigalo").
    (e) *tera*bull ("terrible").
    (f) *deci*mate.
    (g) *centi*pede.
    (h) *nano*nannette. ("No No Nanette").
    (i) *pico*boo ("peek-a-boo").
    (j) *atto*boy ("at-a-boy").
    (k) Two *hecto*withit ("to heck with it").
    (l) Two *kilo*mockingbird ("to kill a mockingbird").

43. The volume removed in one year is

$$V = \left(75 \times 10^4\,\mathrm{m}^2\right)(26\,\mathrm{m}) \approx 2 \times 10^7\ \mathrm{m}^3$$

which we convert to cubic kilometers:

$$V = \left(2 \times 10^7\,\mathrm{m}^3\right)\left(\frac{1\,\mathrm{km}}{1000\,\mathrm{m}}\right)^3 = 0.020\ \mathrm{km}^3\ .$$

44. (a) Using Appendix D, we have $1\,\mathrm{ft} = 0.3048\,\mathrm{m}$, $1\,\mathrm{gal} = 231\,\mathrm{in.}^3$, and $1\,\mathrm{in.}^3 = 1.639 \times 10^{-2}$ L. From the latter two items, we find that $1\,\mathrm{gal} = 3.79$ L. Thus, the quantity $460\mathrm{ft}^2/\mathrm{gal}$ becomes

$$\left(\frac{460\,\mathrm{ft}^2}{\mathrm{gal}}\right)\left(\frac{1\,\mathrm{m}}{3.28\,\mathrm{ft}}\right)^2\left(\frac{1\,\mathrm{gal}}{3.79\,\mathrm{L}}\right) = 11.3\ \mathrm{m}^2/\mathrm{L}\ .$$

    (b) Also, since 1 m^3 is equivalent to 1000 L, our result from part (a) becomes

$$\left(\frac{11.3\,\mathrm{m}^2}{\mathrm{L}}\right)\left(\frac{1000\,\mathrm{L}}{1\,\mathrm{m}^3}\right) = 1.13 \times 10^4\ \mathrm{m}^{-1}\ .$$

    (c) The inverse of the original quantity is $(460\,\mathrm{ft}^2/\mathrm{gal})^{-1} = 2.17 \times 10^{-3}\,\mathrm{gal}/\mathrm{ft}^2$, which is the volume of the paint (in gallons) needed to cover a square foot of area. From this, we could also figure the paint thickness (it turns out to be about a tenth of a millimeter, as one sees by taking the reciprocal of the answer in part (b)).