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 km = 1×10^3 m and 1 m = 1×10^6 μm,

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

The given measurement is 1.0 km (two significant figures), which implies our result should be written as 1.0×10^9 μm.

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

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

We conclude that the fraction of one centimeter equal to 1.0 μm is 1.0×10^{-4}.

(c) Since 1 yd = (3 ft)(0.3048 m/ft) = 0.9144 m,

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

2. (a) Using the conversion factors 1 inch = 2.54 cm exactly and 6 picas = 1 inch, we obtain

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

(b) With 12 points = 1 pica, we have

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

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. The conversion factors $1 \text{ gry} = 1/10 \text{ line}$, $1 \text{ line} = 1/12 \text{ inch}$ and 1 point = 1/72 inch imply that

$$1 \text{ gry} = (1/10)(1/12)(72 \text{ points}) = 0.60 \text{ point}.$$

Thus, $1 \text{ gry}^2 = (0.60 \text{ point})^2 = 0.36 \text{ point}^2$, which means that $0.50 \text{ gry}^2 = 0.18 \text{ point}^2$.

5. Various geometric formulas are given in Appendix E.

(a) Expressing the radius of the Earth as

$$R = \left(6.37 \times 10^6 \text{ m}\right)\left(10^{-3} \text{ km/m}\right) = 6.37 \times 10^3 \text{ km},$$

its circumference is $s = 2\pi R = 2\pi(6.37 \times 10^3 \text{ km}) = 4.00\times10^4 \text{ km}$.

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

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

6. From Figure 1.6, we see that 212 S is equivalent to 258 W and 212 – 32 = 180 S is equivalent to 216 – 60 = 156 Z. The information allows us to convert S to W or Z.

(a) In units of W, we have

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

(b) In units of Z, we have

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

7. The volume of ice is given by the product of the semicircular surface area and the thickness. The area of the semicircle 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

$$z = 3000\,\text{m} = (3000\,\text{m}) \left(\frac{10^2\ \text{cm}}{1\,\text{m}} \right) = 3000 \times 10^2\ \text{cm}$$

which yields $V = \frac{\pi}{2} \left(2000 \times 10^5\ \text{cm}\right)^2 \left(3000 \times 10^2\ \text{cm}\right) = 1.9 \times 10^{22}\ \text{cm}^3.$

8. We make use of Table 1-6.

(a) We look at the first ("cahiz") column: 1 fanega is equivalent to what amount of cahiz? We note from the already completed part of the table that 1 cahiz equals a dozen fanega. Thus, 1 fanega $= \frac{1}{12}$ cahiz, or 8.33×10^{-2} cahiz. Similarly, "1 cahiz = 48 cuartilla" (in the already completed part) implies that 1 cuartilla $= \frac{1}{48}$ cahiz, or 2.08×10^{-2} cahiz. Continuing in this way, the remaining entries in the first column are 6.94×10^{-3} and 3.47×10^{-3}.

(b) In the second ("fanega") column, we similarly find 0.250, 8.33×10^{-2}, and 4.17×10^{-2} for the last three entries.

(c) In the third ("cuartilla") column, we obtain 0.333 and 0.167 for the last two entries.

(d) Finally, in the fourth ("almude") column, we get $\frac{1}{2} = 0.500$ for the last entry.

(e) Since the conversion table indicates that 1 almude is equivalent to 2 medios, our amount of 7.00 almudes must be equal to 14.0 medios.

(f) Using the value (1 almude $= 6.94 \times 10^{-3}$ cahiz) found in part (a), we conclude that 7.00 almudes is equivalent to 4.86×10^{-2} cahiz.

(g) Since each decimeter is 0.1 meter, then 55.501 cubic decimeters is equal to 0.055501 m^3 or 55501 cm^3. Thus, 7.00 almudes $= \frac{7.00}{12}$ fanega $= \frac{7.00}{12}(55501\ cm^3) = 3.24 \times 10^4\ cm^3$.

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

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

11. A week is 7 days, each of which has 24 hours, and an hour is equivalent to 3600 seconds. Thus, two weeks (a fortnight) is 1209600 s. By definition of the micro prefix, this is roughly 1.21×10^{12} μs.

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

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

(b) The percent difference is therefore

$$\frac{52.6\ \text{min} - 50\ \text{min}}{52.6\ \text{min}} = 4.9\%.$$

13. (a) Presuming that a French decimal day is equivalent to a regular day, then the ratio of weeks is simply 10/7 or (to 3 significant figures) 1.43.

(b) In a regular day, there are 86400 seconds, but in the French system described in the problem, there would be 10^5 seconds. The ratio is therefore 0.864.

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

$$f = \frac{1 \text{ rotation}}{1.55780644887275 \times 10^{-3} \text{ s}}$$

(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:

$$N = \left(\frac{1 \text{ rotation}}{1.55780644887275 \times 10^{-3} \text{ s}}\right)(604800 \text{ s}) = 388238218.4$$

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 $N = ft$, or

$$1 \times 10^6 = \left(\frac{1 \text{ rotation}}{1.55780644887275 \times 10^{-3} \text{ s}}\right)t$$

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 $\pm 3\times 10^{-17}$s . We therefore expect that as a result of one million revolutions, the uncertainty should be $(\pm 3\times 10^{-17})(1\times 10^{6}) = \pm 3\times 10^{-11}$ s .

15. 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

$$t_C = \frac{2}{7}t_B + \frac{594}{7}, \quad t_B = \frac{33}{40}t_A - \frac{662}{5}.$$

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

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

17. 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 to worst, the ranking of the clocks is C, D, A, B, E.

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

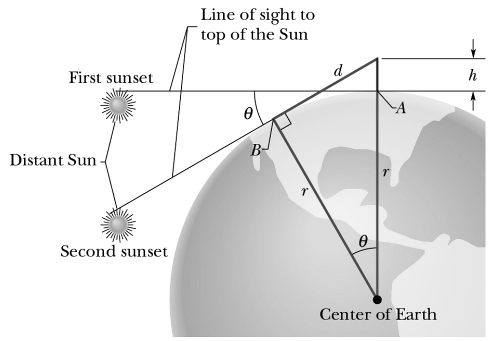
$$(20 \text{ century})\,(0.001 \text{ s/century}) = 0.02 \text{ s}.$$

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.

19. When the Sun first disappears while lying down, your line of sight to the top of the Sun is tangent to the Earth's surface at point A shown in the figure. As you stand, elevating your eyes by a height h, the line of sight to the Sun is tangent to the Earth's surface at point B.



Let d be the distance from point B to your eyes. From Pythagorean theorem, we have

$$d^2 + r^2 = (r+h)^2 = r^2 + 2rh + h^2$$

or $d^2 = 2rh + h^2$, where r is the radius of the Earth. Since $r \gg h$, the second term can be dropped, leading to $d^2 \approx 2rh$. Now the angle between the two radii to the two tangent points A and B is θ, which is also the angle through which the Sun moves about Earth during the time interval t = 11.1 s. The value of θ can be obtained by using

$$\frac{\theta}{360°} = \frac{t}{24 \text{ h}}.$$

This yields

$$\theta = \frac{(360°)(11.1 \text{ s})}{(24 \text{ h})(60 \text{ min/h})(60 \text{ s/min})} = 0.04625°.$$

Using $d = r\tan\theta$, we have $d^2 = r^2 \tan^2\theta = 2rh$, or

$$r = \frac{2h}{\tan^2\theta}$$

Using the above value for θ and h = 1.7 m, we have $r = 5.2 \times 10^6$ m.

20. The density of gold is

$$\rho = \frac{m}{V} = \frac{19.32 \text{ g}}{1 \text{ cm}^3} = 19.32 \text{ g/cm}^3.$$

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

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

We convert the volume to SI units:

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

Since $V = Az$ with $z = 1 \times 10^{-6}$ m (metric prefixes can be found in Table 1–2), we obtain

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

(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 $V = 1.430 \times 10^{-6}$ m^3, we obtain

$$\ell = \frac{V}{\pi r^2} = 7.284 \times 10^4 \text{ m} = 72.84 \text{ km}.$$

21. We introduce the notion of density:

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

and convert to SI units: 1 g = 1 × 10^{-3} kg.

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

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

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):

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

The time is t = (10h)(3600 s/h) = 3.6 × 10^4 s, so the *mass flow rate* R is

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

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

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

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 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

$$\frac{731 \text{kg}}{0.0018 \text{ kg/min}} = 4.06\times 10^5 \text{ min} = 0.77 \text{ y}$$

after dividing by the number of minutes in a year (365 days)(24 h/day) (60 min/h).

23. 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 u = 1.661×10^{-27} kg). Thus,

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

24. (a) The volume of the cloud is (3000 m)π(1000 m)^2 = 9.4 × 10^9 m^3. Since each cubic meter of the cloud contains from 50 × 10^6 to 500 × 10^6 water drops, then we conclude that the entire cloud contains from 4.7 × 10^{18} to 4.7 × 10^{19} drops. Since the volume of each drop is $\frac{4}{3}\pi(10 \times 10^{-6}\text{ m})^3 = 4.2 \times 10^{-15}\text{ m}^3$, then the total volume of water in a cloud is from 2×10^3 to 2×10^4 m^3.

(b) Using the fact that $1\text{ L} = 1\times10^3\text{cm}^3 = 1\times10^{-3}\text{m}^3$, the amount of water estimated in part (a) would fill from 2×10^6 to 2×10^7 bottles.

(c) At 1000 kg for every cubic meter, the mass of water is from two million to twenty million kilograms. The coincidence in numbers between the results of parts (b) and (c) of this problem is due to the fact that each liter has a mass of one kilogram when water is at its normal density (under standard conditions).

25. We introduce the notion of density, $\rho = m/V$, and convert to SI units: 1000 g = 1 kg, and 100 cm = 1 m.

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

$$\rho = \left(7.87\ \text{g/cm}^3\right)\left(\frac{1\ \text{kg}}{1000\ \text{g}}\right)\left(\frac{100\ \text{cm}}{1\ \text{m}}\right)^3 = 7870\ \text{kg/m}^3.$$

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

$$V = \frac{M}{\rho} = \frac{9.27\times10^{-26}\ \text{kg}}{7.87\times10^{3}\ \text{kg/m}^3} = 1.18\times10^{-29}\ \text{m}^3.$$

(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

$$R = \left(\frac{3V}{4\pi}\right)^{1/3} = \left(\frac{3\left(1.18\times10^{-29}\ \text{m}^3\right)}{4\pi}\right)^{1/3} = 1.41\times10^{-10}\ \text{m}.$$

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

26. If we estimate the "typical" large domestic cat mass as 10 kg, and the "typical" atom (in the cat) as 10 u $\approx 2 \times 10^{-26}$ kg, then there are roughly (10 kg)/(2×10^{-26} kg) $\approx 5 \times 10^{26}$ atoms. This is close to being a factor of a thousand greater than Avogradro's number. Thus this is roughly a kilomole of atoms.

27. According to Appendix D, a nautical mile is 1.852 km, so 24.5 nautical miles would be 45.374 km. Also, according to Appendix D, a mile is 1.609 km, so 24.5 miles is 39.4205 km. The difference is 5.95 km.

28. 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 μm = 50 × 10^{-6} m is given by $A = 4\pi(50 \times 10^{-6})^2 = 3.14 \times 10^{-8}$ m^2 (Appendix E contains a variety of geometry formulas). We introduce the notion of density, $\rho = m/V$, so that the mass can be found from $m = \rho V$, where ρ = 2600 kg/m^3. Thus, using $V = 4\pi r^3/3$, the mass of each grain is

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

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 that have a total surface area of 6 m^2 is given by

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

Therefore, the total mass M is $M = Nm = \left(1.91\times 10^8\right)\left(1.36\times 10^{-9}\ \text{kg}\right) = 0.260$ kg.

29. The volume of the section is (2500 m)(800 m)(2.0 m) = 4.0×10^6 m^3. Letting "*d*" stand for the thickness of the mud after it has (uniformly) distributed in the valley, then its volume there would be (400 m)(400 m)*d*. Requiring these two volumes to be equal, we can solve for *d*. Thus, *d* = 25 m. The volume of a small part of the mud over a patch of area of 4.0 m^2 is (4.0)*d* = 100 m^3. Since each cubic meter corresponds to a mass of 1900 kg (stated in the problem), then the mass of that small part of the mud is 1.9×10^5 kg.

30. To solve the problem, we note that the first derivative of the function with respect to time gives the rate. Setting the rate to zero gives the time at which an extreme value of the variable mass occurs; here that extreme value is a maximum.

(a) Differentiating $m(t) = 5.00t^{0.8} - 3.00t + 20.00$ with respect to t gives

$$\frac{dm}{dt} = 4.00t^{-0.2} - 3.00.$$

The water mass is the greatest when $dm/dt = 0,$ or at $t = (4.00/3.00)^{1/0.2} = 4.21\,\text{s}.$

(b) At $t = 4.21\,\text{s},$ the water mass is

$$m(t = 4.21\,\text{s}) = 5.00(4.21)^{0.8} - 3.00(4.21) + 20.00 = 23.2\ \text{g}.$$

(c) The rate of mass change at $t = 2.00\ \text{s}$ is

$$\begin{aligned}\left.\frac{dm}{dt}\right|_{t=2.00\,\text{s}} &= \left[4.00(2.00)^{-0.2} - 3.00\right]\text{g/s} = 0.48\ \text{g/s} = 0.48\frac{\text{g}}{\text{s}}\cdot\frac{1\,\text{kg}}{1000\ \text{g}}\cdot\frac{60\ \text{s}}{1\ \text{min}} \\ &= 2.89\times 10^{-2}\ \text{kg/min}.\end{aligned}$$

(d) Similarly, the rate of mass change at $t = 5.00\ \text{s}$ is

$$\begin{aligned}\left.\frac{dm}{dt}\right|_{t=2.00\,\text{s}} &= \left[4.00(5.00)^{-0.2} - 3.00\right]\text{g/s} = -0.101\ \text{g/s} = -0.101\frac{\text{g}}{\text{s}}\cdot\frac{1\,\text{kg}}{1000\ \text{g}}\cdot\frac{60\ \text{s}}{1\ \text{min}} \\ &= -6.05\times 10^{-3}\ \text{kg/min}.\end{aligned}$$

31. The mass density of the candy is

$$\rho = \frac{m}{V} = \frac{0.0200 \text{ g}}{50.0 \text{ mm}^3} = 4.00\times10^{-4} \text{ g/mm}^3 = 4.00\times10^{-4} \text{ kg/cm}^3.$$

If we neglect the volume of the empty spaces between the candies, then the total mass of the candies in the container when filled to height h is $M = \rho A h$, where $A = (14.0 \text{ cm})(17.0 \text{ cm}) = 238 \text{ cm}^2$ is the base area of the container that remains unchanged. Thus, the rate of mass change is given by

$$\begin{aligned}\frac{dM}{dt} = \frac{d(\rho A h)}{dt} = \rho A \frac{dh}{dt} &= (4.00\times10^{-4} \text{ kg/cm}^3)(238 \text{ cm}^2)(0.250 \text{ cm/s}) \\ &= 0.0238 \text{ kg/s} = 1.43 \text{ kg/min.}\end{aligned}$$

32. Table 7 can be completed as follows:

(a) It should be clear that the first column (under "wey") is the reciprocal of the first row – so that $\frac{9}{10}$ = 0.900, $\frac{3}{40}$ = 7.50×10^{-2}, and so forth. Thus, 1 pottle = 1.56×10^{-3} wey and 1 gill = 8.32×10^{-6} wey are the last two entries in the first column.

(b) In the second column (under "chaldron"), clearly we have 1 chaldron = 1 caldron (that is, the entries along the "diagonal" in the table must be 1's). To find out how many chaldron are equal to one bag, we note that 1 wey = 10/9 chaldron = 40/3 bag so that $\frac{1}{12}$ chaldron = 1 bag. Thus, the next entry in that second column is $\frac{1}{12}$ = 8.33×10^{-2}. Similarly, 1 pottle = 1.74×10^{-3} chaldron and 1 gill = 9.24×10^{-6} chaldron.

(c) In the third column (under "bag"), we have 1 chaldron = 12.0 bag, 1 bag = 1 bag, 1 pottle = 2.08×10^{-2} bag, and 1 gill = 1.11×10^{-4} bag.

(d) In the fourth column (under "pottle"), we find 1 chaldron = 576 pottle, 1 bag = 48 pottle, 1 pottle = 1 pottle, and 1 gill = 5.32×10^{-3} pottle.

(e) In the last column (under "gill"), we obtain 1 chaldron = 1.08×10^{5} gill, 1 bag = 9.02×10^{3} gill, 1 pottle = 188 gill, and, of course, 1 gill = 1 gill.

(f) Using the information from part (c), 1.5 chaldron = (1.5)(12.0) = 18.0 bag. And since each bag is 0.1091 m^3 we conclude 1.5 chaldron = (18.0)(0.1091) = 1.96 m^3.

33. 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) $11 \text{ tuffets} = (11 \text{ tuffets})\left(\dfrac{2 \text{ peck}}{1 \text{ tuffet}}\right) = 22 \text{ pecks}$.

(b) $11 \text{ tuffets} = (11 \text{ tuffets})\left(\dfrac{0.50 \text{ Imperial bushel}}{1 \text{ tuffet}}\right) = 5.5 \text{ Imperial bushels}$.

(c) $11 \text{ tuffets} = (5.5 \text{ Imperial bushel})\left(\dfrac{36.3687 \text{ L}}{1 \text{ Imperial bushel}}\right) \approx 200 \text{ L}$.

34. (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 → rood conversion factor (1 rood/40 perch^2) to obtain the answer: $A_{\text{total}} = 14.5$ roods.

(b) We convert our intermediate result in part (a):

$$A_{\text{total}} = (580\ \text{perch}^2)\left(\frac{16.5\,\text{ft}}{1\,\text{perch}}\right)^2 = 1.58\times10^5\ \text{ft}^2.$$

Now, we use the feet → meters conversion given in Appendix D to obtain

$$A_{\text{total}} = (1.58\times10^5\ \text{ft}^2)\left(\frac{1\,\text{m}}{3.281\,\text{ft}}\right)^2 = 1.47\times10^4\ \text{m}^2.$$

35. (a) Dividing 750 miles by the expected "40 miles per gallon" leads the tourist to believe that the car should need 18.8 gallons (in the U.S.) for the trip.

(b) Dividing the two numbers given (to high precision) in the problem (and rounding off) gives the conversion between U.K. and U.S. gallons. The U.K. gallon is larger than the U.S gallon by a factor of 1.2. Applying this to the result of part (a), we find the answer for part (b) is 22.5 gallons.

36. The customer expects a volume $V_1 = 20 \times 7056$ in^3 and receives $V_2 = 20 \times 5826$ in^3, the difference being $\Delta V = V_1 - V_2 = 24600 \text{ in}^3$, or

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

where Appendix D has been used.

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

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

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

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

(c) The inverse of the original quantity is (460 ft^2/gal)$^{-1}$ = 2.17 × 10^{-3} gal/ft^2.

(d) The answer in (c) represents 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)].

38. The total volume V of the real house is that of a triangular prism (of height h = 3.0 m and base area $A = 20 \times 12 = 240\ \text{m}^2$) 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,

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

39. Using the (exact) conversion 2.54 cm = 1 in. we find that 1 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) In atomic mass units, the mass of one molecule is (16 + 1 + 1)u = 18 u. Using Eq. 1–9, we find

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

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

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

41. (a) The difference between the total amounts in "freight" and "displacement" tons, $(8 - 7)(73) = 73$ barrels bulk, represents the extra M&M's that are shipped. Using the conversions in the problem, this is equivalent to $(73)(0.1415)(28.378) = 293$ U.S. bushels.

(b) The difference between the total amounts in "register" and "displacement" tons, $(20 - 7)(73) = 949$ barrels bulk, represents the extra M&M's are shipped. Using the conversions in the problem, this is equivalent to $(949)(0.1415)(28.378) = 3.81 \times 10^3$ U.S. bushels.

42. (a) The receptacle is a volume of (40 cm)(40 cm)(30 cm) = 48000 cm^3 = 48 L = (48)(16)/11.356 = 67.63 standard bottles, which is a little more than 3 nebuchadnezzars (the largest bottle indicated). The remainder, 7.63 standard bottles, is just a little less than 1 methuselah. Thus, the answer to part (a) is 3 nebuchadnezzars and 1 methuselah.

(b) Since 1 methuselah.= 8 standard bottles, then the extra amount is 8 − 7.63 = 0.37 standard bottle.

(c) Using the conversion factor 16 standard bottles = 11.356 L, we have

$$0.37 \text{ standard bottle} = (0.37 \text{ standard bottle})\left(\frac{11.356 \text{ L}}{16 \text{ standard bottles}}\right) = 0.26 \text{ L}.$$

43. The volume of one unit is 1 $cm^3 = 1 \times 10^{-6}\ m^3$, so the volume of a mole of them is $6.02 \times 10^{23}\ cm^3 = 6.02 \times 10^{17}\ m^3$. The cube root of this number gives the edge length: $8.4 \times 10^5\ m^3$. This is equivalent to roughly 8×10^2 kilometers.

44. Equation 1-9 gives (to very high precision!) the conversion from atomic mass units to kilograms. Since this problem deals with the ratio of total mass (1.0 kg) divided by the mass of one atom (1.0 u, but converted to kilograms), then the computation reduces to simply taking the reciprocal of the number given in Eq. 1-9 and rounding off appropriately. Thus, the answer is 6.0×10^{26}.

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

$$\begin{aligned} 1000 \text{ m} &= 1 \text{ km} \\ 1 \text{ AU} &= 1.50 \times 10^8 \text{ km} \\ 60 \text{ s} &= 1 \text{ min}. \end{aligned}$$

Thus, 3.0×10^8 m/s becomes

$$\left(\frac{3.0 \times 10^8 \text{ m}}{\text{s}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right)\left(\frac{\text{AU}}{1.50 \times 10^8 \text{ km}}\right)\left(\frac{60 \text{ s}}{\text{min}}\right) = 0.12 \text{ AU/min}.$$

46. The volume of the water that fell is

$$
\begin{aligned}
V &= \left(26\ \text{km}^2\right)(2.0\ \text{in.}) = \left(26\ \text{km}^2\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)^2 (2.0\ \text{in.})\left(\frac{0.0254\ \text{m}}{1\ \text{in.}}\right) \\
&= \left(26\times10^6\ \text{m}^2\right)(0.0508\ \text{m}) \\
&= 1.3\times10^6\ \text{m}^3.
\end{aligned}
$$

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

$$\rho = \frac{m}{V} = 1\times10^3\ \text{kg/m}^3.$$

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

$$m = \left(1\times10^3\ \text{kg/m}^3\right)\left(1.3\times10^6\ \text{m}^3\right) = 1.3\times10^9\ \text{kg}.$$

47. A million milligrams comprise a kilogram, so 2.3 kg/week is 2.3×10^6 mg/week. Figuring 7 days a week, 24 hours per day, 3600 second per hour, we find 604800 seconds are equivalent to one week. Thus, $(2.3 \times 10^6$ mg/week$)/(604800$ s/week$) = 3.8$ mg/s.

48. The mass of the pig is 3.108 slugs, or $(3.108)(14.59) = 45.346$ kg. Referring now to the corn, a U.S. bushel is 35.238 liters. Thus, a value of 1 for the *corn-hog ratio* would be equivalent to $35.238/45.346 = 0.7766$ in the indicated metric units. Therefore, a value of 5.7 for the *ratio* corresponds to $5.7(0.777) \approx 4.4$ in the indicated metric units.

49. Two jalapeño peppers have spiciness = 8000 SHU, and this amount multiplied by 400 (the number of people) is 3.2×10^6 SHU, which is roughly ten times the SHU value for a single habanero pepper. More precisely, 10.7 habanero peppers will provide that total required SHU value.

50. The volume removed in one year is

$$V = (75 \times 10^4 \text{ m}^2)(26 \text{ m}) \approx 2 \times 10^7 \text{ m}^3$$

which we convert to cubic kilometers: $V = \left(2 \times 10^7 \text{ m}^3\right)\left(\dfrac{1 \text{ km}}{1000 \text{ m}}\right)^3 = 0.020 \text{ km}^3$.

51. 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 may also be expressed as $\left(10^{-4} \text{ u-day}\right)\left(\dfrac{86400 \text{ u-sec}}{1 \text{ u-day}}\right) = 8.6 \text{ u-sec}.$

52. 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:

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

53. (a) Squaring the relation 1 ken = 1.97 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,

$$\pi r^2\, h = \pi\left(3.00\right)^2\left(5.50\right) = 156\ \text{ken}^3.$$

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

54. 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 1.75×10^3 kg.

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

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

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 m) = 1.15 m, which - to two significant figures - agrees with our first result.

56. Since one atomic mass unit is $1\,\text{u} = 1.66\times10^{-24}$ g (see Appendix D), the mass of one mole of atoms is about $m = (1.66\times10^{-24}\text{ g})(6.02\times10^{23}) = 1\text{ g}$. On the other hand, the mass of one mole of atoms in the common Eastern mole is

$$m' = \frac{75\text{ g}}{7.5} = 10\text{ g}$$

Therefore, in atomic mass units, the average mass of one atom in the common Eastern mole is

$$\frac{m'}{N_A} = \frac{10\text{ g}}{6.02\times10^{23}} = 1.66\times10^{-23}\text{ g} = 10\text{ u}.$$

57. (a) When θ is measured in radians, it is equal to the arc length 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 θ = 1 arcsecond to radians:

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

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

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

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 AU = $1/6.3 \times 10^4 = 1.6 \times 10^{-5}$ ly.

58. The volume of the filled container is 24000 cm^3 = 24 liters, which (using the conversion given in the problem) is equivalent to 50.7 pints (U.S). The expected number is therefore in the range from 1317 to 1927 Atlantic oysters. Instead, the number received is in the range from 406 to 609 Pacific oysters. This represents a shortage in the range of roughly 700 to 1500 oysters (the answer to the problem). Note that the minimum value in our answer corresponds to the minimum Atlantic minus the maximum Pacific, and the maximum value corresponds to the maximum Atlantic minus the minimum Pacific.

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

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

And for the maximum (43 cm) case we obtain

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

(b) Similarly, with 0.43 m $\to$ 430 mm and 0.53 m $\to$ 530 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).

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

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

60. (a) 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 British teaspoons, or 122 U.S. teaspoons since liquid measure is being used. Now with one U.S cup equal to 48 teaspoons, upon dividing $122/48 \approx 2.54$, we find this amount corresponds to 2.5 U.S. cups plus a remainder of precisely 2 teaspoons. In other words,

$$122 \text{ U.S. teaspoons} = 2.5 \text{ U.S. cups} + 2 \text{ U.S. teaspoons.}$$

(b) For the nettle tops, one-half quart is still one-half quart.

(c) For the rice, one British tablespoon is 4 British teaspoons which (since dry-goods measure is being used) corresponds to 2 U.S. teaspoons.

(d) A British saltspoon is $\frac{1}{2}$ British teaspoon which corresponds (since dry-goods measure is again being used) to 1 U.S. teaspoon.