Chapter 1

1. Abbreviating wapentake as "wp" and assuming a hide to be 110 acres, we set up the ratio 43 wp/8.0 barn along with appropriate conversion factors:

$$\frac{(43\ \text{wp})\left(\frac{100\ \text{hide}}{1\ \text{wp}}\right)\left(\frac{110\ \text{acre}}{1\ \text{hide}}\right)\left(\frac{4047\ \text{m}^2}{1\ \text{acre}}\right)}{(8.0\,\text{barns})\left(\frac{1\times 10^{-28}\ \text{m}^2}{1\ \text{barn}}\right)} \approx 2\times 10^{36}.$$

2. 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)

$$x = N_{\text{steps}}\ \Delta x = \left(\frac{9.50}{0.19}\right)(0.05\ \text{m}) = 2.5\ \text{m}.$$

3. 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 day/y) (24 h/day) (60 min/h) (60 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

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

4. 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) $$5.60\ \text{tuffets} = (5.60\,\text{tuffets})\left(\frac{2\ \text{peck}}{1\ \text{tuffet}}\right) = 11.2\ \text{pecks}.$$

(b) $$5.60\ \text{tuffets} = (5.60\ \text{tuffets})\left(\frac{0.50\ \text{Imperial bushel}}{1\ \text{tuffet}}\right) = 2.80\ \text{Imperial bushels}.$$

(c) $5.60 \text{ tuffets} = (2.80 \text{ Imperial bushel})\left(\frac{36.3687 \text{ L}}{1 \text{ Imperial bushel}}\right) \approx 102 \text{ L}$.

5. Equation 1-7 gives (to very high precision!) the conversion from atomic mass units to kilograms. Since this problem deals with the ratio of total mass (3.30 kg) divided by the mass of one atom (1.0078 u, but converted to kilograms), then the computation reduces to simply taking the reciprocal of the number given in Eq. 1-7 and rounding off appropriately. Thus, the answer is $(3.30)(6.0 \times 10^{26}) = 1.97 \times 10^{27}$.

6. **THINK** In this problem we are asked to differentiate between three types of tons: *displacement* ton, *freight* ton and *register* ton, all of which are units of volume.

EXPRESS The three different tons are defined in terms of *barrel bulk*, with $1 \text{ barrel bulk} = 0.1415 \text{ m}^3 = 4.0155 \text{ U.S. bushels}$ (using $1 \text{ m}^3 = 28.378 \text{ U.S. bushels}$). Thus, in terms of U.S. bushels, we have

$$1 \text{ displacement ton} = (7 \text{ barrels bulk}) \times \left(\frac{4.0155 \text{ U.S. bushels}}{1 \text{ barrel bulk}}\right) = 28.108 \text{ U.S. bushels}$$

$$1 \text{ freight ton} = (8 \text{ barrels bulk}) \times \left(\frac{4.0155 \text{ U.S. bushels}}{1 \text{ barrel bulk}}\right) = 32.124 \text{ U.S. bushels}$$

$$1 \text{ register ton} = (20 \text{ barrels bulk}) \times \left(\frac{4.0155 \text{ U.S. bushels}}{1 \text{ barrel bulk}}\right) = 80.31 \text{ U.S. bushels}$$

ANALYZE (a) The difference between 46 “freight” tons and 46 “displacement” tons is

$$\begin{aligned}\Delta V &= 46(\text{freight tons} - \text{displacement tons}) = 46(32.124 \text{ U.S. bushels} - 28.108 \text{ U.S. bushels}) \\ &= 184.736 \text{U.S. bushels} \approx 185 \text{ U.S. bushels}\end{aligned}$$

(b) Similarly, the difference between 46 “register” tons and 46 “displacement” tons is

$$\begin{aligned}\Delta V &= 46(\text{register tons} - \text{displacement tons}) = 46(80.31 \text{ U.S. bushels} - 28.108 \text{ U.S. bushels}) \\ &= 2401.292 \text{ U.S. bushels} \approx 2.40 \times 10^3 \text{ U.S. bushels}\end{aligned}$$

LEARN With $1 \text{ register ton} > 1 \text{ freight ton} > 1 \text{ displacement ton},$ we expect the difference found in (b) to be greater than that in (a). This is indeed the case.

7. The volume of one unit is 1 $cm^3 = 1 \times 10^{-6}\ m^3$, so the volume of 0.20 mole of them is $0.20(6.02 \times 10^{23}\ cm^3) = 1.204 \times 10^{17}\ m^3$. The cube root of this number gives the edge length: 4.9×10^5 m. This is equivalent to 4.9×10^2 km.

8. **THINK** This problem involves expressing the speed of light in astronomical units per minute.

EXPRESS We first convert meters to astronomical units (AU), and seconds to minutes, using

$$1000\ \text{m} = 1\ \text{km},\quad 1\ \text{AU} = 1.50 \times 10^8\ \text{km},\quad 60\ \text{s} = 1\ \text{min}.$$

ANALYZE Using the conversion factors above, the speed of light can be rewritten as

$$c = 3.0 \times 10^8\ \text{m/s} = \left(\frac{3.0 \times 10^8\ \text{m}}{\text{s}}\right)\left(\frac{1\ \text{km}}{1000\ \text{m}}\right)\left(\frac{\text{AU}}{1.50 \times 10^8\ \text{km}}\right)\left(\frac{3600\ \text{s}}{\text{h}}\right) = 7.2\ \text{AU/h}.$$

LEARN When expressed the speed of light c in AU/min, we readily see that it takes about 8.3 (= 1/0.12) minutes for sunlight to reach Earth (i.e., to travel a distance of 1 AU).

9. The volume of the filled container is 40 000 cm^3 = 40 liters, which (using the conversion given in the problem) is equivalent to 84.5 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 of roughly 1690 oysters.

10. 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

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

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

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

11. (a) 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

$$V = (17\ \text{km}^2)(1/6\ \text{ft}) = (17\ \text{km}^2)(3281\ \text{ft/km})^2(1/6\ \text{ft}) = 3.05\times10^7\ \text{ft}^3.$$

Thus,

$$V = \frac{3.05\times10^7\ \text{ft}^3}{4.3560\times10^4\ \text{ft}^3/\text{acre}\cdot\text{ft}} = 7.0\times10^2\ \text{acre}\cdot\text{ft}.$$

(b) We can also write the volume of the water that fell as

$$\begin{aligned} V &= \left(17\ \text{km}^2\right)\left(2.0\ \text{in.}\right) = \left(17\ \text{km}^2\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)^2\left(2.0\ \text{in.}\right)\left(\frac{0.0254\ \text{m}}{1\ \text{in.}}\right) \\ &= \left(17\times10^6\ \text{m}^2\right)\left(0.0508\ \text{m}\right) \\ &= 8.64\times10^5\ \text{m}^3. \end{aligned}$$

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 $m = \rho V$:

$$m = \left(1\times10^3\ \text{kg/m}^3\right)\left(8.64\times10^5\ \text{m}^3\right) = 8.6\times10^8\ \text{kg}.$$

12. **THINK** This problem consists of two parts: in the first part, we are asked to find the mass of water, given its volume and density; the second part deals with the mass flow rate of water, which is expressed as kg/s in SI units.

EXPRESS From the definition of density: $\rho = m/V$, we see that mass can be calculated as $m = \rho V$, the product of the volume of water and its density. With 1 g = 1×10^{-3} kg and 1 cm^3 = $(1\times10^{-2}\text{m})^3 = 1\times10^{-6}\text{m}^3$, the density of water in SI units (kg/m^3) is

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

To obtain the flow rate, we simply divide the total mass of the water by the time taken to drain it.

ANALYZE (a) Using $m = \rho V$, the mass of a cubic meter of water is

$$m = \rho V = (1 \times 10^3\ \text{kg/m}^3)(1\ \text{m}^3) = 1000\ \text{kg}.$$

(b) The total mass of water in the container is

$$M = \rho V = (1 \times 10^3\ \text{kg/m}^3)(4800\ \text{m}^3) = 4.80 \times 10^6\ \text{kg},$$

and the time elapsed is t = (15.7 h)(3600 s/h) = 5.65 × 10^4 s. Thus, the mass flow rate R is

$$R = \frac{M}{t} = \frac{4.80 \times 10^6\ \text{kg}}{5.65 \times 10^4\ \text{s}} = 84.9\ \text{kg/s}.$$

LEARN In terms of volume, the drain rate can be expressed as

$$R' = \frac{V}{t} = \frac{4800\ \text{m}^3}{5.65 \times 10^4\ \text{s}} = 0.0849\ \text{m}^3/\text{s}.$$

The greater the flow rate, the less time required to drain a given amount of water.

13. (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 ≈ 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 6 British teaspoons which (since dry-goods measure is being used) corresponds to 3 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.

14. 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 6.50 for the *ratio* corresponds to 6.50(0.777) ≈ 5.05 in the indicated metric units.

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

$$18\,\text{u} = (18\,\text{u})\left(\frac{1.6605402\times10^{-27}\,\text{kg}}{1\text{u}}\right) = 3.0\times10^{-26}\,\text{kg}.$$

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

$$N \approx \frac{2.8\times10^{8}}{3.0\times10^{-26}} = 9.3\times10^{33}.$$

16. The volume removed in one year is $V = (57\times10^{4}\ \text{m}^2)\,(17\ \text{m}) = 9.69\times10^{6}\ \text{m}^3$, which we convert to cubic kilometers:

$$V = \left(9.69\times10^{6}\ \text{m}^3\right)\left(\frac{1\ \text{km}}{1000\ \text{m}}\right)^3 = 9.7\times10^{-3}\ \text{km}^3.$$

17. 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 = 0.900, = 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 chaldron (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   chaldron = 1 bag. Thus, the next entry in that second column is $= 8.33 \times 10^{-2}$. 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), 3.30 chaldron = (3.30)(12.0) = 39.6 bag. And since each bag is 0.1091 m^3 we conclude 3.30 chaldron = (39.6)(0.1091) = 4.32 m^3.

18. The customer expects a volume $V_1 = 73 \times 7056$ in^3 and receives $V_2 = 73 \times 5826$ $in.^3$, the difference being $\Delta V = V_1 - V_2 = 8.979 \times 10^4 \text{ in.}^3$, or

$$\Delta V = \left(8.979\times10^4 \text{ in.}^3\right)\left(\frac{2.54 \text{ cm}}{1 \text{ inch}}\right)^3\left(\frac{1 \text{ L}}{1000 \text{ cm}^3}\right) = 1471 \text{ L},$$

where Appendix D has been used.

19. According to Appendix D, a nautical mile is 1.852 km, so 45.3 nautical miles would be 83.895 km. Also, according to Appendix D, a mile is 1.609 km, so 45.3 miles is 72.887 km. The difference is 11.0 km.

20. (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

$$230 \text{ ft}^2/\text{gal} = \left(\frac{230 \text{ ft}^2}{\text{gal}}\right)\left(\frac{1 \text{ m}}{3.28 \text{ ft}}\right)^2\left(\frac{1 \text{ gal}}{3.79 \text{ L}}\right) = 5.64 \text{ m}^2/\text{L}.$$

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

$$5.64\ \text{m}^2/\text{L} = \left(\frac{5.64\ \text{m}^2}{\text{L}}\right)\left(\frac{1000\,\text{L}}{1\ \text{m}^3}\right) = 5.64 \times 10^3\ \text{m}^{-1}.$$

(c) The inverse of the original quantity is $(230\ \text{ft}^2/\text{gal})^{-1} = 4.35 \times 10^{-3}\ \text{gal/ft}^2$.

(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)].

21. Two jalapeño peppers have spiciness = 8000 SHU, and this amount multiplied by 312 (the number of people) is 2.50×10^6 SHU, which is roughly ten times the SHU value for a single habanero pepper. More precisely, 8.32 habanero peppers will provide that total required SHU value.

22. **THINK** The objective of this problem is to convert the Earth-Sun distance (1 AU) to parsecs and light-years.

EXPRESS To relate parsec (pc) to AU, we note that 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, the arc may be approximated as the straight line-segment of length 1 AU. Thus,

$$\theta = 1\ \text{arcsec} = (1\ \text{arcsec})\left(\frac{1\ \text{arcmin}}{60\ \text{arcsec}}\right)\left(\frac{1°}{60\ \text{arcmin}}\right)\left(\frac{2\pi\ \text{radian}}{360°}\right) = 4.85 \times 10^{-6}\ \text{rad}.$$

Therefore, one parsec is

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

Next, we relate AU to light-year (ly). Since a year is about 3.16×10^7 s,

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

ANALYZE (a) Since $1\ \text{pc} = 2.06 \times 10^5\ \text{AU}$, inverting the relation gives

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

(b) Given that $1\text{ AU} = 92.9'\ 10^6\text{ mi}$ and $1\text{ ly} = 5.9\times10^{12}\text{ mi}$, the two expressions together lead to

$$1\text{ AU} = 92.9\times10^6\text{ mi} = (92.9\times10^6\text{ mi})\left(\frac{1\text{ ly}}{5.9\times10^{12}\text{ mi}}\right) = 1.57\times10^{-5}\text{ ly}$$

LEARN Our results can be further combined to give $1\text{ pc} = 3.2\text{ ly}$. From the above expression, we readily see that it takes $1.57'\ 10^{-5}\text{ y}$, or about 8.3 min, for Sunlight to travel a distance of 1 AU to reach Earth.

23. (a) Multiply the time interval on *A* by the ratio of an interval on *B* to the corresponding interval on *A*:

$$(350\text{ s})\frac{(290\text{ s} - 125\text{ s})}{(512\text{ s} - 312\text{ s})} = 289\text{ s}.$$

(b) Similarly,

$$(350\text{ s})\frac{(142\text{ s} - 92.0\text{ s})}{(200\text{ s} - 25.0\text{ s})} = 82.5\text{ s}.$$

(c) First convert a time interval above a chosen point:

$$(350\text{ s} - 312\text{ s})\frac{(290\text{ s} - 125\text{ s})}{(512\text{ s} - 312\text{ s})} = 31.35\text{ s}$$

above 125 s. Thus, the time is 125 s + 31.35 s = 156 s.

(d) First convert a time interval relative to a chosen point:

$$(30.0\text{ s} - 92.0\text{ s})\frac{(200\text{ s} - 25.0\text{ s})}{(142\text{ s} - 92.0\text{ s})} = -217\text{ s}$$

below 25.0 s. Thus, the time is 25.0 s - 217 s = -192 s.

24. (a) Using the fact that the area *A* of a rectangle is (width) × (length), we find

$$\begin{aligned}A_{\text{total}} &= (2.80\,\text{acre}) + (13.0\,\text{perch})(3.00\,\text{perch}) \\ &= (2.80\ \text{acre})\left(\frac{(40\ \text{perch})(4\ \text{perch})}{1\,\text{acre}}\right) + 39.0\,\text{perch}^2 \\ &= 487\ \text{perch}^2.\end{aligned}$$

We multiply this by the perch^2 $\to$ rood conversion factor (1 rood/40 perch^2) to obtain the answer: A_{total} = 12.2 roods.

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

$$A_{\text{total}} = (487\ \text{perch}^2)\left(\frac{16.5\,\text{ft}}{1\,\text{perch}}\right)^2 = 1.33\times 10^5\ \text{ft}^2.$$

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

$$A_{\text{total}} = (1.33\times 10^5\ \text{ft}^2)\left(\frac{1\,\text{m}}{3.281\,\text{ft}}\right)^2 = 1.23\times 10^4\ \text{m}^2.$$

25. **THINK** This problem involves converting *cord*, a non-SI unit for volume, to SI unit.

EXPRESS Using the (exact) conversion 1 in. = 2.54 cm = 0.0254 m for length, we have

$$1\ \text{ft} = 12\ \text{in} = (12\ \text{in.})\left(\frac{0.0254\ \text{m}}{1\ \text{in}}\right) = 0.3048\ \text{m}$$
.

Thus, $1\ \text{ft}^3 = (0.3048\ \text{m})^3 = 0.0283\ \text{m}^3$ for volume (these results also can be found in Appendix D).

ANALYZE The volume of a cord of wood is $V = (8\ \text{ft})\times(4\ \text{ft})\times(4\ \text{ft}) = 128\ \text{ft}^3$. Using the conversion factor found above, we obtain

$$V = 1\ \text{cord} = 128\ \text{ft}^3 = (128\ \text{ft}^3)\times\left(\frac{0.0283\ \text{m}^3}{1\ \text{ft}^3}\right) = 3.625\ \text{m}^3.$$

Thus,

$$2 \text{ cords}\left(\frac{3.625 \text{ m}^3}{1 \text{ cord}}\right) = 7.25 \text{ m}^3.$$

LEARN The unwanted units ft^3 all cancel out, as they should. In conversions, units obey the same algebraic rules as variables and numbers.

26. (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,

$$\pi r^2 h = \pi (3.80)^2 (6.90) = 313 \text{ ken}^3.$$

(d) If we multiply this by the result of part (b), we determine the volume in cubic meters: (313)(7.65) = 2.39×10^3 m^3.

27. **THINK** This problem compares the U.K. gallon with U.S. gallon, two non-SI units for volume. The interpretation of the type of gallons, whether U.K. or U.S., affects the amount of gasoline one calculates for traveling a given distance.

EXPRESS If the fuel consumption rate is R (in miles/gallon), then the amount of gasoline (in gallons) needed for a trip of distance *d* (in miles) would be

$$V(\text{gallon}) = \frac{d \ \text{(miles)}}{R \ \text{(miles/gallon)}}$$

Since the car was manufactured in U.K., the fuel consumption rate is calibrated based on U.K. gallon, and the correct interpretation should be “40 miles per U.K. gallon.” In U.K., one would think of gallon as U.K. gallon; however, in the U.S., the word “gallon” would naturally be interpreted as U.S. gallon. Note also that since $1 \text{ U.K. gallon} = 4.5460900 \text{ L}$ and $1 \text{ U.S. gallon} = 3.7854118 \text{ L}$, the relationship between the two is

$$1 \text{ U.K. gallon} = (4.5460900 \text{ L})\left(\frac{1 \text{ U.S. gallon}}{3.7854118 \text{ L}}\right) = 1.20095 \text{ U.S. gallons}$$

ANALYZE (a) The amount of gasoline actually required is

$$V' = \frac{1230 \text{ miles}}{40 \text{ miles/U.K. gallon}} = 30.75 \text{ U.K. gallons} \approx 30.8 \text{ U.K. gallons.}$$

This means that the driver mistakenly believes that the car should need 30.8 U.S. gallons.

(b) Using the conversion factor found above, this is equivalent to

$$V' = (30.75 \text{ U.K. gallons}) \times \left(\frac{1.20095 \text{ U.S. gallons}}{1 \text{ U.K. gallon}}\right) \approx 36.9 \text{ U.S. gallons.}$$

LEARN One U.K. gallon is greater than one U.S gallon by roughly a factor of 1.2 in volume. Therefore, 40 mi/U.K. gallon is less fuel-efficient than 40 mi/U.S. gallon.

28. Since one atomic mass unit is $1 \text{ u} = 1.66 \times 10^{-24} \text{ g}$ (see Appendix D), the mass of one mole of atoms is about $m = (1.66 \times 10^{-24} \text{ g})(6.02 \times 10^{23}) = 1 \text{ g}$. On the other hand, the mass of one mole of atoms in the common Eastern mole is

$$m' = \frac{68 \text{ g}}{6.8} = 10 \text{ g}$$

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

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

29. (a) The receptacle is a volume of (40 cm)(40 cm)(26 cm) = 41600 cm^3 = 41.60 L = (41.60)(16)/11.356 = 58.61 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 2 nebuchadnezzars, 1 balthazar, and 1 magnum.

(b) The extra amount is 0.61 standard bottle.

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

$$0.61 \text{ standard bottle} = (0.61 \text{ standard bottle})\left(\frac{11.356 \text{ L}}{16 \text{ standard bottles}}\right) = 0.43 \text{ L}.$$

30. (a) For the minimum (43 cm) case, 11 cubits converts as follows:

$$11 \text{ cubits } = (11 \text{ cubits})\left(\frac{0.43 \text{ m}}{1 \text{ cubit}}\right) = 4.7 \text{ m}.$$

And for the maximum (53 cm) case we have

$$11 \text{ cubits} = (11 \text{ cubits})\left(\frac{0.53 \text{m}}{1 \text{cubit}}\right) = 5.8 \text{m}.$$

(b) Similarly, with 0.43 m $\rightarrow$ 430 mm and 0.53 m $\rightarrow$ 530 mm, we find 4.7×10^3 mm and 5.8×10^3 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).

$$V_{\text{cylinder, min}} = \frac{\pi}{4}\ell d^2 = 54.0 \text{ cubit}^3 = \left(54.0 \text{ cubit}^3\right)\left(\frac{0.43 \text{m}}{1 \text{ cubit}}\right)^3 = 4.3 \text{ m}^3.$$

Similarly, with 0.43 m replaced by 0.53 m, we obtain $V_{\text{cylinder, max}} = 8.0 \text{ m}^3$.

31. A million milligrams comprise a kilogram, so 0.257 kg/d = 178 mg/min.

32. 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 Avogadro's number. Thus this is roughly a kilomole of atoms (hence, "kill a mole".)