Chapter 1

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

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

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

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).

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

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

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

$$N \approx \frac{2.8\times 10^{8}}{3.0\times 10^{-26}} = 9.3\times 10^{33}.$$

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 $1 \text{ AU} = 92.9\times 10^{6} \text{ mi}$ and $1 \text{ ly} = 5.9\times 10^{12} \text{ mi}$, the two expressions together lead to

$$1 \text{ AU} = 92.9\times 10^{6} \text{ mi} = (92.9\times 10^{6} \text{ mi})\left(\frac{1 \text{ ly}}{5.9\times 10^{12} \text{ mi}}\right) = 1.57\times 10^{-5} \text{ ly}.$$

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} y, or about 8.3 min, for Sunlight to travel a distance of 1 AU to reach Earth.

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.

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 $\to$ 430 mm and 0.53 m $\to$ 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 $V_{\text{cylinder, max}} = 8.0\ \text{m}^3$.