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 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,

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

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

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

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

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

$$V = (26\ \text{km}^2)(1/6\ \text{ft}) = (26\ \text{km}^2)(3281\text{ft/km})^2(1/6\ \text{ft}) = 4.66\times10^7\ \text{ft}^3.$$

Thus,

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

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 $\rho = 19.32\ \text{g/cm}^3$ 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 = $(1 \times 10^{-2}\text{m})^3 = 1 \times 10^{-6}\text{m}^3$. 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

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

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).

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

$$\left.\frac{dm}{dt}\right|_{t=2.00\text{ s}} = \left[4.00(2.00)^{-0.2} - 3.00\right]\text{g/s} = 0.48\text{ g/s} = 0.48\frac{\text{g}}{\text{s}}\cdot\frac{1\text{ kg}}{1000\text{ g}}\cdot\frac{60\text{ s}}{1\text{ min}}$$
$$= 2.89\times10^{-2}\text{ kg/min}.$$

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

$$\left.\frac{dm}{dt}\right|_{t=2.00\text{ s}} = \left[4.00(5.00)^{-0.2} - 3.00\right]\text{g/s} = -0.101\text{ g/s} = -0.101\frac{\text{g}}{\text{s}}\cdot\frac{1\text{ kg}}{1000\text{ g}}\cdot\frac{60\text{ s}}{1\text{ min}}$$
$$= -6.05\times10^{-3}\text{ kg/min}.$$

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 × 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,

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

43. The volume of one unit is 1 cm^3 = 1 × 10^{-6} m^3, so the volume of a mole of them is 6.02 × 10^{23} cm^3 = 6.02 × 10^{17} m^3. The cube root of this number gives the edge length: $8.4\times10^5\ \text{m}^3$. This is equivalent to roughly 8 × 10^2 kilometers.

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

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

Thus, 3.0×10^8 m/s becomes

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

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