1. As we know, 1.00 Gallon = 231 $(\text{inch})^3$. Therefore,

$$
\begin{aligned}
14.0\ \text{Gallon} &= 231 \times 14.0\ (\text{inch})^3 \\
&= 231 \times 14.0 \times (2.54\ \text{cm})^3 && (\because 1.00\ \text{inch} = 2.54\ \text{cm}) \\
&= 231 \times 14.0 \times (2.54)^3 \times (1.0\ \text{cm})^3 \\
&= 231 \times 14.0 \times (2.54)^3\,\text{cm}^3 \\
&= \frac{231 \times 14.0 \times (2.54)^3}{10^3}\,\text{L} && (\because 1.00\ \text{L} = 10^3\,\text{cm}^3) \\
&= 52.995764976 \\
&\approx 53.0\ \text{L}.
\end{aligned}
$$

To fill a 14.0-gallon tank, approximately 53.0 L of gasoline is required.

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

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

Thus, 1 gry^2 = (0.60 point)^2 = 0.36 point^2, which means that $0.75 \text{ gry}^2 = 0.27 \text{ point}^2$.

3. Using ñfactor-label methodò to convert 1.0 mile/h to m/s, we obtain the following:

$$\frac{1.0\ \cancel{\text{mile}}}{1.0\ \cancel{\text{h}}} \times \frac{5280\ \cancel{\text{feet}}}{1.0\ \cancel{\text{mile}}} \times \frac{12.0\ \cancel{\text{inch}}}{1.0\ \cancel{\text{feet}}} \times \frac{2.54\ \cancel{\text{cm}}}{1.0\ \cancel{\text{inch}}} \times \frac{1.0\ \text{m}}{100\ \cancel{\text{cm}}} \times \frac{1.0\ \cancel{\text{h}}}{3600\ \text{s}} = \frac{(5280 \times 12.0 \times 2.54)\ \text{m}}{(100 \times 3600)\ \text{s}}$$

$$= 0.44704\ \text{m/s} \approx 0.45\ \text{m/s}.$$

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

$$0.70 \text{ cm} = (0.70 \text{ cm})\left(\frac{1 \text{ inch}}{2.54 \text{ cm}}\right)\left(\frac{6 \text{ picas}}{1 \text{ inch}}\right) \approx 1.7 \text{ picas}.$$

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

$$0.70 \text{ cm} = (0.70 \text{ cm})\left(\frac{1 \text{ inch}}{2.54 \text{ cm}}\right)\left(\frac{6 \text{ picas}}{1 \text{ inch}}\right)\left(\frac{12 \text{ points}}{1 \text{ pica}}\right) \approx 20 \text{ points}.$$

5. It is given that 24.0 frames cross by in 1.0 s. Therefore, in 2.0 h, the total number of frames that cross by is

$$2.0 \times 60.0 \times 60.0 \times 24.0 = 172{,}800,$$

or about 1.7×10^5 frames. It should be noted that for the calculation of total number of frames, the information on the height of the frame is of no relevance.

6. We make use of Table 1-6.

(a)We look at the first (ñcahizò) 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, ñ1 cahiz = 48 cuartillaò (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 (ñfanegaò) column, we find 0.250, 8.33×10^{-2}, and 4.17×10^{-2} for the last three entries.

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

(d) Finally, in the fourth (ñalmudeò) 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 = 6.94×10^{-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) = 3.24×10^4 cm^3.

7. In 1.0 h, one can drive 70.0 mile. Therefore, in 1.0 year (i.e., 1.0 × 365.0 × 24.0 h), the distance one can drive is

$$1.0 \times 365.0 \times 24.0 \times 70.0 = 6132.00 \text{ miles} = .6.13 \times 10^5 \text{ miles.}$$

8. Microscope is of magnification 100×, which implies that the microscope magnifies the real object to 100 times. Let the thickness of the hair be x mm. Therefore,

$$100x = 3.8\,\text{mm}$$
$$x = \frac{3.8}{100} = 0.038\ \text{mm}.$$

9. The edge length of a cubical object is l = 1.00 cm; the number of cubical units is $N = 6.02\times10^{23}$ units. There are N units in a cubical box which contains cubes whose edge length is 1.00 cm. Volume of single individual cubical object = $1.00\,\text{cm}^3$. Therefore, the volume of a cube that contains N number of cubes is given by

$$\begin{aligned}(\text{Volume of a single cube})\times(\text{Number of cubes}) &= \left(1.00\ \text{cm}^3\right)\times\left(6.02\times10^{23}\right)\\ &= 6.02\times10^{23}\ \text{cm}^3.\end{aligned}$$

Thus, the edge length of the bigger cube is calculated as

$$(6.02\times10^{23}\,\text{cm}^3)^{1/3} = 8.44\times10^{7}\ \text{cm} \approx 8.4\times10^{2}\ \text{km}$$

where we have used $1.00\ \text{cm} = 10^{-5}\ \text{km}$.

10. Let us assume that the initial sale the motor car company to be of 100%. After 1.0 year, sale was down by 43.0%. This implies that after a year, the sale was

100% ï 43.0% = 57.0%.

After 2.0 years also, the sale was down by 43.0%. This implies that after 2.0 years, the sale was down to 43.0% of 57.0%:

$$\frac{43.0}{100} \times 57.0 = 24.51$$

That is,

57.0% ï 24.51% = 32.49%.

In a similar manner, after 3 years, the sale percentage is calculated to be down to 18.5193%; after 4.0 years, the sale percentage is calculated to be down to 10.556001% $\approx$10.5%; after 5.0 years, the sale percentage is calculated to be down to 6.0169% $\approx$ 6.0%. Thus, 5.0 years are needed for the sales to fall below 10.0 %.

11. We have

$$
\begin{aligned}
t &= 100.0 \text{ years} \\
&= 100.0 \times 365.0 \times 86400.0 \,\text{s}
\end{aligned}
$$

and it is given that $\Delta t = 0.020$ s. Therefore, the fractional error is measured as follows:

$$\frac{\Delta t}{t} = \frac{0.02}{100.0 \times 365.0 \times 86400.0} = 0.63 \times 10^{-11}.$$

Thus, the uncertainty is 6.3×10^{-12} s.

12. Let the age of universe be $A_u = 10^{10}$ years; the new age of universe is $A'_u = 1.0$ day; age of mankind is $A_m = 10^6$ years. If the age of universe would have been changed to 1.0 day, the new age of mankind is calculated as follows:

$$A'_m = \frac{10^6}{10^{10}} \times \frac{365.0 \times 24.0 \times 60.0 \times 60.0}{365.0} \qquad \left[\begin{array}{l} \because 1.0 \text{ year} = 365.0 \text{ days} \\ 1.0 \text{ day} = 24.0 \text{ h} \\ 1.0 \text{ h} = 60.0 \text{ min} \\ 1.0 \text{ min} = 60.0 \text{ s} \end{array}\right]$$

$$= 8.64 \text{ s} \approx 9.0 \text{ s}.$$

13. 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

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

(c) Clock B reads

$$t_B = (33/40)(400) - (662/5) \approx 198 \text{ s}$$

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.

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

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

15. 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.

16. 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 = 8.00 days (which is equivalent to 691200 s, if we ignore *significant figure* considerations for a moment), we obtain the number of rotations:

$$N = \left(\frac{1 \text{ rotation}}{1.55780644887275 \times 10^{-3} \text{ s}}\right)(691200 \text{ s}) = 443700.8$$

which should now be rounded to 4.44×10^8 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 .

17. **THINK** In this problem we are asked to rank 5 clocks, based on their performance as timekeepers.

EXPRESS We first note that 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 here is that the clock advance by the same (or nearly the same) amount in each 24-h period. The clock reading can then easily be adjusted to give the correct interval.

ANALYZE The chart below 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.

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 ñperfectò 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.

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

LEARN Of the five clocks, the readings in clocks A, B and E jump around from one 24-h period to another, making it difficult to correct them.

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

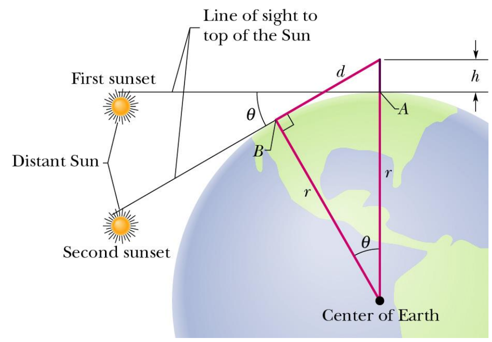
$$(30 \text{ century})\,(0.001\text{ s/century}) = 0.03\text{ s.}$$

The average day during the 30 centuries is (0 + 0.03)/2 = 0.015 s longer than the first day. Since the increase occurs uniformly, the cumulative effect T is

$$\begin{aligned} T &= (\text{average increase in length of a day})(\text{number of days}) \\ &= \left(\frac{0.015\text{ s}}{\text{day}}\right)\left(\frac{365.25\text{ day}}{\text{y}}\right)(3000\text{ y}) \\ &= 1.64\times10^{4}\text{ s} \end{aligned}$$

or roughly 4.6 hours.

19. When the Sun first disappears while lying down, your line of sight to the top of the Sun is tangent to the Earthôs 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 Earthôs surface at point *B*.



Let *d* be the distance from point *B* to your eyes. From the 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 $r = 5.2\times10^6$ m.

20. (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 0.0015 kg/min, this can be filled in

$$\frac{731\text{kg}}{0.0015\text{ kg/min}} = 4.87\times 10^5\text{ min} = 0.93\text{ y}$$

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

21. We know that

$$\text{Density}\,(\rho) = \frac{\text{Mass}\,(m)}{\text{Volume}\,(V)}$$

Substituting the values in the above equation, we get

$$\rho = \frac{9.05\,\text{g}}{3.5\,\text{cc}} = 2.586\,\text{g/cm}^3 \approx 2.6\times10^3\,\text{kg/m}^3,$$

rounded to two significant figures.

22. 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 $m = 29.34$ g, the volume of the leaf is found to be

$$V = \frac{m}{\rho} = \frac{29.34\text{ g}}{19.32\text{ g/cm}^3} = 1.519\text{ cm}^3.$$

We convert the volume to SI units:

$$V = \left(1.519\text{ cm}^3\right)\left(\frac{1\text{ m}}{100\text{ cm}}\right)^3 = 1.519\times10^{-6}\text{ m}^3$$

Since $V = Az$ with $z = 1.000\times10^{-6}$ m (metric prefixes can be found in Table 1ï 2), we obtain

$$A = \frac{1.519\times10^{-6}\text{m}^3}{1\times10^{-6}\text{m}} = 1.519\text{ m}^2.$$

(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 $r = 2.500\times10^{-6}$ m and $V = 1.519\times10^{-6}$ m^3, we obtain

$$\ell = \frac{V}{\pi r^2} = \frac{1.519\times10^{-6}\text{m}^3}{\pi(2.500\times10^{-6}\text{m})^2} = 7.734\times10^4\text{m} = 77.34\text{ km}.$$

23. The density of the aluminum plate is $\rho = 2.70 \times 10^3$ kg/m^3. With mass m = 324.0 kg, we find the plate volume to be

$$V = \frac{m}{\rho} = \frac{324 \text{ kg}}{2.7 \times 10^3 \text{ kg/m}^3} = 0.12 \text{ m}^3.$$

Since volume is $V = lwt$, where l = 3.00 m and w = 2.00 m, the thickness of the plate is

$$t = \frac{V}{lw} = \frac{0.12 \text{ m}^3}{(2.00 \text{ m})(3.00 \text{ m})} = 0.020 \text{ m} = 2.00 \text{cm}.$$

24. The metric prefixes (micro (μ), pico, nano, é) are given for ready reference on the inside front cover of the textbook (see also Table 1ï 2). The surface area A of each grain of sand of radius r = 60 μm = 60 × 10^{-6} m is given by $A = 4\pi(60 \times 10^{-6}\text{m})^2 = 4.52 \times 10^{-8}$ m^2 (Appendix E contains a variety of geometry formulas). The mass is given by $m = \rho V$, where ρ = 2600 kg/m^3 is the density. Thus, using $V = 4\pi r^3/3$, the mass of each grain is

$$m = \rho V = \rho\left(\frac{4\pi r^3}{3}\right) = \left(2600\ \frac{\text{kg}}{\text{m}^3}\right)\frac{4\pi\left(60 \times 10^{-6}\ \text{m}\right)^3}{3} = 2.35 \times 10^{-9}\ \text{kg}.$$

We observe that (because a cube has six equal faces) the indicated surface area is 6.00 m^2. The number of spheres (the grains of sand) N that have a total surface area of 6 m^2 is given by

$$N = \frac{6.00\ \text{m}^2}{4.52 \times 10^{-8}\text{m}^2} = 1.326 \times 10^8.$$

Therefore, the total mass M is $M = Nm = \left(1.326 \times 10^8\right)\left(2.35 \times 10^{-9}\ \text{kg}\right) = 0.312\ \text{kg}.$

25. Given that the radius of the sodium atom = 1.90 Å = 1.90 × 10^{-10} m, the volume of the atom is

$$V = \frac{4}{3}\pi(1.90 \times 10^{-10}\ \text{m})^3 = 2.87 \times 10^{-29}\ \text{m}^3.$$

According to Avogadro's hypothesis, 1 mole of sodium contains 6.023 × 10^{23} atoms. Since the mass of 1 mole of sodium is 23 × 10^{-3} kg, we find the mass of one atom to be

$$M = \frac{23 \times 10^{-3}\ \text{kg}}{6.023 \times 10^{23}} = 3.82 \times 10^{-26}\ \text{kg}.$$

Thus, the density of sodium in its crystalline state is

$$\rho = \frac{M}{V} = \frac{3.82 \times 10^{-26}\ \text{kg}}{2.87 \times 10^{-29}\ \text{m}^3} = 1.3 \times 10^3\ \text{kg/m}^3$$

(b) It is given that the density of sodium in crystalline phase is $\rho_{\text{crystal}} = 970\,\text{kg/m}^3$. On comparing the results, we find that $\rho_{\text{crystal}} < \rho$. The reason is that in crystalline form, due to the body-centered cubic crystal structure, there are gaps between the atoms and hence density is less (the more the gaps between the atoms, lower the density).

26. With a mass of 5.324 g, and volume 2.5 cm^3, we find the density of the body to be

$$\rho = \frac{m}{V} = \frac{5.324\ \text{g}}{2.5\ \text{cm}^3} = 2.13\ \text{g/cm}^3 \approx 2.1\times 10^3\ \text{kg/m}^3.$$

27. Mass of the object is 2.500 kg.

(a) After adding gold pieces, thetotal mass is

$$2.500 + 0.02115 + 0.02117 = 2.54232 \text{ kg}$$
$$= 2.542 \text{ kg},$$

which is rounded to four significant numbers.

(b) Difference of the masses is

$$21.17 - 21.15 = 0.02$$

Correct to one significant digit.

28. Einsteinös massï energy equation is $E = mc^2$; $1\,\text{MeV} = 1.60218 \times 10^{-3}\,\text{J}; 1\,\text{u} = 1.66054 \times 10^{-27}\,\text{kg}.$

Energy equivalent of 1 u is calculated as follows:

$$E = mc^2 = (1.66054 \times 10^{-27}\,\text{kg}) \times (2.998 \times 10^{8}\,\text{m/s})^2$$
$$= 14.924 \times 10^{-11}\,\text{J}.$$

Now, $1\,\text{MeV} = 1.60218 \times 10^{-13}\,\text{J}$. Therefore,

$$14.924 \times 10^{-11} \times \frac{1}{1.60218 \times 10^{-13}}\,\text{MeV} = 9.314809 = 931.5\ \text{MeV}.$$

29. 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.

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

$$\left.\frac{dm}{dt}\right|_{t=3.00\text{ s}} = \left[4.00(3.00)^{-0.2} - 3.00\right]\text{g/s} = 0.211\,\text{g/s} = 1.27\times10^{-2}\text{ kg/min}.$$

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

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

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

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