1
Introduction

ANSWERS TO WARM-UP EXERCISES

1. (a) The number given, 568 017, has six significant figures, which we will retain in converting the number to scientific notation. Moving the decimal five spaces to the left gives us the answer, $\boxed{5.680\,17 \times 10^5}$.

(b) The number given, 0.000 309, has three significant figures, which we will retain in converting the number to scientific notation. Moving the decimal four spaces to the right gives us the answer, $\boxed{3.09 \times 10^{-4}}$.

2. We first collect terms, then simplify:

$$\frac{[M][L]^2}{[T]^3}\cdot\frac{[T]}{[L]}[T]=\frac{[M][L]^2[T]^2}{[T]^3[L]}=\boxed{\frac{[M][L]}{[T]}}$$

As we will see in Chapter 6, these are the units for momentum.

3. Examining the expression shows that the units of meters and seconds squared (s^2) appear in both the numerator and the denominator, and therefore cancel out. We combine the numbers and units separately, squaring the last term before doing so:

$$\left(7.00\frac{\text{m}}{\text{s}^2}\right)\left(\frac{1.00\,\text{km}}{1.00\times10^3\text{m}}\right)\left(\frac{60.0\,\text{s}}{1.00\,\text{min}}\right)^2$$
$$=(7.00)\left(\frac{1.00}{1.00\times10^3}\right)\left(\frac{3600}{1.00}\right)\left(\frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)\left(\frac{\text{km}}{\cancel{\text{m}}}\right)\left(\frac{\cancel{\text{s}^2}}{\text{min}^2}\right)$$
$$=\boxed{25.2\frac{\text{km}}{\text{min}^2}}$$

4. The required conversion can be carried out in one step:

$$h=(2.00\ \cancel{\text{m}})\left(\frac{1.00\,\text{cubitus}}{0.445\ \cancel{\text{m}}}\right)=\boxed{4.49\,\text{cubiti}}$$

5 The area of the house in square feet (1 420 ft^2) contains 3 significant figures. Our answer will therefore also contain three significant figures. Also note that the conversion from feet to meters is squared to account for the ft^2 units in which the area is originally given.

$$A=\left(1\ 420\ \text{ft}^2\right)\left(\frac{1.00\ \text{m}}{3.281\ \text{ft}}\right)^2=131.909\ \text{m}^2=\boxed{132\ \text{m}^2}$$

6. Using a calculator to multiply the length by the width gives a raw answer of 6 783 m^2. This answer must be rounded to contain the same number of significant figures as the least accurate factor in the product. The least accurate factor is the length, which contains 2 significant figures, since the trailing zero is not significant (see Section 1.6). The correct answer for the area of the airstrip is $\boxed{6.80 \times 10^3\ \text{m}^2}$.

7. Adding the three numbers with a calculator gives 21.4 + 15 + 17.17 + 4.003 = 57.573. However, this answer must be rounded to contain the same number of significant figures as the least accurate number in the sum, which is 15, with two significant figures. The correct answer is therefore $\boxed{58}$.

8. The given Cartesian coordinates are $x = -5.00$ and $y = 12.00$. The least accurate of these coordinates contains 3 significant figures, so we will express our answer in three significant figures. The specified point, (–5.00, 12.00), is in the second quadrant since $x < 0$ and $y > 0$. To find the polar coordinates $(r,\ \theta)$ of this point, we use

$$r=\sqrt{x^2+y^2}=\sqrt{(5.00)^2+(12.00)^2}=13.0$$

and

$$\theta = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{12.00}{-5.00}\right) = -67.3°$$

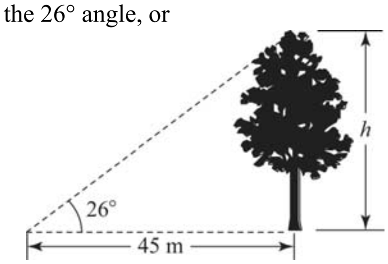
Since the point is in the second quadrant, we add 180° to this angle to obtain $\theta = -67.3° + 180° = 113°$. The polar coordinates of the point are therefore $\boxed{(13.0,\ 113°)}$.

9. Refer to ANS. FIG 9. The height of the tree is described by the tangent of the 26° angle, or

$$\tan 26° = \frac{h}{45\ \text{m}}$$

from which we obtain

$$h = (45\ \text{m})\tan 26° = \boxed{22\ \text{m}}$$



ANS. FIG 9

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

2. Atomic clocks are based on the electromagnetic waves that atoms emit. Also, pulsars are highly regular astronomical clocks.

4. **(a)** $\sim 0.5\ \text{lb} \approx 0.25\ \text{kg}$ or $\sim 10^{-1}\ \text{kg}$

(b) $\sim 4\ \text{lb} \approx 2\ \text{kg}$ or $\sim 10^{0}\ \text{kg}$

(c) $\sim 4000\ \text{lb} \approx 2000\ \text{kg}$ or $\sim 10^{3}\ \text{kg}$

6. Let us assume the atoms are solid spheres of diameter 10^{-10} m. Then, the volume of each atom is of the order of 10^{-30} m^3. (More precisely, volume $= 4\pi r^3/3 = \pi d^3/6$.) Therefore, since $1\ \text{cm}^3 = 10^{-6}\ \text{m}^3$, the number of atoms in the 1 cm^3 solid is on the order of $10^{-6}/10^{-30} = 10^{24}$ atoms. A more precise calculation would require knowledge of the density of the solid and the mass of each atom. However, our estimate agrees with the more precise calculation to within a factor of 10.

8. Realistically, the only lengths you might be able to verify are the length of a football field and the length of a housefly. The only time intervals subject to verification would be the length of a day and the time between normal heartbeats.

10. In the metric system, units differ by powers of ten, so it's very easy and accurate to convert from one unit to another.

12. Both answers (d) and (e) could be physically meaningful. Answers (a), (b), and (c) must be meaningless since quantities can be added or subtracted only if they have the same dimensions.

ANSWERS TO EVEN NUMBERED PROBLEMS

2. **(a)** L/T^2 **(b)** L

4. All three equations are dimensionally incorrect.

6. **(a)** $\text{kg}\cdot\text{m/s}$ **(b)** $Ft = p$

8. **(a)** 22.6 **(b)** 22.7 **(c)** 22.6 is more reliable

10. **(a)** $3.00 \times 10^8\ \text{m/s}$ **(b)** $2.997\,9 \times 10^8\ \text{m/s}$ **(c)** $2.997\,925 \times 10^8\ \text{m/s}$

12. **(a)** $346\ \text{m}^2 \pm 13\ \text{m}^2$ **(b)** $66.0\ \text{m} \pm 1.3\ \text{m}$

14. **(a)** 797 **(b)** 1.1 **(c)** 17.66

16. $3.09\ \text{cm/s}$

18. **(a)** $5.60 \times 10^2\ \text{km} = 5.60 \times 10^5\ \text{m} = 5.60 \times 10^7\ \text{cm}$

(b) $0.491\,2\ \text{km} = 491.2\ \text{m} = 4.912 \times 10^4\ \text{cm}$

(c) $6.192\text{ km} = 6.192\times10^3\text{ m} = 6.192\times10^5\text{ cm}$

(d) $2.499\text{ km} = 2.499\times10^3\text{ m} = 2.499\times10^5\text{ cm}$

20. 10.6 km/L

22. 9.2 nm/s

24. $2.9\times10^2\text{ m}^3 = 2.9\times10^8\text{ cm}^3$

26. $2.57\times10^6\text{ m}^3$

28. $\sim10^8$ steps

30. $\sim10^8$ people with colds on any given day

32. **(a)** $4.2\times10^{-18}\text{ m}^3$ (b) $\sim10^{-1}\text{ m}^3$ (c) $\sim10^{16}$ cells

34. **(a)** $\sim10^{29}$ prokaryotes (b) $\sim10^{14}$ kg

(c) The very large mass of prokaryotes implies they are important to the biosphere. They are responsible for fixing carbon, producing oxygen, and breaking up pollutants, among many other biological roles. Humans depend on them!

36. 2.2 m

38. 8.1 cm

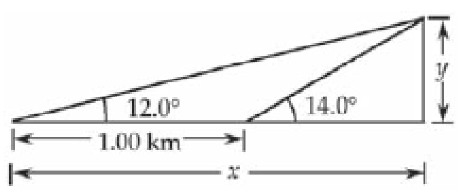
40. $\Delta s = \sqrt{r_1^2 + r_2^2 - 2r_1r_2\cos(\theta_1 - \theta_2)}$

42. 2.33 m

44. **(a)** 1.50 m **(b)** 2.60 m

46. 8.60 m

48. **(a)** and **(b)**



(c) $y/x = \tan 12.0°,\ y/(x - 1.00\text{ km}) = \tan 14.0°$ **(d)** $1.44\times10^3\text{ m}$

50. $y = \dfrac{d\cdot\tan\theta\cdot\tan\phi}{\tan\phi - \tan\theta}$

52. **(a)** 1.609 km/h **(b)** 88 km/h **(c)** 16 km/h

54. Assumes population of 300 million, average of 1 can/week per person, and 0.5 oz per can.

(a) $\sim10^{10}$ cans/yr **(b)** $\sim10^5$ tons/yr

56. **(a)** 7.14×10^{-2} gal/s **(b)** $2.70\times10^{-4}\text{ m}^3/\text{s}$ **(c)** 1.03 h

58. **(a)** $A_2/A_1 = 4$ **(b)** $V_2/V_1 = 8$

60. **(a)** 500 yr **(b)** 6.6×10^4 times

62. $\sim10^4$ balls/yr. Assumes 1 lost ball per hitter, 10 hitters per inning, 9 innings per game, and 81 games per year.

PROBLEM SOLUTIONS

1.1 Substituting dimensions into the given equation $T = 2\pi\sqrt{\ell/g}$, and recognizing that 2π is a dimensionless constant, we have

$$[T] = \sqrt{\frac{[\ell]}{[g]}} \qquad \text{or} \qquad \mathrm{T} = \sqrt{\frac{\mathrm{L}}{\mathrm{L}/\mathrm{T}^2}} = \sqrt{\mathrm{T}^2} = \mathrm{T}$$

Thus, the $\boxed{\text{dimensions are consistent}}$.

1.2 (a) From $x = Bt^2$, we find that $B = \frac{x}{t^2}$. Thus, B has units of

$$[B] = \frac{[x]}{[t^2]} = \boxed{\frac{\mathrm{L}}{\mathrm{T}^2}}$$

(b) If $x = A\sin(2\pi ft)$, then $[A] = [x]/[\sin(2\pi ft)]$

But the sine of an angle is a dimensionless ratio.

Therefore, $[A] = [x] = \boxed{\mathrm{L}}$

1.3 (a) The units of volume, area, and height are:

$[V] = \mathrm{L}^3$, $[A] = \mathrm{L}^2$, and $[h] = \mathrm{L}$

We then observe that $\mathrm{L}^3 = \mathrm{L}^2\mathrm{L}$ or $[V] = [A][h]$

Thus, the equation $V = Ah$ is $\boxed{\text{dimensionally correct}}$.

(b) $V_{\text{cylinder}} = \pi R^2 h = (\pi R^2)h = Ah$, where $\boxed{A = \pi R^2}$

$V_{\text{rectangular box}} = \ell wh = (\ell w)h = Ah$, where $\boxed{A = \ell w = length \times width}$

1.4 (a) In the equation $\frac{1}{2}mv^2 = \frac{1}{2}mv_0^2 + \sqrt{mgh}$, $[mv^2] = [mv_0^2] = \mathrm{M}\left(\frac{\mathrm{L}}{\mathrm{T}}\right)^2 = \frac{\mathrm{ML}^2}{\mathrm{T}^2}$

while $\left[\sqrt{mgh}\right] = \sqrt{\mathrm{M}\left(\frac{\mathrm{L}}{\mathrm{T}^2}\right)\mathrm{L}} = \frac{\mathrm{M}^{\frac{1}{2}}\mathrm{L}}{\mathrm{T}}$. Thus, the equation is $\boxed{\text{dimensionally incorrect}}$.

(b) In $v = v_0 + at^2$, $[v] = [v_0] = \frac{\mathrm{L}}{\mathrm{T}}$ but $[at^2] = [a][t^2] = \left(\frac{\mathrm{L}}{\mathrm{T}^2}\right)(\mathrm{T}^2) = \mathrm{L}$. Hence, this equation is $\boxed{\text{dimensionally incorrect}}$.

(c) In the equation $ma = v^2$, we see that $[ma] = [m][a] = \mathrm{M}\left(\frac{\mathrm{L}}{\mathrm{T}^2}\right) = \frac{\mathrm{ML}}{\mathrm{T}^2}$, while $[v^2] = \left(\frac{\mathrm{L}}{\mathrm{T}}\right)^2 = \frac{\mathrm{L}^2}{\mathrm{T}^2}$. Therefore, this equation is also $\boxed{\text{dimensionally incorrect}}$.

1.5 From the universal gravitation law, the constant G is $G = Fr^2/Mm$. Its units are then

$$[G] = \frac{[F][r^2]}{[M][m]} = \frac{(\cancel{\mathrm{kg}} \cdot \mathrm{m/s^2})(\mathrm{m}^2)}{\cancel{\mathrm{kg}} \cdot \mathrm{kg}} = \boxed{\frac{\mathrm{m}^3}{\mathrm{kg} \cdot \mathrm{s}^2}}$$

1.6 (a) Solving $KE = \dfrac{p^2}{2m}$ for the momentum, p, gives $p = \sqrt{2m(KE)}$ where the numeral 2 is a dimensionless constant. Dimensional analysis gives the units of momentum as:

$$[p] = \sqrt{[m][KE]} = \sqrt{\text{M}\left(\text{M}\cdot\text{L}^2/\text{T}^2\right)} = \sqrt{\text{M}^2\cdot\text{L}^2/\text{T}^2} = \text{M}(\text{L}/\text{T})$$

Therefore, in the SI system, the units of momentum are $\boxed{\text{kg}\cdot(\text{m/s})}$.

(b) Note that the units of force are $\text{kg}\cdot\text{m/s}^2$ or $[F] = \text{M}\cdot\text{L}/\text{T}^2$. Then, observe that

$$[F][t] = \left(\text{M}\cdot\text{L}/\text{T}^2\right)\cdot\text{T} = \text{M}(\text{L}/\text{T}) = [p]$$

From this, it follows that force multiplied by time is proportional to momentum: $\boxed{Ft = p}$. (See the impulse–momentum theorem in Chapter 6, $F\cdot\Delta t = \Delta p$, which says that a constant force F multiplied by a duration of time Δt equals the change in momentum, Δp.)

1.7 $Area = (length)\times(width) = (9.72\text{ m})(5.3\text{ m}) = \boxed{52\text{ m}^2}$

1.8 (a) Computing $\left(\sqrt{8}\right)^3$ without rounding the intermediate result yields

$\left(\sqrt{8}\right)^3 = \boxed{22.6}$ to three significant figures.

(b) Rounding the intermediate result to three significant figures yields

$\sqrt{8} = 2.8284 \quad\rightarrow\quad 2.83$

Then, we obtain $\left(\sqrt{8}\right)^3 = (2.83)^3 = \boxed{22.7}$ to three significant figures.

(c) $\boxed{\text{The answer 22.6 is more reliable}}$ because rounding in part (b) was carried out too soon.

1.9 (a) 78.9 ± 0.2 has $\boxed{\text{3 significant figures}}$ with the uncertainty in the tenths position.

(b) 3.788×10^9 has $\boxed{\text{4 significant figures}}$

(c) 2.46×10^{-6} has $\boxed{\text{3 significant figures}}$

(d) $0.003\,2 = 3.2\times10^{-3}$ has $\boxed{\text{2 significant figures}}$. The two zeros were originally included only to position the decimal.

1.10 $c = 2.997\,924\,58\times10^8\ \text{m/s}$

(a) Rounded to 3 significant figures: $c = \boxed{3.00\times10^8\ \text{m/s}}$

(b) Rounded to 5 significant figures: $c = \boxed{2.997\,9\times10^8\ \text{m/s}}$

(c) Rounded to 7 significant figures: $c = \boxed{2.997\,925\times10^8\ \text{m/s}}$

1.11 Observe that the length $\ell = 5.62$ cm, the width $w = 6.35$ cm, and the height $h = 2.78$ cm all contain 3 significant figures. Thus, any product of these quantities should contain 3 significant figures.

(a) $\ell w = (5.62\text{ cm})(6.35\text{ cm}) = \boxed{35.7\text{ cm}^2}$

(b) $V = (\ell w)h = \left(35.7\text{ cm}^2\right)(2.78\text{ cm}) = \boxed{99.2\text{ cm}^3}$

(c) $wh = (6.35\text{ cm})(2.78\text{ cm}) = \boxed{17.7\text{ cm}^2}$

$$V = (wh)\ell = (17.7\text{ cm}^2)(5.62\text{ cm}) = \boxed{99.5\text{ cm}^3}$$

(d) In the rounding process, small amounts are either added to or subtracted from an answer to satisfy the rules of signify cant figures. For a given rounding, different small adjustments are made, introducing a certain amount of randomness in the last significant digit of the final answer.

1.12 (a) $A = \pi r^2 = \pi(10.5\text{ m} \pm 0.2\text{ m})^2 = \pi\left[(10.5\text{ m})^2 \pm 2(10.5\text{ m})(0.2\text{ m}) + (0.2\text{ m})^2\right]$

Recognize that the last term in the brackets is insignificant in comparison to the other two. Thus, we have

$$A = \pi\left[110\text{ m}^2 \pm 4.2\text{ m}^2\right] = \boxed{346\text{ m}^2 \pm 13\text{ m}^2}$$

(b) $C = 2\pi r = 2\pi(10.5\text{ m} \pm 0.2\text{ m}) = \boxed{66.0\text{ m} \pm 1.3\text{ m}}$

1.13 The least accurate dimension of the box has two significant figures. Thus, the volume (product of the three dimensions) will contain only two significant figures.

$$V = \ell \cdot w \cdot h = (29\text{ cm})(17.8\text{ cm})(11.4\text{ cm}) = \boxed{5.9\times 10^3\text{ cm}^3}$$

1.14 (a) The sum is rounded to $\boxed{797}$ because 756 in the terms to be added has no positions beyond the decimal.

(b) $0.003\,2 \times 356.3 = (3.2\times 10^{-3})\times 356.3 = 1.14016$ must be rounded to $\boxed{1.1}$ because 3.2×10^{-3} has only two significant figures.

(c) $5.620\times\pi$ must be rounded to $\boxed{17.66}$ because 5.620 has only four significant figures.

1.15 $d = (250\,000\text{ mi})\left(\dfrac{5\,280\text{ ft}}{1.000\text{ mi}}\right)\left(\dfrac{1\text{ fathom}}{6\text{ ft}}\right) = \boxed{2\times 10^8\text{ fathoms}}$

The answer is limited to one significant figure because of the accuracy to which the conversion from fathoms to feet is given.

1.16 $v = \dfrac{\ell}{t} = \dfrac{186\text{ furlongs}}{1\text{ fortnight}}\left(\dfrac{1\text{ fortnight}}{14\text{ days}}\right)\left(\dfrac{1\text{ day}}{8.64\times 10^4\text{ s}}\right)\left(\dfrac{220\text{ yds}}{1\text{ furlong}}\right)\left(\dfrac{3\text{ ft}}{1\text{ yd}}\right)\left(\dfrac{100\text{ cm}}{3.281\text{ ft}}\right)$

giving $v = \boxed{3.09\text{ cm/s}}$

1.17 $6.00\text{ firkins} = 6.00\text{ firkins}\left(\dfrac{9\text{ gal}}{1\text{ firkin}}\right)\left(\dfrac{3.786\text{ L}}{1\text{ gal}}\right)\left(\dfrac{10^3\text{ cm}^3}{1\text{ L}}\right)\left(\dfrac{1\text{ m}^3}{10^6\text{ cm}^3}\right) = \boxed{0.204\text{ m}^3}$

1.18 (a) $\ell = (348\text{ mi})\left(\dfrac{1.609\text{ km}}{1.000\text{ mi}}\right) = \boxed{5.60\times 10^2\text{ km}} = \boxed{5.60\times 10^5\text{ m}} = \boxed{5.60\times 10^7\text{ cm}}$

(b) $h = (1\,612\text{ ft})\left(\dfrac{1.609\text{ km}}{5\,280\text{ ft}}\right) = \boxed{0.491\,2\text{ km}} = \boxed{491.2\text{ m}} = \boxed{4.912\times 10^4\text{ cm}}$

(c) $h = (20\,320\text{ ft})\left(\dfrac{1.609\text{ km}}{5\,280\text{ ft}}\right) = \boxed{6.192\text{ km}} = \boxed{6.192\times 10^3\text{ m}} = \boxed{6.192\times 10^5\text{ cm}}$

(d) $d = (8\,200\text{ ft})\left(\dfrac{1.609\text{ km}}{5\,280\text{ ft}}\right) = \boxed{2.499\text{ km}} = \boxed{2.499\times 10^3\text{ m}} = \boxed{2.499\times 10^5\text{ cm}}$

In (a), the answer is limited to three significant figures because of the accuracy of the original data value, 348 miles. In (b), (c), and (d), the answers are limited to four significant figures because of the accuracy to which the kilometers-to-feet conversion factor is given.

1.19 $v = 38.0\ \frac{\text{m}}{\text{s}}\left(\frac{1\ \text{km}}{10^3\ \text{m}}\right)\left(\frac{1\ \text{mi}}{1.609\ \text{km}}\right)\left(\frac{3\,600\ \text{s}}{1\ \text{h}}\right) = 85.0\ \text{mi/h}$

Yes, the driver is exceeding the speed limit by 10.0 mi/h.

1.20 $efficiency = 25.0\ \frac{\text{mi}}{\text{gal}}\left(\frac{1\ \text{km}}{0.621\ \text{mi}}\right)\left(\frac{1\ \text{gal}}{3.786\ \text{L}}\right) = \boxed{10.6\ \text{km/L}}$

1.21 (a) $r = \frac{diameter}{2} = \frac{5.36\ \text{in}}{2}\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right) = \boxed{6.81\ \text{cm}}$

(b) $A = 4\pi r^2 = 4\pi(6.81\ \text{cm})^2 = \boxed{5.83\times10^2\ \text{cm}^2}$

(c) $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(6.81\ \text{cm})^3 = \boxed{1.32\times10^3\ \text{cm}^3}$

1.22 $rate = \left(\frac{1}{32}\ \frac{\text{in}}{\text{day}}\right)\left(\frac{1\ \text{day}}{24\ \text{h}}\right)\left(\frac{1\ \text{h}}{3\,600\ \text{s}}\right)\left(\frac{2.54\ \text{cm}}{1.00\ \text{in}}\right)\left(\frac{10^9\ \text{nm}}{10^2\ \text{cm}}\right) = \boxed{9.2\ \text{nm/s}}$

This means that the proteins are assembled at a rate of many layers of atoms each second!

1.23 $c = \left(3.00\times10^8\ \frac{\text{m}}{\text{s}}\right)\left(\frac{3\,600\ \text{s}}{1\ \text{h}}\right)\left(\frac{1\ \text{km}}{10^3\ \text{m}}\right)\left(\frac{1\ \text{mi}}{1.609\ \text{km}}\right) = \boxed{6.71\times10^8\ \text{mi/h}}$

1.24 $\text{Volume of house} = (50.0\ \text{ft})(26\ \text{ft})(8.0\ \text{ft})\left(\frac{2.832\times10^{-2}\ \text{m}^3}{1\ \text{ft}^3}\right)$

$$= \boxed{2.9\times10^2\ \text{m}^3} = \left(2.9\times10^2\ \text{m}^3\right)\left(\frac{100\ \text{cm}}{1\ \text{m}}\right)^3 = \boxed{2.9\times10^8\ \text{cm}^3}$$

1.25 $\text{Volume} = \left(25.0\ \text{acre ft}\right)\left(\frac{1\ \text{m}}{3.281\ \text{ft}}\right)\left[\left(\frac{43\,560\ \text{ft}^2}{1\ \text{acre}}\right)\left(\frac{1\ \text{m}}{3.281\ \text{ft}}\right)^2\right] = \boxed{3.08\times10^4\ \text{m}^3}$

1.26 $\text{Volume of pyramid} = \frac{1}{3}(\text{area of base})(\text{height})$

$$= \frac{1}{3}\left[(13.0\ \text{acres})\left(43\,560\ \text{ft}^2/\text{acre}\right)\right](481\ \text{ft}) = 9.08\times10^7\ \text{f}$$

$$= \left(9.08\times10^7\ \text{ft}^3\right)\left(\frac{2.832\times10^{-2}\ \text{m}^3}{1\ \text{ft}^3}\right) = \boxed{2.57\times10^6\ \text{m}^3}$$

1.27 Volume of cube $= L^3 = 1$ quart (Where L = length of one side of the cube.)

Thus, $L^3 = (1\ \text{quart})\left(\frac{1\ \text{gallon}}{4\ \text{quarts}}\right)\left(\frac{3.786\ \text{liter}}{1\ \text{gallon}}\right)\left(\frac{1000\ \text{cm}^3}{1\ \text{liter}}\right) = 947\ \text{cm}^3$

and $L = \sqrt[3]{947\ \text{cm}^3} = \boxed{9.82\ \text{cm}}$

1.28 We estimate that the length of a step for an average person is about 18 inches, or roughly 0.5 m.

Then, an estimate for the number of steps required to travel a distance equal to the circumference of the Earth would be

$$N = \frac{\text{Circumference}}{\text{Step Length}} = \frac{2\pi R_E}{\text{Step Length}} \approx \frac{2\pi\left(6.38\times10^6\ \text{m}\right)}{0.5\ \text{m/step}} \approx 8\times10^7\ \text{steps}$$

or $\boxed{N \sim 10^8 \text{ steps}}$

1.29 We assume an average respiration rate of about 10 breaths/minute and a typical life span of 70 years. Then, an estimate of the number of breaths an average person would take in a lifetime is

$$n = \left(10 \ \frac{\text{breaths}}{\cancel{\text{min}}}\right)\left(70 \ \cancel{\text{yr}}\right)\left(\frac{3.156\times10^7 \ \cancel{\text{s}}}{1 \ \cancel{\text{yr}}}\right)\left(\frac{1 \ \cancel{\text{min}}}{60 \ \cancel{\text{s}}}\right) = 4\times10^8 \text{ breaths}$$

or $\boxed{n \sim 10^8 \text{ breaths}}$

1.30 We assume that the average person catches a cold twice a year and is sick an average of 7 days (or 1 week) each time. Thus, on average, each person is sick for 2 weeks out of each year (52 weeks). The probability that a particular person will be sick at any given time equals the percentage of time that person is sick, or

$$probability \ of \ sickness = \frac{2 \text{ weeks}}{52 \text{ weeks}} = \frac{1}{26}$$

The population of the Earth is approximately 7 billion. The number of people expected to have a cold on any given day is then

$$Number \ sick = (population)(probability \ of \ sickness) = (7\times10^9)\left(\frac{1}{26}\right) = 3\times10^8 \text{ or } \boxed{10^8}$$

1.31 (a) Assume that a typical intestinal tract has a length of about 7 m and average diameter of 4 cm. The estimated total intestinal volume is then

$$V_{\text{total}} = A\ell = \left(\frac{\pi d^2}{4}\right)\ell = \frac{\pi(0.04 \text{ m})^2}{4}(7 \text{ m}) = 0.009 \text{ m}^3$$

The approximate volume occupied by a single bacterium is

$$V_{\text{bacteria}} \sim (typical \ length \ scale)^3 = \left(10^{-6} \text{ m}\right)^3 = 10^{-18} \text{ m}^3$$

If it is assumed that bacteria occupy one hundredth of the total intestinal volume, the estimate of the number of microorganisms in the human intestinal tract is

$$n = \frac{V_{\text{total}}/100}{V_{\text{bacteria}}} = \frac{\left(0.009 \text{ m}^3\right)/100}{10^{-18} \text{ m}^3} = 9\times10^{13} \quad \text{or} \quad n \sim \boxed{10^{14}}$$

(b) The large value of the number of bacteria estimated to exist in the intestinal tract means that they are probably not dangerous. Intestinal bacteria help digest food and provide important nutrients. Humans and bacteria enjoy a mutually beneficial symbiotic relationship.

1.32 (a) $V_{\text{cell}} = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(1.0\times10^{-6} \text{ m}\right)^3 = \boxed{4.2\times10^{-18} \text{ m}^3}$

(b) Consider your body to be a cylinder having a radius of about 6 inches (or 0.15 m) and a height of about 1.5 meters. Then, its volume is

$$V_{\text{body}} = Ah = \left(\pi r^2\right)h = \pi(0.15 \text{ m})^2(1.5 \text{ m}) = 0.11 \text{ m}^3 \quad \text{or} \quad \boxed{\sim 10^{-1} \text{ m}^3}$$

(c) The estimate of the number of cells in the body is then

$$n = \frac{V_{\text{body}}}{V_{\text{cell}}} = \frac{0.11 \text{ m}^3}{4.2\times10^{-18} \text{ m}^3} = 2.6\times10^{16} \quad \text{or} \quad \boxed{\sim 10^{16}}$$

1.33 A reasonable guess for the diameter of a tire might be 3 ft, with a circumference ($C = 2\pi r = \pi D$ = distance travels per revolution) of about 9 ft. Thus, the total number of revolutions the tire might make is

$$n = \frac{total\ distance\ traveled}{distance\ per\ revolution} = \frac{(50\,000\text{ mi})(5\,280\text{ ft/mi})}{9\text{ ft/rev}} = 3\times10^7\text{ rev, or }\boxed{\sim10^7\text{ rev}}$$

1.34 Answers to this problem will vary, dependent on the assumptions one makes. This solution assumes that bacteria and other prokaryotes occupy approximately one ten-millionth (10–7) of the Earth's volume, and that the density of a prokaryote, like the density of the human body, is approximately equal to that of water (103 kg/m3).

(a) $$estimated\ number = n = \frac{V_{\text{total}}}{V_{\substack{\text{single}\\\text{prokaryote}}}} \sim \frac{(10^{-7})V_{\text{Earth}}}{V_{\substack{\text{single}\\\text{prokaryote}}}} \sim \frac{(10^{-7})R_{\text{Earth}}^3}{(length\ scale)^3} \sim \frac{(10^{-7})(10^6\text{ m})^3}{(10^{-6}\text{ m})^3} \sim \boxed{10^{29}}$$

(b) $$m_{\text{total}} = (density)(total\ volume) \sim \rho_{\text{water}}\left(nV_{\substack{\text{single}\\\text{prokaryote}}}\right) = \left(10^3\ \frac{\text{kg}}{\text{m}^3}\right)(10^{29})(10^{-6}\text{ m})^3 \sim \boxed{10^{14}\text{ kg}}$$

(c) The very large mass of prokaryotes implies they are important to the biosphere. They are responsible for fixing carbon, producing oxygen, and breaking up pollutants, among many other biological roles. Humans depend on them!

1.35 The x coordinate is found as $x = r\cos\theta = (2.5\text{ m})\cos 35° = \boxed{2.0\text{ m}}$

and the y coordinate $y = r\sin\theta = (2.5\text{ m})\sin 35° = \boxed{1.4\text{ m}}$

1.36 The x distance out to the fly is 2.0 m and the y distance up to the fly is 1.0 m. Thus, we can use the Pythagorean theorem to find the distance from the origin to the fly as

$$d = \sqrt{x^2+y^2} = \sqrt{(2.0\text{ m})^2+(1.0\text{ m})^2} = \boxed{2.2\text{ m}}$$

1.37 The distance from the origin to the fly is r in polar coordinates, and this was found to be 2.2 m in Problem 36. The angle θ is the angle between r and the horizontal reference line (the x axis in this case). Thus, the angle can be found as

$$\tan\theta = \frac{y}{x} = \frac{1.0\text{ m}}{2.0\text{ m}} = 0.50 \qquad \text{and} \qquad \theta = \tan^{-1}(0.50) = 27°$$

The polar coordinates are $\boxed{r = 2.2\text{ m and }\theta = 27°}$

1.38 The x distance between the two points is $|\Delta x| = |x_2 - x_1| = |-3.0\text{ cm} - 5.0\text{ cm}| = 8.0\text{ cm}$ and the y distance between them is $|\Delta y| = |y_2 - y_1| = |3.0\text{ cm} - 4.0\text{ cm}| = 1.0\text{ cm}$. The distance between them is found from the Pythagorean theorem:

$$d = \sqrt{|\Delta x|^2 + |\Delta y|^2} = \sqrt{(8.0\text{ cm})^2 + (1.0\text{ cm})^2} = \sqrt{65\text{ cm}^2} = \boxed{8.1\text{ cm}}$$

1.39 Refer to the Figure given in Problem 1.40 below. The Cartesian coordinates for the two given points are:

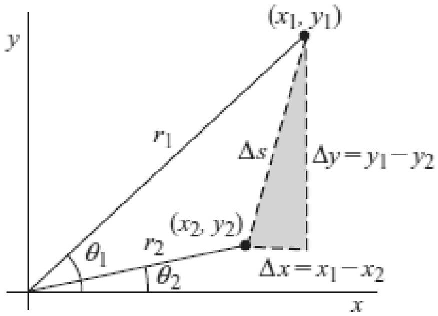
$$x_1 = r_1\cos\theta_1 = (2.00\text{ m})\cos 50.0° = 1.29\text{ m} \qquad x_2 = r_2\cos\theta_2 = (5.00\text{ m})\cos(-50.0°) = 3.21\text{ m}$$
$$y_1 = r_1\sin\theta_1 = (2.00\text{ m})\sin 50.0° = 1.53\text{ m} \qquad y_2 = r_2\sin\theta_2 = (5.00\text{ m})\sin(-50.0°) = -3.83\text{ m}$$

The distance between the two points is then:

$$\Delta s = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(1.29\text{ m} - 3.21\text{ m})^2 + (1.53\text{ m} + 3.83\text{ m})^2} = \boxed{5.69\text{ m}}$$

1.40 Consider the Figure shown at the right. The Cartesian coordinates for the two points are:

$$x_1 = r_1\cos\theta_1 \qquad x_2 = r_2\cos\theta_2$$
$$y_1 = r_1\sin\theta_1 \qquad y_2 = r_2\sin\theta_2$$



The distance between the two points is the length of the hypotenuse of the shaded triangle and is given by

$$\Delta s = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

or

$$\Delta s = \sqrt{\left(r_1^2 \cos^2\theta_1 + r_2^2 \cos^2\theta_2 - 2r_1r_2\cos\theta_1\cos\theta_2\right) + \left(r_1^2 \sin^2\theta_1 + r_2^2 \sin^2\theta_2 - 2r_1r_2\sin\theta_1\sin\theta_2\right)}$$

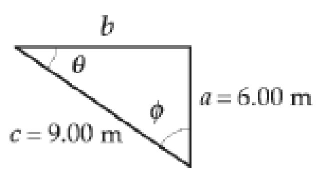
$$= \sqrt{r_1^2\left(\cos^2\theta_1 + \sin^2\theta_1\right) + r_2^2\left(\cos^2\theta_2 + \sin^2\theta_2\right) - 2r_1r_2\left(\cos\theta_1\cos\theta_2 + \sin\theta_1\sin\theta_2\right)}$$

Applying the identities $\cos^2\theta + \sin^2\theta = 1$ and $\cos\theta_1\cos\theta_2 + \sin\theta_1\sin\theta_2 = \cos(\theta_1 - \theta_2)$, this reduces to

$$\boxed{\Delta s = \sqrt{r_1^2 + r_2^2 - 2r_1r_2\left(\cos\theta_1\cos\theta_2 + \sin\theta_1\sin\theta_2\right)}} = \boxed{\sqrt{r_1^2 + r_2^2 - 2r_1r_2\cos(\theta_1 - \theta_2)}}$$

1.41 (a) With $a = 6.00$ m and b being two sides of this right triangle having hypotenuse $c = 9.00$ m, the Pythagorean theorem gives the unknown side as

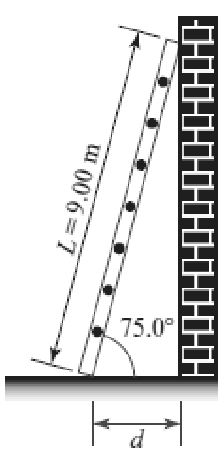
$$b = \sqrt{c^2 - a^2} = \sqrt{(9.00\text{ m})^2 - (6.00\text{ m})^2} = \boxed{6.71\text{ m}}$$



(b) $\tan\theta = \dfrac{a}{b} = \dfrac{6.00\text{ m}}{6.71\text{ m}} = \boxed{0.894}$ (c) $\sin\phi = \dfrac{b}{c} = \dfrac{6.71\text{ m}}{9.00\text{ m}} = \boxed{0.746}$

1.42 From the diagram, $\cos(75.0°) = d/L$

Thus, $d = L\cos(75.0°) = (9.00\text{ m})\cos(75.0°) = \boxed{2.33\text{ m}}$



1.43 The circumference of the fountain is $C = 2\pi r$, so the radius is

$$r = \frac{C}{2\pi} = \frac{15.0 \text{ m}}{2\pi} = 2.39 \text{ m}$$

Thus, $\tan(55.0°) = \frac{h}{r} = \frac{h}{2.39 \text{ m}}$ which gives

$$h = (2.39 \text{ m})\tan(55.0°) = \boxed{3.41 \text{ m}}$$

1.44 (a) $\sin\theta = \frac{\text{opposite side}}{\text{hypotenuse}}$ so, opposite side $= (3.00 \text{ m})\sin(30.0°) = \boxed{1.50 \text{ m}}$

(b) $\cos\theta = \frac{\text{adjacent side}}{\text{hypotenuse}}$ so, adjacent side $= (3.00 \text{ m})\cos(30.0°) = \boxed{2.60 \text{ m}}$

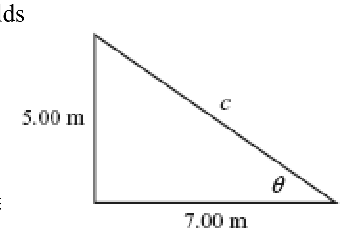
1.45 (a) The side opposite $\theta = \boxed{3.00}$ (b) The side adjacent to $\phi = \boxed{3.00}$

(c) $\cos\theta = \frac{4.00}{5.00} = \boxed{0.800}$ (d) $\sin\phi = \frac{4.00}{5.00} = \boxed{0.800}$

(e) $\tan\phi = \frac{4.00}{3.00} = \boxed{1.33}$

1.46 Using the diagram at the right, the Pythagorean theorem yields

$$c = \sqrt{(5.00 \text{ m})^2 + (7.00 \text{ m})^2} = \boxed{8.60 \text{ m}}$$

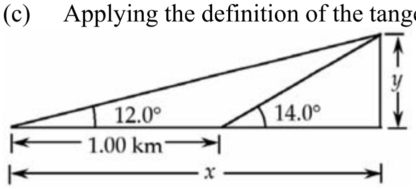


1.47 From the diagram given in Problem 1.46 above, it is seen th

$$\tan\theta = \boxed{\frac{5.00}{7.00}} = 0.714 \quad \text{and} \quad \theta = \tan^{-1}(0.714) = \boxed{35.5°}$$

1.48 (a) and (b) See the Figure given at the right.

(c) Applying the definition of the tangent function to the large right triangle containing the 12.0° angle gives:



$$\boxed{y/x = \tan 12.0°} \qquad [1]$$

Also, applying the definition of the tangent function to the smaller right triangle containing the 14.0° angle gives:

$$\boxed{\frac{y}{x - 1.00 \text{ km}} = \tan 14.0°} \qquad [2]$$

(d) From Equation [1] above, observe that $x = y/\tan 12.0°$

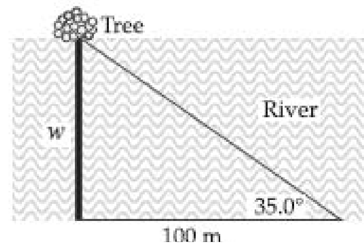
Substituting this result into Equation [2] gives

$$\frac{y \cdot \tan 12.0°}{y - (1.00 \text{ km})\tan 12.0°} = \tan 14.0°$$

Then, solving for the height of the mountain, y, yields

$$y = \frac{(1.00 \text{ km})\tan 12.0° \tan 14.0°}{\tan 14.0° - \tan 12.0°} = 1.44 \text{ km} = \boxed{1.44 \times 10^3 \text{ m}}$$

1.49 Using the sketch at the right:

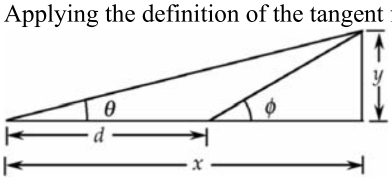


$$\frac{w}{100 \text{ m}} = \tan 35.0°, \text{ or}$$

$$w = (100 \text{ m})\tan 35.0° = \boxed{70.0 \text{ m}}$$

1.50 The figure at the right shows the situation described in the problem statement.

Applying the definition of the tangent function to the large right triangle containing the angle θ in the Figure, one obtains



$$y/x = \tan\theta \qquad [1]$$

Also, applying the definition of the tangent function to the small right triangle containing the angle ϕ gives

$$\frac{y}{x-d} = \tan\phi \qquad [2]$$

Solving Equation [1] for x and substituting the result into Equation [2] yields

$$\frac{y}{y/\tan\theta - d} = \tan\phi \qquad \text{or} \qquad \frac{y \cdot \tan\theta}{y - d \cdot \tan\theta} = \tan\phi$$

The last result simplifies to $y \cdot \tan\theta = y \cdot \tan\phi - d \cdot \tan\theta \cdot \tan\phi$

Solving for y: $y(\tan\theta - \tan\phi) = -d \cdot \tan\theta \cdot \tan\phi$ or

$$y = -\frac{d \cdot \tan\theta \cdot \tan\phi}{\tan\theta - \tan\phi} = \boxed{\frac{d \cdot \tan\theta \cdot \tan\phi}{\tan\phi - \tan\theta}}$$

1.51 (a) Given that $a \propto F/m$, we have $F \propto ma$. Therefore, the units of force are those of ma,

$$[F] = [ma] = [m][a] = \text{M}(\text{L}/\text{T}^2) = \boxed{\text{M L T}^{-2}}$$

(b) $[F] = \text{M}\left(\frac{\text{L}}{\text{T}^2}\right) = \frac{\text{M} \cdot \text{L}}{\text{T}^2}$ so newton = $\boxed{\frac{\text{kg} \cdot \text{m}}{\text{s}^2}}$

1.52 (a) $1 \frac{\text{mi}}{\text{h}} = \left(1 \frac{\text{mi}}{\text{h}}\right)\left(\frac{1.609 \text{ km}}{1 \text{ mi}}\right) = \boxed{1.609 \frac{\text{km}}{\text{h}}}$

(b) $v_{max} = 55 \frac{\text{mi}}{\text{h}} = \left(55 \frac{\text{mi}}{\text{h}}\right)\left(\frac{1.609 \text{ km/h}}{1 \text{ mi/h}}\right) = \boxed{88 \frac{\text{km}}{\text{h}}}$

(c) $\Delta v_{\max} = 65\ \dfrac{\text{mi}}{\text{h}} - 55\ \dfrac{\text{mi}}{\text{h}} = \left(10\ \dfrac{\text{mi}}{\text{h}}\right)\left(\dfrac{1.609\ \text{km/h}}{1\ \text{mi/h}}\right) = \boxed{16\ \dfrac{\text{km}}{\text{h}}}$

1.53 (a) Since $1\ \text{m} = 10^2\ \text{cm}$, then $1\ \text{m}^3 = (1\ \text{m})^3 = (10^2\ \text{cm})^3 = (10^2)^3\ \text{cm}^3 = 10^6\ \text{cm}^3$, giving

$$\text{mass} = (\text{density})(\text{volume}) = \left(\frac{1.0\times10^{-3}\ \text{kg}}{1.0\ \text{cm}^3}\right)(1.0\ \text{m}^3)$$

$$= \left(1.0\times10^{-3}\ \frac{\text{kg}}{\text{cm}^3}\right)(1.0\ \text{m}^3)\left(\frac{10^6\ \text{cm}^3}{1\ \text{m}^3}\right) = \boxed{1.0\times10^3\ \text{kg}}$$

As a rough calculation, treat each of the following objects as if they were 100% water.

(b) cell: $\text{mass} = \text{density}\times\text{volume} = \left(10^3\ \dfrac{\text{kg}}{\text{m}^3}\right)\dfrac{4}{3}\pi(0.50\times10^{-6}\ \text{m})^3 = \boxed{5.2\times10^{-16}\ \text{kg}}$

(c) kidney: $\text{mass} = \text{density}\times\text{volume} = \rho\left(\dfrac{4}{3}\pi r^3\right) = \left(10^3\ \dfrac{\text{kg}}{\text{m}^3}\right)\dfrac{4}{3}\pi(4.0\times10^{-2}\ \text{m})^3 = \boxed{0.27\ \text{kg}}$

$\text{mass} = \text{density}\times\text{volume} = (\text{density})(\pi r^2 h)$

(d) fly:

$$= \left(10^3\ \frac{\text{kg}}{\text{m}^3}\right)\pi(1.0\times10^{-3}\ \text{m})^2(4.0\times10^{-3}\ \text{m}) = \boxed{1.3\times10^{-5}\ \text{kg}}$$

1.54 Assume an average of 1 can per person each week and a population of 300 million.

(a) $$\text{number cans/year} = \left(\frac{\text{number cans/person}}{\text{week}}\right)(\text{population})(\text{weeks/year})$$

$$= \left(1\ \frac{\text{can/person}}{\text{week}}\right)(3\times10^8\ \text{people})(52\ \text{weeks/yr})$$

$$= 2\times10^{10}\ \text{cans/yr, or } \boxed{\sim10^{10}\ \text{cans/yr}}$$

(b) $$\text{number of tons} = (\text{weight/can})(\text{number cans /year})$$

$$= \left[\left(0.5\ \frac{\text{oz}}{\text{can}}\right)\left(\frac{1\ \text{lb}}{16\ \text{oz}}\right)\left(\frac{1\ \text{ton}}{2\,000\ \text{lb}}\right)\right]\left(2\times10^{10}\ \frac{\text{can}}{\text{yr}}\right)$$

$$= 3\times10^5\ \text{ton/yr, or } \boxed{\sim10^5\ \text{ton/yr}}$$

Assumes an average weight of 0.5 oz of aluminum per can.

1.55 The term s has dimensions of L, a has dimensions of LT–2, and t has dimensions of T. Therefore, the equation, $s = k\,a^m t^n$ with k being dimensionless, has dimensions of

$$\text{L} = (\text{LT}^{-2})^m(\text{T})^n \qquad \text{or} \qquad \text{L}^1\text{T}^0 = \text{L}^m\,\text{T}^{n-2m}$$

The powers of L and T must be the same on each side of the equation. Therefore, $\text{L}^1 = \text{L}^m$ and $\boxed{m = 1}$

Likewise, equating powers of T, we see that $n - 2m = 0$, or $\boxed{n = 2m = 2}$

$\boxed{\text{Dimensional analysis cannot determine the value of } k}$, a dimensionless constant.

1.56 (a) The rate of filling in gallons per second is

$$rate = \frac{30.0\text{ gal}}{7.00\text{ min}}\left(\frac{1\text{ min}}{60\text{ s}}\right) = \boxed{7.14\times10^{-2}\text{ gal/s}}$$

(b) Note that Note that $1\text{ m}^3 = \left(10^2\text{ cm}\right)^3 = \left(10^6\text{ cm}^3\right)\left(\frac{1\text{ L}}{10^3\text{ cm}^3}\right) = 10^3\text{ L}$. Thus,

$$rate = 7.14\times10^{-2}\ \frac{\text{gal}}{\text{s}}\left(\frac{3.786\text{ L}}{1\text{ gal}}\right)\left(\frac{1\text{ m}^3}{10^3\text{ L}}\right) = \boxed{2.70\times10^{-4}\text{ m}^3/\text{s}}$$

(c) $$t = \frac{V_{\text{filled}}}{rate} = \frac{1.00\text{ m}^3}{2.70\times10^{-4}\text{ m}^3/\text{s}} = 3.70\times10^3\text{ s}\left(\frac{1\text{ h}}{3\,600\text{ s}}\right) = \boxed{1.03\text{ h}}$$

1.57 The volume of paint used is given by $V = Ah$, where A is the area covered and h is the thickness of the layer. Thus,

$$h = \frac{V}{A} = \frac{3.79\times10^{-3}\text{ m}^3}{25.0\text{ m}^2} = 1.52\times10^{-4}\text{ m} = 152\times10^{-6}\text{ m} = \boxed{152\ \mu\text{m}}$$

1.58 (a) For a sphere, $A = 4\pi R^2$. In this case, the radius of the second sphere is twice that of the first, or $R_2 = 2R_1$.

Hence, $$\frac{A_2}{A_1} = \frac{4\pi R_2^2}{4\pi R_1^2} = \frac{R_2^2}{R_1^2} = \frac{(2R_1)^2}{R_1^2} = \boxed{4}$$

(b) For a sphere, the volume is $V = \frac{4}{3}\pi R^3$

Thus, $$\frac{V_2}{V_1} = \frac{(4/3)\pi R_2^3}{(4/3)\pi R_1^3} = \frac{R_2^3}{R_1^3} = \frac{(2R_1)^3}{R_1^3} = \boxed{8}$$

1.59 The estimate of the total distance cars are driven each year is

$$d = (\text{cars in use})(\text{distance traveled per car}) = \left(100\times10^6\text{ cars}\right)\left(10^4\text{ mi/car}\right) = 1\times10^{12}\text{ mi}$$

At a rate of 20 mi/gal, the fuel used per year would be

$$V_1 = \frac{d}{rate_1} = \frac{1\times10^{12}\text{ mi}}{20\text{ mi/gal}} = 5\times10^{10}\text{ gal}$$

If the rate increased to 25 mi/gal, the annual fuel consumption would be

$$V_2 = \frac{d}{rate_2} = \frac{1\times10^{12}\text{ mi}}{25\text{ mi/gal}} = 4\times10^{10}\text{ gal}$$

and the fuel savings each year would be

$$savings = V_1 - V_2 = 5\times10^{10}\text{ gal} - 4\times10^{10}\text{ gal} = \boxed{1\times10^{10}\text{ gal}}$$

1.60 (a) The time interval required to repay the debt will be calculated by dividing the total debt by the rate at which it is repaid.

$$T = \frac{\$17\text{ trillion}}{\$1000/\text{s}} = \frac{\$16\times10^{12}}{(\$1000/\text{s})\left(3.156\times10^7\text{ s/yr}\right)}$$
$$= 539\text{ yr} \sim \boxed{500\text{ yr}}$$

(b) The number of times \$17 trillion in bills encircles the Earth is given by 17 trillion times the length of one dollar bill divided by the circumference of the Earth ($C = 2\pi R_E$).

$$N = \frac{n\ell}{2\pi R_E} = \frac{(17\times10^{12})(0.155\text{ m})}{2\pi(6.378\times10^6\text{ m})} = \boxed{6.6\times10^4\text{ times}}$$

1.61 (a) $1\text{ yr} = (1\text{ yr})\left(\frac{365.2\text{ days}}{1\text{ yr}}\right)\left(\frac{8.64\times10^4\text{ s}}{1\text{ day}}\right) = \boxed{3.16\times10^7\text{ s}}$

(b) Consider a segment of the surface of the Moon which has an area of 1 m2 and a depth of 1 m. When filled with meteorites, each having a diameter 10^{-6} m, the number of meteorites along each edge of this box is

$$n = \frac{\text{length of an edge}}{\text{meteorite diameter}} = \frac{1\text{ m}}{10^{-6}\text{ m}} = 10^6$$

The total number of meteorites in the filled box is then

$$N = n^3 = (10^6)^3 = 10^{18}$$

At the rate of 1 meteorite per second, the time to fill the box is

$$t = 10^{18}\text{ s} = (10^{18}\text{ s})\left(\frac{1\text{ y}}{3.16\times10^7\text{ s}}\right) = 3\times10^{10}\text{ yr, or } \boxed{\sim10^{10}\text{ yr}}$$

1.62 We will assume that, on average, 1 ball will be lost per hitter, that there will be about 10 hitters per inning, a game has 9 innings, and the team plays 81 home games per season. Our estimate of the number of game balls needed per season is then

$$\begin{aligned}\text{number of balls needed} &= (\text{number lost per hitter})(\text{number hitters/game})(\text{home games/year}) \\ &= (1\text{ ball per hitter})\left[\left(10\ \frac{\text{hitters}}{\text{inning}}\right)\left(9\ \frac{\text{innings}}{\text{game}}\right)\right]\left(81\ \frac{\text{games}}{\text{year}}\right) \\ &= 7300\ \frac{\text{balls}}{\text{year}} \quad\text{or}\quad \boxed{\sim10^4\ \frac{\text{balls}}{\text{year}}}\end{aligned}$$

1.63 The volume of the Milky Way galaxy is roughly

$$V_G = At = \left(\frac{\pi d^2}{4}\right)t = \frac{\pi}{4}(10^{21}\text{ m})^2(10^{19}\text{ m}) \quad\text{or}\quad V_G \sim 10^{61}\text{ m}^3$$

If, within the Milky Way galaxy, there is typically one neutron star in a spherical volume of radius $r = 3\times10^{18}$ m, then the galactic volume per neutron star is

$$V_1 = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(3\times10^{18}\text{ m})^3 = 1\times10^{56}\text{ m}^3 \quad\text{or}\quad V_1 \sim 10^{56}\text{ m}^3$$

The order of magnitude of the number of neutron stars in the Milky Way is then

$$n = \frac{V_G}{V_1} \sim \frac{10^{61}\text{ m}^3}{10^{56}\text{ m}^3} \quad\text{or}\quad \boxed{n \sim 10^5\text{ neutron stars}}$$