Chapter 1
Introduction

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 $\sim 10^{-1}$ kg

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

(c) $\sim 4000 \text{ lb} \approx 2000 \text{ kg}$ or $\sim 10^{3}$ 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 $10^{-30}\ \text{m}^3$. (More precisely, volume = $\frac{4}{3}\pi r^3 = \frac{1}{6}\pi d^3$.) Therefore, since $1\ \text{cm}^3 = 10^{-6}\ \text{m}^3$, the number of atoms in the solid is on the order of $\frac{10^{-6}}{10^{-30}} = 10^{24}$ 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. On the average, a typical person drives about 10 000 miles per year or about 30 miles per day. (A reasonable estimate would be in the range of 5 to 50 miles per day.)

12. In general, the manufacturers are using significant figures correctly. The length and width of the aluminum foil both include three significant figures and the cited value of their product (the area) correctly includes three significant figures in both the metric and English versions. The manufacturer of the tape also gives three significant figures in the dimensions of the tape (metric version) and retains three significant figures in their product (area). However, the width of the tape is given in English units as $1/2''$, which gives no indication of the accuracy of the measurement. To be consistent with the three significant figure accuracy cited in the metric width dimension, the width should be given as $0.500''$.

Answers to Even Numbered Problems

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

4. All three equations are dimensionally incorrect.

6. **(a)** MLT^{-2} **(b)** $kg \cdot m/s^2$

8. $209\ cm^2 \pm 4\ cm^2$

10. **(a)** $3.00 \times 10^8\ m/s$ **(b)** $2.997\,9 \times 10^8\ m/s$ **(c)** $2.997\,924 \times 10^8\ m/s$

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

14. **(a)** 2.96×10^9 **(b)** 6.876×10^{-2}

16. **(a)** $5.60 \times 10^2\ km$, $5.60 \times 10^5\ m$, $5.60 \times 10^7\ cm$
(b) $0.4912\ km$, $491.2\ m$, $4.912 \times 10^4\ cm$
(c) $6.192\ km$, $6.192 \times 10^3\ m$, $6.192 \times 10^5\ cm$
(d) $2.499\ km$, $2.499 \times 10^3\ m$, $2.499 \times 10^5\ cm$

18. $9.2\ nm/s$

20. 3×10^9 yr

22. $2.9 \times 10^2\ m^3$, $2.9 \times 10^8\ cm^3$

24. $2.57 \times 10^6\ m^3$

26. **(a)** $1\ mi/h = 1.609\ km/h$
(b) $88\ km/h$
(c) $16\ km/h$

28. It would require about 47.6 yr to count the money. We advise against it.

30. $\sim 10^{10}$ lb of beef, $\sim 10^7$ head of cattle (assumes 0.25 lb per burger and a net of 300 lb of meat per head of cattle)

32. $\sim 10^7$ blades (assumes $1/16\ in^2$ per blade)

34. $\sim 10^{10}$ cans/yr, $\sim 10^5$ ton/yr (Assumes an average of 1 can per person each week, a population of 250 million, and 0.5 oz of aluminum per can)

36. 2.2 m

38. 8.1 cm

40. 2.33 m

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

44. 8.60 m

46. 70.0 m

48. **(a)** $0.677\ \text{g/cm}^3$ **(b)** $4.63\times10^{17}\ \text{ft}^2$

50. **(a)** $\sim10^2$ kg **(b)** $\sim10^3$ kg

52. **(a)** $\sim10^2$ yr **(b)** $\sim10^4$ times

54. **(a)** 4 **(b)** 8

Problem Solutions

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

$[V] = L^3$, $[A] = L^2$, and $[h] = L$

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

Thus, the equation $V = Ah$ is dimensionally correct.

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

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

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

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

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

But the sine of an angle is a dimensionless ratio.

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

1.3 Substituting in dimensions, we have

$$T = \sqrt{\frac{L}{L/T^2}} = \sqrt{T^2} = T$$

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

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

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

In $v = v_0 + at^2$, $[v] = [v_0] = \dfrac{L}{T}$ but $[at^2] = [a][t^2] = \left(\dfrac{L}{T^2}\right)\left(T^2\right) = L$. Hence, this equation is

$\boxed{\text{dimensionally incorrect}}$

In the equation $ma = v^2$, we see that $[ma]=[m][a]=\mathrm{M}\left(\dfrac{\mathrm{L}}{\mathrm{T}^2}\right)=\dfrac{\mathrm{ML}}{\mathrm{T}^2}$ while $[v^2]=\left(\dfrac{\mathrm{L}}{\mathrm{T}}\right)^2=\dfrac{\mathrm{L}^2}{\mathrm{T}^2}$

Therefore, this equation is also $\boxed{\text{dimensionally incorrect}}$

1.5 $\left(\dfrac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}\right)=\dfrac{G(\mathrm{kg})^2}{(\mathrm{m})^2}$, so cross-multiplying gives the units of G as $\boxed{\dfrac{\mathrm{m}^3}{\mathrm{kg}\cdot\mathrm{s}^2}}$

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

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

(b) newton = $\boxed{\dfrac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}}$

1.7 (a) 78.9 ± 0.2 has $\boxed{\text{3 significant figures}}$

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

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

(d) $0.0032 = 3.2\times10^{-3}$ has $\boxed{\text{2 significant figures}}$

1.8 $A=\ell w=\left[(21.3\pm0.2)\,\mathrm{cm}\right]\left[(9.8\pm0.1)\,\mathrm{cm}\right]$. Multiplying out this product of binominals gives

$$A=\left[21.3(9.8)\pm21.3(0.1)\pm0.2(9.8)+0.2(0.1)\right]\ \mathrm{cm}^2$$

The first term gives the best value of the area. The second and third terms add together to give the uncertainty and the fourth term is negligible in comparison to the other terms. The area and its uncertainty are found to be

$$A=\boxed{209\ \mathrm{cm}^2\pm4\ \mathrm{cm}^2}$$

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

(b) $0.0032\times356.3=\left(3.2\times10^{-3}\right)\times356.3=1.14016$ 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.

1.10 $c = 2.997\ 924\ 574 \times 10^8\ \text{m/s}$

(a) Rounded to 3 significant figures: $c = \boxed{3.00 \times 10^8\ \text{m/s}}$

(b) Rounded to 5 significant figures: $c = \boxed{2.997\ 9 \times 10^8\ \text{m/s}}$

(c) Rounded to 7 significant figures: $c = \boxed{2.997\ 924 \times 10^8\ \text{m/s}}$

1.11 The distance around is $38.44\ \text{m} + 19.5\ \text{m} + 38.44\ \text{m} + 19.5\ \text{m} = 115.88\ \text{m}$, but this answer must be rounded to $\boxed{115.9\ \text{m}}$ because the distance $19.5\ \text{m}$ carries information to only one place past the decimal.

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

giving $A = \boxed{346\ \text{m}^2 \pm 13\ \text{m}^2}$

(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 Adding the two lengths together, we get 228.76 cm. However, 135.3 cm has only one decimal place. Therefore, only one decimal place accuracy is possible in the sum, changing 228.76 cm to $\boxed{228.8\ \text{cm}}$.

1.14 (a) $(2.437 \times 10^4)(6.5211 \times 10^9)/(5.37 \times 10^4) = 2.9594 \times 10^9 = \boxed{2.96 \times 10^9}$

(b) $(3.14159 \times 10^2)(27.01 \times 10^4)/(1234 \times 10^6) = 6.8764 \times 10^{-2} = \boxed{6.876 \times 10^{-2}}$

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 (a) $\ell = (348\text{ mi})\left(\dfrac{1.609\text{ km}}{1.000\text{ mi}}\right) = \boxed{5.60\times10^{2}\text{ km}} = \boxed{5.60\times10^{5}\text{ m}} = \boxed{5.60\times10^{7}\text{ cm}}$

(b) $h = (1\,612\text{ ft})\left(\dfrac{1.609\text{ km}}{5\,280\text{ ft}}\right) = \boxed{0.491\,2\text{ km}} = \boxed{491.2\text{ m}} = \boxed{4.912\times10^{4}\text{ cm}}$

(c) $h = (20\,320\text{ ft})\left(\dfrac{1.609\text{ km}}{5\,280\text{ ft}}\right) = \boxed{6.192\text{ km}} = \boxed{6.192\times10^{3}\text{ m}} = \boxed{6.192\times10^{5}\text{ cm}}$

(d) $d = (8\,200\text{ ft})\left(\dfrac{1.609\text{ km}}{5\,280\text{ ft}}\right) = \boxed{2.499\text{ km}} = \boxed{2.499\times10^{3}\text{ m}} = \boxed{2.499\times10^{5}\text{ cm}}$

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.

1.17 $A = \ell w = (100\text{ ft})(150\text{ ft}) = (1.50\times10^{4}\text{ ft}^2)\left(\dfrac{1\text{ m}}{3.281\text{ ft}}\right)^2 = \boxed{1.39\times10^{3}\text{ m}^2}$

1.18 $rate = \left(\dfrac{1}{32}\ \dfrac{\text{in}}{\text{day}}\right)\left(\dfrac{1\text{ day}}{24\text{ h}}\right)\left(\dfrac{1\text{ h}}{3\,600\text{ s}}\right)\left(\dfrac{2.54\text{ cm}}{1.00\text{ in}}\right)\left(\dfrac{10^{9}\text{ nm}}{10^{2}\text{ cm}}\right) = \boxed{9.2\text{ nm/s}}$

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

1.19 $\text{Distance} = (4\times10^{16}\text{ m})\left(\dfrac{3.281\text{ ft}}{1\text{ m}}\right) = \boxed{1\times10^{17}\text{ ft}}$

1.20 $\text{Age of earth} = (1\times10^{17}\text{ s})\left(\dfrac{1\text{ yr}}{365.242\text{ days}}\right)\left(\dfrac{1\text{ day}}{24\text{ h}}\right)\left(\dfrac{1\text{ h}}{3600\text{ s}}\right) = \boxed{3\times10^{9}\text{ yr}}$

1.21 $c = \left(3.00\times10^{8}\ \dfrac{\text{m}}{\text{s}}\right)\left(\dfrac{3600\text{ s}}{1\text{ h}}\right)\left(\dfrac{1\text{ km}}{10^{3}\text{ m}}\right)\left(\dfrac{1\text{ mi}}{1.609\text{ km}}\right) = \boxed{6.71\times10^{8}\text{ mi/h}}$

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

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

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

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

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

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

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

Thus, $L^3=(1\text{ quart})\left(\dfrac{1\text{ gallon}}{4\text{ quarts}}\right)\left(\dfrac{3.786\text{ liter}}{1\text{ gallon}}\right)\left(\dfrac{1000\text{ cm}^3}{1\text{ liter}}\right)=946\text{ cm}^3$

and $L=\boxed{9.82\text{ cm}}$

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

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

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

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

$$=\left(1.0\times10^{-3}\frac{\text{kg}}{\text{cm}^3}\right)\left(1.0\text{ m}^3\right)\left(\frac{10^2\text{ cm}}{1\text{ m}}\right)^3=\boxed{1.0\times10^3\text{ kg}}$$

(b) As rough calculation, treat as if 100% water.

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

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

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

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

1.28 Since you have only 16 hours (57 600 s) per day, you can count only $57 600 per day. So, the time it would take would be:

$$t = \frac{1.00\times10^9\ \text{dollars}}{5.76\times10^4\ \text{dollars/day}}\left(\frac{1\ \text{yr}}{365\ \text{days}}\right) \approx \boxed{47.6\ \text{yr}}$$

Right now, you are at least 18 yr old, so you would be at least age 65 when you finished counting the money. It would provide a nice retirement, but a very boring life until then. $\boxed{\text{We would advise against it}}$.

1.29 number of balls needed = (number lost per hitter)(number hitters)(games)

$$= \left(\frac{1}{4}\ \text{ball per hitter}\right)\left(10\ \frac{\text{hitters}}{\text{inning}}\right)\left(9\ \frac{\text{innings}}{\text{game}}\right)\left(81\ \frac{\text{games}}{\text{year}}\right)$$

$$= 1800\ \frac{\text{balls}}{\text{year}}\ \text{or}\ \boxed{\sim10^3\ \frac{\text{balls}}{\text{year}}}$$

Assumptions are 1 ball lost for every four hitters, 10 hitters per inning, 9 innings per game, and 81 games per season.

1.30 number of pounds $=(\text{number of burgers})(\text{weight/burger})$

$$=\left(5\times 10^{10}\ \text{burgers}\right)\left(0.25\ \text{lb/burger}\right)=1.25\times 10^{10}\ \text{lb}\text{ , or }\boxed{\sim 10^{10}\ \text{lb}}$$

number of head of cattle $=(\text{weight needed})/(\text{weight per head})$

$$=\left(1.255\times 10^{10}\ \text{lb}\right)/\left(300\ \text{lb/head}\right)=4.17\times 10^{7}\ \text{head}\text{ , or }\boxed{\sim 10^{7}\ \text{head}}$$

Assumptions are 0.25 lb of meat per burger and a net of 300 lb of meat per head of cattle

1.31 A reasonable guess for the diameter of a tire might be 2.5 ft, with a circumference of about 8 ft. Thus, the tire would make

$$\left(50\,000\ \text{mi}\right)\left(5280\ \text{ft/mi}\right)\left(1\ \text{rev/8 ft}\right)=3\times 10^{7}\ \text{rev}\text{ , or }\boxed{\sim 10^{7}\ \text{rev}}$$

1.32 A blade of grass is $\sim 1/4$ inch wide, so we might expect each blade of grass to require at least $1/16\ \text{in}^2=4.3\times 10^{-4}\ \text{ft}^2$. Since $1\ \text{acre}=43\,560\ \text{ft}^2$, the number of blades of grass to be expected on a quarter-acre plot of land is about

$$n=\frac{\text{total area}}{\text{area per blade}}=\frac{(0.25\ \text{acre})\left(43\,560\ \text{ft}^2/\text{acre}\right)}{4.3\times 10^{-4}\ \text{ft}^2/\text{blade}}$$

$$=2.5\times 10^{7}\ \text{blades, or }\boxed{\sim 10^{7}\ \text{blades}}$$

1.33 Consider a room that is 12 ft square with an 8.0 ft high ceiling. The volume of this room is

$$V_{room}=(12\ \text{ft})(12\ \text{ft})(8.0\ \text{ft})\left(\frac{1\ \text{m}}{3.281\ \text{ft}}\right)^3=33\ \text{m}^3$$

A ping pong ball has a radius of about 2.0 cm, so its volume is

$$V_{ball}=\frac{4}{3}\pi r^3=\frac{4}{3}\pi\left(2.0\times 10^{-2}\ \text{m}\right)^3=3.4\times 10^{-5}\ \text{m}^3$$

The number of balls that would easily fit into the room is therefore

$$n=\frac{V_{room}}{V_{ball}}=\frac{33\ \text{m}^3}{3.4\times 10^{-5}\ \text{m}^3}=9.7\times 10^{5}\ \text{or }\boxed{\sim 10^{6}}$$

1.34 Assume an average of 1 can per person each week and a population of 250 million.

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

$$= \left(1\ \frac{\text{can/person}}{\text{week}}\right)\left(2.5\times10^{8}\ \text{people}\right)\left(52\ \text{weeks/yr}\right)$$

$$= 1.3\times10^{10}\ \text{cans/yr}\ \text{, or}\ \boxed{\sim10^{10}\ \text{cans/yr}}$$

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

$$= \left[\left(0.5\ \frac{\text{oz}}{\text{can}}\right)\left(\frac{1\ \text{lb}}{16\ \text{oz}}\right)\left(\frac{1\ \text{ton}}{2000\ \text{lb}}\right)\right]\left(1.3\times10^{10}\ \frac{\text{can}}{\text{yr}}\right)$$

$$= 2\times10^{5}\ \text{ton/yr},\ \text{or}\ \boxed{\sim10^{5}\ \text{ton/yr}}$$

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

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

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

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

$$\tan\theta = \frac{y}{x} = \frac{1.0\ \text{m}}{2.0\ \text{m}} = 0.5\ \text{and}\ \theta = \tan^{-1}(0.50) = 27^\circ$$

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

1.38 The x distance between the two points is 8.0 cm and the y distance between them is 1.0 cm. The distance between them is found from the Pythagorean theorem:

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

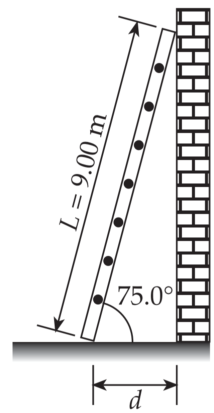
1.39 (a) From the Pythagorean theorem, the unknown side is

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

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

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

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

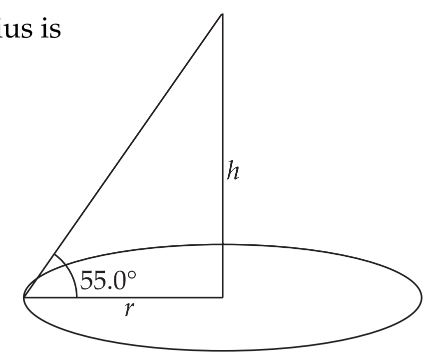


1.41 The circumference of the fountain is $C = 2\pi r$, so the radius is

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

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

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



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

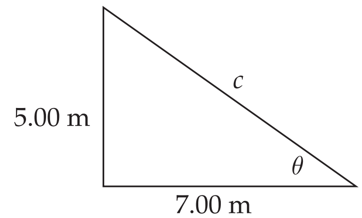
(b) $\cos\theta = \dfrac{\text{adjacent side}}{\text{hypotenuse}}$ so, adjacent side $= (3.00\text{ m})(\cos 30.0°) = \boxed{2.60\text{ m}}$

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

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

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

1.44 Using the diagram at the right, the Pythagorean Theorem yields

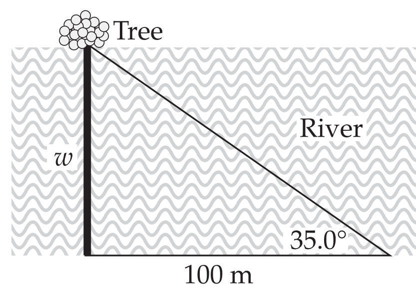


$$c = \sqrt{(5.00\text{ m})^2 + (7.00\text{ m})^2} = \boxed{8.60\text{ m}}$$

1.45 From the diagram given in Problem 1.44 above, it is seen that

$$\tan\theta = \boxed{\frac{5.00}{7.00}} \text{ and } \theta = 35.5°$$

1.46 Using the sketch at the right:



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

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

1.47 The $\boxed{\text{customer is incorrect}}$ as can be seen by considering the ratio of the areas of the two pizzas.

$$\frac{A_{large}}{A_{small}} = \frac{\pi r_{large}^2}{\pi r_{small}^2} = \frac{(9\text{ in})^2}{(6\text{ in})^2} = \frac{81}{36} = \frac{9}{4}$$

If the small pizza costs \$6.00, the cost of the large one should be $(\$6.00)\left(\dfrac{9}{4}\right) = \boxed{\$13.50}$

1.48 (a) The volume of Saturn is $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(5.85\times 10^7\ \text{m}\right)^3 = 8.39\times 10^{23}\ \text{m}^3$ and the density is

$$\frac{m}{V} = \left(\frac{5.68\times 10^{26}\ \text{kg}}{8.39\times 10^{23}\ \text{m}^3}\right)\left(\frac{1\ \text{m}}{10^2\ \text{cm}}\right)^3\left(\frac{10^3\ \text{g}}{1\ \text{kg}}\right) = \boxed{0.677\ \text{g/cm}^3}.$$

(b) The surface area of Saturn is

$$A = 4\pi r^2 = 4\pi\left(5.85\times 10^7\ \text{m}\right)^2\left(\frac{3.281\ \text{ft}}{1\ \text{m}}\right)^2 = \boxed{4.63\times 10^{17}\ \text{ft}^2}$$

1.49 The term s has dimensions of L, a has dimensions of LT^{-2}, and t has dimensions of T. Therefore, the equation, $s = k a^m t^n$ has dimensions of

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

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 terms in T, we see that $n - 2m = 0$. Thus, $\boxed{n = 2m = 2}$

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

1.50 Assume the tub measures 1.3 m by 0.5 m by 0.3 m

(a) It then has a volume $V = 0.2\ \text{m}^3$ and contains a mass of water

$$m = \rho V = \left(10^3\ \text{kg/m}^3\right)\left(0.2\ \text{m}^3\right) = 200\ \text{kg, or } \boxed{\sim 10^2\ \text{kg}}$$

(b) Pennies are now mostly zinc, but consider copper pennies filling 80% of the volume of the tub. Their mass is

$$m = 0.80\left(8.93\times 10^3\ \text{kg/m}^3\right)\left(0.2\ \text{m}^3\right) = 1400\ \text{kg, or } \boxed{\sim 10^3\ \text{kg}}$$

1.51 The volume of oil equals $V = \dfrac{9.00 \times 10^{-7}\ \text{kg}}{918\ \text{kg/m}^3} = 9.80 \times 10^{-10}\ \text{m}^3$

If the diameter of a molecule is d, then this volume must also equal

$$d\left(\pi r^2\right) = (\text{thickness of slick})(\text{area of oil slick}),\ \text{where}\ r = 0.418\ \text{m}$$

Thus, $d = \dfrac{9.80 \times 10^{-10}\ \text{m}^3}{\pi(0.418\ \text{m})^2} = 1.78 \times 10^{-9}\ \text{m},\ \text{or}\ \boxed{\sim 10^{-9}\ \text{m}}$

1.52 (a) The amount paid per year would be

$$\text{amount} = \left(1000\ \frac{\text{dollars}}{\text{s}}\right)\left(\frac{8.64 \times 10^4\ \text{s}}{1.00\ \text{day}}\right)\left(\frac{365.25\ \text{days}}{\text{yr}}\right) = 3.16 \times 10^{10}\ \frac{\text{dollars}}{\text{yr}}$$

Therefore, it would take $\dfrac{7.00 \times 10^{12}\ \text{dollars}}{3.16 \times 10^{10}\ \text{dollars/yr}} = 222\ \text{yr},\ \text{or}\ \boxed{\sim 10^2\ \text{yr}}$

(b) The circumference of the Earth at the equator is

$$C = 2\pi r = 2\pi\left(6.38 \times 10^6\ \text{m}\right) = 4.01 \times 10^7\ \text{m}$$

The length of one dollar bill is 0.155 m so that the length of seven trillion bills is 1.09×10^{12} m. Thus, the seven trillion dollars would encircle the earth

$$n = \frac{1.09 \times 10^{12}\ \text{m}}{4.01 \times 10^7\ \text{m}} = 2.71 \times 10^4,\ \text{or}\ \boxed{\sim 10^4\ \text{times}}$$

1.53 The number of tuners is found by dividing the number of residents of the city by the number of residents serviced by one tuner. We shall assume 1 tuner per 10,000 residents and a population of 7.5 million. Thus,

$$\text{number of tuners} = \frac{7.5 \times 10^6}{1.0 \times 10^4} = 7.5 \times 10^2\ \boxed{\sim 10^3\ \text{tuners}}$$

1.54 (a) For a sphere, $A = 4\pi R^2$. In this case, $R_2 = 2R_1$

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

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

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

1.55 (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) Let us consider a segment of the surface of the moon which has an area of 1 m^2 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

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

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

$$t = 10^{18}\text{ s} = \left(10^{18}\text{ s}\right)\left(\frac{1\text{ y}}{3.156\times10^7\text{ s}}\right) = 3\times10^{10}\text{ yr, or } \boxed{\sim10^{10}\text{ yr}}$$