

CHAPTER 1

1. (a) Assuming one significant figure, we have
 $10 \text{ billion yr} = 10 \times 10^9 \text{ yr} = 1 \times 10^{10} \text{ yr}.$
 (b) $(1 \times 10^{10} \text{ yr})(3 \times 10^7 \text{ s/yr}) = 3 \times 10^{17} \text{ s}.$

2. (a) $8.69 \times 10^4 = 86,900.$
 (b) $7.1 \times 10^3 = 7,100.$
 (c) $6.6 \times 10^{\bar{n}1} = 0.66.$
 (d) $8.76 \times 10^2 = 876.$
 (e) $8.62 \times 10^{\bar{n}5} = 0.000\ 086\ 2.$

3. (a) Assuming the zeros are not significant, we have $1,156,000 = 1.156 \times 10^6.$
 (b) $218 = 2.18 \times 10^2.$
 (c) $0.0068 = 6.8 \times 10^{\bar{n}3}.$
 (d) $27.635 = 2.7635 \times 10^1.$
 (e) $0.21 = 2.1 \times 10^{\bar{n}1}.$
 (f) $22 = 2.2 \times 10^1.$

4. (a) **3 significant figures.**
 (b) Because the zero is not needed for placement, we have **4 significant figures.**
 (c) **3 significant figures.**
 (d) Because the zeros are for placement only, we have **1 significant figure.**
 (e) Because the zeros are for placement only, we have **2 significant figures.**
 (f) **4 significant figures.**
 (g) **2, 3, or 4 significant figures,** depending on the significance of the zeros.

5. % uncertainty = $[(0.25 \text{ m})/(2.26 \text{ m})] 100 = 11\%.$
 Because the uncertainty has 2 significant figures, the % uncertainty has 2 significant figures.

6. We assume an uncertainty of 1 in the last place, i. e., 0.01, so we have
 % uncertainty = $[(0.01)/(1.67)] 100 = 0.6\%.$
 Because the uncertainty has 1 significant figure, the % uncertainty has 1 significant figure.

7. We assume an uncertainty of 0.5 s.
 (a) % uncertainty = $[(0.5 \text{ s})/(5 \text{ s})] 100 = 1 \times 10^1\%.$
 Because the uncertainty has 1 significant figure, the % uncertainty has 1 significant figure.
 (b) % uncertainty = $[(0.5 \text{ s})/(50 \text{ s})] 100 = 1\%.$
 Because the uncertainty has 1 significant figure, the % uncertainty has 1 significant figure.
 (c) % uncertainty = $[(0.5 \text{ s})/(5 \text{ min})(60 \text{ s/min})] 100 = 0.2\%.$
 Because the uncertainty has 1 significant figure, the % uncertainty has 1 significant figure.

8. For multiplication, the number of significant figures in the result is the least number from the multipliers; in this case 2 from the second value.
 $(2.079 \times 10^2 \text{ m})(0.072 \times 10^{\bar{n}1}) = 0.15 \times 10^1 \text{ m} = 1.5 \text{ m}.$

9. To add, we make all of the exponents the same:

$$\begin{aligned} 7.2 \times 10^3 \text{ s} + 8.3 \times 10^4 \text{ s} + 0.09 \times 10^6 \text{ s} &= 0.72 \times 10^4 \text{ s} + 8.3 \times 10^4 \text{ s} + 9 \times 10^4 \text{ s} \\ &= 18.02 \times 10^4 \text{ s} = \mathbf{1.8 \times 10^5 \text{ s}}. \end{aligned}$$

Because we are adding, the location of the uncertain figure for the result is the one furthest to the left. In this case, it is fixed by the third value.

10. We assume an uncertainty of 0.1×10^4 cm. We compare the area for the specified radius to the area for the extreme radius.

$$A_1 = \pi R_1^2 = \pi(2.8 \times 10^4 \text{ cm})^2 = 2.46 \times 10^9 \text{ cm}^2; \quad A_2 = \pi R_2^2 = \pi[(2.8 + 0.1) \times 10^4 \text{ cm}]^2 = 2.64 \times 10^9 \text{ cm}^2,$$

so the uncertainty in the area is $\Delta A = A_2 - A_1 = 0.18 \times 10^9 \text{ cm}^2 = 0.2 \times 10^9 \text{ cm}^2$.

We write the area as $A = (2.5 \pm 0.2) \times 10^9 \text{ cm}^2$.

11. We compare the volume with the specified radius to the volume for the extreme radius.

$$V_1 = \frac{4}{3}\pi R_1^3 = \frac{4}{3}\pi(3.86 \text{ m})^3 = 241 \text{ m}^3; \quad V_2 = \frac{4}{3}\pi R_2^3 = \frac{4}{3}\pi(3.86 \text{ m} + 0.08 \text{ m})^3 = 256 \text{ m}^3,$$

so the uncertainty in the volume is $\Delta V = V_2 - V_1 = 15 \text{ m}^3$; and the % uncertainty is

$$\% \text{ uncertainty} = [(15 \text{ m}^3)/(241 \text{ m}^3)] 100 = \mathbf{6\%}.$$

12. (a) 10^6 volts = 1 megavolt = $\mathbf{1 \text{ Mvolt}}$.

(b) 10^6 meters = 1 micrometer = $\mathbf{1 \mu\text{m}}$.

(c) 5×10^3 days = 5 kilodays = $\mathbf{5 \text{ kdays}}$.

(d) 8×10^2 bucks = 8 hectobucks = $\mathbf{0.8 \text{ kbucks}}$.

(e) 8×10^9 pieces = 8 nanopieces = $\mathbf{8 \text{ npieces}}$.

13. (a) $86.6 \text{ mm} = 86.6 \times 10^{-3} \text{ m} = \mathbf{0.0866 \text{ m}}$.

(b) $35 \mu\text{V} = 35 \times 10^{-6} \text{ V} = \mathbf{0.000035 \text{ V}}$.

(c) $860 \text{ mg} = 860 \times 10^{-3} \text{ g} = \mathbf{0.860 \text{ g}}$. This assumes that the last zero is significant.

(d) $600 \text{ picoseconds} = 600 \times 10^{-12} \text{ s} = \mathbf{0.000000000600 \text{ s}}$. This assumes that both zeros are significant.

(e) $12.5 \text{ femtometers} = 12.5 \times 10^{-15} \text{ m} = \mathbf{0.0000000000125 \text{ m}}$.

(f) $250 \text{ gigavolts} = 250 \times 10^9 \text{ volts} = \mathbf{250,000,000,000 \text{ volts}}$.

14. $50 \text{ hectokisses} = 50 \times 10^2 \text{ kisses} = \mathbf{5,000 \text{ kisses}}$.

$1 \text{ megabuck/yr} = 1 \times 10^6 \text{ bucks/yr} = 1,000,000 \text{ bucks/yr}$ ($\mathbf{\text{millionaire}}$).

15. If we assume a height of 5 ft 10 in, we have

$$\text{height} = 5 \text{ ft } 10 \text{ in} = 70 \text{ in} = (70 \text{ in})[(1 \text{ m})/(39.37 \text{ in})] = \mathbf{1.8 \text{ m}}.$$

16. (a) $93 \text{ million mi} = 93 \times 10^6 \text{ mi} = (93 \times 10^6 \text{ mi})[(1610 \text{ m})/(1 \text{ mi})] = \mathbf{1.5 \times 10^{11} \text{ m}}$.

(b) $1.5 \times 10^{11} \text{ m} = 150 \times 10^9 \text{ m} = \mathbf{150 \text{ Gm}}$.

17. (a) $1.0 \times 10^{10} \text{ m} = (1.0 \times 10^{10} \text{ m})[(1 \text{ in})/(2.54 \text{ cm})][(100 \text{ cm})/(1 \text{ m})] = \mathbf{3.9 \times 10^9 \text{ in}}$.

(b) We let the units lead us to the answer:

$$(1.0 \text{ cm})[(1 \text{ m})/(100 \text{ cm})][(1 \text{ atom})/(1.0 \times 10^{10} \text{ m})] = \mathbf{1.0 \times 10^8 \text{ atoms}}.$$

18. To add, we make all of the units the same:

$$1.00 \text{ m} + 142.5 \text{ cm} + 1.24 \times 10^5 \mu\text{m} = 1.00 \text{ m} + 1.425 \text{ m} + 0.124 \text{ m} \\ = 2.549 \text{ m} = 2.55 \text{ m}.$$

Because we are adding, the location of the uncertain figure for the result is the one furthest to the left. In this case, it is fixed by the first value.

19. (a) $1 \text{ km/h} = (1 \text{ km/h})[(0.621 \text{ mi})/(1 \text{ km})] = 0.621 \text{ mi/h}.$

(b) $1 \text{ m/s} = (1 \text{ m/s})[(1 \text{ ft})/(0.305 \text{ m})] = 3.28 \text{ ft/s}.$

(c) $1 \text{ km/h} = (1 \text{ km/h})[(1000 \text{ m})/(1 \text{ km})][(1 \text{ h})/(3600 \text{ s})] = 0.278 \text{ m/s}.$

A useful alternative is

$$1 \text{ km/h} = (1 \text{ km/h})[(1 \text{ h})/(3.600 \text{ ks})] = 0.278 \text{ m/s}.$$

20. For the length of a one-mile race in m, we have

$$1 \text{ mi} = (1 \text{ mi})[(1610 \text{ m})/(1 \text{ mi})] = 1610 \text{ m}; \text{ so the difference is } 110 \text{ m}.$$

The % difference is

$$\% \text{ difference} = [(110 \text{ m})/(1500 \text{ m})] 100 = 7.3\%.$$

21. (a) $1.00 \text{ ly} = (2.998 \times 10^8 \text{ m/s})(1.00 \text{ yr})[(365.25 \text{ days})/(1 \text{ yr})][(24 \text{ h})/(1 \text{ day})][(3600 \text{ s})/(1 \text{ h})] \\ = 9.46 \times 10^{15} \text{ m}.$

(b) $1.00 \text{ ly} = (9.46 \times 10^{15} \text{ m})[(1 \text{ AU})/(1.50 \times 10^8 \text{ km})][(1 \text{ km})/(1000 \text{ m})] = 6.31 \times 10^4 \text{ AU}.$

(c) $\text{speed of light} = (2.998 \times 10^8 \text{ m/s})[(1 \text{ AU})/(1.50 \times 10^8 \text{ km})][(1 \text{ km})/(1000 \text{ m})][(3600 \text{ s})/(1 \text{ h})] \\ = 7.20 \text{ AU/h}.$

22. For the surface area of a sphere, we have

$$A_{\text{moon}} = 4^1 r_{\text{moon}}^2 = 4^1 [(3.48 \times 10^6 \text{ m})]^2 = 3.80 \times 10^{13} \text{ m}^2.$$

We compare this to the area of the earth by finding the ratio:

$$A_{\text{moon}}/A_{\text{Earth}} = 4^1 r_{\text{moon}}^2 / 4^1 r_{\text{Earth}}^2 = (r_{\text{moon}}/r_{\text{Earth}})^2 = [(1.74 \times 10^3 \text{ km})/(6.38 \times 10^3 \text{ km})]^2 = 7.42 \times 10^{-2}.$$

Thus we have

$$A_{\text{moon}} = 7.42 \times 10^{-2} A_{\text{Earth}}.$$

23. (a) $7800 = 7.8 \times 10^3 \approx 10 \times 10^3 = 10^4.$

(b) $9.630 \times 10^2 \approx 10 \times 10^2 = 10^3.$

(c) $0.00076 = 0.76 \times 10^{-3} \approx 10^{-3}.$

(d) $150 \times 10^8 = 1.50 \times 10^{10} \approx 10^{10}.$

24. We assume that a good runner can run 6 mi/h (equivalent to a 10-min mile) for 5 h/day. Using 3000 mi for the distance across the U. S., we have

$$\text{time} = (3000 \text{ mi})/(6 \text{ mi/h})(5 \text{ h/day}) \approx 100 \text{ days}.$$

25. We assume a rectangular house 40 ft \times 30 ft, 8 ft high; so the total wall area is

$$A_{\text{total}} = [2(40 \text{ ft}) + 2(30 \text{ ft})](8 \text{ ft}) \approx 1000 \text{ ft}^2.$$

If we assume there are 12 windows with dimensions 3 ft \times 5 ft, the window area is

$$A_{\text{window}} = 12(3 \text{ ft})(5 \text{ ft}) \approx 200 \text{ ft}^2.$$

Thus we have

$$\% \text{ window area} = [A_{\text{window}}/A_{\text{total}}](100) = [(200 \text{ ft}^2)/(1000 \text{ ft}^2)](100) \approx 20\%.$$

26. If we take an average lifetime to be 70 years and the average pulse to be 60 beats/min, we have

$$N = (60 \text{ beats/min})(70 \text{ yr})(365 \text{ day/yr})(24 \text{ h/day})(60 \text{ min/h}) \approx 2 \times 10^9 \text{ beats.}$$
27. If we approximate the body as a box with dimensions 6 ft, 1 ft, and 8 in, we have

$$\text{volume} = (72 \text{ in})(12 \text{ in})(8 \text{ in})(2.54 \text{ cm/in})^3 \approx 1 \times 10^5 \text{ cm}^3.$$
28. We assume the distance from Beijing to Paris is 10,000 mi.
 (a) If we assume that today's race car can travel for an extended period at an average speed of 40 mi/h, we have

$$\text{time} = [(10,000 \text{ mi})/(40 \text{ mi/h})](1 \text{ day}/24 \text{ h}) \approx 10 \text{ days.}$$

 (b) If we assume that in 1906 a race car could travel for an extended period at an average speed of 5 mi/h, we have

$$\text{time} = [(10,000 \text{ mi})/(5 \text{ mi/h})](1 \text{ day}/24 \text{ h}) \approx 80 \text{ days.}$$
29. We assume that 12 patients visit a dentist each day. If a dentist works 5 days/wk for 48 wk/yr, the total number of visits per year for a dentist is

$$n_{\text{visits}} = (12 \text{ visits/day})(5 \text{ days/wk})(48 \text{ wk/yr}) \approx 3000 \text{ visits/yr.}$$

 We assume that each person visits a dentist 2 times/yr.
 (a) We assume that the population of San Francisco is 700,000. We let the units lead us to the answer:

$$N = (700,000 \text{ persons})(2 \text{ visits/yr} \cdot \text{person}) / (3000 \text{ visits/yr} \cdot \text{dentist}) \approx 500 \text{ dentists.}$$

 (b) Left to the reader to estimate the population.
30. If we assume that the person can mow at a speed of 1 m/s and the width of the mower cut is 0.5 m, the rate at which the field is mown is $(1 \text{ m/s})(0.5 \text{ m}) = 0.5 \text{ m}^2/\text{s}$.
 If we take the dimensions of the field to be 110 m by 50 m, we have

$$\text{time} = [(110 \text{ m})(50 \text{ m}) / (0.5 \text{ m}^2/\text{s})] / (3600 \text{ s/h}) \approx 3 \text{ h.}$$
31. We assume an average time of 3 yr for the tire to wear $d = 1 \text{ cm}$ and the tire has a radius of $r = 30 \text{ cm}$ and a width of $w = 10 \text{ cm}$. Thus the volume of rubber lost by a tire in 3 yr is $V = wd2^1r$. If we assume there are 100 million vehicles, each with 4 tires, we have

$$m = (100 \times 10^6 \text{ vehicles})(4 \text{ tires/vehicle})(0.1 \text{ m})(0.01 \text{ m})^2(0.3 \text{ m})(1200 \text{ kg/m}^3) / (3 \text{ yr})$$

$$\approx 3 \times 10^8 \text{ kg/yr.}$$
32. (a) $1.0 \text{ \AA} = (1.0 \times 10^{\text{n}10} \text{ m}) / (10^{\text{n}9} \text{ m/nm}) = 0.10 \text{ nm.}$
 (b) $1.0 \text{ \AA} = (10^{\text{n}10} \text{ m}) / (10^{\text{n}15} \text{ m/fm}) = 1.0 \times 10^5 \text{ fm.}$
 (c) $1.0 \text{ m} = (1.0 \text{ m}) / (10^{\text{n}10} \text{ m/\AA}) = 1.0 \times 10^{10} \text{ \AA.}$
 (d) From the result for Problem 21, we have

$$1.0 \text{ ly} = (9.5 \times 10^{15} \text{ m}) / (10^{\text{n}10} \text{ m/\AA}) = 9.5 \times 10^{25} \text{ \AA.}$$
33. (a) $1.00 \text{ yr} = (365.25 \text{ days})(24 \text{ h/day})(3600 \text{ s/h}) = 3.16 \times 10^7 \text{ s.}$
 (b) $1.00 \text{ yr} = (3.16 \times 10^7 \text{ s}) / (10^{\text{n}9} \text{ s/ns}) = 3.16 \times 10^{16} \text{ ns.}$
 (c) $1.00 \text{ s} = (1.00 \text{ s}) / (3.16 \times 10^7 \text{ s/yr}) = 3.17 \times 10^{\text{n}8} \text{ yr.}$

34. (a) The maximum number of buses is needed during rush hour. If we assume that at any time there are 40,000 persons commuting by bus and each bus has 30 passengers, we have

$$N = (40,000 \text{ commuters}) / (30 \text{ passengers/bus}) \approx 1000 \text{ buses} \approx \mathbf{1,000 \text{ drivers.}}$$

- (b) Left to the reader.

35. If we ignore any loss of material from the slicing, we find the number of wafers from
 $(30 \text{ cm})(10 \text{ mm/cm}) / (0.60 \text{ mm/wafer}) = 500 \text{ wafers.}$

For the maximum number of chips, we have

$$(500 \text{ wafers})(100 \text{ chips/wafer}) = \mathbf{50,000 \text{ chips.}}$$

36. If we assume there is 1 automobile for 2 persons and a U. S. population of 250 million, we have 125 million automobiles. We estimate that each automobile travels 15,000 miles in a year and averages 20 mi/gal. Thus we have

$$N = (125 \times 10^6 \text{ automobiles})(15,000 \text{ mi/yr}) / (20 \text{ mi/gal}) \approx \mathbf{1 \times 10^{11} \text{ gal/yr.}}$$

37. We let D represent the diameter of a gumball. Because there are air gaps around the gumballs, we estimate the volume occupied by a gumball as a cube with volume D^3 . The machine has a square cross-section with sides equivalent to 10 gumballs and is about 14 gumballs high, so we have

$$N = \text{volume of machine} / \text{volume of gumball} = (14D)(10D)^2 / D^3 \approx \mathbf{1.4 \times 10^3 \text{ gumballs.}}$$

38. The volume used in one year is

$$V = [(40,000 \text{ persons}) / (4 \text{ persons/family})] (1200 \text{ L/family} \cdot \text{day}) (365 \text{ days/yr}) (10^{\text{m}^3} \text{ m}^3/\text{L}) \\ \approx \mathbf{4 \times 10^6 \text{ m}^3.}$$

If we let d represent the loss in depth, we have

$$d = V / \text{area} = (4 \times 10^6 \text{ m}^3) / (50 \text{ km}^2) (10^3 \text{ m/km})^2 \approx 0.09 \text{ m} \approx \mathbf{9 \text{ cm.}}$$

39. For the volume of a 1-ton rock, we have

$$V = (2000 \text{ lb}) / (3)(62 \text{ lb/ft}^3) \approx 11 \text{ ft}^3.$$

If we assume the rock is a sphere, we find the radius from

$$11 \text{ ft}^3 = \frac{4}{3}\pi r^3, \text{ which gives } r \approx 1.4 \text{ ft, so the diameter would be } \approx \mathbf{3 \text{ ft} \approx 1 \text{ m.}}$$

40. We find the amount of water from its volume:

$$m = (5 \text{ km})(8 \text{ km})(1.0 \text{ cm})(10^5 \text{ cm/km})^2 (10^{\text{m}^3} \text{ kg/cm}^3) / (10^3 \text{ kg/t}) = 40 \times 10^4 \text{ t} \approx \mathbf{4 \times 10^5 \text{ t.}}$$

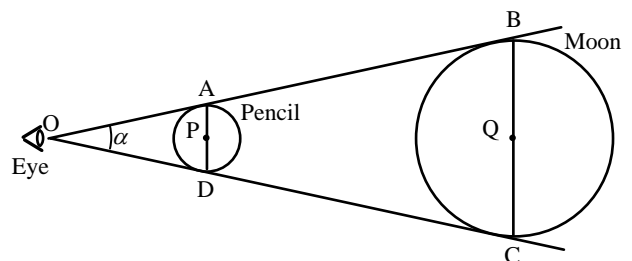
41. We will use a pencil with a diameter of 5 mm and assume that it is held 0.5 m from the eye. Because the triangles AOD and BOC are similar, we can equate the ratio of distances:

$$BC / AD = OQ / OP;$$

$$BC / (0.005 \text{ m}) = (3.8 \times 10^5 \text{ km}) / (0.5 \text{ m}),$$

which gives

$$BC \approx \mathbf{4 \times 10^3 \text{ km.}}$$



42. (a) $V = (1,000 \text{ m}^3)(10^2 \text{ cm/m})^3 = 1.00 \times 10^9 \text{ cm}^3$.
(b) $V = (1,000 \text{ m}^3)(3.28 \text{ ft/m})^3 = 3.53 \times 10^3 \text{ ft}^3$.
(c) $V = (1,000 \text{ m}^3)(10^2 \text{ cm/m})^3 / (2.54 \text{ cm/in})^3 = 6.10 \times 10^7 \text{ in}^3$.
43. We assume that we can walk an average of 15 miles a day. If we ignore the impossibility of walking on water and travel around the equator, the time required is
 $\text{time} = 2^1 R_{\text{Earth}} / \text{speed} = 2^1 (6 \times 10^3 \text{ km})(0.621 \text{ mi/km}) / (15 \text{ mi/day})(365 \text{ days/yr}) \approx 4 \text{ yr}$.
44. If we use 0.5 m for the cubit, for the dimensions we have
150 m long, 25 m wide, and 15 m high.