

# Chapter 1

## INTRODUCTION

### Conceptual Questions

1. Knowledge of physics is important for a full understanding of many scientific disciplines, such as chemistry, biology, and geology. Furthermore, much of our current technology can only be understood with knowledge of the underlying laws of physics. In the search for more efficient and environmentally safe sources of energy, for example, physics is essential. Also, many study physics for the sense of fulfillment that comes with learning about the world we inhabit.
2. Without precise definitions of words for scientific use, unambiguous communication of findings and ideas would be impossible.
3. Even when simplified models do not exactly match real conditions, they can still provide insight into the features of a physical system. Often a problem would become too complicated if one attempted to match the real conditions exactly, and an approximation can yield a result that is close enough to the exact one to still be useful.
4. (a) 3  
(b) 9
5. Scientific notation eliminates the need to write many zeros in very large or small numbers. Also, the appropriate number of significant digits is unambiguous when written this way.
6. In scientific notation the decimal point is placed after the first (leftmost) numeral. The number of digits written equals the number of significant figures.
7. Not all of the significant digits are precisely known. The least significant digit (rightmost) is an estimate and is less precisely known than the others.
8. It is important to list the correct number of significant figures so that we can indicate how precisely a quantity is known and not mislead the reader by writing digits that are not at all known to be correct.
9. The kilogram, meter, and second are three of the base units used in the SI system.
10. The SI system uses a well-defined set of internationally agreed upon standard units and makes measurements in terms of these units and their powers of ten. The U.S. Customary system contains units that are primarily of historical origin and are not based upon powers of ten. As a result of this international acceptance and the ease of manipulation that comes from dealing with powers of ten, scientists around the world prefer to use the SI system.
11. Fathoms, kilometers, miles, and inches are units with dimensions of length. Grams and kilograms are units with dimensions of mass. Years, months, and seconds are units with dimensions of time.
12. The first step toward successfully solving almost any physics problem is to thoroughly read the question and obtain a precise understanding of the scenario. The second step is to visualize the problem, often making a quick sketch to outline the details of the situation and the known parameters.
13. Trends in a set of data are often the most interesting aspect of the outcome of an experiment. Such trends are more apparent when data is plotted graphically rather than listed in numerical tables.
14. The statement gives a numerical value for the speed of sound in air, but fails to indicate the units used for the measurement. Without units, the reader cannot relate the speed to one given in familiar units such as km/s.

15. After solving a problem, it is a good idea to check that the solution is reasonable and makes intuitive sense. It may also be useful to explore other possible methods of solution as a check on the validity of the first.

## Problems

1. **Strategy** The new fence will be  $100\% + 37\% = 137\%$  of the height of the old fence.

**Solution** Find the height of the new fence.

$$1.37 \times 1.8 \text{ m} = \boxed{2.5 \text{ m}}$$

2. **Strategy** There are  $\frac{60 \text{ s}}{1 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ h}} \times \frac{24 \text{ h}}{1 \text{ d}} = 86,400$  seconds in one day and 24 hours in one day.

**Solution** Find the ratio of the number of seconds in a day to the number of hours in a day.

$$\frac{86,400}{24} = \frac{24 \times 3600}{24} = \boxed{3600/1}$$

3. **Strategy** Relate the surface area  $S$  to the radius  $r$  using  $S = 4\pi r^2$ .

**Solution** Find the ratio of the new radius to the old.

$$S_1 = 4\pi r_1^2 \text{ and } S_2 = 4\pi r_2^2 = 1.160S_1 = 1.160(4\pi r_1^2).$$

$$4\pi r_2^2 = 1.160(4\pi r_1^2)$$

$$r_2^2 = 1.160r_1^2$$

$$\left(\frac{r_2}{r_1}\right)^2 = 1.160$$

$$\frac{r_2}{r_1} = \sqrt{1.160} = 1.077$$

The radius of the balloon increases by  $\boxed{7.7\%}$ .

4. **Strategy** Relate the surface area  $S$  to the radius  $r$  using  $S = 4\pi r^2$ .

**Solution** Find the ratio of the new radius to the old.

$$S_1 = 4\pi r_1^2 \text{ and } S_2 = 4\pi r_2^2 = 2.0S_1 = 2.0(4\pi r_1^2).$$

$$4\pi r_2^2 = 2.0(4\pi r_1^2)$$

$$r_2^2 = 2.0r_1^2$$

$$\left(\frac{r_2}{r_1}\right)^2 = 2.0$$

$$\frac{r_2}{r_1} = \sqrt{2.0} = 1.4$$

The radius of the balloon increases by a factor of  $\boxed{1.4}$ .

5. **Strategy** The surface area  $S$  and the volume  $V$  are given by  $S = 6s^2$  and  $V = s^3$ , respectively.

**Solution** Find the ratio of the surface area to the volume.

$$\frac{S}{V} = \frac{6s^2}{s^3} = \boxed{\frac{6}{s}}$$

6. **Strategy** To find the factor Samantha's height increased, divide her new height by her old height. Subtract 1 from this value and multiply by 100 to find the percent increase.

**Solution** Find the factor.

$$\frac{1.65 \text{ m}}{1.50 \text{ m}} = \boxed{1.10}$$

Find the percentage.

$$1.10 - 1 = 0.10, \text{ so the percent increase is } \boxed{10\%}.$$

7. **Strategy** Recall that area has dimensions of length squared.

**Solution** Find the ratio of the area of the park as represented on the map to the area of the actual park.

$$\frac{\text{map length}}{\text{actual length}} = \frac{1}{10,000} = 10^{-4}, \text{ so } \frac{\text{map area}}{\text{actual area}} = (10^{-4})^2 = \boxed{10^{-8}}.$$

8. **Strategy** Let  $X$  be the original value of the index.

**Solution** Find the net percentage change in the index for the two days.

$$(\text{first day change}) \times (\text{second day change}) = [X \times (1 + 0.0500)] \times (1 - 0.0500) = 0.9975X$$

$$\text{The net percentage change is } (0.9975 - 1) \times 100\% = -0.25\%, \text{ or } \boxed{\text{down } 0.25\%}.$$

9. **Strategy** Use a proportion.

**Solution** Find Jupiter's orbital period.

$$T^2 \propto R^3, \text{ so } \frac{T_J^2}{T_E^2} = \frac{R_J^3}{R_E^3} = 5.19^3. \text{ Thus, } T_J = 5.19^{3/2} T_E = \boxed{11.8 \text{ yr}}.$$

10. **Strategy** The area of the circular garden is given by  $A = \pi r^2$ . Let the original and final areas be  $A_1 = \pi r_1^2$  and  $A_2 = \pi r_2^2$ , respectively.

**Solution** Calculate the percentage increase of the area of the garden plot.

$$\frac{\Delta A}{A} \times 100\% = \frac{\pi r_2^2 - \pi r_1^2}{\pi r_1^2} \times 100\% = \frac{r_2^2 - r_1^2}{r_1^2} \times 100\% = \frac{1.25^2 r_1^2 - r_1^2}{r_1^2} \times 100\% = \frac{1.25^2 - 1}{1} \times 100\% = \boxed{56\%}$$

11. **Strategy** The area of the poster is given by  $A = \ell w$ . Let the original and final areas be  $A_1 = \ell_1 w_1$  and  $A_2 = \ell_2 w_2$ , respectively.

**Solution** Calculate the percentage reduction of the area.

$$A_2 = \ell_2 w_2 = (0.800 \ell_1)(0.800 w_1) = 0.640 \ell_1 w_1 = 0.640 A_1$$

$$\frac{A_1 - A_2}{A_1} \times 100\% = \frac{A_1 - 0.640 A_1}{A_1} \times 100\% = \boxed{36.0\%}$$

12. **Strategy** The volume of the rectangular room is given by  $V = \ell wh$ . Let the original and final volumes be  $V_1 = \ell_1 w_1 h_1$  and  $V_2 = \ell_2 w_2 h_2$ , respectively.

**Solution** Find the factor by which the volume of the room increased.

$$\frac{V_2}{V_1} = \frac{\ell_2 w_2 h_2}{\ell_1 w_1 h_1} = \frac{(1.50\ell_1)(2.00w_1)(1.20h_1)}{\ell_1 w_1 h_1} = \boxed{3.60}$$

13. (a) **Strategy** Rewrite the numbers so that the power of 10 is the same for each. Then add and give the answer with the number of significant figures determined by the less precise of the two numbers.

**Solution** Perform the operation with the appropriate number of significant figures.

$$3.783 \times 10^6 \text{ kg} + 1.25 \times 10^8 \text{ kg} = 0.03783 \times 10^8 \text{ kg} + 1.25 \times 10^8 \text{ kg} = \boxed{1.29 \times 10^8 \text{ kg}}$$

- (b) **Strategy** Find the quotient and give the answer with the number of significant figures determined by the number with the fewest significant figures.

**Solution** Perform the operation with the appropriate number of significant figures.

$$(3.783 \times 10^6 \text{ m}) \div (3.0 \times 10^{-2} \text{ s}) = \boxed{1.3 \times 10^8 \text{ m/s}}$$

14. (a) **Strategy** Move the decimal point eight places to the left and multiply by  $10^8$ .

**Solution** Write the number in scientific notation.

$$290,000,000 \text{ people} = \boxed{2.9 \times 10^8 \text{ people}}$$

- (b) **Strategy** Move the decimal point 15 places to the right and multiply by  $10^{-15}$ .

**Solution** Write the number in scientific notation.

$$0.000\ 000\ 000\ 000\ 003\ 8 \text{ m} = \boxed{3.8 \times 10^{-15} \text{ m}}$$

15. (a) **Strategy** Rewrite the numbers so that the power of 10 is the same for each. Then subtract and give the answer with the number of significant figures determined by the less precise of the two numbers.

**Solution** Perform the calculation using an appropriate number of significant figures.

$$3.68 \times 10^7 \text{ g} - 4.759 \times 10^5 \text{ g} = 3.68 \times 10^7 \text{ g} - 0.04759 \times 10^7 \text{ g} = \boxed{3.63 \times 10^7 \text{ g}}$$

- (b) **Strategy** Find the quotient and give the answer with the number of significant figures determined by the number with the fewest significant figures.

**Solution** Perform the calculation using an appropriate number of significant figures.

$$\frac{6.497 \times 10^4 \text{ m}^2}{5.1037 \times 10^2 \text{ m}} = \boxed{1.273 \times 10^2 \text{ m}}$$

16. (a) **Strategy** Rewrite the numbers so that the power of 10 is the same for each. Then add and give the answer with the number of significant figures determined by the less precise of the two numbers.

**Solution** Write your answer using the appropriate number of significant figures.

$$6.85 \times 10^{-5} \text{ m} + 2.7 \times 10^{-7} \text{ m} = 6.85 \times 10^{-5} \text{ m} + 0.027 \times 10^{-5} \text{ m} = \boxed{6.88 \times 10^{-5} \text{ m}}$$

- (b) **Strategy** Add and give the answer with the number of significant figures determined by the less precise of the two numbers.

**Solution** Write your answer using the appropriate number of significant figures.

$$702.35 \text{ km} + 1897.648 \text{ km} = \boxed{2600.00 \text{ km}}$$

- (c) **Strategy** Multiply and give the answer with the number of significant figures determined by the number with the fewest significant figures.

**Solution** Write your answer using the appropriate number of significant figures.

$$5.0 \text{ m} \times 4.3 \text{ m} = \boxed{22 \text{ m}^2}$$

- (d) **Strategy** Find the quotient and give the answer with the number of significant figures determined by the number with the fewest significant figures.

**Solution** Write your answer using the appropriate number of significant figures.

$$(0.04/\pi) \text{ cm} = \boxed{0.01 \text{ cm}}$$

- (e) **Strategy** Find the quotient and give the answer with the number of significant figures determined by the number with the fewest significant figures.

**Solution** Write your answer using the appropriate number of significant figures.

$$(0.040/\pi) \text{ m} = \boxed{0.013 \text{ m}}$$

17. **Strategy** Multiply and give the answer in scientific notation with the number of significant figures determined by the number with the fewest significant figures.

**Solution** Solve the problem.

$$(3.2 \text{ m}) \times (4.0 \times 10^{-3} \text{ m}) \times (1.3 \times 10^{-8} \text{ m}) = \boxed{1.7 \times 10^{-10} \text{ m}^3}$$

18. **Strategy** Follow the rules for identifying significant figures.

**Solution**

- (a) All three digits are significant, so 7.68 g has  $\boxed{3}$  significant figures.
- (b) The first zero is not significant, since it is used only to place the decimal point. The digits 4 and 2 are significant, as is the final zero, so 0.420 kg has  $\boxed{3}$  significant figures.
- (c) The first two zeros are not significant, since they are used only to place the decimal point. The digits 7 and 3 are significant, so 0.073 m has  $\boxed{2}$  significant figures.
- (d) All three digits are significant, so  $7.68 \times 10^5 \text{ g}$  has  $\boxed{3}$  significant figures.

(e) The zero is significant, since it comes after the decimal point. The digits 4 and 2 are significant as well, so  $4.20 \times 10^3 \text{ kg}$  has 3 significant figures.

(f) Both 7 and 3 are significant, so  $7.3 \times 10^{-2} \text{ m}$  has 2 significant figures.

(g) Both 2 and 3 are significant. The two zeros are significant as well, since they come after the decimal point, so  $2.300 \times 10^4 \text{ s}$  has 4 significant figures.

19. **Strategy** Divide and give the answer with the number of significant figures determined by the number with the fewest significant figures.

**Solution** Solve the problem.

$$\frac{3.21 \text{ m}}{7.00 \text{ ms}} = \frac{3.21 \text{ m}}{7.00 \times 10^{-3} \text{ s}} = \boxed{459 \text{ m/s}}$$

20. **Strategy** Convert each length to meters. Then, rewrite the numbers so that the power of 10 is the same for each. Finally, add and give the answer with the number of significant figures determined by the less precise of the two numbers.

**Solution** Solve the problem.

$$3.08 \times 10^{-1} \text{ km} + 2.00 \times 10^3 \text{ cm} = 3.08 \times 10^2 \text{ m} + 2.00 \times 10^1 \text{ m} = 3.08 \times 10^2 \text{ m} + 0.200 \times 10^2 \text{ m} = \boxed{3.28 \times 10^2 \text{ m}}$$

21. **Strategy** There are approximately 39.37 inches per meter.

**Solution** Find the thickness of the cell membrane in inches.

$$7.0 \times 10^{-9} \text{ m} \times 39.37 \text{ inches/m} = \boxed{2.8 \times 10^{-7} \text{ inches}}$$

22. (a) **Strategy** There are approximately 3.785 liters per gallon and 128 ounces per gallon.

**Solution** Find the number of fluid ounces in the bottle.

$$\frac{128 \text{ fl oz}}{1 \text{ gal}} \times \frac{1 \text{ gal}}{3.785 \text{ L}} \times 355 \text{ mL} \times \frac{1 \text{ L}}{10^3 \text{ mL}} = \boxed{12.0 \text{ fluid ounces}}$$

- (b) **Strategy** From part (a), we have  $355 \text{ mL} = 12.0 \text{ fluid ounces}$ .

**Solution** Find the number of milliliters in the drink.

$$16.0 \text{ fl oz} \times \frac{355 \text{ mL}}{12.0 \text{ fl oz}} = \boxed{473 \text{ mL}}$$

23. **Strategy** There are approximately 3.281 feet per meter.

**Solution** Convert to meters and identify the order of magnitude.

$$(a) \quad 1595.5 \text{ ft} \times \frac{1 \text{ m}}{3.281 \text{ ft}} = \boxed{4.863 \times 10^2 \text{ m}}; \text{ the order of magnitude is } \boxed{10^2}.$$

$$(b) \quad 6016 \text{ ft} \times \frac{1 \text{ m}}{3.281 \text{ ft}} = \boxed{1.834 \times 10^3 \text{ m}}; \text{ the order of magnitude is } \boxed{10^3}.$$

- 24. Strategy** There are 3600 seconds in one hour and 1000 m in one kilometer.

**Solution** Convert 1.00 kilometers per hour to meters per second.

$$\frac{1.00 \text{ km}}{1 \text{ h}} \times \frac{1 \text{ h}}{3600 \text{ s}} \times \frac{1000 \text{ m}}{1 \text{ km}} = \boxed{0.278 \text{ m/s}}$$

- 25. (a) Strategy** There are 60 seconds in one minute, 5280 feet in one mile, and 3.28 feet in one meter.

**Solution** Express 0.32 miles per minute in meters per second.

$$\frac{0.32 \text{ mi}}{1 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{5280 \text{ ft}}{1 \text{ mi}} \times \frac{1 \text{ m}}{3.28 \text{ ft}} = \boxed{8.6 \text{ m/s}}$$

- (b) Strategy** There are 60 minutes in one hour.

**Solution** Express 0.32 miles per minute in miles per hour.

$$\frac{0.32 \text{ mi}}{1 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ h}} = \boxed{19 \text{ mi/h}}$$

- 26. Strategy** There are 0.6214 miles in 1 kilometer.

**Solution** Find the length of the marathon race in miles.

$$42.195 \text{ km} \times \frac{0.6214 \text{ mi}}{1 \text{ km}} = \boxed{26.22 \text{ mi}}$$

- 27. Strategy** Calculate the change in the exchange rate and divide it by the original price to find the drop.

**Solution** Find the actual drop in the value of the dollar over the first year.

$$\frac{1.27 - 1.45}{1.45} = \frac{-0.18}{1.45} = -0.12$$

The actual drop is  $\boxed{0.12 \text{ or } 12\%}$ .

- 28. Strategy** There are 1000 watts in one kilowatt and 100 centimeters in one meter.

**Solution** Convert  $1.4 \text{ kW/m}^2$  to  $\text{W/cm}^2$ .

$$\frac{1.4 \text{ kW}}{1 \text{ m}^2} \times \frac{1000 \text{ W}}{1 \text{ kW}} \times \left( \frac{1 \text{ m}}{100 \text{ cm}} \right)^2 = \boxed{0.14 \text{ W/cm}^2}$$

- 29. Strategy** There are 1000 grams in one kilogram and 100 centimeters in one meter.

**Solution** Find the density of mercury in units of  $\text{g/cm}^3$ .

$$\frac{1.36 \times 10^4 \text{ kg}}{1 \text{ m}^3} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \left( \frac{1 \text{ m}}{100 \text{ cm}} \right)^3 = \boxed{13.6 \text{ g/cm}^3}$$

- 30. Strategy** The distance traveled  $d$  is equal to the rate of travel  $r$  times the time of travel  $t$ . There are 1000 milliseconds in one second.

**Solution** Find the distance the molecule would move.

$$d = rt = \frac{459 \text{ m}}{1 \text{ s}} \times 7.00 \text{ ms} \times \frac{1 \text{ s}}{1000 \text{ ms}} = \boxed{3.21 \text{ m}}$$

- 31. Strategy** There are 1000 meters in a kilometer and 1,000,000 millimeters in a kilometer.

**Solution** Find the product and express the answer in  $\text{km}^3$  with the appropriate number of significant figures.

$$(3.2 \text{ km}) \times (4.0 \text{ m}) \times (13 \times 10^{-3} \text{ mm}) \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{1 \text{ km}}{1,000,000 \text{ mm}} = \boxed{1.7 \times 10^{-10} \text{ km}^3}$$

- 32. (a) Strategy** There are 12 inches in one foot and 2.54 centimeters in one inch.

**Solution** Find the number of square centimeters in one square foot.

$$1 \text{ ft}^2 \times \left( \frac{12 \text{ in}}{1 \text{ ft}} \right)^2 \times \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right)^2 = \boxed{929 \text{ cm}^2}$$

- (b) Strategy** There are 100 centimeters in one meter.

**Solution** Find the number of square centimeters in one square meter.

$$1 \text{ m}^2 \times \left( \frac{100 \text{ cm}}{1 \text{ m}} \right)^2 = \boxed{1 \times 10^4 \text{ cm}^2}$$

- (c) Strategy** Divide one square meter by one square foot. Estimate the quotient.

**Solution** Find the approximate number of square feet in one square meter.

$$\frac{1 \text{ m}^2}{1 \text{ ft}^2} = \frac{10,000 \text{ cm}^2}{929 \text{ cm}^2} \approx \boxed{11}$$

- 33. (a) Strategy** There are 12 inches in one foot, 2.54 centimeters in one inch, and 60 seconds in one minute.

**Solution** Express the snail's speed in feet per second.

$$\frac{5.0 \text{ cm}}{1 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ ft}}{12 \text{ in}} = \boxed{2.7 \times 10^{-3} \text{ ft/s}}$$

- (b) Strategy** There are 5280 feet in one mile, 12 inches in one foot, 2.54 centimeters in one inch, and 60 minutes in one hour.

**Solution** Express the snail's speed in miles per hour.

$$\frac{5.0 \text{ cm}}{1 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ h}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ ft}}{12 \text{ in}} \times \frac{1 \text{ mi}}{5280 \text{ ft}} = \boxed{1.9 \times 10^{-3} \text{ mi/h}}$$

- 34. Strategy** A micrometer is  $10^{-6} \text{ m}$  and a millimeter is  $10^{-3} \text{ m}$ ; therefore, a micrometer is  $10^{-6}/10^{-3} = 10^{-3} \text{ mm}$ .

**Solution** Find the area in square millimeters.

$$150 \text{ } \mu\text{m}^2 \times \left( \frac{10^{-3} \text{ mm}}{1 \text{ } \mu\text{m}} \right)^2 = \boxed{1.5 \times 10^{-4} \text{ mm}^2}$$

- 35. Strategy** Replace each quantity in  $U = mgh$  with its SI base units.

**Solution** Find the combination of SI base units that are equivalent to joules.

$$U = mgh \Rightarrow \text{J} = \text{kg} \times \text{m/s}^2 \times \text{m} = \boxed{\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-2}}$$



36. (a) **Strategy** Replace each quantity in  $ma$  and  $kx$  with its dimensions.

**Solution** Show that the dimensions of  $ma$  and  $kx$  are equivalent.

$$ma \text{ has dimensions } [M] \times \frac{[L]}{[T]^2} \text{ and } kx \text{ has dimensions } \frac{[M]}{[T]^2} \times [L] = [M] \times \frac{[L]}{[T]^2}.$$

Since  $[M][L][T]^{-2} = [M][L][T]^{-2}$ , the dimensions are equivalent.

- (b) **Strategy** Use the results of part (a).

**Solution** Since  $F = ma$  and  $F = -kx$ , the dimensions of the force unit are  $[M][L][T]^{-2}$ .

37. **Strategy** Replace each quantity in  $T^2 = 4\pi^2 r^3 / (GM)$  with its dimensions.

**Solution** Show that the equation is dimensionally correct.

$$T^2 \text{ has dimensions } [T]^2 \text{ and } \frac{4\pi^2 r^3}{GM} \text{ has dimensions } \frac{[L]^3}{\frac{[L]^3}{[M][T]^2} \times [M]} = \frac{[L]^3}{[M]} \times \frac{[M][T]^2}{[L]^3} = [T]^2.$$

Since  $[T]^2 = [T]^2$ , the equation is dimensionally correct.

38. **Strategy** Determine the SI unit of momentum using a process of elimination.

**Solution** Find the SI unit of momentum.

$K = \frac{p^2}{2m}$  has units of  $\frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$ . Since the SI unit for  $m$  is kg, the SI unit for  $p^2$  is  $\frac{\text{kg}^2 \cdot \text{m}^2}{\text{s}^2}$ . Taking the square root, we find that the SI unit for momentum is  $\text{kg} \cdot \text{m} \cdot \text{s}^{-1}$ .

39. (a) **Strategy** Replace each quantity (except for  $V$ ) in  $F_B = \rho g V$  with its dimensions.

**Solution** Find the dimensions of  $V$ .

$$V = \frac{F_B}{\rho g} \text{ has dimensions } \frac{[MLT^{-2}]}{[ML^{-3}] \times [LT^{-2}]} = [L^3].$$

- (b) **Strategy and Solution** Since velocity has dimensions  $[LT^{-1}]$  and volume has dimensions  $[L^3]$ , the correct interpretation of  $V$  is that it represents  $\text{volume}$ .

40. **Strategy** Replace  $v$ ,  $r$ ,  $\omega$ , and  $m$  with their dimensions. Then use dimensional analysis to determine how  $v$  depends upon some or all of the other quantities.

**Solution**  $v$ ,  $r$ ,  $\omega$ , and  $m$  have dimensions  $\frac{[L]}{[T]}$ ,  $[L]$ ,  $\frac{1}{[T]}$ , and  $[M]$ , respectively. No combination of  $r$ ,  $\omega$ , and  $m$  gives dimensions without  $[M]$ , so  $v$  does not depend upon  $m$ . Since  $[L] \times \frac{1}{[T]} = \frac{[L]}{[T]}$  and there is no dimensionless constant involved in the relation,  $v$  is equal to the product of  $\omega$  and  $r$ , or  $v = \omega r$ .

41. **Strategy** Approximate the distance from your eyes to a book held at your normal reading distance.

**Solution** The normal reading distance is about 30-40 cm, so the approximate distance from your eyes to a book you are reading is  $\boxed{30-40 \text{ cm}}$ .

42. **Strategy** Estimate the length, width, and height of your textbook. Then use  $V = \ell wh$  to estimate its volume.

**Solution** Find the approximate volume of your physics textbook in  $\text{cm}^3$ .

The length, width, and height of your physics textbook are approximately 30 cm, 20 cm, and 4.0 cm, respectively.

$$V = \ell wh = (30 \text{ cm})(20 \text{ cm})(4.0 \text{ cm}) = \boxed{2400 \text{ cm}^3}$$

43. (a) **Strategy and Solution** The mass of the lower leg is about 5 kg and that of the upper leg is about 7 kg, so an order of magnitude estimate of the mass of a person's leg is  $\boxed{10 \text{ kg}}$ .

(b) **Strategy and Solution** The length of a full size school bus is greater than 1 m and less than 100 m, so an order of magnitude estimate of the length of a full size school bus is  $\boxed{10 \text{ m}}$ .

44. **Strategy and Solution** A normal heart rate is about 70 beats per minute and a person lives for about 70 years, so

$$\text{the heart beats about } \frac{70 \text{ beats}}{1 \text{ min}} \times \frac{70 \text{ y}}{\text{lifetime}} \times \frac{5.26 \times 10^5 \text{ min}}{1 \text{ y}} = 2.6 \times 10^9 \text{ times per lifetime, or about } \boxed{3 \times 10^9}.$$

45. **Strategy** (Answers will vary.) In this case, we use San Francisco, CA for the city. The population of San Francisco is approximately 750,000. Assume that there is one automobile for every two residents of San Francisco, that an average automobile needs three repairs or services per year, and that the average shop can service 10 automobiles per day.

**Solution** Estimate the number of automobile repair shops in San Francisco.

$$\text{If an automobile needs three repairs or services per year, then it needs } \frac{3 \text{ repairs}}{\text{auto} \cdot \text{y}} \times \frac{1 \text{ y}}{365 \text{ d}} \approx \frac{0.01 \text{ repairs}}{\text{auto} \cdot \text{d}}.$$

$$\text{If there is one auto for every two residents, then there are } \frac{1 \text{ auto}}{2 \text{ residents}} \times 750,000 \text{ residents} \approx 4 \times 10^5 \text{ autos.}$$

If a shop requires one day to service 10 autos, then the number of shops-days per repair is

$$1 \text{ shop} \times \frac{1 \text{ d}}{10 \text{ repairs}} = \frac{0.1 \text{ shop} \cdot \text{d}}{\text{repair}}.$$

$$\text{The estimated number of auto shops is } 4 \times 10^5 \text{ autos} \times \frac{0.01 \text{ repairs}}{\text{auto} \cdot \text{d}} \times \frac{0.1 \text{ shop} \cdot \text{d}}{\text{repair}} = \boxed{400 \text{ shops}}.$$

Checking the phone directory, we find that there are approximately 463 automobile repair and service shops in

San Francisco. The estimate is off by  $\frac{400 - 463}{400} \times 100\% = \boxed{-16\%}$ . The estimate was 16% too low, but in the ballpark!

46. **Strategy** Estimate the appropriate orders of magnitude.

**Solution** Find the order of magnitude of the number of seconds in one year.

$$\text{seconds/minute} \sim 10^2 \quad \text{minutes/hour} \sim 10^2 \quad \text{hours/day} \sim 10^1 \quad \text{days/year} \sim 10^2$$

$$10^2 \cdot 10^2 \cdot 10^1 \cdot 10^2 = \boxed{10^7 \text{ s}}$$

47. **Strategy** One story is about 3 m high.

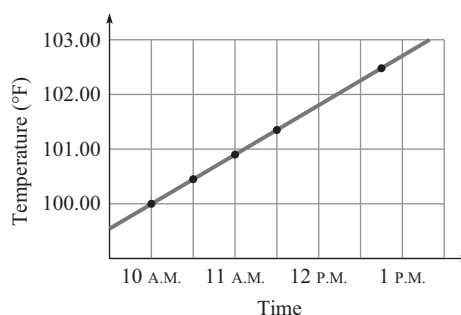
**Solution** Find the order of magnitude of the height in meters of a 40-story building.

$$(3 \text{ m})(40) \sim \boxed{100 \text{ m}}$$

48. **Strategy** To determine if  $c$  and  $A_0$  are correct, graph  $A$  versus  $B^3$ .

**Solution** To graph  $A$  versus  $B^3$ , graph  $A$  on the vertical axis and  $B^3$  on the horizontal axis.

49. **Strategy** The plot of temperature versus elapsed time is shown. Use the graph to answer the questions.



**Solution**

- (a) By inspection of the graph, it appears that the temperature at noon was  $\boxed{101.8^\circ\text{F}}$ .

- (b) Estimate the slope of the line.

$$m = \frac{102.6^\circ\text{F} - 100.0^\circ\text{F}}{1:00 \text{ P.M.} - 10:00 \text{ A.M.}} = \frac{2.6^\circ\text{F}}{3 \text{ h}} = \boxed{0.9^\circ\text{F/h}}$$

- (c) In twelve hours, the temperature would, according to the trend, be approximately

$$T = (0.9^\circ\text{F/h})(12 \text{ h}) + 102.5^\circ\text{F} = 113^\circ\text{F}.$$

The patient would be dead before the temperature reached this level. So, the answer is  $\boxed{\text{no}}$ .

50. **Strategy** Use the slope-intercept form,  $y = mx + b$ .

**Solution** Since  $x$  is on the vertical axis, it corresponds to  $y$ . Since  $t^4$  is on the horizontal axis, it corresponds to  $x$

(in  $y = mx + b$ ). So, the equation for  $x$  as a function of  $t$  is  $\boxed{x = (25 \text{ m/s}^4)t^4 + 3 \text{ m}}$ .

51. **Strategy** Use the two temperatures and their corresponding times to find the rate of temperature change with respect to time (the slope of the graph of temperature vs. time). Then, write the linear equation for the temperature with respect to time and find the temperature at 3:35 P.M.

**Solution** Find the rate of temperature change.

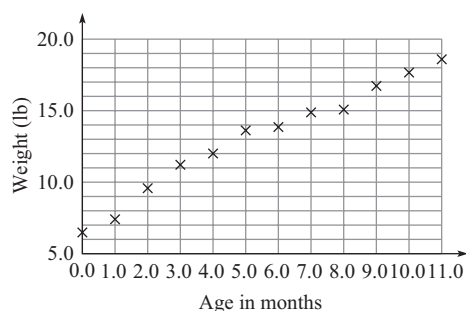
$$m = \frac{\Delta T}{\Delta t} = \frac{101.0^\circ\text{F} - 97.0^\circ\text{F}}{4.0 \text{ h}} = 1.0^\circ\text{F/h}$$

Use the slope-intercept form of a graph of temperature vs. time to find the temperature at 3:35 P.M.

$$T = mt + T_0 = (1.0^\circ\text{F/h})(3.5 \text{ h}) + 101.0^\circ\text{F} = \boxed{104.5^\circ\text{F}}$$

52. (a) **Strategy** Plot the weights and ages on a weight versus age graph.

**Solution** See the graph.



- (b) **Strategy** Find the slope of the best-fit line between age 0.0 and age 5.0 months.

**Solution** Find the slope.

$$m = \frac{13.6 \text{ lb} - 6.6 \text{ lb}}{5.0 \text{ mo} - 0.0 \text{ mo}} = \frac{7.0 \text{ lb}}{5.0 \text{ mo}} = \boxed{1.4 \text{ lb/mo}}$$

- (c) **Strategy** Find the slope of the best-fit line between age 5.0 and age 10.0 months.

**Solution** Find the slope.

$$m = \frac{17.5 \text{ lb} - 13.6 \text{ lb}}{10.0 \text{ mo} - 5.0 \text{ mo}} = \frac{3.9 \text{ lb}}{5.0 \text{ mo}} = \boxed{0.78 \text{ lb/mo}}$$

- (d) **Strategy** Write a linear equation for the weight of the baby as a function of time. The slope is that found in part (b), 1.4 lb/mo. The intercept is the weight of the baby at five months of age.

**Solution** Find the projected weight of the child at age 12.

$$W = (1.4 \text{ lb/mo})(144 \text{ mo} - 5 \text{ mo}) + 13.6 \text{ lb} = \boxed{210 \text{ lb}}$$

53. **Strategy** Put the equation that describes the line in slope-intercept form,  $y = mx + b$ .

$$at = v - v_0$$

$$v = at + v_0$$

**Solution**

- (a)  $v$  is the dependent variable and  $t$  is the independent variable, so  $\boxed{a}$  is the slope of the line.

- (b) The slope-intercept form is  $y = mx + b$ . Find the vertical-axis intercept.

$$v \leftrightarrow y, t \leftrightarrow x, a \leftrightarrow m, \text{ so } v_0 \leftrightarrow b.$$

Thus,  $\boxed{+v_0}$  is the vertical-axis intercept of the line.

54. (a) **Strategy** The equation of the speed versus time is given by  $v = at + v_0$ , where  $a = 6.0 \text{ m/s}^2$  and  $v_0 = 3.0 \text{ m/s}$ .

**Solution** Find the change in speed.

$$\begin{aligned} v_2 &= at_2 + v_0 \\ -(v_1 &= at_1 + v_0) \\ \hline v_2 - v_1 &= a(t_2 - t_1) \\ v_2 - v_1 &= (6.0 \text{ m/s}^2)(6.0 \text{ s} - 4.0 \text{ s}) = \boxed{12 \text{ m/s}} \end{aligned}$$

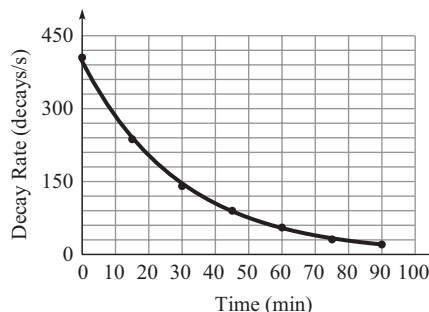
- (b) **Strategy** Use the equation found in part (a).

**Solution** Find the speed when the elapsed time is equal to 5.0 seconds.

$$v = (6.0 \text{ m/s}^2)(5.0 \text{ s}) + 3.0 \text{ m/s} = \boxed{33 \text{ m/s}}$$

55. (a) **Strategy** Plot the decay rate on the vertical axis and the time on the horizontal axis.

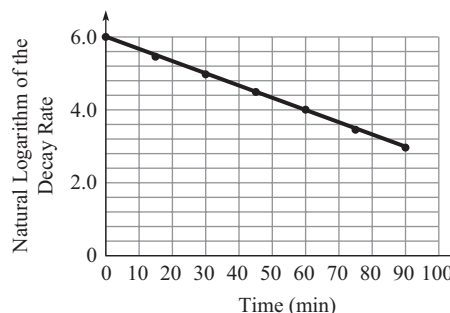
**Solution** The plot is shown.



- (b) **Strategy** Plot the natural logarithm of the decay rate on the vertical axis and the time on the horizontal axis.

**Solution** The plot is shown.

Presentation of the data in this form—as the natural logarithm of the decay rate—might be useful because the graph is linear.



56. (a) **Strategy** Refer to the figure. Use the definition of the slope of a line and the fact that the vertical axis intercept is the  $x$ -value corresponding to  $t = 0$ .

**Solution** Compute the slope.

$$\frac{\Delta x}{\Delta t} = \frac{17.0 \text{ km} - 3.0 \text{ km}}{9.0 \text{ h} - 0.0 \text{ h}} = \boxed{1.6 \text{ km/h}}$$

When  $t = 0$ ,  $x = 3.0 \text{ km}$ ; therefore, the vertical axis intercept is 3.0 km.

- (b) **Strategy and Solution** The physical significance of the slope of the graph is that it represents the speed of the object. The physical significance of the vertical axis intercept is that it represents the starting position of the object (position at time zero).

**57. Strategy** For parts (a) through (d), perform the calculations.

**Solution**

(a)  $186.300 + 0.0030 = \boxed{186.303}$

(b)  $186.300 - 0.0030 = \boxed{186.297}$

(c)  $186.300 \times 0.0030 = \boxed{0.56}$

(d)  $186.300 / 0.0030 = \boxed{62,000}$

(e) **Strategy** For cases (a) and (b), the percent error is given by  $\frac{0.0030}{\text{Actual Value}} \times 100\%$ .

**Solution** Find the percent error.

Case (a):  $\frac{0.0030}{186.303} \times 100\% = \boxed{0.0016\%}$

Case (b):  $\frac{0.0030}{186.297} \times 100\% = \boxed{0.0016\%}$

For case (c), ignoring 0.0030 causes you to multiply by zero and get a zero result. For case (d), ignoring 0.0030 causes you to divide by zero.

(f) **Strategy** Make a rule about neglecting small values using the results obtained above.

**Solution**

You can neglect small values when they are added to or subtracted from sufficiently large values. The term “sufficiently large” is determined by the number of significant figures required.

**58. Strategy** The weight is proportional to the mass and inversely proportional to the square of the radius, so  $W \propto m/r^2$ . Thus, for Earth and Jupiter, we have  $W_E \propto m_E/r_E^2$  and  $W_J \propto m_J/r_J^2$ .

**Solution** Form a proportion.

$$\frac{W_J}{W_E} = \frac{m_J/r_J^2}{m_E/r_E^2} = \frac{m_J}{m_E} \left( \frac{r_E}{r_J} \right)^2 = \frac{320m_E}{m_E} \left( \frac{r_E}{11r_E} \right)^2 = \frac{320}{121}$$

On Jupiter, the apple would weigh  $\frac{320}{121}(1.0 \text{ N}) = \boxed{2.6 \text{ N}}$ .

**59. Strategy** Assuming that the cross section of the artery is a circle, we use the area of a circle,  $A = \pi r^2$ .

**Solution**

$A_1 = \pi r_1^2$  and  $A_2 = \pi r_2^2 = \pi(2.0r_1)^2 = 4.0\pi r_1^2$ .

Form a proportion.

$$\frac{A_2}{A_1} = \frac{4.0\pi r_1^2}{\pi r_1^2} = 4.0$$

The cross-sectional area of the artery increases by a factor of  $\boxed{4.0}$ .

60. (a) **Strategy** The diameter of the xylem vessel is one six-hundredth of the magnified image.

**Solution** Find the diameter of the vessel.

$$d_{\text{actual}} = \frac{d_{\text{magnified}}}{600} = \frac{3.0 \text{ cm}}{600} = \boxed{5.0 \times 10^{-3} \text{ cm}}$$

- (b) **Strategy** The area of the cross section is given by  $A = \pi r^2 = \pi(d/2)^2 = (1/4)\pi d^2$ .

**Solution** Find by what factor the cross-sectional area has been increased in the micrograph.

$$\frac{A_{\text{magnified}}}{A_{\text{actual}}} = \frac{\frac{1}{4}\pi d_{\text{magnified}}^2}{\frac{1}{4}\pi d_{\text{actual}}^2} = \left(\frac{3.0 \text{ cm}}{5.0 \times 10^{-3} \text{ cm}}\right)^2 = \boxed{360,000}.$$

61. **Strategy** If  $s$  is the speed of the molecule, then  $s \propto \sqrt{T}$  where  $T$  is the temperature.

**Solution** Form a proportion.

$$\frac{s_{\text{cold}}}{s_{\text{warm}}} = \frac{\sqrt{T_{\text{cold}}}}{\sqrt{T_{\text{warm}}}}$$

Find  $s_{\text{cold}}$ .

$$s_{\text{cold}} = s_{\text{warm}} \sqrt{\frac{T_{\text{cold}}}{T_{\text{warm}}}} = (475 \text{ m/s}) \sqrt{\frac{250.0 \text{ K}}{300.0 \text{ K}}} = \boxed{434 \text{ m/s}}$$

62. **Strategy** Use dimensional analysis to convert from furlongs per fortnight to the required units.

**Solution**

- (a) Convert to  $\mu\text{m/s}$ .

$$\frac{1 \text{ furlong}}{1 \text{ fortnight}} \times \frac{220 \text{ yd}}{1 \text{ furlong}} \times \frac{1 \text{ fortnight}}{14 \text{ days}} \times \frac{1 \text{ day}}{86,400 \text{ s}} \times \frac{3 \text{ ft}}{1 \text{ yd}} \times \frac{1 \text{ m}}{3.28 \text{ ft}} \times \frac{1,000,000 \mu\text{m}}{1 \text{ m}} = \boxed{166 \mu\text{m/s}}$$

- (b) Convert to  $\text{km/day}$ .

$$\frac{1 \text{ furlong}}{1 \text{ fortnight}} \times \frac{220 \text{ yd}}{1 \text{ furlong}} \times \frac{1 \text{ fortnight}}{14 \text{ days}} \times \frac{3 \text{ ft}}{1 \text{ yd}} \times \frac{1 \text{ m}}{3.28 \text{ ft}} \times \frac{1 \text{ km}}{1000 \text{ m}} = \boxed{0.0144 \text{ km/day}}$$

63. **Strategy** Use the rules for determining significant figures and for writing numbers in scientific notation.

**Solution**

- (a) 0.00574 kg has three significant figures, 5, 7, and 4. The zeros are not significant, since they are used only to place the decimal point. To write this measurement in scientific notation, we move the decimal point three places to the right and multiply by  $10^{-3}$ .
- (b) 2 m has one significant figure, 2. This measurement is already written in scientific notation
- (c)  $0.450 \times 10^{-2} \text{ m}$  has three significant figures, 4, 5, and the 0 to the right of 5. The zero is significant, since it comes after the decimal point and is not used to place the decimal point. To write this measurement in scientific notation, we move the decimal point one place to the right and multiply by  $10^{-1}$ .

- (d) 45.0 kg has three significant figures, 4, 5, and 0. The zero is significant, since it comes after the decimal point and is not used to place the decimal point. To write this measurement in scientific notation, we move the decimal point one place to the left and multiply by  $10^1$ .
- (e)  $10.09 \times 10^4$  s has four significant figures, 1, 9, and the two zeros. The zeros are significant, since they are between two significant figures. To write this measurement in scientific notation, we move the decimal point one place to the left and multiply by  $10^1$ .
- (f)  $0.09500 \times 10^5$  mL has four significant figures, 9, 5, and the two zeros to the right of 5. The zeros are significant, since they come after the decimal point and are not used to place the decimal point. To write this measurement in scientific notation, we move the decimal point two places to the right and multiply by  $10^{-2}$ .

The results of parts (a) through (f) are shown in the table below.

	Measurement	Significant Figures	Scientific Notation
(a)	0.00574 kg	3	$5.74 \times 10^{-3}$ kg
(b)	2 m	1	2 m
(c)	$0.450 \times 10^{-2}$ m	3	$4.50 \times 10^{-3}$ m
(d)	45.0 kg	3	$4.50 \times 10^1$ kg
(e)	$10.09 \times 10^4$ s	4	$1.009 \times 10^5$ s
(f)	$0.09500 \times 10^5$ mL	4	$9.500 \times 10^3$ mL

64. **Strategy** Use the conversion factors from the inside cover of the book.

**Solution**

$$(a) \frac{12.5 \text{ US gal}}{1} \times \frac{3.785 \text{ L}}{\text{US gal}} \times \frac{10^3 \text{ mL}}{\text{L}} \times \frac{0.06102 \text{ in}^3}{\text{mL}} = \boxed{2890 \text{ in}^3}$$

$$(b) \frac{2887 \text{ in}^3}{1} \times \left( \frac{1 \text{ cubit}}{18 \text{ in}} \right)^3 = \boxed{0.495 \text{ cubic cubits}}$$

65. **Strategy** Use the metric prefixes n ( $10^{-9}$ ),  $\mu$  ( $10^{-6}$ ), m ( $10^{-3}$ ), or M ( $10^6$ ).

**Solution**

$$(a) \text{ M (or mega) is equal to } 10^6, \text{ so } 6 \times 10^6 \text{ m} = \boxed{6 \text{ Mm}}.$$

$$(b) \text{ There are approximately 3.28 feet in one meter, so } 6 \text{ ft} \times \frac{1 \text{ m}}{3.28 \text{ ft}} = \boxed{2 \text{ m}}.$$

$$(c) \mu \text{ (or micro) is equal to } 10^{-6}, \text{ so } 10^{-6} \text{ m} = \boxed{1 \mu\text{m}}.$$



(d) n (or nano) is equal to  $10^{-9}$ , so  $3 \times 10^{-9} \text{ m} = \boxed{3 \text{ nm}}$ .

(e) n (or nano) is equal to  $10^{-9}$ , so  $3 \times 10^{-10} \text{ m} = \boxed{0.3 \text{ nm}}$ .

- 66. Strategy** The volume of the spherical virus is given by  $V_{\text{virus}} = (4/3)\pi r_{\text{virus}}^3$ . The volume of viral particles is one billionth the volume of the saliva.

**Solution** Calculate the number of viruses that have landed on you.

$$\text{number of viral particles} = \frac{10^{-9} V_{\text{saliva}}}{V_{\text{virus}}} = \frac{0.010 \text{ cm}^3}{10^9 \left( \frac{4}{3} \pi \right) \left( \frac{85 \text{ nm}}{2} \right)^3 \left( \frac{10^{-7} \text{ cm}}{1 \text{ nm}} \right)^3} = \boxed{10^4 \text{ viruses}}$$

- 67. Strategy** The circumference of a viroid is approximately 300 times 0.35 nm. The diameter is given by  $C = \pi d$ , or  $d = C/\pi$ .

**Solution** Find the diameter of the viroid in the required units.

(a)  $d = \frac{300(0.35 \text{ nm})}{\pi} \times \frac{10^{-9} \text{ m}}{1 \text{ nm}} = \boxed{3.3 \times 10^{-8} \text{ m}}$

(b)  $d = \frac{300(0.35 \text{ nm})}{\pi} \times \frac{10^{-3} \mu\text{m}}{1 \text{ nm}} = \boxed{3.3 \times 10^{-2} \mu\text{m}}$

(c)  $d = \frac{300(0.35 \text{ nm})}{\pi} \times \frac{10^{-7} \text{ cm}}{1 \text{ nm}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = \boxed{1.3 \times 10^{-6} \text{ in}}$

- 68. (a) Strategy** There are 3.28 feet in one meter.

**Solution** Find the length in meters of the largest recorded blue whale.

$$1.10 \times 10^2 \text{ ft} \times \frac{1 \text{ m}}{3.28 \text{ ft}} = \boxed{33.5 \text{ m}}$$

- (b) **Strategy** Divide the length of the largest recorded blue whale by the length of a double-decker London bus.

**Solution** Find the length of the blue whale in double-decker-bus lengths.

$$\frac{1.10 \times 10^2 \text{ ft}}{8.0 \frac{\text{m}}{\text{bus length}}} \times \frac{1 \text{ m}}{3.28 \text{ ft}} = \boxed{4.2 \text{ bus lengths}}$$

- 69. Strategy** The volume of the blue whale can be found by dividing the mass of the whale by its average density.

**Solution** Find the volume of the blue whale in cubic meters.

$$V = \frac{m}{\rho} = \frac{1.9 \times 10^5 \text{ kg}}{0.85 \text{ g/cm}^3} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \left( \frac{1 \text{ m}}{100 \text{ cm}} \right)^3 = \boxed{2.2 \times 10^2 \text{ m}^3}$$

- 70. Strategy** The shape of a sheet of paper (when not deformed) is a rectangular prism. The volume of a rectangular prism is equal to the product of its length, width, and height (or thickness).

**Solution** Find the volume of a sheet of paper in cubic meters.

$$27.95 \text{ cm} \times 8.5 \text{ in} \times 0.10 \text{ mm} \times \frac{1 \text{ m}}{100 \text{ cm}} \times \frac{0.0254 \text{ m}}{1 \text{ in}} \times \frac{1 \text{ m}}{1000 \text{ mm}} = \boxed{6.0 \times 10^{-6} \text{ m}^3}$$

- 71. (a) Strategy**  $a$  has dimensions  $\frac{[L]}{[T]^2}$ ;  $v$  has dimensions  $\frac{[L]}{[T]}$ ;  $r$  has dimension  $[L]$ .

**Solution** If we square  $v$  and divide by  $r$ , we have  $\frac{v^2}{r}$ , which implies that  $\frac{[L]^2}{[T]^2} \cdot \frac{1}{[L]} = \frac{[L]}{[T]^2}$ , which are the dimensions for  $a$ . Therefore, we can write  $a = K \frac{v^2}{r}$ , where  $K$  is a dimensionless constant.

- (b) Strategy** Divide the new acceleration by the old, and use the fact that the new speed is 1.100 times the old.

**Solution** Find the percent increase in the radial acceleration.

$$\frac{a_2}{a_1} = \frac{K \frac{v_2^2}{r}}{K \frac{v_1^2}{r}} = \left( \frac{v_2}{v_1} \right)^2 = \left( \frac{1.100 v_1}{v_1} \right)^2 = 1.100^2 = 1.210$$

$1.210 - 1 = 0.210$ , so the radial acceleration increases by  $\boxed{21.0\%}$ .

- 72. Strategy** Replace each quantity in  $v = K \lambda^p g^q$  by its units. Then, use the relationships between  $p$  and  $q$  to determine their values.

**Solution** Find the values of  $p$  and  $q$ .

$$\text{In units, } \frac{\text{m}}{\text{s}} = \text{m}^p \cdot \frac{\text{m}^q}{\text{s}^{2q}} = \frac{\text{m}^{p+q}}{\text{s}^{2q}}.$$

So, we have the following restrictions on  $p$  and  $q$ :  $p + q = 1$  and  $2q = 1$ .

Solve for  $q$  and  $p$ .

$$\begin{aligned} 2q &= 1 & p + q &= 1 \\ q &= \boxed{\frac{1}{2}} & p + \frac{1}{2} &= 1 \\ & & p &= \boxed{\frac{1}{2}} \end{aligned}$$

$$\text{Thus, } v = K \lambda^{1/2} g^{1/2} = \boxed{K \sqrt{\lambda g}}.$$

- 73. Strategy** There are 2.54 cm in one inch and 3600 seconds in one hour.

**Solution** Find the conversion factor for changing meters per second to miles per hour.

$$\frac{1 \text{ m}}{1 \text{ s}} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ ft}}{12 \text{ in}} \times \frac{1 \text{ mi}}{5280 \text{ ft}} \times \frac{3600 \text{ s}}{1 \text{ h}} = \boxed{2.24 \text{ mi/h} = 1 \text{ m/s}}$$

So, for a quick, approximate conversion, multiply by 2.

- 74. Strategy** The order of magnitude of the volume of water required to fill a bathtub is  $10^1 \text{ ft}^3$ . The order of magnitude of the number of cups in a cubic foot is  $10^2$ .

**Solution** Find the order of magnitude of the number of cups of water required to fill a bathtub.

$$10^1 \text{ ft}^3 \times 10^2 \text{ cups/ft}^3 = \boxed{10^3 \text{ cups}}$$

- 75. Strategy** Since there are hundreds of millions of people in the U.S., a reasonable order-of-magnitude estimate of the number of automobiles is  $10^8$ . There are about 365 days per year; that is, about  $10^2$ . A reasonable estimate of the gallons used per day per person is greater than one, but less than one hundred; that is,  $10^1$ .

**Solution** Calculate the estimate.

$$10^8 \text{ automobiles} \times 10^2 \text{ days} \times 10^1 \frac{\text{gallons}}{\text{automobile} \cdot \text{day}} = \boxed{10^{11} \text{ gallons}}$$

- 76. (a) Strategy** There are 10,000 ( $10^4$ ) half dollars in \$5000. The mass of a half-dollar coin is about 10 grams, or  $10^{-2}$  kilograms.

**Solution** Estimate the mass of the coins.

$$10^4 \text{ coins} \times 10^{-2} \text{ kg/coin} = 10^2 \text{ kg, or } \boxed{100 \text{ kg}}.$$

- (b) Strategy** There are  $\$1,000,000/\$20 = 50,000$  twenty-dollar bills in \$1,000,000. The mass of a twenty-dollar bill is about 1 gram, or  $10^{-3}$  kilograms.

**Solution** Estimate the mass of the bills.

$$50,000 \text{ bills} \times 10^{-3} \text{ kg/bill} = \boxed{50 \text{ kg}}.$$

- 77. Strategy** The SI base unit for mass is kg. Replace each quantity in  $W = mg$  with its SI base units.

**Solution** Find the SI unit for weight.

$$\text{kg} \cdot \frac{\text{m}}{\text{s}^2} = \boxed{\frac{\text{kg} \cdot \text{m}}{\text{s}^2}}$$

- 78. Strategy** It is given that  $T^2 \propto r^3$ . Divide the period of Mars by that of Venus.

**Solution** Compare the period of Mars to that of Venus.

$$\frac{T_{\text{Mars}}^2}{T_{\text{Venus}}^2} = \frac{r_{\text{Mars}}^3}{r_{\text{Venus}}^3}, \text{ so } T_{\text{Mars}}^2 = \left( \frac{r_{\text{Mars}}}{r_{\text{Venus}}} \right)^3 T_{\text{Venus}}^2, \text{ or } T_{\text{Mars}} = \left( \frac{2r_{\text{Venus}}}{r_{\text{Venus}}} \right)^{3/2} T_{\text{Venus}} = \boxed{2^{3/2} T_{\text{Venus}} \approx 2.8 T_{\text{Venus}}}.$$

- 79. Strategy** \$59,000,000,000 has a precision of 1 billion dollars; \$100 has a precision of 100 dollars, so the net worth is the same to one significant figure.

**Solution** Find the net worth.

$$\$59,000,000,000 - \$100 = \boxed{\$59,000,000,000}$$

- 80. Strategy** There are about  $10^3$  hairs in a one-square-inch area of the average human head. An order-of-magnitude estimate of the area of the average human head is  $10^2$  square inches.

**Solution** Calculate the estimate.

$$10^3 \text{ hairs/in}^2 \times 10^2 \text{ in}^2 = \boxed{10^5 \text{ hairs}}$$

- 81. (a) Strategy** There are 7.0 leagues in one pace and 4.8 kilometers in one league.

**Solution** Find your speed in kilometers per hour.

$$\frac{120 \text{ paces}}{1 \text{ min}} \times \frac{7.0 \text{ leagues}}{1 \text{ pace}} \times \frac{4.8 \text{ km}}{1 \text{ league}} \times \frac{60 \text{ min}}{1 \text{ h}} = \boxed{2.4 \times 10^5 \text{ km/h}}$$

- (b) Strategy** The circumference of the earth is approximately 40,000 km. The time it takes to march around the Earth is found by dividing the distance by the speed.

**Solution** Find the time of travel.

$$40,000 \text{ km} \times \frac{1 \text{ h}}{2.4 \times 10^5 \text{ km}} \times \frac{60 \text{ min}}{1 \text{ h}} = \boxed{10 \text{ min}}$$

- 82. Strategy** Use the fact that  $R_B = 1.42R_A$ .

**Solution** Calculate the ratio of  $P_B$  to  $P_A$ .

$$\frac{P_B}{P_A} = \frac{\frac{V^2}{R_B}}{\frac{V^2}{R_A}} = \frac{R_A}{R_B} = \frac{R_A}{1.42R_A} = \frac{1}{1.42} = \boxed{0.704}$$

- 83. (a) Strategy** Inspect the units of  $G$ ,  $c$ , and  $h$  and use trial-and-error to find the correct combination of these constants.

**Solution** Through a process of trial and error, we find that the only combination of  $G$ ,  $c$ , and  $h$  that has the dimensions of time is  $\boxed{\sqrt{\frac{hG}{c^5}}}$ .

- (b) Strategy** Substitute the values of the constants into the formula found in part (a).

**Solution** Find the time in seconds.

$$\sqrt{\frac{hG}{c^5}} = \sqrt{\frac{\left(6.6 \times 10^{-34} \frac{\text{kg} \cdot \text{m}^2}{\text{s}}\right) \left(6.7 \times 10^{-11} \frac{\text{m}^3}{\text{kg} \cdot \text{s}^2}\right)}{\left(3.0 \times 10^8 \frac{\text{m}}{\text{s}}\right)^5}} = \boxed{1.3 \times 10^{-43} \text{ s}}$$

- 84. Strategy** The dimensions of  $L$ ,  $g$ , and  $m$  are length, length per time squared, and mass, respectively. The period has units of time, so  $T$  cannot depend upon  $m$ . (There are no other quantities with units of mass with which to cancel the units of  $m$ .) Use a combination of  $L$  and  $g$ .

**Solution** The square root of  $L/g$  has dimensions of time, so

$$\boxed{T = C \sqrt{\frac{L}{g}}, \text{ where } C \text{ is a constant of proportionality.}}$$

- 85. Strategy** The dimensions of  $k$  and  $m$  are mass per time squared and mass, respectively. Dividing either quantity by the other will eliminate the mass dimension.

**Solution** The square root of  $k/m$  has dimensions of inverse time, which is correct for frequency.

So,  $f = \sqrt{k/m}$ . Find  $k$ .

$$f_1 = \sqrt{\frac{k}{m_1}}, \text{ so } f_1^2 = \frac{k}{m_1}, \text{ or } k = m_1 f_1^2.$$

Find the frequency of the chair with the 75-kg astronaut.

$$f_2 = \sqrt{\frac{k}{m_2}} = \sqrt{\frac{m_1 f_1^2}{m_2}} = f_1 \sqrt{\frac{m_1}{m_2}} = (0.50 \text{ s}^{-1}) \sqrt{\frac{62 \text{ kg} + 10.0 \text{ kg}}{75 \text{ kg} + 10.0 \text{ kg}}} = \boxed{0.46 \text{ s}^{-1}}$$

- 86. Strategy** Solutions will vary. One example follows:

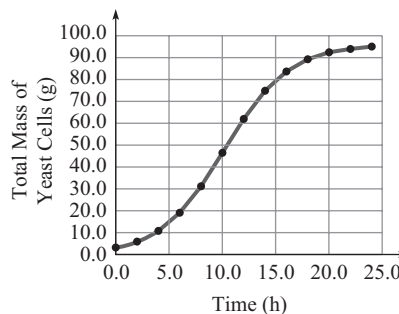
The radius of the Earth is about  $10^6 \text{ m}$ . The area of a sphere is  $4\pi r^2$ , or about  $10^1 \cdot r^2$ . The average depth of the oceans is about  $4 \times 10^3 \text{ m}$ . The oceans cover more than two-thirds of the Earth's surface, but in this rough estimation, we assume that oceans cover the entire Earth.

**Solution** Calculate an order-of-magnitude estimate of the volume of water contained in Earth's oceans.

The surface area of the Earth is about  $10^1 \cdot (10^6 \text{ m})^2 = 10^{13} \text{ m}^2$ ; therefore, the volume of water in the oceans is about  $\text{area} \times \text{depth} = (10^{13} \text{ m}^2)(4 \times 10^3 \text{ m}) = 4 \times 10^{16} \text{ m}^3 \sim \boxed{10^{16} \text{ m}^3}$ .

- 87. (a) Strategy** Plot the data on a graph with mass on the vertical axis and time on the horizontal axis. Then, draw a best-fit smooth curve.

**Solution** See the graph.



- (b) Strategy** Answers will vary. Estimate the value of the total mass that the graph appears to be approaching asymptotically.

**Solution** The graph appears to be approaching asymptotically a maximum value of 100 g, so the carrying capacity is  $\boxed{\text{about } 100 \text{ g}}$ .

- (c) Strategy** Plot the data on a graph with the natural logarithm of  $m/m_0$  on the vertical axis and time on the horizontal axis. Draw a line through the points and find its slope to estimate the intrinsic growth rate.

**Solution** See the graph. From the plot of  $\ln \frac{m}{m_0}$  vs.  $t$ ,

the slope  $r$  appears to be

$$r = \frac{1.8 - 0.0}{6.0 \text{ s} - 0.0 \text{ s}} = \frac{1.8}{6.0 \text{ s}} = \boxed{0.30 \text{ s}^{-1}}.$$

