1

Getting Started

1. Convert the time to seconds.

$$t = (81\ \text{yr})\left(\frac{365\ \text{day}}{1\ \text{yr}}\right)\left(\frac{24\ \text{hr}}{1\ \text{day}}\right)\left(\frac{60\ \text{min}}{1\ \text{hr}}\right)\left(\frac{60\ \text{s}}{1\ \text{min}}\right) = \boxed{2.6\times10^{9}\ \text{s}}$$

2. (a) The answer to this question will vary from student to student, depending on his or her height. Say, for example, that the student is 5 feet and 9 inches tall, or 69 in. Convert the height to cm.

$$(69\ \text{in})\cdot\left(\frac{2.54\ \text{cm}}{1\ \text{in.}}\right) = \boxed{1.8\times10^{2}\ \text{cm}}$$

(b) Beginning again with the height of 69 in., or the answer to part (a), convert the height to m.

$$(1.8\times10^{2}\ \text{cm})\cdot\left(\frac{1\ \text{m}}{100\ \text{cm}}\right) = \boxed{1.8\ \text{m}}$$

3. Convert the time to seconds.

$$t = (4.5\times10^{9}\ \text{yr})\left(\frac{365\ \text{day}}{1\ \text{yr}}\right)\left(\frac{24\ \text{hr}}{1\ \text{day}}\right)\left(\frac{60\ \text{min}}{1\ \text{hr}}\right)\left(\frac{60\ \text{s}}{1\ \text{min}}\right) = \boxed{1.4\times10^{17}\ \text{s}}$$

4. We need to cube the conversion factor to cancel the units of cubic meters.

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

5. (a) Convert the measurement in cm to m.

$$(0.53\text{ cm})\times\left(\frac{1\text{ m}}{100\text{ cm}}\right)=\boxed{5.3\times10^{-3}\text{ m}}$$

(b) Convert the measurement in g to kg.

$$(128.92\text{ g})\times\left(\frac{1\text{ kg}}{1000\text{ g}}\right)=\boxed{0.12892\text{ kg}}$$

(c) Convert the measurement in cm^3 to m^3.

$$(35.7\text{ cm}^3)\times\left(\frac{1\text{ m}}{100\text{ cm}}\right)^3=\boxed{3.57\times10^{-5}\text{ m}^3}$$

(d) Convert the g/cm^3 to kg/ m^3.

$$(65.7\text{ g/cm}^3)\times\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\times\left(\frac{100\text{ cm}}{1\text{ m}}\right)^3=\boxed{6.57\times10^4\text{ kg/m}^3}$$

6. All conversion factors are fractions, equivalent to one, multiplied by measurements to convert the units of the measurements, and they do not change the dimensions of the measurements.

7. Density is defined as mass per unit volume, or $\rho=\frac{m}{V}$. We convert the numbers given in the problem to SI units and solve.

$$\rho=\frac{m}{V}=\frac{311\text{ g}}{16.1\text{ cm}^3}\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\left(\frac{100\text{ cm}}{1\text{ m}}\right)^3=\boxed{1.93\times10^4\text{ kg/m}^3}$$

8. (a) Convert the number of leagues to meters by using the conversion factor given in the problem statement.

$$(2.000\times10^4\text{ leagues})\times\left(\frac{3.500\text{ km}}{1.00\text{ league}}\right)\times\left(\frac{1000\text{ m}}{1\text{ km}}\right)=\boxed{7.00\times10^7\text{ m}}$$

(b) Subtract the radius of the Earth from the answer in part (a).

$$\Delta x = 7.00\times10^{7}\ \text{m} - 6.38\times10^{6}\ \text{m} = \boxed{6.36\times10^{7}\ \text{m}}$$

9. Convert miles to meters.

$$\left(93\times10^{6}\ \text{mi}\right)\times\left(\frac{1.609\times10^{3}\ \text{m}}{1\ \text{mi}}\right) = \boxed{1.5\times10^{11}\ \text{m}}$$

10. Suppose that you estimate the distance between your elbow and the end of your outstretched middle finger to be about 46 cm. You are then able to create a conversion factor for centimeters to cubits. Then, convert 1 mi into the units of cubits.

$$\left(1\ \text{mi}\right)\times\left(\frac{1.609\times10^{3}\ \text{m}}{1\ \text{mi}}\right)\times\left(\frac{100\ \text{cm}}{1\ \text{m}}\right)\times\left(\frac{1\ \text{cubits}}{46\ \text{cm}}\right) = \boxed{3.5\times10^{3}\ \text{cubits}}$$

11. Convert the density of the raisin into the odd units of planet Betatron.

$$\rho_{raisin} = 2\times10^{3}\ \text{kg/m}^{3} = \left(2\times10^{3}\ \text{kg/m}^{3}\right)\times\left(\frac{0.23\ \text{bloobits}}{1\ \text{kg}}\right)\times\left(\frac{1\ \text{m}}{1.41\ \text{bot}}\right)^{3} = \boxed{2\times10^{2}\ \text{bloobits/bot}^{3}}$$

12. The answer to this question will vary from student to student. Suppose the student's weight is measured to be 160 lb. Then convert lb to kg.

$$\left(160\ \text{lb}\right)\times\left(\frac{1\ \text{kg}}{2.2\ \text{lb}}\right) = \boxed{73\ \text{kg}}$$

13. The distance is given in centimeters and the elapsed time in minutes. These will need to be converted to meters and seconds, respectively.

$$d = \left(33\ \text{cm}\right)\left(\frac{1\ \text{m}}{100\,\text{cm}}\right) = 0.33\ \text{m}$$

$$t = \left(2.0\ \text{min}\right)\left(\frac{60\ \text{s}}{1\ \text{min}}\right) = 120\ \text{s}$$

The average speed can now be found using the equation in the problem statement.

$$S_{\text{av}} = \frac{0.33 \text{ m}}{120 \text{ s}} = \boxed{2.8\times10^{-3} \text{ m/s}}$$

14. Even though the pebbles do not look the same or have the exact same size and shape, they can be used as a standard mass set. One must select a set of pebbles in which each pebble balances with every other pebble. In this situation, every pebble will have the same mass. That's the important property for objects in a standard mass set to have.

First, make sure the equal arm balance is balanced with nothing in either pan. Second, pick out a pebble and place it in one pan of the balance. This pebble will never leave this pan! Third, select a new pebble from the beach, and place it in the vacant pan. If the system balances, then remove the new pebble and put it in your pocket. It is now a member of the standard mass set. If the system does not balance, then take the new pebble and throw it back on the beach. Repeat the second and third steps. In this manner, each pebble that is a candidate for the standard mass set will be compared against a single, "reference" pebble. As more and more pebbles are tested in this way, you will accumulate a pocket full of pebbles that all balance with each other. This set of pebbles is a standard mass set. To use the standard pebble set to measure the mass of a mollusk, simply place the mollusk on one side of the balance and place pebbles from the standard mass set, one at a time, on the other side until balance is achieved. The number of pebbles required is the mollusk's mass in units of pebbles. The actual mass of one pebble can be found when returning to the lab and your standard set of gram masses.

15. (a) To find the rate at which the pool is filled, divide the pool's capacity by the amount of time it takes to fill the pool.

$$\text{rate} = \left(\frac{660{,}000 \text{ gal}}{10.0 \text{ hr}}\right)\times\left(\frac{1 \text{ hr}}{60 \text{ min}}\right) = \boxed{1.10\times10^{3} \text{ gal/min}}$$

(b) We multiply the rate found in part (a) of this problem by the appropriate unit conversions to convert to L/s.

$$\text{rate} = \left(1.10\times10^{3} \text{ gal/min}\right)\times\left(\frac{1 \text{ min}}{60 \text{ s}}\right)\times\left(\frac{231 \text{ in}^3}{1 \text{ gal}}\right)\times\left(\frac{2.54 \text{ cm}}{1 \text{ in}}\right)^3\times\left(\frac{1 \text{ L}}{1000 \text{ cm}^3}\right) = \boxed{69.4 \text{ L/s}}$$

(c) To fill a 40.0-m^3 pool, we first invert the rate found in part (b) of this problem to obtain the amount of time needed to fill one liter at this rate. Then multiply by 1000 to get the time to fill one cubic meter.

$$\left(\frac{1}{69.4\ \text{L/s}}\right)\times\left(\frac{1000\ \text{L}}{1\ \text{m}^3}\right)=14.4\ \text{s/m}^3$$

Then, multiplying this by 40.0 m^3 gives us

$$t=\left(14.4\ \text{s/m}^3\right)\times\left(40.0\ \text{m}^3\right)=\boxed{576\ \text{s}}$$, or just under 10 min.

16. The light-year is a unit of distance. Thus, statement (b) is using the term correctly, though surely exaggerating the distance.

17. Density is defined as mass per unit volume, or $\rho=\frac{m}{V}$. The volume of a right circular cylinder is the area of its base times its height, or $V=A\cdot h=\left(\pi r^2\right)h$. This gives a density of

$$\rho=\frac{m}{V}=\frac{m}{\left(\pi r^2\right)h}=\frac{1.00\ \text{kg}}{\pi\left(\frac{39.17\ \text{mm}}{2}\right)^2\left(39.17\ \text{mm}\right)}\left(\frac{10^3\ \text{mm}}{1\ \text{m}}\right)^3=\boxed{2.12\times10^4\ \text{kg/m}^3}$$

18. Only (c) may be correct. This can be seen by examining the combination of dimensions in each equation. The acceleration must have dimensions of $[\![a]\!]=\text{L}/\text{T}^2$.

$$\text{In (a), } [\![vr]\!]=\left(\text{L}/\text{T}\right)\left(\text{L}\right)=\text{L}^2/\text{T}$$

$$\text{In (b), } [\![v/r]\!]=\frac{\left(\text{L}/\text{T}\right)}{\text{L}}=1/\text{T}$$

$$\text{In (c), } [\![v^2/r]\!]=\frac{\left(\text{L}/\text{T}\right)^2}{\text{L}}=\boxed{\text{L}/\text{T}^2}$$

$$\text{In (d), } [\![v/r^2]\!]=\frac{\left(\text{L}/\text{T}\right)}{\text{L}^2}=1/\left(\text{LT}^2\right)$$

19. (a) $[\![ma]\!]=\left(\text{M}\right)\left(\text{L}/\text{T}^2\right)=\boxed{\left(\text{M}\cdot\text{L}\right)/\text{T}^2}$

(b) $[\![mv^2/r]\!]=\dfrac{\left(\text{M}\right)\left(\text{L}/\text{T}\right)^2}{\text{L}}=\boxed{\left(\text{M}\cdot\text{L}\right)/\text{T}^2}$

(c) $[\![mv]\!] = (\text{M})(\text{L}/\text{T}) = \boxed{(\text{M}\cdot\text{L})/\text{T}}$

(d) $[\![mvr]\!] = (\text{M})(\text{L}/\text{T})(\text{L}) = \boxed{(\text{M}\cdot\text{L}^2)/\text{T}}$

20. (a) The definition of energy density *u*, the energy per unit volume, allows us to generate a quantitative expression for *u* in terms of total energy *E* and the volume of available space *V*: $u = E/V$. This expression serves as a basis for dimensional analysis. From the Concept Exercise 1.3, the dimensions of *E* are $(\text{M}\cdot\text{L}^2)/\text{T}^2$. The dimensions of *u* are

$$[\![u]\!] = \frac{(\text{M}\cdot\text{L}^2)/\text{T}^2}{\text{L}^3} = \boxed{\text{M}/(\text{L}\cdot\text{T}^2)}$$

(b) In SI units, mass is measured in kg, length in m, and time in s. Substituting these units into the dimensional analysis equation above will yield the SI units of energy density:

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

21. First, we consider the expression for kinetic energy, replacing the quantities, *m* and *v*, with their dimensions. We reduce these units down to the most fundamental combination of length, mass, and time.

$$[\![K]\!] = \frac{1}{2}[\![m]\!][\![v]\!]^2 = \text{M}(\text{L}/\text{T})^2 = \boxed{(\text{M}\cdot\text{L}^2)/\text{T}^2}$$

We now consider the expression for gravitational potential energy, replacing the quantities, *m*, *g*, and *y*, with their dimensions. We reduce these units down to the most fundamental combination of length, mass, and time.

$$[\![U]\!] = [\![m]\!][\![g]\!][\![y]\!] = \text{M}(\text{L}/\text{T}^2)\text{L} = \boxed{(\text{M}\cdot\text{L}^2)/\text{T}^2}$$

So, $[\![K]\!] = [\![U]\!]$.

22. The dimensions for *v* are L/T, while the dimensions for *A* are L^2 and the dimensions for *R* are L^3/T. Comparing the dimensions on each side of the equation suggests

$$\llbracket v \rrbracket \to \llbracket R \rrbracket \llbracket A \rrbracket$$
$$\mathrm{L/T} \to \left(\mathrm{L^3/T}\right)\left(\mathrm{L^2}\right)$$
$$\mathrm{L/T} \to \mathrm{L^5/T}$$

which cannot be true. $\boxed{\text{Thus, the equation cannot be correct.}}$

23. The dimensions on each side of the equation must be the same. On one side, the dimensions of frequency are T^{-1}. Thus, the correct combination of *m*'s and *k*'s must reduce to units of T^{-1} as well. Start by computing the dimensions of the ratio *k/m*.

$$\llbracket k/m \rrbracket = \llbracket k \rrbracket / \llbracket m \rrbracket = \mathrm{M}/\left(\mathrm{T^2} \cdot \mathrm{M}\right) = \mathrm{T^{-2}}$$

If we take the square root of *k*/*m*, the dimensions would be the same as that of *f*. While there could be an unknown constant of proportionality, we can say via the dimensional analysis that these quantities could be related as $\boxed{f \propto \sqrt{k/m}}$.

24. When we multiply or divide two numbers with the same unit of measure, the resulting units are easily interpretable. For example, dividing a length in meters by another length in meters results in a unitless expression. But if in the same calculation we were to divide a length in meters by a length in feet, we would get an entirely different numeric answer that would have units of m/ft. Likewise, finding an area, by multiplying two lengths in meters, results in a quantity with units of m^2. If the two numbers have the same dimension, but do not have the same units (i.e., one is in meters and the other is in feet), then the resulting quantity would not be easily interpretable. The area for example would be in units of m·ft. This mixing of unit systems complicates our interpretation of the results.

25. (a) In order to use dimensional analysis, we first need to rearrange the given equation as an expression for force in terms of mass and acceleration: $F = ma$. The dimensions are then

$$\llbracket F \rrbracket = \llbracket m \rrbracket \llbracket a \rrbracket = \mathrm{M}\left(\mathrm{L/T^2}\right) = \boxed{\mathrm{M} \cdot \left(\mathrm{L/T^2}\right)}$$

(b) $\mathrm{N} = \boxed{\mathrm{kg} \cdot \left(\mathrm{m/s^2}\right)}$

(c) Rearranging the equation, we see that the units of k would be the units of F/x, or $\left(\text{kg}\cdot\left(\text{m/s}^2\right)\right)/\text{m}$ or $\boxed{\text{kg/s}^2}$. This could also be expressed as $\boxed{\text{N/m}}$.

26. Convert the time from yr to s.

$$t=\left(13.7\times10^9\ \text{yr}\right)\times\left(\frac{365\ \text{day}}{1\ \text{yr}}\right)\times\left(\frac{24\ \text{hr}}{1\ \text{day}}\right)\times\left(\frac{3600\ \text{s}}{1\ \text{hr}}\right)=\boxed{4.32\times10^{17}\ \text{s}}$$

27. Using the rules for significant figures, in the number 0.00130, only the 1, 3, and final 0 are significant. Thus, there are $\boxed{3}$ significant figures.

28. According to the rule for significant figures when dividing, the number of significant figures in the answer is dictated by the one with the fewest. Thus, there should be $\boxed{2}$ significant figures in the final answer.

29. Applying the rules for significant figures, we find the following number in each case.
(a) $\boxed{4}$. Each of the digits is nonzero, so each is significant in the number 7.193×10^{11}.
(b) $\boxed{3}$. Each of the zeros in 0.00643 is not significant since they only serve to locate the decimal point correctly. We can see these zeros would not be present when we write the number in scientific notation, 6.43×10^{-3}.
(c) $\boxed{2}$. Each of the digits is nonzero, so each is significant in the number 4.1×10^{-4}.
(d) $\boxed{3}$. Each of the digits is nonzero, so each is significant in the number 615 ± 3.

30. The difference between the times is $10.56\ \text{s}-10.53\ \text{s}=0.03\ \text{s}$. In order to find the uncertainty between the two measurements, divide the difference by 2, so that the uncertainty is $0.03\ \text{s}/2=0.015\ \text{s}$. The average time will then allow us to report the measured time and its error.

$$t_{\text{avg}}=\frac{10.53+10.56}{2}\ \text{s}=10.545\ \text{s}$$

So the reported time would be $\boxed{(10.545 \pm 0.015)\ \text{s}}$.

31. In each of the following cases, use the rules for significant figures in arithmetic computations.
(a) $56.2\times0.154=\boxed{8.65}$
(b) $9.8+43.4+124=\boxed{177}$

(c) $81.340/\pi = \boxed{25.891}$

32. In each of the following cases, use the rules for significant figures in arithmetic computations.

(a) $3.07670 - 10.988 = \boxed{-7.911}$

(b) $1.0093\times10^5 - 9.98\times10^4 = 1.0093\times10^5 - 0.998\times10^5 = 0.011\times10^5 = \boxed{1.1\times10^3}$

(c) $\left(5.4423\times10^6\right)/\left(4.008\times10^3\right) = \boxed{1358}$

33. Here we must compute the following computation and apply the rule for significant figures to the final result of the calculation. We begin with the two divisions on the far right of the set of operations, and find that there will be only two significant figures from that set, with the precision up to the tenths place after the decimal. This is the limiting factor when then adding and subtracting the remaining three values.

$$3.07670 - 10.988 + \frac{\left(5.4423\times10^6\right)/\left(4.008\times10^3\right)}{1.0093\times10^5 - 9.98\times10^4} = 3.07670 - 10.988 + \frac{1358}{1.1\times10^3}$$
$$= 3.07670 - 10.988 + 1.2 = \boxed{-6.7}$$

34. The difference between the times is $17.92\text{ s} - 17.89\text{ s} = 0.03\text{ s}$. In order to find the uncertainty between the two measurements, divide the difference by 2, so that the uncertainty is $0.03\text{ s}/2 = 0.015\text{ s}$. The average time will then allow us to report the measured time and its error.

$$t_{\text{avg}} = \frac{17.92 + 17.89}{2}\text{ s} = 17.905\text{ s}$$

So the reported time would be $\boxed{(17.905 \pm 0.015)\text{ s}}$. However, because the researcher has made an error, he should probably repeat the experiment and not yet report a final result!

35. In each of the following cases, use the rules for significant figures in arithmetic computations.

(a) Using the formula for the volume of a sphere,

$$V = (4/3)\pi r^3 = (4/3)\pi(6378.1\text{ km})^3 = 1.0868\times10^{12}\text{ km}^3$$

Or, $V = 1.0868\times10^{12}\ \text{km}^3 \times \left(\dfrac{1000\ \text{m}}{1\ \text{km}}\right)^3 = \boxed{1.0868\times10^{21}\ \text{m}^3}$

(b) Using the result from the previous problem,

$$\rho = m/V = \left(5.98\times10^{24}\ \text{kg}\right)\big/\left(1.0868\times10^{21}\ \text{m}^3\right) = \boxed{5.50\times10^{3}\ \text{kg/m}^3}$$

36. Johanna is correct in her assertion that the two results are consistent with one another, and that the conclusion must be that the mass of the bob does not appear to affect the period of the pendulum. This is because Jimmy's result falls within the range of uncertainty in Johanna's measurement. There is no certainty that the increased bob mass has changed the period at all.

37. (a) For m = 1.23 ± 0.1 g, the uncertainty of 0.1 g indicates that the "2" in the value 1.23 g is uncertain. This in turn implies that the "3" is meaningless, in that it suggests a higher level of precision than the measurement allows. The result should be reported as 1.2 ± 0.1 g instead.

(b) For m = 10.64 ± 0.03 g, this reported result makes sense. The reported uncertainty matches the precision of the measurement.

(c) For m = 18.70 ± 0.01 g, this result also makes sense. Note that the final "0" in the measured value of 18.70 g does constitute a significant figure and indicates that the true value is more likely to be 18.70 than 18.71 or 18.69.

(d) For m = 7.6 ± 0.01 g, the reported result contains only one digit to the right of the decimal, whereas the reported uncertainty would suggest knowledge of the value out to two digits to the right of the decimal. Either the uncertainty has been underestimated (and should be 0.1 g instead of 0.01 g), or the measured value has been reported erroneously (and should read 7.60 g instead of 7.6 g).

38. Answers may vary. A typical dorm room might have a floor area of 12 ft × 9 ft, or 4 m × 3 m. The estimated area is then, $A = (4\ \text{m})(3\ \text{m}) = \boxed{12\ \text{m}^2}$. Here, we have kept two significant figures given the leading "1" in the answer. This answer is also an estimate.

39. Answers may vary. Assume that a student studies 2 hr a week for each 1 hr of class time each week. If we assume that a student has a total of 6 hr of class time each week, then in a given 15-week semester,

$t = (2\text{ study hr/class hr})\times(6\text{ class hr/week})\times(15\text{ week}) = \boxed{180\text{ study hr}}$. We have kept 2 significant figures since we are estimating and have a leading "1" in the answer. If there are 50 students in your physics class, then an estimate for the total time spent studying by the entire class would be, $t_{tot} = (180\text{ study hr/student})\times(50\text{ students}) = \boxed{9000\text{ study hr}}$.

40. Answers may vary. Measuring your pinky-thumb distance, when both are outstretched, you may find them to be about 18 cm apart. You can then use this as a unit length to measure the top surface area, and volume of your desk. You need to measure the number of pinky-thumb distances in each dimension.

(a) Using the top surface of a rectangular-box dresser, suppose you measure the dimensions as 2.3 pinky-thumb × 5.5 pinky-thumb. The estimated area would then be,

$$A = (2.3\text{ pinky-thumb})\times(5.5\text{ pinky-thumb})\times\left(\frac{18\text{ cm}}{1\text{ pinky-thumb}}\right)^2\times\left(\frac{1\text{ m}}{100\text{ cm}}\right)^2 = \boxed{0.41\text{ m}^2}$$

(b) In order to get the volume of the dresser, the height must be measured. Suppose the height is measured to be 3.0 pinky-thumb distances. The volume is then

$$V = (2.3\text{ pinky-thumb})\times(5.5\text{ pinky-thumb})\times(3.0\text{ pinky-thumb})\times\left(\frac{18\text{ cm}}{1\text{ pinky-thumb}}\right)^3\times\left(\frac{1\text{ m}}{100\text{ cm}}\right)^3$$

$$V = \boxed{0.22\text{ m}^3}$$

41. Answers may vary. Suppose that your height is 5 ft and 5 in. This is a total height of 65 in. If the height of the shower stall is about 1.3× your height, then an estimate for the height of the shower stall would be

$$h = (65\text{ in.})\times\left(\frac{0.0254\text{ m}}{1\text{ in.}}\right)\times(1.3) = \boxed{2.1\text{ m}}$$

42. Answers may vary. Suppose that you estimate the dimensions of your class room to be 18 ft × 24 ft × 12 ft. Given that there are 0.3048 m in 1 ft, the volume estimate is

$$V = (18\text{ ft})\times(24\text{ ft})\times(12\text{ ft})\times\left(\frac{0.3048\text{ m}}{1\text{ ft}}\right)^3 = \boxed{1.5\times10^2\text{ m}^3}$$

43. Answers may vary. One might consider using his or her hand to measure the volume of the lungs to get a better estimate. A possible result is that a person's set of lungs might be about 1 hand wide, 2 hands tall, and 0.4 hands thick. This would mean modeling the lungs as a rectangular box. If the length of the hand is about 18 cm, or 0.18 m, the volume can be estimated to be

$$V = (1\text{ hand})\times(2\text{ hand})\times(0.4\text{ hand})\times\left(\frac{0.18\text{ m}}{1\text{ hand}}\right)^3 = \boxed{5\times10^{-3}\text{ m}^3}$$

Note that we are probably overestimating the size here, since the lungs would not fill the rectangular box we have used to estimate the volume.

Modeling the stomach as a cube, we estimate the length of each side to be 0.13 m (a little less than a hand on each side.. Then, calculate the estimate for the volume of the stomach.

$$V = (0.13\text{ m})^3 = \boxed{2\times10^{-3}\text{ m}^3}$$

44. Answers may vary. One student may have the following estimated expenses: $10.00/month for Netflix, $100.00/month for cable/internet, $20.00/month to see two movies, $40.00/month for two concerts. This would be a total of $170.00/month. With 12 months in a year, the annual entertainment cost would be

$$\text{annual cost} = (\$170.00/\text{month})\times(12\text{ months}) = \boxed{\$2000.00}$$

45. Answers may vary. In order to estimate the number of cells in a living tiger, it would be helpful to estimate the volume of a tiger and the volume of a cell within a tiger. The ratio of these quantities could be used to estimate the number of cells within the tiger. Here, choose to model the head of the tiger as a small box and the body of the tiger as a larger rectangular box. For the head, estimate that the volume is the volume of a box with side length 30 cm, or 0.3 m. The volume of the head is then

$$V_{\text{head}} = (0.3\text{ m})^3 = 0.027\text{ m}^3$$

The body of the tiger might be estimated to have dimensions of 1.5 m × 0.50 m × 0.75 m. The volume of the body would then be

$$V_{\text{body}} = (1.5\text{ m})\times(0.50\text{ m})\times(0.75\text{ m}) = 0.56\text{ m}^3$$

An estimate for the total volume of the tiger is then

$$V_{\text{tiger}} = 0.027 \text{ m}^3 + 0.56 \text{ m}^3 = 0.59 \text{ m}^3$$

We now need to estimate the volume of a cell. In Table 1.4, we see an estimate for the size of a living cell to be 10 μm. If this is the side length of a box that represents the cell, then an estimate for the volume of a cell would be

$$V_{\text{cell}} = (10\ \mu\text{m})\times(10\ \mu\text{m})\times(10\ \mu\text{m})\times\left(\frac{1 \text{ m}}{1\times10^{6}\ \mu\text{m}}\right)^3 = 1\times10^{-15} \text{ m}^3$$

Then, an estimate for the number of cells in the tiger, *N*, involves the ratio of the volume of the tiger and the volume of one cell:

$$N = \frac{V_{\text{tiger}}}{V_{\text{cell}}} = \frac{0.59 \text{ m}^3}{1\times10^{-15} \text{ m}^3} = 6\times10^{14} \text{ cells} \approx \boxed{10^{14} \text{ cells}}$$

46. Answers may vary. Approximately 100 g is an estimate for the mass of a deck of 52 cards. The mass of a proton can be found in the Appendices of the book and is 1.67 × 10^{-27} kg. The ratio of these two numbers gives an estimate for *N*, the number of protons in the deck of cards.

$$N = \frac{m_{\text{cards}}}{m_{\text{proton}}} = \frac{100 \text{ g}\times(1 \text{ kg}/1000 \text{ g})}{1.67\times10^{-27} \text{ kg}} = \boxed{6\times10^{25} \text{ protons}}$$

47. Answers may vary. Suppose that your average stride is about 1 m and that when walking, you take about 20 strides every 10 s. You then move 20 m/10 s, or 2 m/s. The distance from Boston to Miami is about 2500 km, or 2.5 × 10^6 m. The time required to travel this distance can be found by taking this distance and dividing it by how fast you estimate you could walk.

$$t = \frac{2.5\times10^{6} \text{ m}}{2 \text{ m/s}} = \boxed{1.3\times10^{6} \text{ s}}$$

Converting this to a more common unit for measuring this time required:

$$t = (1.3\times10^{6} \text{ s})\times\left(\frac{1 \text{ hr}}{3600 \text{ s}}\right)\times\left(\frac{1 \text{ day}}{24 \text{ hr}}\right) = \boxed{15 \text{ days}}$$

48. Answers may vary. In order to make this estimate, we start by estimating the area of the walls of a room. Then, we can use the area of a dollar bill as shown in Table 1.3, 100 cm^2. If we assume the room is 12 ft × 9 ft × 8 ft, where 8 ft is the height, then the total area of the walls would be

$$A = 2\times(12\text{ ft}\times 8\text{ ft}) + 2\times(9\text{ ft}\times 8\text{ ft}) = 300\text{ ft}^2$$

With 30.48 cm in 1 ft, the area can be expressed as

$$A = 300\text{ ft}^2\times\left(\frac{30.48\text{ cm}}{1\text{ ft}}\right)^2 = 3\times 10^5\text{ cm}^2$$

The number of dollar bills required, N, is then $N = \dfrac{3\times 10^5\text{ cm}^2}{100\text{ cm}^2} = 3000$, or it would cost about $\boxed{\$3000.00}$.

49. The number of electrons necessary to equal the mass of one proton can be found by taking the ratio of the two values.

$$N = \frac{m_p}{m_e} = \frac{1.67\times 10^{-27}\text{kg}}{9.11\times 10^{-31}\text{kg}} = \boxed{1.83\times 10^3}$$

50. Converting, we find

$$d_1 = 1.02\text{ km}\times\left(\frac{1000\text{ m}}{1\text{ km}}\right) = \boxed{1.02\times 10^3\text{ m}}$$

$$d_2 = 102\times 10^{-5}\text{ Mm}\times\left(\frac{1\times 10^6\text{ m}}{1\text{ Mm}}\right) = \boxed{1.02\times 10^3\text{ m}}$$

The distances are the same.

51. (a) The volume of the concert hall can be found by multiplying the dimensions and using the fact that 1 ft = 0.3048 m.

$$V = (60.0\text{ ft})\times(81.0\text{ ft})\times(26.0\text{ ft})\times\left(\frac{0.3048\text{ m}}{1\text{ ft}}\right)^3 = \boxed{3.58\times 10^3\text{ m}^3}$$

(b) To find the weight of the air in the room, we use the weight density that is given in the problem statement and the volume so that $W = \rho V$.

$$W = \rho V = (0.0755\text{ lbs/ft}^3)(1.26\times 10^5\text{ ft}^3) = 9.54\times 10^3\text{ lbs}$$

$$W = 9.54\times 10^3\text{ lbs}\times\left(\frac{4.448\text{ N}}{1\text{ lb}}\right) = \boxed{4.24\times 10^4\text{ N}}$$

52. We first need to calculate $1/\lambda$ in each case. The results are presented here in a table with the associated frequency in each case.

1/λ (1/m)	f (1/s)
1.282	440.0
1.439	493.9
1.525	523.2
1.711	587.3
1.921	659.3
2.035	698.5
2.284	784.0

In the plot shown in Figure P1.52ANS, the slope of the line represents the speed with which the waves move. We can see this by examining the graphed equation $f = v(1/\lambda)$ and calculating the slope between two points. For example,

$$m = \left(\frac{523.2 - 440}{1.525 - 1.282}\right)\frac{1/\text{s}}{1/\text{m}} = 342 \text{ m/s}$$

or

$$m = \left(\frac{698.5 - 659.3}{2.035 - 1.921}\right)\frac{1/\text{s}}{1/\text{m}} = 344 \text{ m/s}$$

An average of these values gives a slope of about $\boxed{343 \text{ m/s}}$.

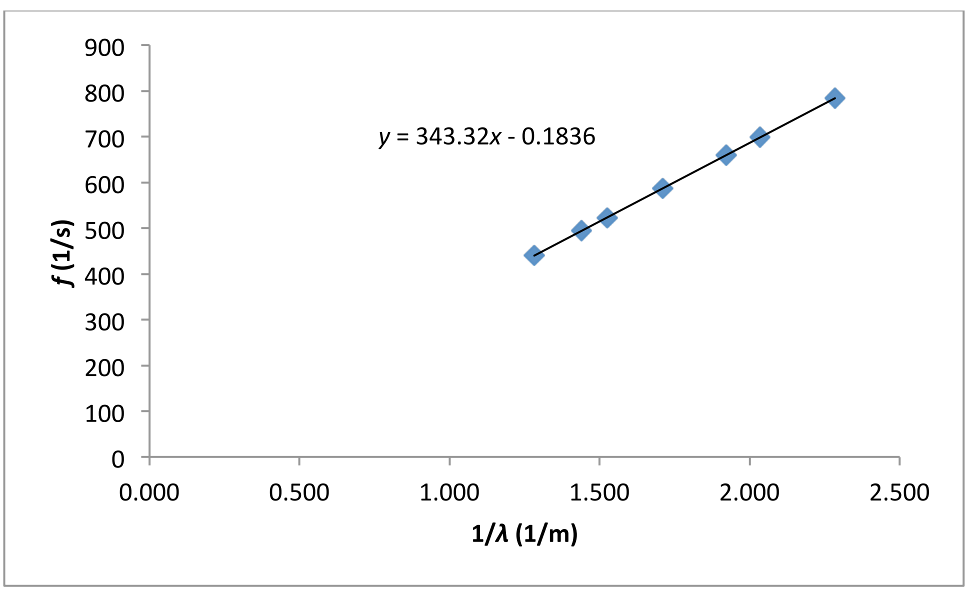

Figure P1.52ANS

53. The volume of both spheres is given by $V = (4/3)\pi r^3$, and the mass of each sphere is given by $m = \rho V = (4/3)\pi\rho r^3$. Labeling the large sphere with the subscript 1 and knowing the larger sphere has 4 times the mass of the smaller sphere, we can express the ratio of the masses of the two spheres as

$$\frac{m_1}{m_2} = \frac{(4/3)\pi\rho r_1^3}{(4/3)\pi\rho r_2^3} = 4, \text{ which gives } r_1^3/r_2^3 = 4.$$

Solving for r_2, we get

$$r_2 = r_1/\sqrt[3]{4} = (14.5 \text{ in})/\sqrt[3]{4} = \boxed{9.13 \text{ in}}$$

54. In order to find the SI units of *G*, we first rearrange the equation to solve for *G* in terms of the other variables.

$$F = (Gm_1m_2)/r^2$$
$$G = Fr^2/(m_1m_2)$$

Writing the units for each quantity on the right side of the equations, we have

$$\frac{(\text{kg}\cdot\text{m/s}^2)\text{m}^2}{\text{kg}^2} = \boxed{\frac{\text{m}^3}{\text{kg}\cdot\text{s}^2}}$$

55. First, we consider the expression *F* = *ma*, replacing the quantities, *m* and *a*, with their dimensions. We reduce these units down to the most fundamental combination of length, mass, and time.

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

We now consider the second expression, first substituting the quantities *mv* for the quantity *p*.

$$F = \frac{p_f - p_i}{t_f - t_i} = \frac{mv_f - mv_i}{t_f - t_i} = \frac{m(v_f - v_i)}{t_f - t_i}$$

Now replace the quantities, *m*, *v* and *t*, with their dimensions, reducing these units down to the most fundamental combination of length, mass, and time.

$$[\![F]\!] = \frac{[\![m]\!][\![(v_f - v_i)]\!]}{[\![t_f - t_i]\!]}$$
$$[\![F]\!] = \frac{\text{M}(\text{L}/\text{T})}{\text{T}}$$
$$[\![F]\!] = \text{M}(\text{L}/\text{T}^2)$$

The dimensions of each expression for force are equivalent.

56. (a) Divide the area of a sphere by the volume of a sphere in order to solve the ratio.

$$A/V = (4\pi r^2)/[(4/3)\pi r^3] = \boxed{3/r}$$

(b) To begin graphing the function, we start by calculating data points. As an example, we find the value of *A/V* when *r* is equal to 1 μm.

$$A/V = 3/1\ \mu\text{m} = 3\ \mu\text{m}^{-1}$$
$$(r,\ A/V) = (1\ \mu\text{m},\ 3\ \mu\text{m}^{-1})$$

After calculating several other data points, graph the function (Figure P1.56ANS).

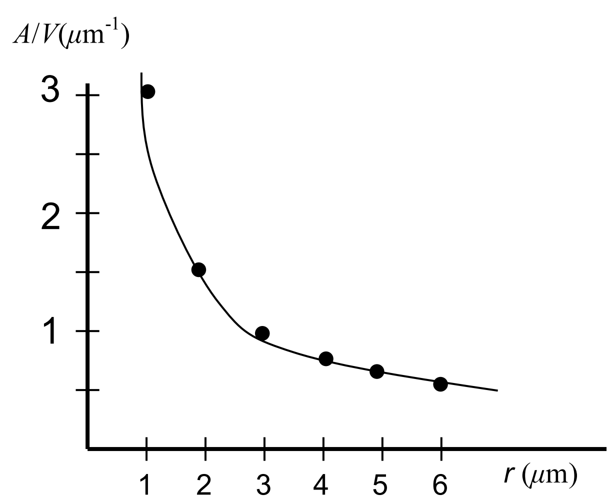

Figure P1.56ANS

57. The triangles in Figure P1.57ANS illustrate Lil's original distance from the building, *d*, and the height of the building *h*, both before and after she walks closer towards the building. From the first triangle, $\tan(20.0°) = h/d$, or $d = h/\tan(20.0°)$. The second triangle gives us $\tan(25.0°) = h/(d - 9.0\times10^2\ \text{ft})$ or $d = h/\tan(25.0°) + 9.0\times10^2\ \text{ft}$. Setting the two expressions for *d* equal and solving for *h* gives us

$$\frac{h}{\tan 20.0°} = \frac{h}{\tan 25.0°} + 9.0\times10^2\ \text{ft}$$

$$2.7474\ h = 2.1445\ h + 900\ \text{ft}$$

$$0.603\ h = 900\ \text{ft}$$

$$h = \frac{900\ \text{ft}}{0.603} = 1500\ \text{ft} = \boxed{1.50\times10^3\ \text{ft}}$$

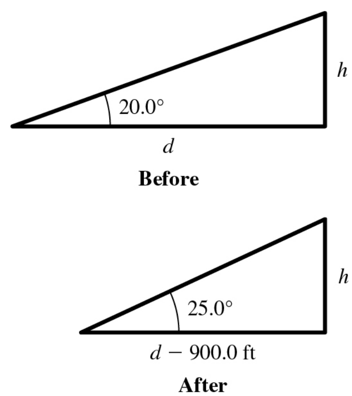

Figure P1.57ANS

58. The best estimate for the measured period of the first pendulum is 0.40 s. If the period is proportional to length, the best prediction for the period of the second pendulum with double the length would thus be $T_2 = 2\times0.40\ \text{s} = 0.80\ \text{s}$. Considering the range of possibilities for the period of the first pendulum, it could have a period as high as 0.48 seconds, or as low as 0.32 s. This leads to a prediction for the maximum and minimum period of the second pendulum.

$$T_{2,\ \text{max}} = 2\times0.48\ \text{s} = 0.96\ \text{s}$$

$$T_{2,\ \text{min}} = 2\times0.32\ \text{s} = 0.64\ \text{s}$$

These predictions for the period of the second pendulum can be displayed on a number line as in Figure P1.58ANS, along with the measured value and its range of uncertainty for the second pendulum.

Since the two ranges of uncertainty overlap, there is a reasonable chance that the measured period for the second pendulum is twice the value of the measured period of the first pendulum. Although the experiment could not be said to have proved it, the data is *consistent* with the notion that the period of a pendulum is proportional to its length.

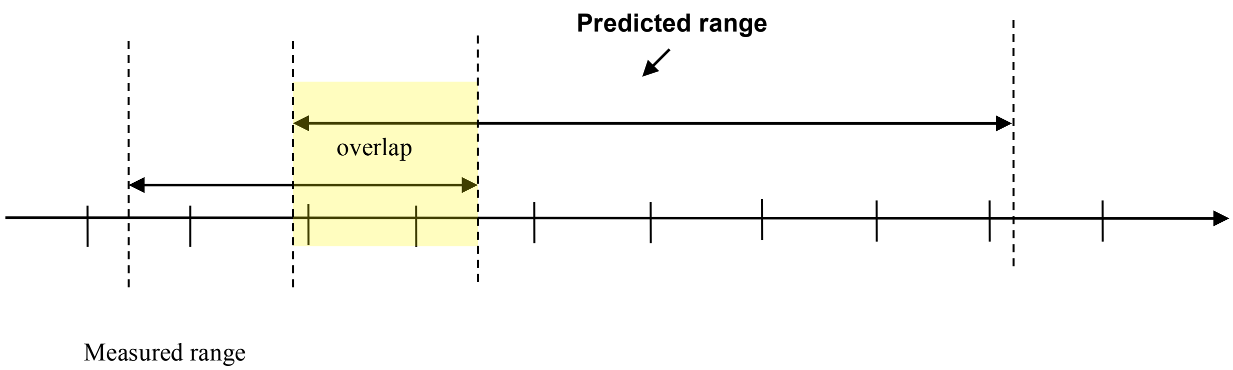

Figure P1.58ANS

59. (a) When summing two measured values to calculate a new result, the best estimate for the result is simply the sum of the two measured values. To estimate the uncertainty in the result, we can apply a "worst-case scenario analysis." This means to consider the errors in the individual measurements to have all "conspired" to make the result as high or low as possible. The maximum error in the measurement of the total mass of the vest is the sum of the errors of the individual measurements: $\pm 0.3\ \text{g} \pm 0.3\ \text{g} = \pm 0.6\ \text{g}$. The best estimate for the total mass of foam is the sum of the two measured values: $128.3\ \text{g} + 77.0\ \text{g} = 205.3\ \text{g}$. Thus, the maximum value of the total mass of the life vest would be $205.3\ \text{g} + 0.6\ \text{g} = \boxed{205.9\ \text{g}}$ and the minimum value would be $205.3\ \text{g} - 0.6\ \text{g} = \boxed{204.7\ \text{g}}$.

(b) Summarizing, the best estimate for the mass of the foam is $\boxed{(205.3 \pm 0.6)\ \text{g}}$

60. In order to verify the expression, we must first find an expression for r that depends on m, h, and any of the other given quantities. This can be used to substitute for r when writing an expression for the total surface area of the cylinders.

The volume of any cylinder is area of its base times its height. There are three cylinders so we add their volumes to get the total volume.

$$V = \pi r^2 (h/2) + 2\left(\pi (r/2)^2 (h/2)\right)$$
$$V = (3/4)\pi r^2 h$$

We can then write an expression for the average density of the cylinders and solve the expression for *r*.

$$\rho = m/V = 4m/\left(3\pi r^2 h\right)$$
$$r = \sqrt{4m/(3\pi\rho h)}$$

The surface area of any cylinder is its circumference times its height plus the area of its base and top. We assume the area of the base and top is small and so we ignore it. We add the area of each cylinder to get the total area:

$$A = 2\pi r (h/2) + 2\left[2\pi (r/2)(h/2)\right]$$
$$A = 2\pi r h$$

Substituting for the radius in this expression in terms of *m*, *h*, and using the density of 1000 kg/m^3, we are able to verify the expression.

$$A = 2\pi\left(\sqrt{4m/(3\pi\rho h)}\right)h$$
$$A = 2\pi\left(\sqrt{4/\left(3\pi\left(1000\ \text{kg/m}^3\right)\right)}\right)\left(\sqrt{m}\right)\left(h/\sqrt{h}\right)$$
$$\boxed{A = 0.129 m^{0.5} h^{0.5}}$$

61. First, construct a conversion factor between parsecs and light years from the information given: $3.26\ \text{ly}/1\ \text{pc} = 1$. Then, convert the distance to ly.

$$d = 1.3\ \text{pc} \times (3.26\ \text{ly}/1\ \text{pc})$$
$$d = \boxed{4.2\ \text{ly}}$$

Now, use the conversion for ly to m: $9.46 \times 10^{15}\ \text{m}/1\ \text{ly} = 1$, and convert from ly to m.

$$d = 4.2\ \text{ly} \times \left(9.46 \times 10^{15}\ \text{m}/1\ \text{ly}\right) = 3.97 \times 10^{16}\ \text{m}$$
$$d = \boxed{4.0 \times 10^{16}\ \text{m}}$$