# Chapter 1: Introduction to Physics

## Answers to Even-Numbered Conceptual Questions

**2.** The quantity $T + d$ does not make sense physically, because it adds together variables that have different physical dimensions. The quantity $d/T$ does make sense, however; it could represent the distance $d$ traveled by an object in the time $T$.

**4.** **(a)** $10^7$ s; **(b)** 10,000 s; **(c)** 1 s; **(d)** $10^{17}$ s; **(e)** $10^8$ s to $10^9$ s.

## Solutions to Problems and Conceptual Exercises

1. **Picture the Problem**: This is simply a units conversion problem.

**Strategy:** Multiply the given number by conversion factors to obtain the desired units.

**Solution: (a)** Convert the units:

$$\$114{,}000{,}000 \times \frac{1 \text{ gigadollars}}{1\times10^9 \text{ dollars}} = \boxed{0.114 \text{ gigadollars}}$$

**(b)** Convert the units again:

$$\$114{,}000{,}000 \times \frac{1 \text{ teradollars}}{1\times10^{12} \text{ dollars}} = \boxed{1.14\times10^{-4} \text{ teradollars}}$$

**Insight:** The inside back cover of the textbook has a helpful chart of the metric prefixes.

2. **Picture the Problem**: This is simply a units conversion problem.

**Strategy:** Multiply the given number by conversion factors to obtain the desired units.

**Solution: (a)** Convert the units:

$$70 \ \mu\text{m} \times \frac{1.0\times10^{-6} \text{ m}}{\mu\text{m}} = \boxed{7.0\times10^{-5} \text{ m}}$$

**(b)** Convert the units again:

$$70 \ \mu\text{m} \times \frac{1.0\times10^{-6} \text{ m}}{\mu\text{m}} \times \frac{1 \text{ km}}{1000 \text{ m}} = \boxed{7.0\times10^{-8} \text{ km}}$$

**Insight:** The inside back cover of the textbook has a helpful chart of the metric prefixes.

3. **Picture the Problem**: This is simply a units conversion problem.

**Strategy:** Multiply the given number by conversion factors to obtain the desired units.

**Solution:** Convert the units:

$$0.3 \ \frac{\text{Gm}}{\text{s}} \times \frac{1\times10^9 \text{ m}}{\text{Gm}} = \boxed{3\times10^8 \text{ m/s}}$$

**Insight:** The inside back cover of the textbook has a helpful chart of the metric prefixes.

4. **Picture the Problem**: This is simply a units conversion problem.

**Strategy:** Multiply the given number by conversion factors to obtain the desired units.

**Solution:** Convert the units:

$$70.72 \ \frac{\text{teracalculation}}{\text{s}} \times \frac{1\times10^{12} \text{ calculations}}{\text{teracalculation}} \times \frac{1\times10^{-6} \text{ s}}{\mu\text{s}}$$

$$= \boxed{7.072\times10^7 \text{ calculations}/\mu\text{s}}$$

**Insight:** The inside back cover of the textbook has a helpful chart of the metric prefixes.

5. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution: 1. (a)** Substitute dimensions for the variables:

$$x = vt$$

$$\text{m} = \left(\frac{\text{m}}{\text{s}}\right)(\text{s}) = \text{m} \quad \therefore \boxed{\text{The equation is dimensionally consistent.}}$$

**2. (b)** Substitute dimensions for the variables:

$$x = \tfrac{1}{2}at^2$$

$$\text{m} = \tfrac{1}{2}\left(\frac{\text{m}}{\text{s}^2}\right)(\text{s})^2 = \text{m} \quad \therefore \boxed{\text{dimensionally consistent}}$$

**3. (c)** Substitute dimensions for the variables:

$$t = \sqrt{\frac{2x}{a}} \Rightarrow \text{s} = \sqrt{\frac{\text{m}}{\text{m/s}^2}} = \sqrt{\text{s}^2} = \text{s} \quad \therefore \boxed{\text{dimensionally consistent}}$$

**Insight:** The number 2 does not contribute any dimensions to the problem.

6. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution: 1. (a)** Substitute dimensions for the variables:

$$vt = \left(\frac{\text{m}}{\text{s}}\right)(\text{s}) = \text{m} \quad \boxed{\text{Yes}}$$

**2. (b)** Substitute dimensions for the variables:

$$\tfrac{1}{2}at^2 = \tfrac{1}{2}\left(\frac{\text{m}}{\text{s}^2}\right)(\text{s})^2 = \text{m} \quad \boxed{\text{Yes}}$$

**3. (c)** Substitute dimensions for the variables:

$$2at = 2\left(\frac{\text{m}}{\text{s}^2}\right)(\text{s}) = \frac{\text{m}}{\text{s}} \quad \boxed{\text{No}}$$

**4. (d)** Substitute dimensions for the variables:

$$\frac{v^2}{a} = \frac{(\text{m/s})^2}{\text{m/s}^2} = \text{m} \quad \boxed{\text{Yes}}$$

**Insight:** When squaring the velocity you must remember to square the dimensions of both the numerator (meters) and the denominator (seconds).

7. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution: 1. (a)** Substitute dimensions for the variables:

$$\tfrac{1}{2}at^2 = \tfrac{1}{2}\left(\frac{\text{m}}{\text{s}^2}\right)(\text{s})^2 = \text{m} \quad \boxed{\text{No}}$$

**2. (b)** Substitute dimensions for the variables:

$$at = \left(\frac{\text{m}}{\text{s}^2}\right)(\text{s}) = \frac{\text{m}}{\text{s}} \quad \boxed{\text{Yes}}$$

**3. (c)** Substitute dimensions for the variables:

$$\sqrt{\frac{2x}{a}} = \sqrt{\frac{2\,\text{m}}{\text{m/s}^2}} = \text{s} \quad \boxed{\text{No}}$$

**4. (d)** Substitute dimensions for the variables:

$$\sqrt{2ax} = \sqrt{2\left(\frac{\text{m}}{\text{s}^2}\right)(\text{m})} = \frac{\text{m}}{\text{s}} \quad \boxed{\text{Yes}}$$

**Insight:** When taking the square root of dimensions you need not worry about the positive and negative roots; only the positive root is physical.

8. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution:** Substitute dimensions for the variables:

$$v^2 = 2ax^p$$

$$\left(\frac{\text{m}}{\text{s}}\right)^2 = \left(\frac{\text{m}}{\text{s}^2}\right)(\text{m})^p$$

$$\text{m}^2 = \text{m}^{p+1} \quad \text{therefore} \quad \boxed{p = 1}$$

**Insight:** The number 2 does not contribute any dimensions to the problem.

9. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution:** Substitute dimensions for the variables:

$$a = 2xt^p$$

$$\frac{[\text{L}]}{[\text{T}]^2} = [\text{L}][\text{T}]^p$$

$$[\text{T}]^{-2} = [\text{T}]^p \quad \text{therefore} \quad \boxed{p = -2}$$

**Insight:** The number 2 does not contribute any dimensions to the problem.

10. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution:** Substitute dimensions for the variables on both sides of the equation:

$$v = v_0 + at$$

$$\frac{[\text{L}]}{[\text{T}]} = \frac{[\text{L}]}{[\text{T}]} + \frac{[\text{L}]}{[\text{T}]^2}[\text{T}]$$

$$\frac{[\text{L}]}{[\text{T}]} = \frac{[\text{L}]}{[\text{T}]} \quad \text{It is dimensionally consistent!}$$

**Insight:** Two numbers must have the same dimensions in order to be added or subtracted.

11. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution:** Substitute dimensions for the variables, where [M] represents the dimension of mass:

$$F = ma = \boxed{[\text{M}]\frac{[\text{L}]}{[\text{T}]^2}}$$

**Insight:** This unit (kg $^{\text{m/s2}}$) will later be given the name "Newton."

12. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Solve the formula for *k* and substitute the units.

**Solution: 1.** Solve for *k*:

$$T = 2\pi\sqrt{\frac{m}{k}} \quad \text{square both sides:} \quad T^2 = 4\pi^2\frac{m}{k} \quad \text{or} \quad k = \frac{4\pi^2 m}{T^2}$$

**2.** Substitute the dimensions, where [M] represents the dimension of mass:

$$k = \boxed{\frac{[\text{M}]}{[\text{T}]^2}}$$

**Insight:** This unit will later be renamed "Newton/m." The $4\pi^2$ does not contribute any dimensions.

13. **Picture the Problem**: This is a significant figures question.

**Strategy:** Follow the given rules regarding the calculation and display of significant figures.

**Solution: (a)** Round to the 3rd digit: $3.14159265358979 \Rightarrow \boxed{3.14}$

**(b)** Round to the 5th digit: $3.14159265358979 \Rightarrow \boxed{3.1416}$

**(c)** Round to the 7th digit: $3.14159265358979 \Rightarrow \boxed{3.141593}$

**Insight:** It is important not to round numbers off too early when solving a problem because excessive rounding can cause your answer to significantly differ from the true answer.

14. **Picture the Problem**: This is a significant figures question.

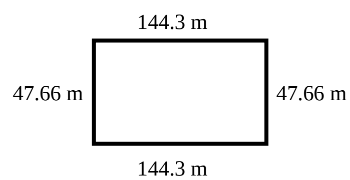
**Strategy:** Follow the given rules regarding the calculation and display of significant figures.

**Solution:** Round to the 3rd digit: $2.9979\times10^8 \text{ m/s} \Rightarrow \boxed{3.00\times10^8 \text{ m/s}}$

**Insight:** It is important not to round numbers off too early when solving a problem because excessive rounding can cause your answer to significantly differ from the true answer.

15. **Picture the Problem**: The parking lot is a rectangle.

**Strategy:** The perimeter of the parking lot is the sum of the lengths of its four sides. Apply the rule for addition of numbers: the number of decimal places after addition equals the smallest number of decimal places in any of the individual terms.




**Solution: 1.** Add the numbers: 144.3 + 47.66 + 144.3 + 47.66 m = 383.92 m

**2.** Round to the smallest number of decimal places in any of the individual terms: $383.92 \text{ m} \Rightarrow \boxed{383.9 \text{ m}}$

**Insight:** Even if you changed the problem to $(2\times144.3 \text{ m})+(2\times47.66 \text{ m})$ you'd still have to report 383.9 m as the answer; the 2 is considered an exact number so it's the 144.3 m that limits the number of significant digits.

$\boxed{16.}$ **Picture the Problem**: The weights of the fish are added.

**Strategy:** Apply the rule for addition of numbers, which states that the number of decimal places after addition equals the smallest number of decimal places in any of the individual terms.

**Solution: 1.** Add the numbers: 2.35 + 12.1 + 12.13 lb = 26.58 lb

**2.** Round to the smallest number of decimal places in any of the individual terms: $26.58 \text{ lb} \Rightarrow \boxed{26.6 \text{ lb}}$

**Insight:** The 12.1 lb rock cod is the limiting figure in this case; it is only measured to within an accuracy of 0.1 lb.

17. **Picture the Problem**: This is a significant figures question.

**Strategy:** Follow the given rules regarding the calculation and display of significant figures.

**Solution: 1. (a)** The leading zeros are not significant: $0.0000\underline{5}\,\underline{4}$ has $\boxed{\text{2 significant figures}}$

**2. (b)** The middle zeros are significant: $\underline{3}.\underline{0}\,\underline{0}\,\underline{1}\times10^5$ has $\boxed{\text{4 significant figures}}$

**Insight:** Zeros are the hardest part of determining significant figures. Scientific notation can remove the ambiguity of whether a zero is significant because any trailing zero to the right of the decimal point is significant.

18. **Picture the Problem**: This is a significant figures question.

**Strategy:** Apply the rule for multiplication of numbers, which states that the number of significant figures after multiplication equals the number of significant figures in the *least* accurately known quantity.

**Solution: 1. (a)** Calculate the area and round to four significant figures:

$$A = \pi r^2 = \pi (14.37\text{ m})^2 = 648.729144\text{ m}^2 \Rightarrow \boxed{648.7\text{ m}^2}$$

**2. (b)** Calculate the area and round to two significant figures:

$$A = \pi r^2 = \pi (3.8\text{ m})^2 = 45.3645979\text{ m}^2 \Rightarrow \boxed{45\text{ m}^2}$$

**Insight:** The number π is considered exact so it will never limit the number of significant digits you report in an answer.

19. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** Convert to feet per second:

$$\left(23\ \frac{\text{m}}{\text{s}}\right)\left(\frac{3.28\text{ ft}}{1\text{ m}}\right) = \boxed{75\ \frac{\text{ft}}{\text{s}}}$$

**2. (b)** Convert to miles per hour:

$$\left(23\frac{\text{m}}{\text{s}}\right)\left(\frac{1\text{ mi}}{1609\text{ m}}\right)\left(\frac{3600\text{ s}}{1\text{ hr}}\right) = \boxed{51\ \frac{\text{mi}}{\text{h}}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

20. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** Find the length in feet:

$$(631\text{ m})\left(\frac{3.28\text{ ft}}{1\text{ m}}\right) = 2069\text{ ft}$$

**2.** Find the width in feet:

$$(707\text{ yd})\left(\frac{3\text{ ft}}{1\text{ yd}}\right) = 2121\text{ ft}$$

**3.** Find the volume in cubic feet:

$$V = LWH = (2069\text{ ft})(2121\text{ ft})(110\text{ ft}) = \boxed{4.83\times10^8\ \text{ft}^3}$$

**4. (b)** Convert to cubic meters:

$$(4.83\times10^8\ \text{ft}^3)\left(\frac{1\text{ m}}{3.28\text{ ft}}\right)^3 = \boxed{1.37\times10^7\ \text{m}^3}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

21. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1.** Find the length in feet:

$$(2.5\text{ cubit})\left(\frac{17.7\text{ in}}{1\text{ cubit}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right) = 3.68\text{ ft}$$

**2.** Find the width and height in feet:

$$(1.5\text{ cubit})\left(\frac{17.7\text{ in}}{1\text{ cubit}}\right)\left(\frac{1\text{ ft}}{12\text{ in}}\right) = 2.21\text{ ft}$$

**3.** Find the volume in cubic feet:

$$V = LWH = (3.68\text{ ft})(2.21\text{ ft})(2.21\text{ ft}) = \boxed{18\text{ ft}^3}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

22. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Convert the frequency of cesium-133 given on page 4 to units of microseconds per megacycle, then multiply by the number of megacycles to find the elapsed time.

**Solution:** Convert to micro seconds per megacycle and multiply by 1.5 megacycles:

$$\left(\frac{1\text{ s}}{9{,}192{,}631{,}770\text{ cycles}}\right)\left(\frac{1\times10^{6}\text{ cycles}}{\text{Mcycle}}\right)\times\left(\frac{1\ \mu\text{s}}{1\times10^{-6}\text{ s}}\right)=108.7827757\ \frac{\mu\text{s}}{\text{Mcycle}}$$

$$108.7827757\ \frac{\mu\text{s}}{\text{Mcycle}}\ \times 1.5\text{ Mcycle}=\boxed{160\ \mu\text{s}}=1.6\times10^{-4}\text{ s}$$

**Insight:** Only two significant figures remain in the answer because of the 1.5 Mcycle figure given in the problem statement. The metric prefix conversions are considered exact and have an unlimited number of significant figures, but most other conversion factors have a limited number of significant figures.

23. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert feet to kilometers:

$$(3212\text{ ft})\left(\frac{1\text{ mi}}{5280\text{ ft}}\right)\left(\frac{1.609\text{ km}}{1\text{ mi}}\right)=\boxed{0.9788\text{ km}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

24. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert seconds to weeks:

$$\left(\frac{1\text{ msg}}{7\text{ s}}\right)\left(\frac{3600\text{ s}}{\text{h}}\right)\left(\frac{24\text{ h}}{\text{d}}\right)\left(\frac{7\text{ d}}{\text{wk}}\right)=\boxed{9\times10^{4}\ \frac{\text{msg}}{\text{wk}}}$$

**Insight:** In this problem there is only one significant figure associated with the phrase, "7 seconds."

25. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert feet to meters:

$$(108\text{ ft})\left(\frac{1\text{ m}}{3.28\text{ ft}}\right)=\boxed{32.9\text{ m}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

26. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert carats to pounds:

$$(530.2\text{ ct})\left(\frac{0.20\text{ g}}{\text{ct}}\right)\left(\frac{1\text{ kg}}{1000\text{ g}}\right)\left(\frac{2.21\text{ lb}}{\text{kg}}\right)=\boxed{0.23\text{ lb}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

27. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** The speed must be $\boxed{\text{greater than}}$ 55 km/h because 1 mi/h = 1.609 km/h.

**2. (b)** Convert the miles to kilometers: $$\left(55\ \frac{\text{mi}}{\text{h}}\right)\left(\frac{1.609\ \text{km}}{\text{mi}}\right)=\boxed{88\ \frac{\text{km}}{\text{h}}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

$\boxed{28.}$ **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert m/s to miles per hour: $$\left(3.00\times10^{8}\ \frac{\text{m}}{\text{s}}\right)\left(\frac{1\ \text{mi}}{1609\ \text{m}}\right)\left(\frac{3600\ \text{s}}{1\ \text{h}}\right)=\boxed{6.71\times10^{8}\ \frac{\text{mi}}{\text{h}}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

29. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert to ft per second per second: $$\left(98.1\ \frac{\text{m}}{\text{s}^2}\right)\left(\frac{3.28\ \text{ft}}{1\ \text{m}}\right)=\boxed{322\ \frac{\text{ft}}{\text{s}^2}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

30. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units. In this problem, one "jiffy" corresponds to the time in seconds that it takes light to travel one centimeter.

**Solution: 1. (a)**: Determine the magnitude of a jiffy: $$\left(\frac{1\ \text{s}}{2.9979\times10^{8}\ \text{m}}\right)\left(\frac{1\ \text{m}}{100\ \text{cm}}\right)=3.3357\times10^{-11}\ \frac{\text{s}}{\text{cm}}=1\ \frac{\text{jiffy}}{\text{cm}}$$

$$1\ \text{jiffy}=\boxed{3.3357\times10^{-11}\ \text{s}}$$

**2. (b)** Convert minutes to jiffys: $$(1\ \text{minute})\left(\frac{60\ \text{s}}{1\ \text{min}}\right)\left(\frac{1\ \text{jiffy}}{3.3357\times10^{-11}\ \text{s}}\right)=\boxed{1.7987\times10^{12}\ \text{jiffy}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

31. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** Convert cubic feet to mutchkins: $$\left(1\ \text{ft}^3\right)\left(\frac{28.3\ \text{L}}{\text{ft}^3}\right)\left(\frac{1\ \text{mutchkin}}{0.42\ \text{L}}\right)=\boxed{67\ \text{mutchkin}}$$

**2. (b)** Convert noggins to gallons: $$(1\ \text{noggin})\left(\frac{0.28\ \text{mutchkin}}{\text{noggin}}\right)\left(\frac{0.42\ \text{L}}{\text{mutchkin}}\right)\left(\frac{1\ \text{gal}}{3.785\ \text{L}}\right)=\boxed{0.031\ \text{gal}}$$

**Insight:** To convert noggins to gallons, multiply the number of noggins by 0.031 gal/noggin. Conversely, there are 1 noggin/0.031 gal = 32 noggins/gallon. That means a noggin is about half a cup.

32. **Picture the Problem**: The volume of the oil is spread out into a slick that is one molecule thick.

**Strategy:** The volume of the slick equals its area times its thickness. Use this fact to find the area.

**Solution:** Calculate the area for the known volume and thickness:

$$A = \frac{V}{h} = \frac{1.0\ \text{m}^3}{0.50\ \mu\text{m}}\left(\frac{1\ \mu\text{m}}{1\times10^{-6}\ \text{m}}\right) = \boxed{2.0\times10^6\ \text{m}^2}$$

**Insight:** Two million square meters is about 772 square miles!

33. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units. Then use a ratio to find the factor change in part (b).

**Solution: 1. (a)** Convert square inches to square meters:

$$A = (8.5\ \text{in} \times 11\ \text{in})\left(\frac{1\ \text{m}^2}{1550\ \text{in}^2}\right) = \boxed{0.060\ \text{m}^2}$$

**2. (b)** Calculate a ratio to find the new area:

$$\frac{A_{\text{new}}}{A_{\text{old}}} = \frac{L_{\text{new}}W_{\text{new}}}{L_{\text{old}}W_{\text{old}}} = \frac{\left(\frac{1}{2}L_{\text{old}}\right)\left(\frac{1}{2}W_{\text{old}}\right)}{L_{\text{old}}W_{\text{old}}} = \frac{1}{4}$$

$$A_{\text{new}} = \boxed{\tfrac{1}{4}A_{\text{old}}}$$

**Insight:** If you learn to use ratios you can often make calculations like these very easily. Always put the new quantity in the numerator and the old quantity in the denominator to make the new quantity easier to calculate at the end.

34. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1.** Convert m/s to ft/s:

$$\left(20.0\ \frac{\text{m}}{\text{s}}\right)\left(\frac{3.28\ \text{ft}}{\text{m}}\right) = \boxed{65.6\ \text{ft/s}}$$

**2. (b)** Convert m/s to mi/h:

$$\left(20.0\ \frac{\text{m}}{\text{s}}\right)\left(\frac{1\ \text{mi}}{1609\ \text{m}}\right)\left(\frac{3600\ \text{s}}{1\ \text{h}}\right) = \boxed{44.7\ \text{mi/h}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

35. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert meters to feet:

$$\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\left(\frac{3.28\ \text{ft}}{1\ \text{m}}\right) = \boxed{32.2\ \text{ft/s}^2}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

$\boxed{36.}$ **Picture the Problem**: The rows of seats are arranged into roughly a circle.

**Strategy:** Estimate that a baseball field is a circle around 300 ft in diameter, with 100 rows of seats around outside of the field, arranged in circles that have perhaps an average diameter of 500 feet. The length of each row is then the circumference of the circle, or $\pi d = \pi(500\ \text{ft})$. Suppose there is a seat every 3 feet.

**Solution:** Multiply the quantities to make an estimate:

$$N = (100\ \text{rows})\left(\pi 500\ \frac{\text{ft}}{\text{row}}\right)\left(\frac{1\ \text{seat}}{3\ \text{ft}}\right) = 52,400\ \text{seats} \cong \boxed{10^5\ \text{seats}}$$

**Insight:** Some college football stadiums can hold as many as 100,000 spectators, but most less than that. Still, for an order of magnitude we round to the nearest factor of ten, in this case it's $10^5$.

37. **Picture the Problem**: Suppose all milk is purchased by the gallon in plastic containers.

**Strategy:** There are about 300 million people in the United States, and if each of these were to drink a half gallon of milk every week, that's about 25 gallons per person per year. Each plastic container is estimated to weigh about an ounce.

**Solution: 1. (a)** Multiply the quantities to make an estimate:

$$\left(300\times10^{6}\text{ people}\right)\left(25\text{ gal/y/person}\right)=7.5\times10^{9}\text{ gal/y}\cong\boxed{10^{10}\text{ gal/y}}$$

**2. (b)** Multiply the gallons by the weight of the plastic:

$$\left(1\times10^{10}\text{ gal/y}\right)\left(1\text{ oz/gal}\right)\left(\frac{1\text{ lb}}{16\text{ oz}}\right)=6.25\times10^{8}\text{ lb/y}\cong\boxed{10^{9}\text{ lb/y}}$$

**Insight:** About half a billion pounds of plastic! Concerted recycling can prevent much of these containers from clogging up our landfills.

38. **Picture the Problem**: The Earth is roughly a sphere rotating about its axis.

**Strategy:** Use the fact the Earth spins once about its axis every 24 hours to find the estimated quantities.

**Solution: 1. (a)** Divide distance by time:

$$v=\frac{d}{t}=\frac{3000\text{ mi}}{3\text{ h}}=1000\text{ mi/h}\cong\boxed{10^{3}\text{ mi/h}}$$

**2. (b)** Multiply speed by 24 hours:

$$\text{circumference }=vt=\left(3000\text{ mi/h}\right)\left(24\text{ h}\right)=24,000\text{ mi}\cong\boxed{10^{4}\text{ mi}}$$

**3. (c)** Circumference equals $2\pi r$:

$$r=\frac{\text{circumference}}{2\pi}=\frac{24,000\text{ mi}}{2\pi}=3800\text{ mi}=\boxed{10^{3}\text{ mi}}$$

**Insight:** These estimates are "in the ballpark." The speed of a point on the equator is 1038 mi/h, the circumference of the equator is 24,900 mi, and the equatorial radius of the Earth is 3963 mi.

39. **Picture the Problem**: The lottery winnings are represented either by quarters or paper dollars.

**Strategy:** There are about 5 quarters and about 30 dollar bills per ounce.

**Solution: 1. (a)** Multiply by conversion factors:

$$\left(4\times12\times10^{6}\text{ quarters}\right)\left(\frac{1\text{ oz}}{5\text{ quarters}}\right)\left(\frac{1\text{ lb}}{16\text{ oz}}\right)=600,000\text{ lb}\cong\boxed{10^{6}\text{ lb}}$$

**2. (b)** Repeat for the dollar bills:

$$\left(12\times10^{6}\text{ dollars}\right)\left(\frac{1\text{ oz}}{30\text{ dollars}}\right)\left(\frac{1\text{ lb}}{16\text{ oz}}\right)=25,000\text{ lb}\cong\boxed{10^{4}\text{ lb}}$$

**Insight:** Better go with large denominations or perhaps a single check when you collect your lottery winnings! Even the dollar bills weigh over ten tons!

40. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution: 1. (a)** Substitute dimensions for the variables:

$$v = at$$

$$\frac{\text{m}}{\text{s}} = \left(\frac{\text{m}}{\text{s}^2}\right)(\text{s}) = \frac{\text{m}}{\text{s}} \quad \therefore \boxed{\text{The equation is dimensionally consistent.}}$$

**2. (b)** Substitute dimensions for the variables:

$$v = \tfrac{1}{2}at^2$$

$$\frac{\text{m}}{\text{s}} \neq \tfrac{1}{2}\left(\frac{\text{m}}{\text{s}^2}\right)(\text{s})^2 = \text{m} \quad \therefore \boxed{\textbf{NOT}\text{ dimensionally consistent}}$$

**3. (c)** Substitute dimensions for the variables:

$$t = \frac{a}{v} \quad \Rightarrow \quad \text{s} \neq \frac{\text{m/s}^2}{\text{m/s}} = \frac{1}{\text{s}} \quad \therefore \boxed{\textbf{NOT}\text{ dimensionally consistent}}$$

**4. (d)** Substitute dimensions for the variables:

$$v^2 = 2ax$$

$$\frac{\text{m}^2}{\text{s}^2} = 2\left(\frac{\text{m}}{\text{s}^2}\right)(\text{m}) = \frac{\text{m}^2}{\text{s}^2} \quad \therefore \boxed{\text{dimensionally consistent}}$$

**Insight:** The number 2 does not contribute any dimensions to the problem.

41. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Manipulate the dimensions in the same manner as algebraic expressions.

**Solution: 1. (a)** Substitute dimensions for the variables:

$$xt^2 = (\text{m})(\text{s})^2 = \text{m}\cdot\text{s}^2 \quad \boxed{\text{No}}$$

**2. (b)** Substitute dimensions for the variables:

$$\frac{v^2}{x} = \frac{\text{m}^2/\text{s}^2}{\text{m}} = \frac{\text{m}}{\text{s}^2} \quad \boxed{\text{Yes}}$$

**3. (c)** Substitute dimensions for the variables:

$$\frac{x}{t^2} = \frac{\text{m}}{\text{s}^2} \quad \boxed{\text{Yes}}$$

**4. (d)** Substitute dimensions for the variables:

$$\frac{v}{t} = \frac{\text{m/s}}{\text{s}} = \frac{\text{m}}{\text{s}^2} \quad \boxed{\text{Yes}}$$

**Insight:** One of the equations to be discussed later is for calculating centripetal acceleration, where we'll note that $a_{\text{centripetal}} = v^2/r$ has units of acceleration, as we verified in part (b).

42. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** Convert nm to mm:

$$(675\ \text{nm})\left(\frac{1\times10^{-9}\ \text{m}}{1\ \text{nm}}\right)\left(\frac{1\ \text{mm}}{1\times10^{-3}\ \text{m}}\right) = \boxed{6.75\times10^{-4}\ \text{mm}}$$

**2. (b)** Convert nm to in:

$$(675\ \text{nm})\left(\frac{1\times10^{-9}\ \text{m}}{1\ \text{nm}}\right)\left(\frac{39.4\ \text{in}}{1\ \text{m}}\right) = \boxed{2.66\times10^{-5}\ \text{mm}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

43. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution:** Convert ft/day to m/s:

$$\left(210\ \frac{\text{ft}}{\text{day}}\right)\left(\frac{1\ \text{m}}{3.28\ \text{ft}}\right)\left(\frac{1\ \text{day}}{86400\ \text{s}}\right) = \boxed{7.41\times10^{-4}\ \text{m/s}}$$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

44. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** Convert seconds to minutes: $\left(\frac{605 \text{ beats}}{\text{s}}\right)\left(\frac{60 \text{ s}}{\text{min}}\right) = \boxed{3.63\times10^4 \text{ beats/min}}$

**2. (b)** Convert beats to cycles: $\left(\frac{1 \text{ s}}{605 \text{ beats}}\right)\left(\frac{9,192,631,770 \text{ cycles}}{\text{s}}\right) = \boxed{15,194,433 \text{ cycles/beat}}$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

45. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1.** Convert ten feet to m: $(10.0 \text{ ft})\left(\frac{1 \text{ m}}{3.28 \text{ ft}}\right) = \boxed{3.05 \text{ m}}$ above the water

**2.** Convert ten knots to m/s: $(10.0 \text{ knot})\left(\frac{1.0 \text{ n.mi/hr}}{\text{knot}}\right)\left(\frac{1.852 \text{ km}}{\text{n.mi}}\right)\left(\frac{1000 \text{ m}}{\text{km}}\right)\left(\frac{1 \text{ hr}}{3600 \text{ s}}\right) = \boxed{5.14 \text{ m/s}}$

**Insight:** If we were to describe the flying parameters of the helicopter in SI units, we would say it is flying "3 and 5"!

46. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** The acceleration must be greater than 14 ft/s$^2$ because there are about 3 ft per meter.

**2. (b)** Convert m/s$^2$ to ft/s$^2$: $\left(14 \ \frac{\text{m}}{\text{s}^2}\right)\left(\frac{3.28 \text{ ft}}{\text{m}}\right) = \boxed{46 \ \frac{\text{ft}}{\text{s}^2}}$

**3. (c)** Convert m/s$^2$ to km/h$^2$: $\left(14 \ \frac{\text{m}}{\text{s}^2}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right)\left(\frac{3600 \text{ s}}{\text{h}}\right)^2 = \boxed{1.8\times10^5 \ \frac{\text{km}}{\text{h}^2}}$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

47. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** Convert m/s to mi/h: $\left(140 \ \frac{\text{m}}{\text{s}}\right)\left(\frac{1 \text{ mi}}{1609 \text{ m}}\right)\left(\frac{3600 \text{ s}}{1 \text{ h}}\right) = \boxed{310 \ \frac{\text{mi}}{\text{h}}}$

**2. (b)** Convert m/s to m/ms $\left(140 \ \frac{\text{m}}{\text{s}}\right)\left(\frac{1\times10^{-3} \text{ s}}{1 \text{ ms}}\right) = 0.14 \ \frac{\text{m}}{\text{ms}} \times 5.0 \text{ ms} = \boxed{0.70 \text{ m}}$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

48. **Picture the Problem**: This is a units conversion problem.

**Strategy:** Multiply the known quantity by appropriate conversion factors to change the units.

**Solution: 1. (a)** Convert mg/min to g/day: $\left(1.6 \ \frac{\text{mg}}{\text{min}}\right)\left(\frac{1\times10^{-3} \text{ g}}{\text{mg}}\right)\left(\frac{1440 \text{ min}}{1 \text{ day}}\right) = \boxed{2.3 \ \frac{\text{g}}{\text{day}}}$

**2. (b)** Divide the mass gain by the rate: $t = \frac{\Delta m}{rate} = \frac{0.0075 \text{ kg} \times 1000 \text{ g/kg}}{2.3 \text{ g/day}} = \boxed{3.3 \text{ days}}$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

49. **Picture the Problem**: The probe rotates many times per minute.

**Strategy:** Find the time it takes the probe to travel 150 yards and then determine how many rotations occurred during that time interval. Convert units to figure out the distance moved per revolution.

**Solution: 1. (a)** Find the time to travel 150 yards: $\left(\frac{1\text{ s}}{31\text{ cm}}\right)\left(\frac{30.5\text{ cm}}{\text{ft}}\right)\left(\frac{3\text{ ft}}{\text{yd}}\right)=2.95\ \frac{\text{s}}{\text{yd}}\times 150\text{ yd}=443\text{ s}$

**2.** Find the number of rotations in that time: $\left(\frac{7\text{ rev}}{\text{min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)\times 443\text{ s}=51.6\text{ rev}=\boxed{51\text{ complete revolutions}}$

**3. (b)** Convert min/rev to ft/rev: $\left(\frac{1\text{ min}}{7\text{ rev}}\right)\left(\frac{60\text{ s}}{1\text{ min}}\right)\left(\frac{31\text{ cm}}{\text{s}}\right)\left(\frac{1\text{ ft}}{30.5\text{ cm}}\right)=\boxed{8.7\text{ ft/rev}}$

**Insight:** Conversion factors are conceptually equal to one, even though numerically they often equal something other than one. They are often helpful in displaying a number in a convenient, useful, or easy-to-comprehend fashion.

50. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Find *p* to make the length dimensions match and *q* to make the time dimensions match.

**Solution: 1.** Make the length dimensions match: $\frac{[\text{L}]}{[\text{T}]^2}=\left(\frac{[\text{L}]}{[\text{T}]}\right)^p[\text{T}]^q$ implies $\boxed{p=1}$

**2.** Now make the time units match: $\frac{1}{[\text{T}]^2}=\frac{[\text{T}]^q}{[\text{T}]^1}$ or $[\text{T}]^{-2}=[\text{T}]^q[\text{T}]^{-1}$ implies $\boxed{q=-1}$

**Insight:** Sometimes you can determine whether you've made a mistake in your calculations simply by checking to ensure the dimensions work out correctly on both sides of your equations.

51. **Picture the Problem**: This is a dimensional analysis question.

**Strategy:** Find *q* to make the time dimensions match and then *p* to make the distance dimensions match. Recall *L* must have dimensions of meters and *g* dimensions of m/s$^2$.

**Solution: 1.** Make the time dimensions match: $[\text{T}]=[\text{L}]^p\left(\frac{[\text{L}]}{[\text{T}]^2}\right)^q=[\text{L}]^p\left([\text{L}]\ [\text{T}]^{-2}\right)^q$ implies $\boxed{q=-\tfrac{1}{2}}$

**2.** Now make the distance units match: $[\text{T}]=[\text{L}]^p\left(\frac{[\text{L}]}{[\text{T}]^2}\right)^{-\frac{1}{2}}$ implies $\boxed{p=\tfrac{1}{2}}$

**Insight:** Sometimes you can determine whether you've made a mistake in your calculations simply by checking to ensure the dimensions work out correctly on both sides of your equations.

52. **Picture the Problem**: Your car travels 1.0 mile in each situation, but the speed and times are different in the second case than the first.

**Strategy:** Set the distances traveled equal to each other, then mathematically solve for the initial speed $v_0$. The known quantities are that the change in speed is $\Delta v=7.9$ mi/h and the change in time is $\Delta t=-13$ s.

**Solution: 1.** Set the distances equal: $d_1=d_2$

**2.** Substitute for the distances: $v_0t=(v_0+\Delta v)(t+\Delta t)$

**3.** Multiply the terms on the right side: $v_0t=v_0t+\Delta v\,t+\Delta t v_0+\Delta v\Delta t$

**4.** Subtract $v_0t$ from both sides and substitute $t=\frac{d}{v_0}$: $0=\Delta v\left(\frac{d}{v_0}\right)+v_0\Delta t+\Delta v\Delta t$

**5.** Multiply both sides by $v_0$ and rearrange: $0=v_0^2\Delta t+(\Delta v\Delta t)v_0+\Delta v d$

**6.** Solve the quadratic equation for $v_0$:

$$v_0 = \frac{-\Delta v\Delta t \pm \sqrt{\Delta v^2 \Delta t^2 - 4(\Delta t)(\Delta vd)}}{2\Delta t}$$

**7.** Substitute in the numbers:

$$\Delta v\Delta t = \left(+7.9\ \frac{\text{mi}}{\text{h}}\right)(-13\ \text{s})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = -0.0285\ \text{mi} \quad \text{and}$$

$$\Delta t = (-13\ \text{s})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = -0.00361\ \text{h}, \quad \text{and } d = 1\ \text{mi}$$

**8.** Find $v_0$:

$$v_0 = \frac{-(-0.0285\,\text{mi}) \pm \sqrt{(-0.0285\,\text{mi})^2 - 4(-0.0285\,\text{mi})(1\,\text{mi})}}{2(-0.00361\ \text{h})}$$

$$v_0 = \boxed{43\ \text{mi/h}},\ -51\ \text{mi/h}$$

**Insight:** This was a very complex problem, but it does illustrate that it is necessary to know how to convert units in order to properly solve problems. The units must be consistent with each other in order for the math to succeed.

53. **Picture the Problem**: The snowy cricket chirps at a rate that is linearly dependent upon the temperature.

**Strategy:** Take note of the given mathematical relationship between the number of chirps $N$ in 13 seconds and the temperature $T$ in Fahrenheit. Use the relationship to determine the appropriate graph of $N$ vs. $T$.

**Solution:** The given formula, $N = T - 40$, is a linear equation of the form $y = mx + b$. By comparing the two expressions we see that $N$ is akin to $y$, $T$ is akin to $x$, the slope $m$ = 1.00 chirps °F$^{-1}$, and $b$ = −40 °F. In the displayed graphs of $N$ vs. $T$, only two of the plots are linear, plots A and C, so we consider only those. Of those two, only one has an intercept of −40 °F, so we conclude that the correct plot is $\boxed{\text{plot C}}$.

**Insight:** Plot B would be an appropriate depiction of a formula like $N = T^2 - 40$.

54. **Picture the Problem**: The snowy cricket chirps at a rate that is linearly dependent upon the temperature.

**Strategy:** Use the given formula to determine the number of chirps $N$ in 13 seconds, and then use that rate to find the time elapsed for the snowy cricket to chirp 12 times.

**Solution: 1.** Find the number of chirps per second:

$$\frac{N}{t} = \frac{T-40}{13\ \text{s}} = \frac{43-40}{13\ \text{s}} = \frac{0.23\ \text{chirps}}{\text{s}}$$

**2.** Find the time elapsed for 12 chirps:

$$\frac{1\ \text{s}}{0.23\ \text{chirp}} \times 12\ \text{chirps} = \boxed{52\ \text{s}}$$

**Insight:** Note that we can employ either the ratio $0.23\ \text{chirp}/1\ \text{s}$ or the ratio $1\ \text{s}/0.23\ \text{chirp}$, whichever is most useful for answering the particular question that is posed.

55. **Picture the Problem**: The snowy cricket chirps at a rate that is linearly dependent upon the temperature.

**Strategy:** Use the given formula to determine the temperature $T$ that corresponds to the given number of chirps per minute by your pet cricket.

**Solution: 1.** Find the number of chirps per second:

$$\frac{N}{t} = \frac{112\ \text{chirps}}{60.0\ \text{s}} = \frac{1.87\ \text{chirps}}{\text{s}}$$

**2.** Find the number of chirps $N$ per 13 s:

$$N = \frac{1.87\ \text{chirps}}{1\ \text{s}} \times 13.0\ \text{s} = 24.3\ \text{chirps}$$

**3.** Determine the temperature from the formula:

$$N = T - 40.0 \ \Rightarrow\ T = N + 40.0 = 24.3 + 40\,°\text{F} = \boxed{64.3\,°\text{F}}$$

**Insight:** The number of significant figures might be limited by the precision of the numbers 13 and 40 that are given in the description of the formula. In this case we interpreted them as exact and let the precision of the measurements 112 and 60.0 s limit the significant digits of our answer.

56. **Picture the Problem**: The cesium atom oscillates many cycles during the time it takes the cricket to chirp once.

**Strategy:** Find the time in between chirps using the given formula and then find the number of cycles the cesium atom undergoes during that time.

**Solution: 1.** Find the time in between chirps:

$$\frac{N}{t} = \frac{T - 40.0}{13.0\text{ s}} = \frac{65.0 - 40.0}{13.0\text{ s}} = 1.92\ \frac{\text{chirps}}{\text{s}}$$

**2.** Find the number of cesium atom cycles:

$$\left(\frac{9{,}192{,}631{,}770\text{ cycles}}{\text{s}}\right)\left(\frac{1\text{ s}}{1.92\text{ chirp}}\right) = \boxed{4.78\times10^{9}\text{ cycles/chirp}}$$

**Insight:** The number of significant figures might be limited by the precision of the numbers 13 and 40 that are given in the description of the formula. In this case we interpreted them as exact and let the precision of the measurement 65.0°F limit the significant digits of our answer.