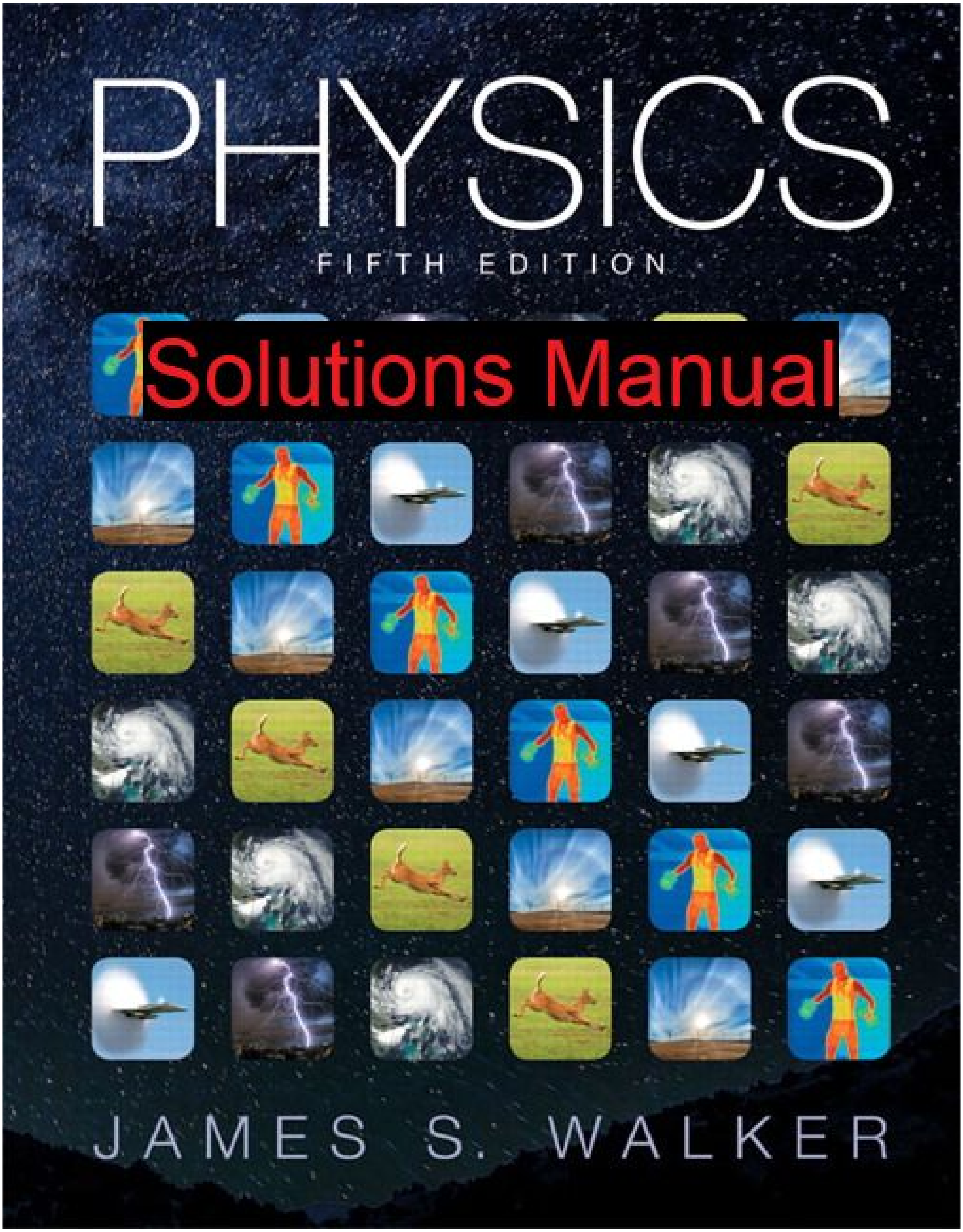
PHYSICS
FIFTH EDITION
Solutions Manual
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Chapter 1: Introduction to Physics

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. The frequency is a scalar quantity. It has a numerical value, but no associated direction.

6. **(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 problem is about the conversion of units.

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

Solution: (a) Convert the units: $\$152{,}000{,}000 \times \dfrac{1 \text{ gigadollars}}{1\times10^9 \text{ dollars}} = \boxed{0.152 \text{ gigadollars}}$

(b) Convert the units again: $\$152{,}000{,}000 \times \dfrac{1 \text{ teradollars}}{1\times10^{12} \text{ dollars}} = \boxed{1.52\times10^{-4} \text{ teradollars}}$

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

2. **Picture the Problem**: This problem is about the conversion of units.

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

Solution: (a) Convert the units: $85\ \mu\text{m} \times \dfrac{1.0\times10^{-6} \text{ m}}{\mu\text{m}} = \boxed{8.5\times10^{-5} \text{ m}}$

(b) Convert the units again: $85\ \mu\text{m} \times \dfrac{1.0\times10^{-6} \text{ m}}{\mu\text{m}} \times \dfrac{1000 \text{ mm}}{1 \text{ m}} = \boxed{0.085 \text{ mm}}$

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

3. **Picture the Problem**: This problem is about the conversion of units.

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

Solution: Convert the units: $0.3\ \dfrac{\text{Gm}}{\text{s}} \times \dfrac{1\times10^9 \text{ m}}{\text{Gm}} = \boxed{3\times10^8 \text{ m/s}}$

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

4. **Picture the Problem**: This problem is about the conversion of units.

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

Solution: Convert the units:

$$136.8\ \frac{\text{teracalculation}}{\text{s}}\times\frac{1\times10^{12}\ \text{calculations}}{\text{teracalculation}}\times\frac{1\times10^{-9}\ \text{s}}{\text{ns}}$$
$$=\boxed{136{,}800\ \text{calculations/ns}}=1.368\times10^{5}\ \text{calculations/ns}$$

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:

$$x=\frac{1}{2}at^2$$
$$[\text{L}]=\frac{1}{2}\left(\frac{[\text{L}]}{[\text{T}]^2}\right)[\text{T}]^2=[\text{L}]\ \therefore\ \boxed{\text{The equation is dimensionally consistent.}}$$

2. (b) Substitute dimensions for the variables:

$$t=\frac{v}{x}$$
$$[\text{T}]=\frac{[\text{L}]/[\text{T}]}{[\text{L}]}\neq\frac{1}{[\text{T}]}\quad\therefore\ \boxed{\text{Not dimensionally consistent}}$$

3. (c) Substitute dimensions for the variables:

$$t=\sqrt{\frac{2x}{a}}$$
$$[\text{T}]=\sqrt{\frac{[\text{L}]}{[\text{L}]/[\text{T}]^2}}=\sqrt{[\text{T}]^2}=[\text{T}]\quad\therefore\ \boxed{\text{Dimensionally consistent}}$$

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:

$$\frac{x}{v}=\frac{[\text{L}]}{[\text{L}]/[\text{T}]}=\frac{1}{1/[\text{T}]}=[\text{T}]\quad\boxed{\text{Yes}}$$

2. (b) Substitute dimensions for the variables:

$$\frac{a}{v}=\frac{[\text{L}]/[\text{T}]^2}{[\text{L}]/[\text{T}]}=\frac{1/([\text{T}]\cdot[\text{T}])}{1/[\text{T}]}=\frac{1}{[\text{T}]}\quad\boxed{\text{No}}$$

3. (c) Substitute dimensions for the variables:

$$\sqrt{\frac{2x}{a}}=\sqrt{\frac{[\text{L}]}{[\text{L}]/[\text{T}]^2}}=\sqrt{\frac{1}{1/[\text{T}]^2}}=\sqrt{[\text{T}]^2}=[\text{T}]\quad\boxed{\text{Yes}}$$

4. (d) Substitute dimensions for the variables:

$$\frac{v^2}{a}=\frac{([\text{L}]/[\text{T}])^2}{[\text{L}]/[\text{T}]^2}=\frac{[\text{L}]^2/[\text{T}]^2}{[\text{L}]/[\text{T}]^2}=\frac{[\text{L}]^2}{[\text{L}]}=[\text{L}]\quad\boxed{\text{No}}$$

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:

$$vt = \left(\frac{[\mathrm{L}]}{[\mathrm{T}]}\right)[\mathrm{T}] = [\mathrm{L}] \quad \boxed{\text{Yes}}$$

2. (b) Substitute dimensions for the variables:

$$\tfrac{1}{2}at^2 = \tfrac{1}{2}\left(\frac{[\mathrm{L}]}{[\mathrm{T}]^2}\right)[\mathrm{T}]^2 = [\mathrm{L}] \quad \boxed{\text{Yes}}$$

3. (c) Substitute dimensions for the variables:

$$2at = 2\left(\frac{[\mathrm{L}]}{[\mathrm{T}]^2}\right)[\mathrm{T}] = \frac{[\mathrm{L}]}{[\mathrm{T}]} \quad \boxed{\text{No}}$$

4. (d) Substitute dimensions for the variables:

$$\frac{v^2}{a} = \frac{\left([\mathrm{L}]/[\mathrm{T}]\right)^2}{[\mathrm{L}]/[\mathrm{T}]^2} = \frac{[\mathrm{L}]^2/[\mathrm{T}]^2}{[\mathrm{L}]/[\mathrm{T}]^2} = \frac{[\mathrm{L}]^2}{[\mathrm{L}]} = [\mathrm{L}] \quad \boxed{\text{Yes}}$$

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

8. **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:

$$\tfrac{1}{2}at^2 = \tfrac{1}{2}\left(\frac{[\mathrm{L}]}{[\mathrm{T}]^2}\right)[\mathrm{T}]^2 = [\mathrm{L}] \quad \boxed{\text{No}}$$

2. (b) Substitute dimensions for the variables:

$$at = \left(\frac{[\mathrm{L}]}{[\mathrm{T}]^2}\right)[\mathrm{T}] = \frac{[\mathrm{L}]}{[\mathrm{T}]} \quad \boxed{\text{Yes}}$$

3. (c) Substitute dimensions for the variables:

$$\sqrt{\frac{2x}{a}} = \sqrt{\frac{2[\mathrm{L}]}{[\mathrm{L}]/[\mathrm{T}]^2}} = [\mathrm{T}] \quad \boxed{\text{No}}$$

4. (d) Substitute dimensions for the variables:

$$\sqrt{2ax} = \sqrt{2\left(\frac{[\mathrm{L}]}{[\mathrm{T}]^2}\right)[\mathrm{L}]} = \sqrt{\frac{[\mathrm{L}]^2}{[\mathrm{T}]^2}} = \frac{[\mathrm{L}]}{[\mathrm{T}]} \quad \boxed{\text{Yes}}$$

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

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:

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

$$\left(\frac{[\mathrm{L}]}{[\mathrm{T}]}\right)^2 = \left(\frac{[\mathrm{L}]}{[\mathrm{T}]^2}\right)[\mathrm{L}]^p$$

$$[\mathrm{L}]^2 = [\mathrm{L}]^{p+1} \quad \text{therefore } \boxed{p = 1}$$

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:

$$a = 2xt^p$$

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

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

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

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:

$$t = h^p\sqrt{\frac{2}{g}}$$

$$[\mathrm{T}] = [\mathrm{L}]^p\sqrt{\frac{1}{[\mathrm{L}]/[\mathrm{T}]^2}} = [\mathrm{L}]^p\,\frac{[\mathrm{T}]}{[\mathrm{L}]^{1/2}}$$

$$[\mathrm{T}] = [\mathrm{L}]^{p-\frac{1}{2}}[\mathrm{T}] \quad \text{therefore} \quad \boxed{p = \tfrac{1}{2}}$$

Insight: We conclude the h belongs inside the square root, and the time to fall from rest a distance h is $t = \sqrt{2h/g}$.

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

Strategy: Rearrange the expression to solve for the force F, and then substitute the appropriate dimensions for the corresponding variables.

Solution: Substitute dimensions for the variables, using [M] to represent the dimension of mass:

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

Insight: This unit, kg·m/s^2, will later be given the name "Newton" and abbreviated as N.

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

Strategy: Rearrange the expression to solve for the force constant k, and then substitute the appropriate dimensions for the corresponding variables.

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, using [M] to represent the dimension of mass:

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

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

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

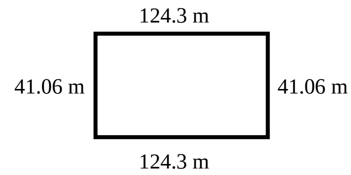
Strategy: Follow the given rules regarding the calculation and display of significant figures.

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, especially when two large values are subtracted to find a small difference between them.

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: $124.3 + 41.06 + 124.3 + 41.06 \text{ m} = 330.72 \text{ m}$

2. Round to the smallest number of decimal places in any of the individual terms: $330.72 \text{ m} \Rightarrow \boxed{330.7 \text{ m}}$

Insight: Even if you changed the problem to $(2\times 124.3 \text{ m})+(2\times 41.06 \text{ m})$, you'd still have to report 330.7 m as the answer; the 2 is considered an exact number so it's the "124.3 m" value that limits the number of significant digits.

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: $2.77 + 14.3 + 13.43 \text{ lb} = 30.50 \text{ lb}$

2. Round to the smallest number of decimal places in any of the individual terms: $30.50 \text{ lb} \Rightarrow \boxed{30.5 \text{ lb}}$

Insight: The 14.3-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: $0.0000\,\underline{3}\,\underline{0}\,\underline{3}$ has $\boxed{\text{3 significant figures}}$

2. (b) The middle zeros are significant: $\underline{6}.\underline{2}\,\underline{0}\,\underline{1}\times 10^{5}$ 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 zero written 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: $A = \pi r^2 = \pi(11.37 \text{ m})^2 = 406.13536 \text{ m}^2 \Rightarrow \boxed{406.1 \text{ m}^2}$

2. (b) Calculate the area and round to two significant figures: $A = \pi r^2 = \pi(6.8 \text{ m})^2 = 145.2672443 \text{ m}^2 \Rightarrow \boxed{1.5\times 10^2 \text{ m}^2}$

Insight: The number π is considered exact so it will never limit the number of significant digits you report in an answer. If we present the answer to part (b) as 150 m the number of significant figures is ambiguous, so we present the result in scientific notation to clarify that there are only two significant figures.

19. **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.

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

Strategy: Convert each speed to m/s units to compare their magnitudes.

Solution: 1. (a) The speed is already in m/s units: $v_a = 0.25 \text{ m/s}$

2. (b) Convert the speed to m/s units: $v_b = \left(0.75\ \frac{\text{km}}{\text{h}}\right)\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = 0.21 \text{ m/s}$

3. (c) Convert the speed to m/s units: $v_c = \left(12\ \frac{\text{ft}}{\text{s}}\right)\left(\frac{1 \text{ m}}{3.281 \text{ ft}}\right) = 3.7 \text{ m/s}$

4. (d) Convert the speed to m/s units: $v_d = \left(16\ \frac{\text{cm}}{\text{s}}\right)\left(\frac{1 \text{ m}}{100 \text{ cm}}\right) = 0.16 \text{ m/s}$

5. Rank the four speeds: $\boxed{v_d < v_b < v_a < v_c}$

Insight: To one significant digit the speeds in (b) and (d) are identical (0.2 m/s), but it is ambiguous how to round the 0.25 m/s of (a) to one significant digit (either 0.2 or 0.3 m/s). Notice that it is impossible to compare these speeds without converting to the same unit of measure.

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

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 problem is about the conversion of units.

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

Solution: Convert mi/h to km/h: $\left(68\ \frac{\text{mi}}{\text{h}}\right)\left(\frac{1.609 \text{ km}}{1 \text{ mi}}\right) = 109 \text{ km/h} = \boxed{1.1\times10^2 \text{ km/h}}$

Insight: The given 68 mi/h has only two significant figures, thus the answer is limited to two significant figures. If we present the answer as 110 km/h the zero is ambiguous, thus we use scientific notation to remove the ambiguity.

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

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 problem is about the conversion of units.

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

Solution: Convert seconds to weeks: $$\left(\frac{1\text{ msg}}{9\text{ s}}\right)\left(\frac{3600\text{ s}}{\text{h}}\right)\left(\frac{24\text{ h}}{\text{d}}\right)\left(\frac{7\text{ d}}{\text{wk}}\right)=67,200\ \frac{\text{msg}}{\text{wk}}=\boxed{7\times10^4\ \frac{\text{msg}}{\text{wk}}}$$

Insight: In this problem there is only one significant figure associated with the phrase, "every 9 seconds."

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

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

Solution: Convert feet to meters: $$(108\text{ ft})\left(\frac{1\text{ m}}{3.281\text{ ft}}\right)=\boxed{32.9\text{ m}}$$

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 problem is about the conversion of units.

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 problem is about the conversion of units.

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

Solution: Convert m/s^2 to feet 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.

28. **Picture the Problem**: This problem is about the conversion of units.

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 are equal to something other than one. They often help to display a number in a convenient, useful, or easy-to-comprehend fashion.

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

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: Mantis shrimp have been known to shatter the glass walls of the aquarium in which they are kept.

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

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: A jiffy is 33.357 billionths of a second. In other terms 1 jiffy = 33.357 picosecond (ps).

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

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. A mutchkin is about 1.8 cups.

32. **Picture the Problem**: A cubic meter of 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 problem is about the conversion of units.

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 are equal to something other than one. They often help to display a number in a convenient, useful, or easy-to-comprehend fashion.

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

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

Solution: 1. (a) Convert m/s to ft/s:

$$\left(25.0\ \frac{\text{m}}{\text{s}}\right)\left(\frac{3.281\ \text{ft}}{\text{m}}\right)=\boxed{82.0\ \text{ft/s}}$$

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

$$\left(25.0\ \frac{\text{m}}{\text{s}}\right)\left(\frac{1\ \text{mi}}{1609\ \text{m}}\right)\left(\frac{3600\ \text{s}}{1\ \text{h}}\right)=\boxed{55.9\ \text{mi/h}}$$

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**: The rows of seats in a ballpark 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. Regardless, for an order of magnitude estimate we round to the nearest factor of ten, in this case 10^5.

36. **Picture the Problem**: Hair grows at a steady rate.

Strategy: Estimate that your hair grows about a centimeter a month, or 0.010 m in 30 days.

Solution: Multiply the quantities to make an estimate:

$$v=\left(\frac{0.010\ \text{m}}{30\ \text{d}}\right)\left(\frac{1\ \text{d}}{24\ \text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)=3.9\times10^{-9}\ \text{m/s}=3.9\ \text{nm/s}\cong\boxed{10^{-9}\ \text{m/s}}$$

Insight: This rate corresponds to about 40 atomic diameters per second. The length of human hair accumulates 0.12 m or about 5 inches per year.

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:

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

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

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

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

2. (b) Multiply speed by 24 hours: $\text{circumference } = vt = (3000\text{ mi/h})(24\text{ h}) = 24{,}000\text{ mi} \cong \boxed{10^4\text{ mi}}$

3. (c) Circumference equals $2\pi r$: $r = \dfrac{\text{circumference}}{2\pi} = \dfrac{24{,}000\text{ mi}}{2\pi} = 3800\text{ mi} = \boxed{10^3\text{ mi}}$

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**: 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.

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

2. (b) Substitute dimensions for the variables: $\dfrac{v^2}{x} = \dfrac{\text{m}^2/\text{s}^2}{\text{m}} = \dfrac{\text{m}}{\text{s}^2} \quad \boxed{\text{Yes}}$

3. (c) Substitute dimensions for the variables: $\dfrac{x}{t^2} = \dfrac{\text{m}}{\text{s}^2} \quad \boxed{\text{Yes}}$

4. (d) Substitute dimensions for the variables: $\dfrac{v}{t} = \dfrac{\text{m/s}}{\text{s}} = \dfrac{\text{m}}{\text{s}^2} \quad \boxed{\text{Yes}}$

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).

41. **Picture the Problem**: This problem is about the conversion of units.

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

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

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

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

Solution: Convert ft/day to m/s: $$\left(210\ \frac{\text{ft}}{\text{day}}\right)\left(\frac{1\text{ m}}{3.281\text{ ft}}\right)\left(\frac{1\text{ day}}{86,400\text{ s}}\right)=\boxed{7.41\times10^{-4}\text{ m/s}}$$

Insight: This is a much slower speed than the 1.3 m/s average walking speed of a human being.

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

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

Solution: Convert cubic feet of gold to pounds: $$(1.0\text{ ft}^3)\left(\frac{28.3\text{ L}}{1\text{ ft}^3}\right)\left(\frac{42.5\text{ lb}}{1\text{ L}}\right)=1200\text{ lb}=\boxed{1.2\times10^3\text{ lb}}$$

Insight: A cube of solid gold one foot on a side weighs over half a ton! You will need help moving your valuable discovery.

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

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

Solution: Convert m/s to miles per hour: $$\left(3.00\times10^8\ \frac{\text{m}}{\text{s}}\right)\left(\frac{1\text{ mi}}{1609\text{ m}}\right)=\boxed{1.86\times10^5\ \frac{\text{mi}}{\text{s}}}$$

Insight: The equatorial circumference of the Earth is 40,075 km or 24,907 mi. Thus a beam of light, traveling at 186,000 miles per second, can travel around the globe 7.5 times every second.

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

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

Solution: Convert shakes per minute to shakes per second: $$\left(3300\ \frac{\text{shakes}}{\text{min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)=\boxed{55\text{ shakes/second}}$$

Insight: When analyzing the characteristic shake frequencies of rattlesnakes, it is advisable to work from a distance.

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

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

Solution: 1. (a) Convert pg to kg: $(27\ \text{pg})\left(\dfrac{10^{-12}\ \text{g}}{\text{pg}}\right)\left(\dfrac{1\ \text{kg}}{1000\ \text{g}}\right)=\boxed{2.7\times10^{-14}\ \text{kg}}$

2. (b) Convert pg to ng: $(27\ \text{pg})\left(\dfrac{10^{-12}\ \text{g}}{\text{pg}}\right)\left(\dfrac{1\ \text{ng}}{10^{-9}\ \text{g}}\right)=\boxed{0.027\ \text{ng}}$

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

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

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

Solution: 1. (a) Convert cm/day to mm/s: $\left(4.1\ \dfrac{\text{cm}}{\text{d}}\right)\left(\dfrac{10\ \text{mm}}{\text{cm}}\right)\left(\dfrac{1\ \text{d}}{24\ \text{h}}\right)\left(\dfrac{1\ \text{h}}{3600\ \text{s}}\right)=\boxed{4.7\times10^{-4}\ \text{mm/s}}$

2. (b) Convert cm/day to ft/week: $\left(4.1\ \dfrac{\text{cm}}{\text{d}}\right)\left(\dfrac{1\ \text{ft}}{30.5\ \text{cm}}\right)\left(\dfrac{7\ \text{d}}{1\ \text{week}}\right)=\boxed{0.94\ \text{ft/week}}$

Insight: Given that the average width of a human hair is 0.10 mm, a corn plant that grows at this rate gains the additional height of the width of a human hair every 3.5 minutes.

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

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

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

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

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

49. **Picture the Problem**: This problem is about the conversion of units.

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

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

2. (b) Convert m/s^2 to ft/s^2: $\left(14\ \dfrac{\text{m}}{\text{s}^2}\right)\left(\dfrac{3.281\ \text{ft}}{\text{m}}\right)=\boxed{46\ \dfrac{\text{ft}}{\text{s}^2}}$

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

50. **Picture the Problem**: A speeding bullet covers a large distance in a small interval of time.

Strategy: Use conversion factors to change the units from ft/s to mi/h. Then multiply the speed of the bullet by the time interval to find the distance traveled.

Solution: 1. (a) Convert ft/s to mi/h:

$$\left(4225\ \frac{\text{ft}}{\text{s}}\right)\left(\frac{1\text{ mi}}{5280\text{ ft}}\right)\left(\frac{3600\text{ s}}{1\text{ h}}\right)=\boxed{2881\text{ mi/h}}$$

2. (b) Multiply the speed by the time to find the distance *d*:

$$d=\left(4225\ \frac{\text{ft}}{\text{s}}\times\frac{1\text{ m}}{3.281\text{ ft}}\right)\left(5.0\text{ ms}\times\frac{0.001\text{ s}}{1\text{ ms}}\right)=\boxed{6.4\text{ m}}$$

Insight: The bullet covers 21 feet in 5.0 milliseconds. Because the normal length of a blink is 300 milliseconds, the bullet can cover 1270 ft (nearly a quarter mile) in a blink of an eye.

51. **Picture the Problem**: Nerve impulses cover a large distance in a small interval of time.

Strategy: Use conversion factors to change the units from m/s to mi/h. Then multiply the speed of the nerve impulses by the time interval to find the distance traveled.

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) Multiply the speed by the time to find the distance *d*:

$$d=\left(140\ \frac{\text{m}}{\text{s}}\right)\left(\frac{1\times10^{-3}\text{ s}}{1\text{ ms}}\right)\times5.0\text{ ms}=\boxed{0.70\text{ m}}$$

Insight: The nerve impulses travel more than two feet in 5.0 milliseconds. Because the normal length of a blink is 300 milliseconds, the nerve impulses can cover 42 ft in a blink of an eye.

52. **Picture the Problem**: This problem is about the conversion of units.

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:

$$t=\frac{\Delta m}{rate}=\frac{0.0075\text{ kg}\times1000\text{ g/kg}}{2.3\text{ g/day}}=\boxed{3.3\text{ days}}$$

Insight: The rate of brain growth slows down considerably as the child matures, and stops growing at around 10 years of age. Brain weight decreases a small amount, and very slowly, after age 20.

53. **Picture the Problem**: The Huygens space 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:

$$\left(\frac{1\text{ s}}{31\text{ cm}}\right)\left(\frac{30.5\text{ cm}}{\text{ft}}\right)\left(\frac{3\text{ ft}}{\text{yd}}\right)=2.95\ \frac{\text{s}}{\text{yd}}\times150\text{ yd}=443\text{ s}$$

2. Find the number of rotations in that time:

$$(443\text{ s})\left(\frac{7\text{ rev}}{\text{min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)=51.6\text{ rev}=\boxed{51\text{ complete revolutions}}$$

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: In later chapters the rotation rate will be represented by the symbol ω and we will discover that the total angle through which the probe rotated is given by $\Delta\theta=\omega\Delta t$.

54. **Picture the Problem**: A dragonfly spins rapidly while being recorded by a high-speed video camera.

Strategy: Convert the spin revolution per frame value into units of revolutions per minute.

Solution: Convert rev/frame to rev/min: $\left(\frac{1\text{ rev}}{14\text{ frames}}\right)\left(\frac{240\text{ frames}}{1\text{ s}}\right)\left(\frac{60\text{ s}}{1\text{ min}}\right)=1029\text{ rev/min}=\boxed{1.0\times10^3\text{ rpm}}$

Insight: The value of one spin revolution every 14 frames contains only two significant figures, so our answer is accurate to only two significant figures. Greater precision can be achieved by averaging the rotation rate over many frames.

55. **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.

56. **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.

57. **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 $\Delta v = 7.9\text{ mi/h}$ and the change in time is $\Delta t = -13\text{ s}$.

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

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

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

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

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: $v_0 = \dfrac{-\Delta v \Delta t \pm \sqrt{\Delta v^2 \Delta t^2 - 4(\Delta t)(\Delta v d)}}{2\Delta t}$

7. Substitute in the numbers: $\Delta v \Delta t = \left(+7.9\ \dfrac{\text{mi}}{\text{h}}\right)(-13\text{ s})\left(\dfrac{1\text{ h}}{3600\text{ s}}\right) = -0.0285\text{ mi}$ 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.

58. **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 $b = -40$ chirps. In the displayed graphs of N vs. T, only three of the plots are linear with nonzero slope, plots A, C, and E, so we consider only those. Of those three, only two have positive slopes, A and C, so we rule out plot E. Using the formula at 70°F, we expect the number of chirps to be N = (1.00 chirps °F^{-1})(70°F) – 40 chirps = 30 chirps, and by noting the values of plots A and C at 70°F we conclude that the correct plot is $\boxed{\text{plot C}}$.

Insight: Plot B is quadratic and corresponds to the formula $N = (T-40)^2/30$.

59. **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: $\dfrac{N}{t} = \dfrac{T-40}{13\text{ s}} = \dfrac{43-40}{13\text{ s}} = \dfrac{0.23\text{ chirps}}{\text{s}}$

2. Find the time elapsed for 12 chirps: $\dfrac{1\text{ s}}{0.23\text{ chirp}} \times 12\text{ chirps} = \boxed{52\text{ s}}$

Insight: Notice 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.

60. **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 s" and "60.0 s" limit the significant digits of our answer.

61. **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: $\left(\frac{9{,}192{,}631{,}770\text{ cycles}}{\text{s}}\right)\left(\frac{1\text{ s}}{1.92\text{ chirp}}\right) = \boxed{4.78 \times 10^9\ \text{cycles/chirp}}$

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.