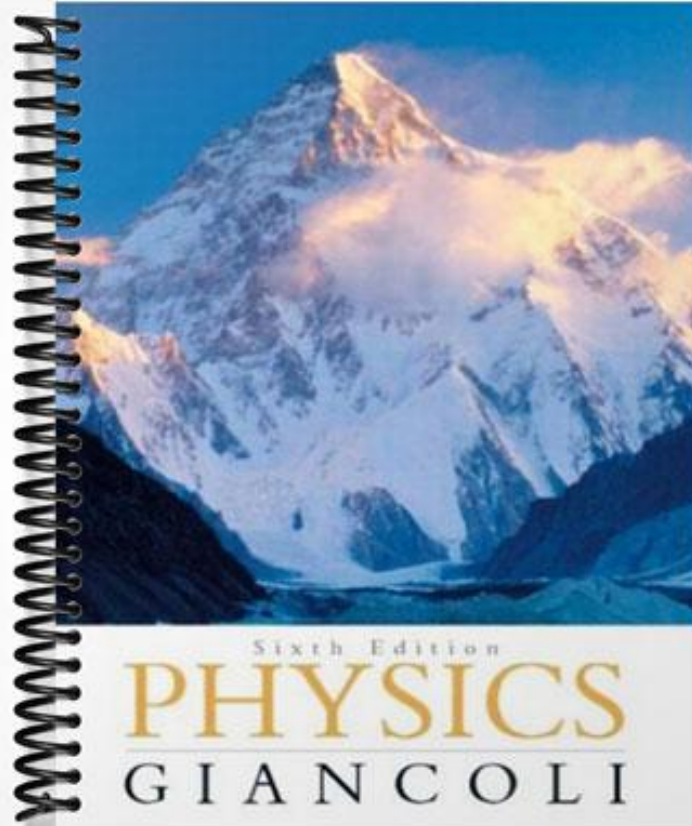


**SOLUTIONS MANUAL**



## PREFACE

This *Instructor's Solutions Manual* provides answers and worked-out solutions to all end of chapter questions and problems from chapters 1 – 15 of *Physics: Principles with Applications, 6th Edition*, by Douglas C. Giancoli. At the end of the manual are grids that correlate the 5th edition questions and problems to the 6th edition questions and problems.

We formulated the solutions so that they are, in most cases, useful both for the student and the instructor. Accordingly, some solutions may seem to have more algebra than necessary for the instructor. Other solutions may seem to take bigger steps than a student would normally take: e.g. simply quoting the solutions from a quadratic equation instead of explicitly solving for them. There has been an emphasis on algebraic solutions, with the substitution of values given as a very last step in most cases. We feel that this helps to keep the physics of the problem foremost in the solution, rather than the numeric evaluation.

Much effort has been put into having clear problem statements, reasonable values, pedagogically sound solutions, and accurate answers/solutions for all of the questions and problems. Working with us was a team of three additional solvers – David Curott (University of North Alabama), Bryan Long (Columbia State Community College), and Rich Louie (Pacific Lutheran University). Between the five solvers we had either 3 or 4 complete solutions for every question and problem. From those solutions we uncovered questions about the wording of the problems, style of the possible solutions, reasonableness of the values and framework of the questions and problems, and then consulted with one another and Doug Giancoli until we reached what we feel is both a good statement and a good solution for each question and problem from the text.

Many people have been involved in the production of this manual. We especially thank Doug Giancoli for his helpful conversations. Christian Botting and Karen Karlin at Prentice Hall have been helpful, encouraging, and patient as we have turned our thoughts into a manual. And the solutions from David Curott, Bryan Long, and Rich Louie were often thought-provoking and always appreciated. We also acknowledge the benefit of having solutions from the previous edition, prepared by Irv Miller.

Even with all the assistance we have had, the final responsibility for the content of this manual is ours. We would appreciate being notified via e-mail of any errors that are discovered. We hope that you will find this presentation of answers and solutions useful.

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## CHAPTER 1: Introduction, Measurement, Estimating

### Answers to Questions

1.
  - (a) Fundamental standards should be accessible, invariable, indestructible, and reproducible. A particular person's foot would not be very accessible, since the person could not be at more than one place at a time. The standard would be somewhat invariable if the person were an adult, but even then, due to swelling or injury, the length of the standard foot could change. The standard would not be indestructible – the foot would not last forever. The standard could be reproducible – tracings or plaster casts could be made as secondary standards.
  - (b) If any person's foot were to be used as a standard, "standard" would vary significantly depending on the person whose foot happened to be used most recently for a measurement. The standard would be very accessible, because wherever a measurement was needed, it would be very easy to find someone with feet. The standard would be extremely variable – perhaps by a factor of 2. That also renders the standard as not reproducible, because there could be many reproductions that were quite different from each other. The standard would be almost indestructible in that there is essentially a limitless supply of feet to be used.
2. There are various ways to alter the signs. The number of meters could be expressed in one significant figure, as "900 m (3000 ft)". Or, the number of feet could be expressed with the same precision as the number of meters, as "914 m (2999 ft)". The signs could also be moved to different locations, where the number of meters was more exact. For example, if a sign was placed where the elevation was really 1000 m to the nearest meter, then the sign could read "1000 m (3280 ft)".
3. Including more digits in an answer does not necessarily increase its accuracy. The accuracy of an answer is determined by the accuracy of the physical measurement on which the answer is based. If you draw a circle, measure its diameter to be 168 mm and its circumference to be 527 mm, their quotient, representing  $\pi$ , is 3.136904762. The last seven digits are meaningless – they imply a greater accuracy than is possible with the measurements.
4. The problem is that the precision of the two measurements are quite different. It would be more appropriate to give the metric distance as 11 km, so that the numbers are given to about the same precision (nearest mile or nearest km).
5. A measurement must be measured against a scale, and the units provide that scale. Units must be specified or the answer is meaningless – the answer could mean a variety of quantities, and could be interpreted in a variety of ways. Some units are understood, such as when you ask someone how old they are. You assume their answer is in years. But if you ask someone how long it will be until they are done with their task, and they answer "five", does that mean five minutes or five hours or five days? If you are in an international airport, and you ask the price of some object, what does the answer "ten" mean? Ten dollars, or ten pounds, or ten marks, or ten euros?
6. If the jar is rectangular, for example, you could count the number of marbles along each dimension, and then multiply those three numbers together for an estimate of the total number of marbles. If the jar is cylindrical, you could count the marbles in one cross section, and then multiply by the number of layers of marbles. Another approach would be to estimate the volume of one marble. If we assume that the marbles are stacked such that their centers are all on vertical and horizontal lines, then each marble would require a cube of edge  $2R$ , or a volume of  $8R^3$ , where  $R$  is the radius of a marble. The number of marbles would then be the volume of the container divided by  $8R^3$ .

7. The result should be written as 8.32 cm. The factor of 2 used to convert radius to diameter is exact – it has no uncertainty, and so does not change the number of significant figures.
8.  $\sin 30.0^\circ = 0.500$
9. Since the size of large eggs can vary by 10%, the random large egg used in a recipe has a size with an uncertainty of about  $\pm 5\%$ . Thus the amount of the other ingredients can also vary by about  $\pm 5\%$  and not adversely affect the recipe.
10. In estimating the number of car mechanics, the assumptions and estimates needed are:  
 the population of the city  
 the number of cars per person in the city  
 the number of cars that a mechanic can repair in a day  
 the number of days that a mechanic works in a year  
 the number of times that a car is taken to a mechanic, per year

We estimate that there is 1 car for every 2 people, that a mechanic can repair 3 cars per day, that a mechanic works 250 days a year, and that a car needs to be repaired twice per year.

- (a) For San Francisco, we estimate the population at one million people. The number of mechanics is found by the following calculation.

$$(1 \times 10^6 \text{ people}) \left( \frac{1 \text{ car}}{2 \text{ people}} \right) \left( \frac{2 \frac{\text{repairs}}{\text{year}}}{1 \text{ car}} \right) \left( \frac{1 \text{ yr}}{250 \text{ workdays}} \right) \left( \frac{1 \text{ mechanic}}{3 \frac{\text{repairs}}{\text{workday}}} \right) = \boxed{1300 \text{ mechanics}}$$

- (b) For Upland, Indiana, the population is about 4000. The number of mechanics is found by a similar calculation, and would be  $\boxed{5 \text{ mechanics}}$ . There are actually two repair shops in Upland, employing a total of 6 mechanics.

## Solutions to Problems

1. (a) 14 billion years =  $\boxed{1.4 \times 10^{10} \text{ years}}$   
 (b)  $(1.4 \times 10^{10} \text{ y})(3.156 \times 10^7 \text{ s/1 y}) = \boxed{4.4 \times 10^{17} \text{ s}}$
2. (a) 214  $\boxed{3 \text{ significant figures}}$   
 (b) 81.60  $\boxed{4 \text{ significant figures}}$   
 (c) 7.03  $\boxed{3 \text{ significant figures}}$   
 (d) 0.03  $\boxed{1 \text{ significant figure}}$   
 (e) 0.0086  $\boxed{2 \text{ significant figures}}$   
 (f) 3236  $\boxed{4 \text{ significant figures}}$   
 (g) 8700  $\boxed{2 \text{ significant figures}}$

3. (a)  $1.156 = 1.156 \times 10^0$

(b)  $21.8 = 2.18 \times 10^1$

(c)  $0.0068 = 6.8 \times 10^{-3}$

(d)  $27.635 = 2.7635 \times 10^1$

(e)  $0.219 = 2.19 \times 10^{-1}$

(f)  $444 = 4.44 \times 10^2$

4. (a)  $8.69 \times 10^4 = 86,900$

(b)  $9.1 \times 10^3 = 9,100$

(c)  $8.8 \times 10^{-1} = 0.88$

(d)  $4.76 \times 10^2 = 476$

(e)  $3.62 \times 10^{-5} = 0.0000362$

5. The uncertainty is taken to be 0.01 m.

$$\% \text{ uncertainty} = \frac{0.01 \text{ m}}{1.57 \text{ m}} \times 100\% = 1\%$$

$$6. \quad \% \text{ uncertainty} = \frac{0.25 \text{ m}}{3.76 \text{ m}} \times 100\% = 6.6\%$$

7. (a)  $\% \text{ uncertainty} = \frac{0.2 \text{ s}}{5 \text{ s}} \times 100\% = 4\%$

(b)  $\% \text{ uncertainty} = \frac{0.2 \text{ s}}{50 \text{ s}} \times 100\% = 0.4\%$

(c)  $\% \text{ uncertainty} = \frac{0.2 \text{ s}}{300 \text{ s}} \times 100\% = 0.07\%$

8. To add values with significant figures, adjust all values to be added so that their exponents are all the same.

$$9.2 \times 10^3 \text{ s} + 8.3 \times 10^4 \text{ s} + 0.008 \times 10^6 \text{ s} = 9.2 \times 10^3 \text{ s} + 83 \times 10^3 \text{ s} + 8 \times 10^3 \text{ s} = (9.2 + 83 + 8) \times 10^3 \text{ s}$$

$$= 100 \times 10^3 \text{ s} = 1.00 \times 10^5 \text{ s}$$

When adding, keep the least accurate value, and so keep to the “ones” place in the parentheses.

9.  $(2.079 \times 10^2 \text{ m})(0.082 \times 10^{-1}) = 1.7 \text{ m}$ . When multiplying, the result should have as many digits as the number with the least number of significant digits used in the calculation.10. To find the approximate uncertainty in the area, calculate the area for the specified radius, the minimum radius, and the maximum radius. Subtract the extreme areas. The uncertainty in the area is then half this variation in area. The uncertainty in the radius is assumed to be  $0.1 \times 10^4 \text{ cm}$ .



$$A_{\text{specified}} = \pi r_{\text{specified}}^2 = \pi (3.8 \times 10^4 \text{ cm})^2 = 4.5 \times 10^9 \text{ cm}^2$$

$$A_{\text{min}} = \pi r_{\text{min}}^2 = \pi (3.7 \times 10^4 \text{ cm})^2 = 4.30 \times 10^9 \text{ cm}^2$$

$$A_{\text{max}} = \pi r_{\text{max}}^2 = \pi (3.9 \times 10^4 \text{ cm})^2 = 4.78 \times 10^9 \text{ cm}^2$$

$$\Delta A = \frac{1}{2}(A_{\text{max}} - A_{\text{min}}) = \frac{1}{2}(4.78 \times 10^9 \text{ cm}^2 - 4.30 \times 10^9 \text{ cm}^2) = 0.24 \times 10^9 \text{ cm}^2$$

Thus the area should be quoted as  $A = (4.5 \pm 0.2) \times 10^9 \text{ cm}^2$

11. To find the approximate uncertainty in the volume, calculate the volume for the specified radius, the minimum radius, and the maximum radius. Subtract the extreme volumes. The uncertainty in the volume is then half this variation in volume.

$$V_{\text{specified}} = \frac{4}{3}\pi r_{\text{specified}}^3 = \frac{4}{3}\pi (2.86 \text{ m})^3 = 9.80 \times 10^1 \text{ m}^3$$

$$V_{\text{min}} = \frac{4}{3}\pi r_{\text{min}}^3 = \frac{4}{3}\pi (2.77 \text{ m})^3 = 8.903 \times 10^1 \text{ m}^3$$

$$V_{\text{max}} = \frac{4}{3}\pi r_{\text{max}}^3 = \frac{4}{3}\pi (2.95 \text{ m})^3 = 10.754 \times 10^1 \text{ m}^3$$

$$\Delta V = \frac{1}{2}(V_{\text{max}} - V_{\text{min}}) = \frac{1}{2}(10.754 \times 10^1 \text{ m}^3 - 8.903 \times 10^1 \text{ m}^3) = 0.926 \times 10^1 \text{ m}^3$$

The percent uncertainty is  $\frac{\Delta V}{V_{\text{specified}}} = \frac{0.923 \times 10^1 \text{ m}^3}{9.80 \times 10^1 \text{ m}^3} \times 100 = 0.09444 = 9\%$

12. (a) 286.6 mm       $286.6 \times 10^{-3} \text{ m}$        $0.286 \text{ 6 m}$   
 (b) 85  $\mu\text{V}$        $85 \times 10^{-6} \text{ V}$        $0.000 \text{ 085 V}$   
 (c) 760 mg       $760 \times 10^{-6} \text{ kg}$        $0.000 \text{ 760 kg}$  (if last zero is significant)  
 (d) 60.0 ps       $60.0 \times 10^{-12} \text{ s}$        $0.000 \text{ 000 000 0600 s}$   
 (e) 22.5 fm       $22.5 \times 10^{-15} \text{ m}$        $0.000 \text{ 000 000 000 022 5 m}$   
 (f) 2.50 gigavolts       $2.5 \times 10^9 \text{ volts}$        $2,500,000,000 \text{ volts}$

13. (a)  $1 \times 10^6 \text{ volts}$        $1 \text{ megavolt} = 1 \text{ Mvolt}$   
 (b)  $2 \times 10^{-6} \text{ meters}$        $2 \text{ micrometers} = 2 \mu\text{m}$   
 (c)  $6 \times 10^3 \text{ days}$        $6 \text{ kilodays} = 6 \text{ kdays}$   
 (d)  $18 \times 10^2 \text{ bucks}$        $18 \text{ hectobucks} = 18 \text{ hbucks}$   
 (e)  $8 \times 10^{-9} \text{ pieces}$        $8 \text{ nanopieces} = 8 \text{ npieces}$

14. (a) Assuming a height of 5 feet 10 inches, then  $5'10" = (70 \text{ in})(1 \text{ m}/39.37 \text{ in}) = 1.8 \text{ m}$   
 (b) Assuming a weight of 165 lbs, then  $(165 \text{ lbs})(0.456 \text{ kg}/1 \text{ lb}) = 75.2 \text{ kg}$

Technically, pounds and mass measure two separate properties. To make this conversion, we have to assume that we are at a location where the acceleration due to gravity is  $9.8 \text{ m/s}^2$ .

15. (a)  $93 \text{ million miles} = (93 \times 10^6 \text{ miles})(1610 \text{ m/1 mile}) = \boxed{1.5 \times 10^{11} \text{ m}}$

(b)  $1.5 \times 10^{11} \text{ m} = 150 \times 10^9 \text{ m} = \boxed{150 \text{ gigameters}}$  or  $1.5 \times 10^{11} \text{ m} = 0.15 \times 10^{12} \text{ m} = \boxed{0.15 \text{ terameters}}$

16. (a)  $1 \text{ ft}^2 = (1 \text{ ft}^2)(1 \text{ yd}/3 \text{ ft})^2 = \boxed{0.111 \text{ yd}^2}$

(b)  $1 \text{ m}^2 = (1 \text{ m}^2)(3.28 \text{ ft}/1 \text{ m})^2 = \boxed{10.8 \text{ ft}^2}$

17. Use the speed of the airplane to convert the travel distance into a time.

$$1.00 \text{ km} \left( \frac{1 \text{ h}}{950 \text{ km}} \right) \left( \frac{3600 \text{ s}}{1 \text{ h}} \right) = \boxed{3.8 \text{ s}}$$

18. (a)  $1.0 \times 10^{-10} \text{ m} = (1.0 \times 10^{-10} \text{ m})(39.37 \text{ in}/1 \text{ m}) = \boxed{3.9 \times 10^{-9} \text{ in}}$

(b)  $(1.0 \text{ cm}) \left( \frac{1 \text{ m}}{100 \text{ cm}} \right) \left( \frac{1 \text{ atom}}{1.0 \times 10^{-10} \text{ m}} \right) = \boxed{1.0 \times 10^8 \text{ atoms}}$

19. To add values with significant figures, adjust all values to be added so that their units are all the same.

$$1.80 \text{ m} + 142.5 \text{ cm} + 5.34 \times 10^5 \mu\text{m} = 1.80 \text{ m} + 1.425 \text{ m} + 0.534 \text{ m} = 3.759 \text{ m} = \boxed{3.76 \text{ m}}$$

When adding, the final result is to be no more accurate than the least accurate number used. In this case, that is the first measurement, which is accurate to the hundredths place.

20. (a)  $(1 \text{ k/h}) \left( \frac{0.621 \text{ mi}}{1 \text{ km}} \right) = \boxed{0.621 \text{ mi/h}}$

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

(c)  $(1 \text{ km/h}) \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) = \boxed{0.278 \text{ m/s}}$

21. One mile is  $1.61 \times 10^3 \text{ m}$ . It is 110 m longer than a 1500-m race. The percentage difference is

$$\frac{110 \text{ m}}{1500 \text{ m}} \times 100\% = \boxed{7.3\%}$$

22. (a)  $1.00 \text{ ly} = (2.998 \times 10^8 \text{ m/s})(3.156 \times 10^7 \text{ s}) = \boxed{9.46 \times 10^{15} \text{ m}}$

(b)  $(1.00 \text{ ly}) \left( \frac{9.462 \times 10^{15} \text{ m}}{1.00 \text{ ly}} \right) \left( \frac{1 \text{ AU}}{1.50 \times 10^{11} \text{ m}} \right) = \boxed{6.31 \times 10^4 \text{ AU}}$

(c)  $(2.998 \times 10^8 \text{ m/s}) \left( \frac{1 \text{ AU}}{1.50 \times 10^{11} \text{ m}} \right) \left( \frac{3600 \text{ s}}{1 \text{ hr}} \right) = \boxed{7.20 \text{ AU/hr}}$

23. The surface area of a sphere is found by  $A = 4\pi r^2 = 4\pi (d/2)^2 = \pi d^2$ .

$$(a) \quad A_{\text{Moon}} = \pi D_{\text{Moon}}^2 = \pi (3.48 \times 10^6 \text{ m})^2 = \boxed{3.80 \times 10^{13} \text{ m}^2}$$

$$(b) \quad \frac{A_{\text{Earth}}}{A_{\text{Moon}}} = \frac{\pi D_{\text{Earth}}^2}{\pi D_{\text{Moon}}^2} = \left( \frac{D_{\text{Earth}}}{D_{\text{Moon}}} \right)^2 = \left( \frac{R_{\text{Earth}}}{R_{\text{Moon}}} \right)^2 = \left( \frac{6.38 \times 10^6 \text{ m}}{1.74 \times 10^6 \text{ m}} \right)^2 = \boxed{13.4}$$

$$24. (a) \quad 2800 = 2.8 \times 10^3 \approx 1 \times 10^3 = \boxed{10^3}$$

$$(b) \quad 86.30 \times 10^2 = 8.630 \times 10^3 \approx 10 \times 10^3 = \boxed{10^4}$$

$$(c) \quad 0.0076 = 7.6 \times 10^{-3} \approx 10 \times 10^{-3} = \boxed{10^{-2}}$$

$$(d) \quad 15.0 \times 10^8 = 1.5 \times 10^9 \approx 1 \times 10^9 = \boxed{10^9}$$

25. The textbook is approximately 20 cm deep and 4 cm wide. With books on both sides of a shelf, with a little extra space, the shelf would need to be about 50 cm deep. If the aisle is 1.5 meter wide, then about 1/4 of the floor space is covered by shelving. The number of books on a single shelf level is then  $\frac{1}{4}(3500 \text{ m}^2) \left( \frac{1 \text{ book}}{(0.25 \text{ m})(0.04 \text{ m})} \right) = 8.75 \times 10^4 \text{ books}$ . With 8 shelves of books, the total number of books stored is as follows.

$$\left( 8.75 \times 10^4 \frac{\text{books}}{\text{shelf level}} \right) (8 \text{ shelves}) \approx \boxed{7 \times 10^5 \text{ books}}$$

26. The distance across the United States is about 3000 miles.

$$(3000 \text{ mi})(1 \text{ km}/0.621 \text{ mi})(1 \text{ hr}/10 \text{ km}) \approx \boxed{500 \text{ hr}}$$

Of course, it would take more time on the clock for the runner to run across the U.S. The runner could obviously not run for 500 hours non-stop. If they could run for 5 hours a day, then it would take about 100 days for them to cross the country.

27. An NCAA-regulation football field is 360 feet long (including the end zones) and 160 feet wide, which is about 110 meters by 50 meters, or  $5,500 \text{ m}^2$ . The mower has a cutting width of 0.5 meters. Thus the distance to be walked is

$$d = \frac{\text{Area}}{\text{width}} = \frac{5500 \text{ m}^2}{0.5 \text{ m}} = 11000 \text{ m} = 11 \text{ km}$$

At a speed of 1 km/hr, then it will take about  $\boxed{11 \text{ h}}$  to mow the field.

28. A commonly accepted measure is that a person should drink eight 8-oz. glasses of water each day. That is about 2 quarts, or 2 liters of water per day. Then approximate the lifetime as 70 years.

$$(70 \text{ y})(365 \text{ d}/1 \text{ y})(2 \text{ L}/1 \text{ d}) \approx \boxed{5 \times 10^4 \text{ L}}$$

29. Consider the body to be a cylinder, about 170 cm tall, and about 12 cm in cross-sectional radius (a 30-inch waist). The volume of a cylinder is given by the area of the cross section times the height.

$$V = \pi r^2 h = \pi (12 \text{ cm})^2 (170 \text{ cm}) = 9 \times 10^4 \text{ cm}^3 \approx \boxed{8 \times 10^4 \text{ cm}^3}$$

30. Estimate one side of a house to be about 40 feet long, and about 10 feet high. Then the wall area of that particular wall is  $400 \text{ ft}^2$ . There would perhaps be 4 windows in that wall, each about 3 ft wide and 4 feet tall, so  $12 \text{ ft}^2$  per window, or about  $50 \text{ ft}^2$  of window per wall. Thus the percentage of wall area that is window area is  $\frac{50 \text{ ft}^2}{400 \text{ ft}^2} \times 100 = 12.5\%$ . Thus a rough estimate would be  $\boxed{10\% - 15\%}$  of the house's outside wall area.

31. Assume that the tires last for 5 years, and so there is a tread wearing of  $0.2 \text{ cm/year}$ . Assume the average tire has a radius of  $40 \text{ cm}$ , and a width of  $10 \text{ cm}$ . Thus the volume of rubber that is becoming pollution each year from one tire is the surface area of the tire, times the thickness per year that is wearing. Also assume that there are  $150,000,000$  automobiles in the country – approximately one automobile for every two people. So the mass wear per year is given by

$$\begin{aligned} \left( \frac{\text{Mass}}{\text{year}} \right) &= \left( \frac{\text{Surface area}}{\text{tire}} \right) \left( \frac{\text{Thickness wear}}{\text{year}} \right) (\text{density of rubber}) (\# \text{ of tires}) \\ &= [2\pi(0.4 \text{ m})(0.1 \text{ m})](0.002 \text{ m/y})(1200 \text{ kg/m}^3)(600,000,000 \text{ tires}) \\ &= \boxed{4 \times 10^8 \text{ kg/y}} \end{aligned}$$

32. For the equation  $v = At^3 - Bt$ , the units of  $At^3$  must be the same as the units of  $v$ . So the units of  $A$  must be the same as the units of  $v/t^3$ , which would be  $\boxed{\text{distance/time}^4}$ . Also, the units of  $Bt$  must be the same as the units of  $v$ . So the units of  $B$  must be the same as the units of  $v/t$ , which would be  $\boxed{\text{distance/time}^2}$ .

33. (a) The quantity  $vt^2$  has units of  $(\text{m/s})(\text{s}^2) = \text{m} \cdot \text{s}$ , which do not match with the units of meters for  $x$ . The quantity  $2at$  has units  $(\text{m/s}^2)(\text{s}) = \text{m/s}$ , which also do not match with the units of meters for  $x$ . Thus this equation  $\boxed{\text{cannot be correct}}$ .
- (b) The quantity  $v_0t$  has units of  $(\text{m/s})(\text{s}) = \text{m}$ , and  $\frac{1}{2}at^2$  has units of  $(\text{m/s}^2)(\text{s}^2) = \text{m}$ . Thus, since each term has units of meters, this equation  $\boxed{\text{can be correct}}$ .
- (c) The quantity  $v_0t$  has units of  $(\text{m/s})(\text{s}) = \text{m}$ , and  $2at^2$  has units of  $(\text{m/s}^2)(\text{s}^2) = \text{m}$ . Thus, since each term has units of meters, this equation  $\boxed{\text{can be correct}}$ .

34. The percentage accuracy is  $\frac{2 \text{ m}}{2 \times 10^7 \text{ m}} \times 100\% = \boxed{1 \times 10^{-5}\%}$ . The distance of  $20,000,000 \text{ m}$  needs to be distinguishable from  $20,000,002 \text{ m}$ , which means that  $\boxed{8 \text{ significant figures}}$  are needed in the distance measurements.

35. Multiply the number of chips per wafer times the number of wafers that can be made from a cylinder.

$$\left( 100 \frac{\text{chips}}{\text{wafer}} \right) \left( \frac{1 \text{ wafer}}{0.60 \text{ mm}} \right) \left( \frac{300 \text{ mm}}{1 \text{ cylinder}} \right) = \boxed{50,000 \frac{\text{chips}}{\text{cylinder}}}$$

36. (a) # of seconds in 1.00 y:  $1.00 \text{ y} = (1.00 \text{ y}) \left( \frac{3.156 \times 10^7 \text{ s}}{1 \text{ y}} \right) = \boxed{3.16 \times 10^7 \text{ s}}$
- (b) # of nanoseconds in 1.00 y:  $1.00 \text{ y} = (1.00 \text{ y}) \left( \frac{3.156 \times 10^7 \text{ s}}{1 \text{ y}} \right) \left( \frac{1 \times 10^9 \text{ ns}}{1 \text{ s}} \right) = \boxed{3.16 \times 10^{16} \text{ ns}}$
- (c) # of years in 1.00 s:  $1.00 \text{ s} = (1.00 \text{ s}) \left( \frac{1 \text{ y}}{3.156 \times 10^7 \text{ s}} \right) = \boxed{3.17 \times 10^{-8} \text{ y}}$

37. Assume that the alveoli are spherical, and that the volume of a typical human lung is about 2 liters, which is  $.002 \text{ m}^3$ . The diameter can be found from the volume of a sphere,  $\frac{4}{3}\pi r^3$ .

$$\frac{4}{3}\pi r^3 = \frac{4}{3}\pi (d/2)^3 = \frac{\pi d^3}{6}$$

$$(3 \times 10^8) \pi \frac{d^3}{6} = 2 \times 10^{-3} \text{ m}^3 \rightarrow d = \left[ \frac{6(2 \times 10^{-3})}{3 \times 10^8 \pi} \text{ m}^3 \right]^{1/3} = \boxed{2 \times 10^{-4} \text{ m}}$$

38. 1 hectare = (1 hectare)  $\left( \frac{10^4 \text{ m}^2}{1 \text{ hectare}} \right) \left( \frac{3.28 \text{ ft}}{1 \text{ m}} \right)^2 \left( \frac{1 \text{ acre}}{4 \times 10^4 \text{ ft}^2} \right) = \boxed{2.69 \text{ acres}}$

39. (a)  $\left( \frac{10^{-15} \text{ kg}}{1 \text{ bacterium}} \right) \left( \frac{1 \text{ proton or neutron}}{10^{-27} \text{ kg}} \right) = \boxed{10^{12} \text{ protons or neutrons}}$
- (b)  $\left( \frac{10^{-17} \text{ kg}}{1 \text{ DNA molecule}} \right) \left( \frac{1 \text{ proton or neutron}}{10^{-27} \text{ kg}} \right) = \boxed{10^{10} \text{ protons or neutrons}}$
- (c)  $\left( \frac{10^2 \text{ kg}}{1 \text{ human}} \right) \left( \frac{1 \text{ proton or neutron}}{10^{-27} \text{ kg}} \right) = \boxed{10^{29} \text{ protons or neutrons}}$
- (d)  $\left( \frac{10^{41} \text{ kg}}{1 \text{ galaxy}} \right) \left( \frac{1 \text{ proton or neutron}}{10^{-27} \text{ kg}} \right) = \boxed{10^{68} \text{ protons or neutrons}}$

40. There are about 300,000,000 people in the United States. Assume that half of them have cars, that they each drive 12,000 miles per year, and their cars get 20 miles per gallon of gasoline.

$$(3 \times 10^8 \text{ people}) \left( \frac{1 \text{ automobile}}{2 \text{ people}} \right) \left( \frac{12,000 \text{ mi}}{1 \text{ y}} \right) \left( \frac{1 \text{ gallon}}{20 \text{ mi}} \right) \approx \boxed{1 \times 10^{11} \text{ gallons/y}}$$

41. Approximate the gumball machine as a rectangular box with a square cross-sectional area. In counting gumballs across the bottom, there are about 10 in a row. Thus we estimate that one layer contains about 100 gumballs. In counting vertically, we see that there are about 15 rows. Thus we estimate that there are about  $\boxed{1500 \text{ gumballs}}$  in the machine.

42. The volume of water used by the people can be calculated as follows:

$$(4 \times 10^4 \text{ people}) \left( \frac{1200 \text{ L/day}}{4 \text{ people}} \right) \left( \frac{365 \text{ day}}{1 \text{ y}} \right) \left( \frac{1000 \text{ cm}^3}{1 \text{ L}} \right) \left( \frac{1 \text{ km}}{10^5 \text{ cm}} \right)^3 = 4.4 \times 10^{-3} \text{ km}^3/\text{y}$$

The depth of water is found by dividing the volume by the area.

$$d = \frac{V}{A} = \frac{4.4 \times 10^{-3} \text{ km}^3/\text{y}}{50 \text{ km}^2} = \left( 8.76 \times 10^{-5} \frac{\text{km}}{\text{y}} \right) \left( \frac{10^5 \text{ cm}}{1 \text{ km}} \right) = 8.76 \text{ cm/y} \approx \boxed{9 \text{ cm/y}}$$

43. The volume of a sphere is given by  $V = \frac{4}{3}\pi r^3$ . For our 1-ton rock, we can calculate the volume to be

$$V = (1 \text{ T}) \left( \frac{2000 \text{ lb}}{1 \text{ T}} \right) \left( \frac{1 \text{ ft}^3}{186 \text{ lb}} \right) = 10.8 \text{ ft}^3.$$

Then the radius is found by

$$d = 2r = 2 \left( \frac{3V}{4\pi} \right)^{1/3} = 2 \left[ \frac{3(10.8 \text{ ft}^3)}{4\pi} \right]^{1/3} = 2.74 \text{ ft} \approx \boxed{3 \text{ ft}}$$

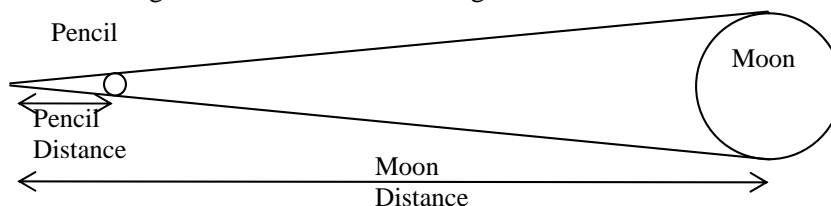
44. To calculate the mass of water, we need to find the volume of water, and then convert the volume to mass.

$$\left[ (4 \times 10^1 \text{ km}^2) \left( \frac{10^5 \text{ cm}}{1 \text{ km}} \right)^2 \right] (1.0 \text{ cm}) \left( \frac{10^{-3} \text{ kg}}{1 \text{ cm}^3} \right) \left( \frac{1 \text{ ton}}{10^3 \text{ kg}} \right) = \boxed{4 \times 10^5 \text{ ton}}$$

To find the number of gallons, convert the volume to gallons.

$$\left[ (4 \times 10^1 \text{ km}^2) \left( \frac{10^5 \text{ cm}}{1 \text{ km}} \right)^2 \right] (1.0 \text{ cm}) \left( \frac{1 \text{ L}}{1 \times 10^3 \text{ cm}^3} \right) \left( \frac{1 \text{ gal}}{3.78 \text{ L}} \right) = \boxed{1 \times 10^8 \text{ gal}}$$

45. A pencil has a diameter of about 0.7 cm. If held about 0.75 m from the eye, it can just block out the Moon. The ratio of pencil diameter to arm length is the same as the ratio of Moon diameter to Moon distance. From the diagram, we have the following ratios.



$$\frac{\text{Pencil diameter}}{\text{Pencil distance}} = \frac{\text{Moon diameter}}{\text{Moon distance}} \rightarrow$$

$$\text{Moon diameter} = \frac{\text{pencil diameter}}{\text{pencil distance}} (\text{Moon distance}) = \frac{7 \times 10^{-3} \text{ m}}{0.75 \text{ m}} (3.8 \times 10^5 \text{ km}) \approx \boxed{3500 \text{ km}}$$

46. The person walks 4 km/h, 10 hours each day. The radius of the Earth is about 6380 km, and the distance around the world at the equator is the circumference,  $2\pi R_{\text{Earth}}$ . We assume that the person can “walk on water”, and so ignore the existence of the oceans.

$$2\pi (6380 \text{ km}) \left( \frac{1 \text{ h}}{4 \text{ km}} \right) \left( \frac{1 \text{ d}}{10 \text{ h}} \right) = \boxed{1 \times 10^3 \text{ d}}$$

47. A cubit is about a half of a meter, by measuring several people's forearms. Thus the dimensions of Noah's ark would be  $\boxed{150 \text{ m long, 25 m wide, 15 m high}}$ . The volume of the ark is found by multiplying the three dimensions.

$$V = (150 \text{ m})(25 \text{ m})(15 \text{ m}) = 5.625 \times 10^4 \text{ m}^3 \approx \boxed{6 \times 10^4 \text{ m}^3}$$

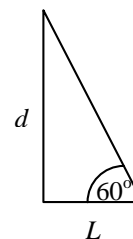
48. The volume of the oil will be the area times the thickness. The area is  $\pi r^2 = \pi (d/2)^2$ , and so

$$V = \pi (d/2)^2 t \rightarrow d = 2\sqrt{\frac{V}{\pi t}} = 2\sqrt{\frac{1000 \text{ cm}^3 \left(\frac{1 \text{ m}}{100 \text{ cm}}\right)^3}{\pi (2 \times 10^{-10} \text{ m})}} = \boxed{3 \times 10^3 \text{ m}}$$

49. Consider the diagram shown.  $L$  is the distance she walks upstream, which is about 120 yards. Find the distance across the river from the diagram.

$$\tan 60^\circ = \frac{d}{L} \rightarrow d = L \tan 60^\circ = (120 \text{ yd}) \tan 60^\circ = \boxed{210 \text{ yd}}$$

$$(210 \text{ yd}) \left(\frac{3 \text{ ft}}{1 \text{ yd}}\right) \left(\frac{0.305 \text{ m}}{1 \text{ ft}}\right) = \boxed{190 \text{ m}}$$



50.  $\left(\frac{8 \text{ s}}{1 \text{ y}}\right) \left(\frac{1 \text{ y}}{3.156 \times 10^7 \text{ s}}\right) \times 100\% = \boxed{3 \times 10^{-5}\%}$

- 51.** The volume of a sphere is found by  $V = \frac{4}{3} \pi r^3$ .

$$V_{\text{Moon}} = \frac{4}{3} \pi R_{\text{Moon}}^3 = \frac{4}{3} \pi (1.74 \times 10^6 \text{ m})^3 = \boxed{2.21 \times 10^{19} \text{ m}^3}$$

$$\frac{V_{\text{Earth}}}{V_{\text{Moon}}} = \frac{\frac{4}{3} \pi R_{\text{Earth}}^3}{\frac{4}{3} \pi R_{\text{Moon}}^3} = \left(\frac{R_{\text{Earth}}}{R_{\text{Moon}}}\right)^3 = \left(\frac{6.38 \times 10^6 \text{ m}}{1.74 \times 10^6 \text{ m}}\right)^3 = 49.3.$$

Thus it would take about  $\boxed{49.3}$  Moons to create a volume equal to that of the Earth.

52. (a)  $1.0 \overset{\circ}{\text{A}} = (1.0 \overset{\circ}{\text{A}}) \left(\frac{10^{-10} \text{ m}}{1 \overset{\circ}{\text{A}}}\right) \left(\frac{1 \text{ nm}}{10^{-9} \text{ m}}\right) = \boxed{0.10 \text{ nm}}$

(b)  $1.0 \overset{\circ}{\text{A}} = (1.0 \overset{\circ}{\text{A}}) \left(\frac{10^{-10} \text{ m}}{1 \overset{\circ}{\text{A}}}\right) \left(\frac{1 \text{ fm}}{10^{-15} \text{ m}}\right) = \boxed{1.0 \times 10^5 \text{ fm}}$

(c)  $1.0 \text{ m} = (1.0 \text{ m}) \left(\frac{1 \overset{\circ}{\text{A}}}{10^{-10} \text{ m}}\right) = \boxed{1.0 \times 10^{10} \overset{\circ}{\text{A}}}$

(d)  $1.0 \text{ ly} = (1.0 \text{ ly}) \left(\frac{9.46 \times 10^{15} \text{ m}}{1 \text{ ly}}\right) \left(\frac{1 \overset{\circ}{\text{A}}}{10^{-10} \text{ m}}\right) = \boxed{9.5 \times 10^{25} \overset{\circ}{\text{A}}}$

53. (a) Note that  $\sin 15.0^\circ = 0.259$  and  $\sin 15.5^\circ = 0.267$ .

$$\left(\frac{\Delta\theta}{\theta}\right)100 = \left(\frac{0.5^\circ}{15.0^\circ}\right)100 = \boxed{3\%} \qquad \left(\frac{\Delta \sin \theta}{\sin \theta}\right)100 = \left(\frac{8 \times 10^{-3}}{0.259}\right)100 = \boxed{3\%}$$

- (b) Note that  $\sin 75.0^\circ = 0.966$  and  $\sin 75.5^\circ = 0.968$ .

$$\left(\frac{\Delta\theta}{\theta}\right)100 = \left(\frac{0.5^\circ}{75.0^\circ}\right)100 = \boxed{0.7\%} \qquad \left(\frac{\Delta \sin \theta}{\sin \theta}\right)100 = \left(\frac{2 \times 10^{-3}}{0.966}\right)100 = \boxed{0.2\%}$$

A consequence of this result is that when using a protractor, and you have a fixed uncertainty in the angle ( $\pm 0.5^\circ$  in this case), you should measure the angles from a reference line that gives a large angle measurement rather than a small one. Note above that the angles around  $75^\circ$  had only a 0.2% error in  $\sin \theta$ , while the angles around  $15^\circ$  had a 3% error in  $\sin \theta$ .

54. Utilize the fact that walking totally around the Earth along the meridian would trace out a circle whose full  $360^\circ$  would equal the circumference of the Earth.

$$(1 \text{ minute}) \left(\frac{1^\circ}{60 \text{ minute}}\right) \left(\frac{2\pi(6.38 \times 10^3 \text{ km})}{360^\circ}\right) \left(\frac{0.621 \text{ m}}{1 \text{ km}}\right) = \boxed{1.15 \text{ mi}}$$

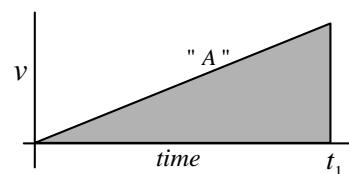


## CHAPTER 2: Describing Motion: Kinematics in One Dimension

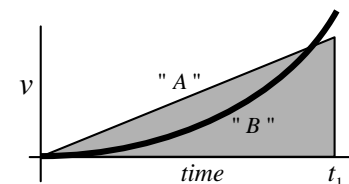
### Answers to Questions

1. A car speedometer measures only speed. It does not give any information about the direction, and so does not measure velocity.
2. By definition, if an object has a constant velocity, then both the object's speed and its direction of motion are constant. Therefore the object CANNOT have a varying speed if its velocity is constant.
3. When an object moves with constant velocity, its average velocity over any time interval is exactly equal to its instantaneous velocity at all times

4. For both cars, the time elapsed is the distance traveled divided by the average velocity. Since both cars travel the same distance, the car with the larger average velocity will have the smaller elapsed time. Consider this scenario. Assume that one car has a constant acceleration down the track. Then a graph of its speed versus time would look like line "A" on the first graph. The shaded area of the graph represents the distance traveled, and the graph is plotted to such a time that the shaded area represents the length of the track. The time for this car to finish the race is labeled " $t_1$ ".

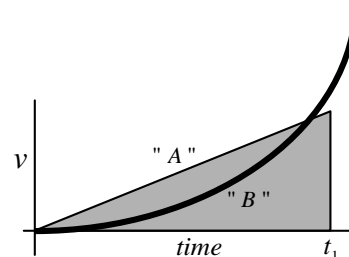


Now let the second car have a much smaller acceleration initially, but with an increasing acceleration. A graph of its velocity, superimposed on the above graph and labeled "B", might look like the second diagram.



It is seen that at the time  $t_1$  when the first car finished the race, the second car is going faster than the first car, because the heavy line is "higher" on the graph than the line representing the first car.

However, the area under the "B" line (the distance that the second car has traveled) is smaller than the shaded area, and so is less than the full track length. For the area under the "B" line to be the same as the area under the "A" line, the graph would need to look like the third diagram, indicating a longer time for the second car to finish the race.



5. There is no general relationship between the magnitude of speed and the magnitude of acceleration. For example, one object may have a large but constant speed. The acceleration of that object is then 0. Another object may have a small speed but be gaining speed, and therefore have a positive acceleration. So in this case the object with the greater speed has the lesser acceleration.

Or consider two objects that are dropped from rest at different times. If we ignore air resistance, then the object dropped first will always have a greater speed than the object dropped second, but both will have the same acceleration of  $9.80 \text{ m/s}^2$ .

6. The acceleration of both the motorcycle and the bicycle are the same, since the same change in velocity occurred during the same time interval.

If you do a further calculation, you will find that the distance traveled by the motorcycle during the acceleration is 17 times the distance traveled by the bicycle.

7. If an object is traveling to the north but slowing down, it has a northward velocity and a southward acceleration.
8. The velocity of an object can be negative when its acceleration is positive. If we define the positive direction to be to the right, then an object traveling to the left that is having a reduction in speed will have a negative velocity with a positive acceleration.
- If again we define the positive direction to be to the right, then an object traveling to the right that is having a reduction in speed will have a positive velocity and a negative acceleration.
9. If north is defined as the positive direction, then an object traveling to the south and increasing in speed has both a negative velocity and a negative acceleration. Or, if up is defined as the positive direction, then an object falling due to gravity has both a negative velocity and a negative acceleration.
10. If the two cars emerge side by side, then the one moving faster is passing the other one. Thus car A is passing car B. With the acceleration data given for the problem, the ensuing motion would be that car A would pull away from car B for a time, but eventually car B would catch up to and pass car A.
11. Assume that north is the positive direction. If a car is moving south and gaining speed at an increasing rate, then the acceleration will be getting larger in magnitude. However, since the acceleration is directed southwards, the acceleration is negative, and is getting more negative. That is a decreasing acceleration as the speed increases.
- Another example would be an object falling WITH air resistance. As the object falls, it gains speed, the air resistance increases. As the air resistance increases, the acceleration of the falling object decreases, and it gains speed less quickly the longer it falls.
12. Assuming that the catcher catches the ball at the same height at which it left the bat, then the ball will be traveling with a speed of 120 km/h when caught. This is proven in problem 41.
13. As a freely falling object speeds up, its acceleration due to gravity stays the same. If air resistance is considered, then the acceleration of the object is due to both gravity and air resistance. The total acceleration gets smaller as the object speeds up, until the object reaches a terminal velocity, at which time its total acceleration is zero. Thereafter its speed remains constant.
14. To estimate the height, throw the ball upward and time the flight from throwing to catching. Then, ignoring air resistance, the time of rising would be half of the time of flight. With that "half" time, assuming that the origin is at the top of the path and that downward is positive, knowing that the ball started from the top of the path with a speed of 0, use the equation  $y = \frac{1}{2}gt^2$  with that time and the acceleration due to gravity to find the distance that the ball fell. With the same "half" time, we know that at the top of the path, the speed is 0. Taking the upward direction as positive, use the equation  $v = v_0 + at \rightarrow 0 = v_0 - gt \rightarrow v_0 = gt$  to find the throwing speed.
15. The average speed is NOT 80 km/h. Since the two distances traveled were the same, the times of travel were unequal. The time to travel from A to B at 70 km/h is longer than the time to travel from B to C at 90 km/h. Thus we cannot simply average the speed numbers. To find the average speed, we need to calculate (total distance) / (total time). We assume the distance from A to B and the distance from B to C are both  $d$  km. The time to travel a distance  $d$  with a speed  $v$  is  $t = d / v$ .

$$\bar{v} = \frac{d_{AB} + d_{BC}}{t_{AB} + t_{BC}} = \frac{(d \text{ km}) + (d \text{ km})}{\frac{d \text{ km}}{70 \text{ km/h}} + \frac{d \text{ km}}{90 \text{ km/h}}} = 78.75 \text{ km/h} . \text{ The average speed is } 78.75 \text{ km/h} .$$

16. The sounds will not occur at equal time intervals because the longer any particular nut falls, the faster it will be going. With equal distances between nuts, each successive nut, having fallen a longer time when its predecessor reaches the plate, will have a higher average velocity and thus travel the inter-nut distance in shorter periods of time. Thus the sounds will occur with smaller and smaller intervals between sounds.

To hear the sounds at equal intervals, the nuts would have to be tied at distances corresponding to equal time intervals. Since for each nut the distance of fall and time of fall are related by  $d_i = \frac{1}{2} g t_i^2$ , assume that  $d_1 = \frac{1}{2} g t_1^2$ . If we want  $t_2 = 2t_1$ ,  $t_3 = 3t_1$ ,  $t_4 = 4t_1$ ,  $\dots$ , then  $d_2 = \frac{1}{2} g (2t_1)^2 = 4d_1$ ,  $d_3 = \frac{1}{2} g (3t_1)^2 = 9d_1$ ,  $d_4 = \frac{1}{2} g (4t_1)^2 = 16d_1$ , etc.

17. The elevator moving from the second floor to the fifth floor is NOT an example of constant acceleration. The elevator accelerates upward each time it starts to move, and it accelerates downward each time it stops.

Ignoring air resistance, a rock falling from a cliff would have a constant acceleration. (If air resistance is included, then the acceleration will be decreasing as the rock falls.) A dish resting on a table has an acceleration of 0, so the acceleration is constant.

18. As an object rises WITH air resistance, the acceleration is larger in magnitude than  $g$ , because both gravity and air resistance will be causing a downward acceleration. As the object FALLS with air resistance, the acceleration will be smaller in magnitude than  $g$ , because gravity and resistance will be opposing each other. Because of the smaller acceleration being applied over the same distance, the return speed will be slower than the launch speed.
19. If an object is at the instant of reversing direction (like an object thrown upward, at the top of its path), it instantaneously has a zero velocity and a non-zero acceleration at the same time. A person at the exact bottom of a “bungee” cord plunge also has an instantaneous velocity of zero but a non-zero (upward) acceleration at the same time.
20. An object moving with a constant velocity has a non-zero velocity and a zero acceleration at the same time. So a car driving at constant speed on a straight, level roadway would meet this condition.
21. The object starts with a constant velocity in the positive direction. At about  $t = 17$  s, when the object is at the 5 meter position, it begins to gain speed – it has a positive acceleration. At about  $t = 27$  s, when the object is at about the 12 m position, it begins to slow down – it has a negative acceleration. The object instantaneously stops at about  $t = 37$  s, reaching its maximum distance from the origin of 20 m. The object then reverses direction, gaining speed while moving backwards. At about  $t = 47$  s, when the object is again at about the 12 m position, the object starts to slow down, and appears to stop at  $t = 50$  s, 10 m from the starting point.
22. Initially, the object moves in the positive direction with a constant acceleration, until about  $t = 45$  s, when it has a velocity of about 37 m/s in the positive direction. The acceleration then decreases, reaching an instantaneous acceleration of 0 at about  $t = 50$  s, when the object has its maximum speed of about 38 m/s. The object then begins to slow down, but continues to move in the positive

direction. The object stops moving at  $t = 90$  s and stays at rest until about  $t = 108$  s. Then the object begins to move to the right again, at first with a large acceleration, and then a lesser acceleration. At the end of the recorded motion, the object is still moving to the right and gaining speed.

## Solutions to Problems

1. The average speed is given by:

$$\bar{v} = d/\Delta t = 235 \text{ km}/3.25 \text{ h} = \boxed{72.3 \text{ km/h}}$$

2. The time of travel can be found by rearranging the average speed equation.

$$\bar{v} = d/\Delta t \rightarrow \Delta t = d/\bar{v} = (15 \text{ km})/(25 \text{ km/h}) = \boxed{0.60 \text{ h}} = 36 \text{ min}$$

3. The distance of travel (displacement) can be found by rearranging the average speed equation. Also note that the units of the velocity and the time are not the same, so the speed units will be converted.

$$\bar{v} = \frac{d}{\Delta t} \rightarrow d = \bar{v}\Delta t = (110 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(2.0 \text{ s}) = 0.061 \text{ km} = \boxed{61 \text{ m}}$$

4. (a)  $35 \text{ mi/h} = (35 \text{ mi/h})(1.61 \text{ km/mi}) = \boxed{56 \text{ km/h}}$

(b)  $35 \text{ mi/h} = (35 \text{ mi/h})(1610 \text{ m/mi})(1 \text{ h}/3600 \text{ s}) = \boxed{16 \text{ m/s}}$

(c)  $35 \text{ mi/h} = (35 \text{ mi/h})(5280 \text{ ft/mi})(1 \text{ h}/3600 \text{ s}) = \boxed{51 \text{ ft/s}}$

5. The average velocity is given by  $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{-4.2 \text{ cm} - 3.4 \text{ cm}}{6.1 \text{ s} - 3.0 \text{ s}} = \frac{-7.6 \text{ cm}}{3.1 \text{ s}} = \boxed{-2.5 \text{ cm/s}}$ .

6. The average velocity is given by  $\bar{v} = \frac{\Delta x}{\Delta t} = \frac{8.5 \text{ cm} - 3.4 \text{ cm}}{4.5 \text{ s} - (-2.0 \text{ s})} = \frac{5.1 \text{ cm}}{6.5 \text{ s}} = \boxed{0.78 \text{ cm/s}}$ .

The average speed cannot be calculated. To calculate the average speed, we would need to know the actual distance traveled, and it is not given.

7. The time for the first part of the trip is calculated from the initial speed and the first distance.

$$\text{ave speed}_1 = v_1 = \frac{d_1}{\Delta t_1} \rightarrow \Delta t_1 = \frac{d_1}{v_1} = \frac{130 \text{ km}}{95 \text{ km/h}} = 1.37 \text{ h} = 82 \text{ min}$$

The time for the second part of the trip is therefore

$$\Delta t_2 = \Delta t_{\text{tot}} - \Delta t_1 = 3.33 \text{ h} - 1.37 \text{ h} = 1.96 \text{ h} = 118 \text{ min}$$

The distance for the second part of the trip is calculated from the average speed for that part of the trip and the time for that part of the trip.

$$\text{ave speed}_2 = v_2 = \frac{d_2}{\Delta t_2} \rightarrow d_2 = v_2\Delta t_2 = (65 \text{ km/h})(1.96 \text{ h}) = 127.5 \text{ km} = 1.3 \times 10^2 \text{ km}$$

(a) The total distance is then  $d_{\text{total}} = d_1 + d_2 = 130 \text{ km} + 127.5 \text{ km} = 257.5 \text{ km} \approx \boxed{2.6 \times 10^2 \text{ km}}$

(b) The average speed is NOT the average of the two speeds. Use the definition of average speed.

$$\text{ave speed} = \frac{d_{\text{total}}}{\Delta t_{\text{total}}} = \frac{257.5 \text{ km}}{3.33 \text{ h}} = \boxed{77 \text{ km/h}}$$

8. The speed of sound is intimated in the problem as 1 mile per 5 seconds. The speed is calculated by:

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \left( \frac{1 \text{ mi}}{5 \text{ s}} \right) \left( \frac{1610 \text{ m}}{1 \text{ mi}} \right) = \boxed{300 \text{ m/s}}$$

Note that only 1 significant figure is given, (5 sec), and so only 1 significant figure is justified in the result.

9. The distance traveled is 2.0 miles (8 laps  $\times$  0.25 mi/lap). The displacement is 0 because the ending point is the same as the starting point.

$$(a) \text{ Average speed} = \frac{d}{\Delta t} = \frac{2.0 \text{ mi}}{12.5 \text{ min}} = \left( \frac{2 \text{ mi}}{12.5 \text{ min}} \right) \left( \frac{1610 \text{ m}}{1 \text{ mi}} \right) \left( \frac{1 \text{ min}}{60 \text{ s}} \right) = \boxed{4.3 \text{ m/s}}$$

$$(b) \text{ Average velocity} = \bar{v} = \Delta x / \Delta t = \boxed{0 \text{ m/s}}$$

10. The distance traveled is  $116 \text{ km} + \frac{1}{2}(116 \text{ km}) = 174 \text{ km}$ , and the displacement is  $116 \text{ km} - \frac{1}{2}(116 \text{ km}) = 58 \text{ km}$ . The total time is  $14.0 \text{ s} + 4.8 \text{ s} = 18.8 \text{ s}$ .

$$(a) \text{ Average speed} = \frac{d}{\Delta t} = \frac{174 \text{ m}}{18.8 \text{ s}} = \boxed{9.26 \text{ m/s}}$$

$$(b) \text{ Average velocity} = \bar{v} = \frac{\Delta x}{\Delta t} = \frac{58 \text{ m}}{18.8 \text{ s}} = \boxed{3.1 \text{ m/s}}$$

11. Since the locomotives have the same speed, they each travel half the distance, 4.25 km. Find the time of travel from the average speed.

$$\text{ave speed} = v = \frac{d}{\Delta t} \rightarrow \Delta t = \frac{d}{v} = \frac{4.25 \text{ km}}{95 \text{ km/h}} = 0.0447 \text{ h} \left( \frac{60 \text{ min}}{1 \text{ h}} \right) = 2.68 \text{ min} \cong \boxed{2.7 \text{ min}}$$

12. Both objects will have the same time of travel. If the truck travels a distance  $d_{\text{truck}}$ , then the distance the car travels will be  $d_{\text{car}} = d_{\text{truck}} + 110 \text{ m}$ . Using the equation for average speed,  $\bar{v} = d/\Delta t$ , solve for time, and equate the two times.

$$\Delta t = \frac{d_{\text{truck}}}{\bar{v}_{\text{truck}}} = \frac{d_{\text{car}}}{\bar{v}_{\text{car}}} \quad \frac{d_{\text{truck}}}{75 \text{ km/h}} = \frac{d_{\text{truck}} + 110 \text{ m}}{88 \text{ km/h}}$$

$$\text{Solving for } d_{\text{truck}} \text{ gives } d_{\text{truck}} = (110 \text{ m}) \frac{(75 \text{ km/h})}{(88 \text{ km/h} - 75 \text{ km/h})} = 634.6 \text{ m}.$$

The time of travel is

$$\Delta t = \frac{d_{\text{truck}}}{\bar{v}_{\text{truck}}} = \left( \frac{634.6 \text{ m}}{75000 \text{ m/h}} \right) \left( \frac{60 \text{ min}}{1 \text{ h}} \right) = 0.5077 \text{ min} = 30.46 \text{ s} = \boxed{3.0 \times 10^1 \text{ s}}.$$

$$\text{Also note that } \Delta t = \frac{d_{\text{car}}}{\bar{v}_{\text{car}}} = \left( \frac{634.6 \text{ m} + 110 \text{ m}}{88000 \text{ m/h}} \right) \left( \frac{60 \text{ min}}{1 \text{ h}} \right) = 0.5077 \text{ min} = 30.46 \text{ s}.$$

## ALTERNATE SOLUTION:

The speed of the car relative to the truck is  $88 \text{ km/h} - 75 \text{ km/h} = 13 \text{ km/h}$ . In the reference frame of the truck, the car must travel 110 m to catch it.

$$\Delta t = \frac{0.11 \text{ km}}{13 \text{ km/h}} \left( \frac{3600 \text{ s}}{1 \text{ h}} \right) = 30.46 \text{ s}$$

13. The average speed for each segment of the trip is given by  $\bar{v} = \frac{d}{\Delta t}$ , so  $\Delta t = \frac{d}{\bar{v}}$  for each segment.

$$\text{For the first segment, } \Delta t_1 = \frac{d_1}{\bar{v}_1} = \frac{3100 \text{ km}}{790 \text{ km/h}} = 3.924 \text{ h}.$$

$$\text{For the second segment, } \Delta t_2 = \frac{d_2}{\bar{v}_2} = \frac{2800 \text{ km}}{990 \text{ km/h}} = 2.828 \text{ h}.$$

Thus the total time is  $\Delta t_{\text{tot}} = \Delta t_1 + \Delta t_2 = 3.924 \text{ h} + 2.828 \text{ h} = 6.752 \text{ h} \approx \boxed{6.8 \text{ h}}$ .

The average speed of the plane for the entire trip is

$$\bar{v} = \frac{d_{\text{tot}}}{\Delta t_{\text{tot}}} = \frac{3100 \text{ km} + 2800 \text{ km}}{6.752 \text{ h}} = 873.8 \approx \boxed{8.7 \times 10^2 \text{ km/h}}.$$

14. The distance traveled is 500 km (250 km outgoing, 250 km return, keep 2 significant figures). The displacement ( $\Delta x$ ) is 0 because the ending point is the same as the starting point.

(a) To find the average speed, we need the distance traveled (500 km) and the total time elapsed.

During the outgoing portion,  $\bar{v}_1 = \frac{d_1}{\Delta t_1}$  and so  $\Delta t_1 = \frac{d_1}{\bar{v}_1} = \frac{250 \text{ km}}{95 \text{ km/h}} = 2.632 \text{ h}$ . During the return

portion,  $\bar{v}_2 = \frac{d_2}{\Delta t_2}$ , and so  $\Delta t_2 = \frac{d_2}{\bar{v}_2} = \frac{250 \text{ km}}{55 \text{ km/h}} = 4.545 \text{ h}$ . Thus the total time, including lunch, is

$$\Delta t_{\text{total}} = \Delta t_1 + \Delta t_{\text{lunch}} + \Delta t_2 = 8.177 \text{ h}. \text{ Average speed} = \frac{d_{\text{total}}}{\Delta t_{\text{total}}} = \frac{500 \text{ km}}{8.177 \text{ h}} = \boxed{61 \text{ km/h}}.$$

(b) Average velocity =  $\boxed{\bar{v} = \Delta x / \Delta t = 0}$

15. The average speed of sound is given by  $\bar{v} = d / \Delta t$ , and so the time for the sound to travel from the end of the lane back to the bowler is  $\Delta t_{\text{sound}} = \frac{d}{\bar{v}_{\text{sound}}} = \frac{16.5 \text{ m}}{340 \text{ m/s}} = 4.85 \times 10^{-2} \text{ s}$ . Thus the time for the ball to travel from the bowler to the end of the lane is given by

$\Delta t_{\text{ball}} = \Delta t_{\text{total}} - \Delta t_{\text{sound}} = 2.50 \text{ s} - 4.85 \times 10^{-2} \text{ s} = 2.4515 \text{ s}$ . And so the speed of the ball is:

$$\bar{v}_{\text{ball}} = \frac{d}{\Delta t_{\text{ball}}} = \frac{16.5 \text{ m}}{2.4515 \text{ s}} = \boxed{6.73 \text{ m/s}}.$$

16. The average acceleration is given by

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{95 \text{ km/h} - 0 \text{ km/h}}{6.2 \text{ s}} = \frac{(95 \text{ km/h}) \left( \frac{1 \text{ m/s}}{3.6 \text{ km/h}} \right)}{6.2 \text{ s}} = \boxed{4.3 \text{ m/s}^2}.$$

17. (a) The average acceleration of the sprinter is  $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{10.0 \text{ m/s} - 0.0 \text{ m/s}}{1.35 \text{ s}} = \boxed{7.41 \text{ m/s}^2}$ .

(b)  $\bar{a} = (7.41 \text{ m/s}^2) \left( \frac{1 \text{ km}}{1000 \text{ m}} \right) \left( \frac{3600 \text{ s}}{1 \text{ h}} \right)^2 = \boxed{9.60 \times 10^4 \text{ km/h}^2}$

18. The time can be found from the average acceleration,  $\bar{a} = \frac{\Delta v}{\Delta t}$ .

$$\Delta t = \frac{\Delta v}{\bar{a}} = \frac{110 \text{ km/h} - 80 \text{ km/h}}{1.6 \text{ m/s}^2} = \frac{(30 \text{ km/h}) \left( \frac{1 \text{ m/s}}{3.6 \text{ km/h}} \right)}{1.6 \text{ m/s}^2} = \boxed{5.2 \text{ s}}$$

19. The initial velocity of the car is the average speed of the car before it accelerates.

$$\bar{v} = \frac{d}{\Delta t} = \frac{110 \text{ m}}{5.0 \text{ s}} = 22 \text{ m/s} = v_0$$

The final speed is  $v = 0$ , and the time to stop is 4.0 s. Use Eq. 2-11a to find the acceleration.

$$v = v_0 + at \rightarrow$$

$$a = \frac{v - v_0}{t} = \frac{0 - 22 \text{ m/s}}{4.0 \text{ s}} = \boxed{-5.5 \text{ m/s}^2} = (-5.5 \text{ m/s}^2) \left( \frac{1 \text{ g}}{9.80 \text{ m/s}^2} \right) = \boxed{-0.56 \text{ g's}}$$

20. To estimate the velocity, find the average velocity over each time interval, and assume that the car had that velocity at the midpoint of the time interval. To estimate the acceleration, find the average acceleration over each time interval, and assume that the car had that acceleration at the midpoint of the time interval. A sample of each calculation is shown.

From 2.00 s to 2.50 s, for average velocity:

$$t_{\text{mid}} = \frac{2.50 \text{ s} + 2.00 \text{ s}}{2} = 2.25 \text{ s}$$

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{13.79 \text{ m} - 8.55 \text{ m}}{2.50 \text{ s} - 2.00 \text{ s}} = \frac{5.24 \text{ m}}{0.50 \text{ s}} = 10.48 \text{ m/s}$$

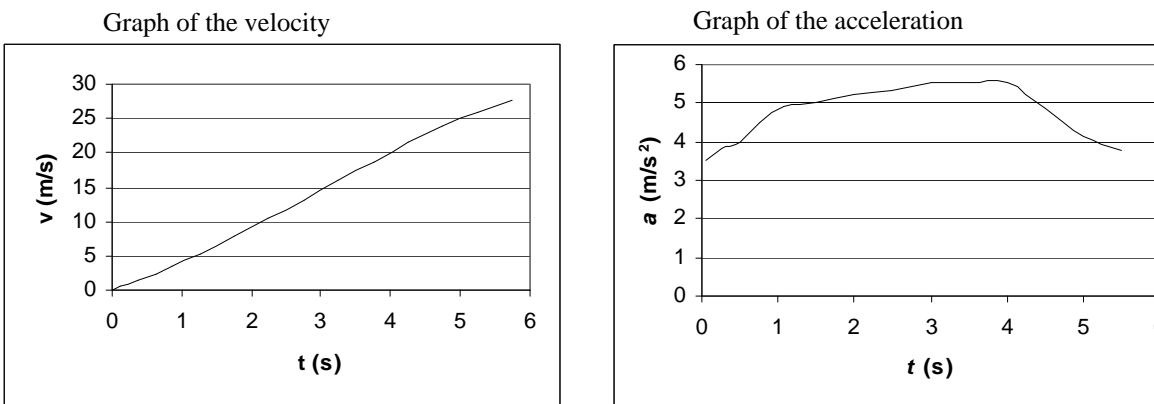
From 2.25 s to 2.75 s, for average acceleration:

$$t_{\text{mid}} = \frac{2.25 \text{ s} + 2.75 \text{ s}}{2} = 2.50 \text{ s}$$

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{13.14 \text{ m/s} - 10.48 \text{ m/s}}{2.75 \text{ s} - 2.25 \text{ s}} = \frac{2.66 \text{ m/s}}{0.50 \text{ s}} = 5.32 \text{ m/s}^2$$

Table of Calculations

$t$ (s)	$x$ (m)	$t$ (s)	$v$ (m/s)	$t$ (s)	$a$ (m/s <sup>2</sup> )
0.00	0.00	0.00	0.00	0.063	3.52
		0.125	0.44	0.25	3.84
0.25	0.11	0.375	1.40	0.50	4.00
		0.625	2.40	0.75	4.48
0.50	0.46	0.875	3.52	1.06	4.91
		1.25	5.36	1.50	5.00
0.75	1.06	1.75	7.86	2.00	5.24
		2.25	10.48	2.50	5.32
1.00	1.94	2.75	13.14	3.00	5.52
		3.25	15.90	3.50	5.56
1.50	4.62	3.75	18.68	4.00	5.52
		4.25	21.44	4.50	4.84
2.00	8.55	4.75	23.86	5.00	4.12
		5.25	25.92	5.50	3.76
2.50	13.79	5.75	27.80		
		6.00	27.80		
3.00	20.36				
3.50	28.31				
4.00	37.65				
4.50	48.37				
5.00	60.30				
5.50	73.26				
6.00	87.16				



21. By definition, the acceleration is  $a = \frac{v - v_0}{t} = \frac{25 \text{ m/s} - 13 \text{ m/s}}{6.0 \text{ s}} = \boxed{2.0 \text{ m/s}^2}$ .

The distance of travel can be found from Eq. 2-11b.

$$x - x_0 = v_0 t + \frac{1}{2} a t^2 = (13 \text{ m/s})(6.0 \text{ s}) + \frac{1}{2} (2.0 \text{ m/s}^2)(6.0 \text{ s})^2 = \boxed{114 \text{ m}}$$

22. The acceleration can be found from Eq. (2-11c).

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - (23 \text{ m/s})^2}{2(85 \text{ m})} = \boxed{-3.1 \text{ m/s}^2}$$

23. Assume that the plane starts from rest. The runway distance is found by solving Eq. 2-11c for  $x - x_0$ .

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow x - x_0 = \frac{v^2 - v_0^2}{2a} = \frac{(33 \text{ m/s})^2 - 0}{2(3.0 \text{ m/s}^2)} = \boxed{1.8 \times 10^2 \text{ m}}$$

24. The sprinter starts from rest. The average acceleration is found from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(11.5 \text{ m/s})^2 - 0}{2(15.0 \text{ m})} = 4.408 \text{ m/s}^2 \approx \boxed{4.41 \text{ m/s}^2}$$

The elapsed time is found by solving Eq. 2-11a for time.

$$v = v_0 + at \rightarrow t = \frac{v - v_0}{a} = \frac{11.5 \text{ m/s} - 0}{4.408 \text{ m/s}^2} = \boxed{2.61 \text{ s}}$$

25. The words “slowing down uniformly” implies that the car has a constant acceleration. The distance of travel is found from combining Eqs. 2-7 and 2-8.

$$x - x_0 = \frac{v_0 + v}{2} t = \left( \frac{21.0 \text{ m/s} + 0 \text{ m/s}}{2} \right) (6.00 \text{ sec}) = \boxed{63.0 \text{ m}}$$

**26.** The final velocity of the car is zero. The initial velocity is found from Eq. 2-11c with  $v = 0$  and solving for  $v_0$ .

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow v_0 = \sqrt{v^2 - 2a(x - x_0)} = \sqrt{0 - 2(-7.00 \text{ m/s}^2)(92 \text{ m})} = \boxed{36 \text{ m/s}}$$



27. The final velocity of the driver is zero. The acceleration is found from Eq. 2-11c with  $v = 0$  and solving for  $a$ .

$$a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0 - \left[ (85 \text{ km/h}) \left( \frac{1 \text{ m/s}}{3.6 \text{ km/h}} \right) \right]^2}{2(0.80 \text{ m})} = -348.4 \text{ m/s}^2 \approx \boxed{-3.5 \times 10^2 \text{ m/s}^2}$$

Converting to "g's":  $a = \frac{-3.484 \times 10^2 \text{ m/s}^2}{(9.8 \text{ m/s}^2)/g} = \boxed{-36 \text{ g's}}$ .

28. The origin is the location of the car at the beginning of the reaction time. The initial speed of the car is  $(95 \text{ km/h}) \left( \frac{1 \text{ m/s}}{3.6 \text{ km/h}} \right) = 26.39 \text{ m/s}$ . The location where the brakes are applied is found from

the equation for motion at constant velocity:  $x_0 = v_0 t_R = (26.39 \text{ m/s})(1.0 \text{ s}) = 26.39 \text{ m}$ . This is now the starting location for the application of the brakes. In each case, the final speed is 0.

(a) Solve Eq. 2-11c for the final location.

$$v^2 = v_0^2 + 2a(x - x_0) \rightarrow x = x_0 + \frac{v^2 - v_0^2}{2a} = 26.39 \text{ m} + \frac{0 - (26.39 \text{ m/s})^2}{2(-4.0 \text{ m/s}^2)} = \boxed{113 \text{ m}}$$

(b) Solve Eq. 2-11c for the final location with the second acceleration.

$$x = x_0 + \frac{v^2 - v_0^2}{2a} = 26.39 \text{ m} + \frac{0 - (26.39 \text{ m/s})^2}{2(-8.0 \text{ m/s}^2)} = \boxed{70 \text{ m}}$$

29. The origin is the location of the car at the beginning of the reaction time. The location where the brakes are applied is found from the equation for motion at constant velocity:  $x_0 = v_0 t_R$ . This is the starting location for the application of the brakes. Solve Eq. 2-11c for the final location of the car, with  $v = 0$ .

$$x = x_0 + \frac{v^2 - v_0^2}{2a} = v_0 t_R - \frac{v_0^2}{2a}$$

30. The critical condition is that the total distance covered by the passing car and the approaching car must be less than 400 m so that they do not collide. The passing car has a total displacement composed of several individual parts. These are: i) the 10 m of clear room at the rear of the truck, ii) the 20 m length of the truck, iii) the 10 m of clear room at the front of the truck, and iv) the distance the truck travels. Since the truck travels at a speed of  $\bar{v} = 25 \text{ m/s}$ , the truck will have a displacement of  $\Delta x_{\text{truck}} = (25 \text{ m/s})t$ . Thus the total displacement of the car during passing is

$$\Delta x_{\text{passing car}} = 40 \text{ m} + (25 \text{ m/s})t.$$

To express the motion of the car, we choose the origin to be at the location of the passing car when the decision to pass is made. For the passing car, we have an initial velocity of  $v_0 = 25 \text{ m/s}$  and an acceleration of  $a = 1.0 \text{ m/s}^2$ . Find  $\Delta x_{\text{passing car}}$  from Eq. 2-11b.

$$\Delta x_{\text{passing car}} = x_c - x_0 = v_0 t + \frac{1}{2} a t^2 = (25 \text{ m/s})t + \frac{1}{2} (1.0 \text{ m/s}^2) t^2$$

Set the two expressions for  $\Delta x_{\text{passing car}}$  equal to each other in order to find the time required to pass.

$$40 \text{ m} + (25 \text{ m/s})t_{\text{pass}} = (25 \text{ m/s})t_{\text{pass}} + \frac{1}{2}(1.0 \text{ m/s}^2)t_{\text{pass}}^2 \rightarrow 40 \text{ m} = \frac{1}{2}(1.0 \text{ m/s}^2)t_{\text{pass}}^2 \rightarrow$$

$$t_{\text{pass}} = \sqrt{80 \text{ s}^2} = 8.94 \text{ s}$$

Calculate the displacements of the two cars during this time.

$$\Delta x_{\text{passing car}} = 40 \text{ m} + (25 \text{ m/s})(8.94 \text{ s}) = 264 \text{ m}$$

$$\Delta x_{\text{approaching car}} = v_{\text{approaching car}} t = (25 \text{ m/s})(8.94 \text{ s}) = 224 \text{ m}$$

Thus the two cars together have covered a total distance of 488 m, which is more than allowed.

The car should not pass.

31. During the final part of the race, the runner must have a displacement of 1100 m in a time of 180 s (3 min). Assume that the starting speed for the final part is the same as the average speed thus far.

$$\text{Average speed} = \frac{d}{\Delta t} = \frac{8900 \text{ m}}{(27 \times 60) \text{ s}} = 5.494 \text{ m/s} = v_0$$

The runner will accomplish this by accelerating from speed  $v_0$  to speed  $v$  for  $t$  seconds, covering a distance  $d_1$ , and then running at a constant speed of  $v$  for  $(180 - t)$  seconds, covering a distance  $d_2$ .

We have these relationships:

$$v = v_0 + at \quad d_1 = v_0 t + \frac{1}{2} at^2 \quad d_2 = v(180 - t) = (v_0 + at)(180 - t)$$

$$1100 \text{ m} = d_1 + d_2 = v_0 t + \frac{1}{2} at^2 + (v_0 + at)(180 - t) \rightarrow 1100 \text{ m} = 180v_0 + 180at - \frac{1}{2} at^2 \rightarrow$$

$$1100 \text{ m} = (180 \text{ s})(5.494 \text{ m/s}) + (180 \text{ s})(0.2 \text{ m/s}^2)t - \frac{1}{2}(0.2 \text{ m/s}^2)t^2$$

$$0.1t^2 - 36t + 111 = 0 \quad t = 357 \text{ s}, 3.11 \text{ s}$$

Since we must have  $t < 180 \text{ s}$ , the solution is  $t = 3.1 \text{ s}$ .

32. The car's initial speed is  $v_0 = (45 \text{ km/h})\left(\frac{1 \text{ m/s}}{3.6 \text{ km/h}}\right) = 12.5 \text{ m/s}$ .

Case I: trying to stop. The constraint is, with the braking deceleration of the car ( $a = -5.8 \text{ m/s}^2$ ), can the car stop in a 28 m displacement? The 2.0 seconds has no relation to this part of the problem. Using equation (2-11c), the distance traveled during braking is

$$(x - x_0) = \frac{v^2 - v_0^2}{2a} = \frac{0 - (12.5 \text{ m/s})^2}{2(-5.8 \text{ m/s}^2)} = 13.5 \text{ m} \quad \boxed{\text{She can stop the car in time.}}$$

Case II: crossing the intersection. The constraint is, with the acceleration of the car

$$\left[ a = \left( \frac{65 \text{ km/h} - 45 \text{ km/h}}{6.0 \text{ s}} \right) \left( \frac{1 \text{ m/s}}{3.6 \text{ km/h}} \right) = 0.9259 \text{ m/s}^2 \right], \text{ can she get through the intersection}$$

(travel 43 meters) in the 2.0 seconds before the light turns red? Using equation (2.11b), the distance traveled during the 2.0 sec is

$$(x - x_0) = v_0 t + \frac{1}{2} at^2 = (12.5 \text{ m/s})(2.0 \text{ s}) + \frac{1}{2}(0.927 \text{ m/s}^2)(2.0 \text{ s})^2 = 26.9 \text{ m}.$$

She should stop.

33. Choose downward to be the positive direction, and take  $y_0 = 0$  at the top of the cliff. The initial velocity is  $v_0 = 0$ , and the acceleration is  $a = 9.80 \text{ m/s}^2$ . The displacement is found from equation (2-11b), with  $x$  replaced by  $y$ .

$$y = y_0 + v_0 t + \frac{1}{2} a t^2 \rightarrow y - 0 = 0 + \frac{1}{2} (9.80 \text{ m/s}^2) (3.25 \text{ s})^2 \rightarrow y = \boxed{51.8 \text{ m}}$$

34. Choose downward to be the positive direction. The initial velocity is  $v_0 = 0$ , the final velocity is  $v = (85 \text{ km/h}) \left( \frac{1 \text{ m/s}}{3.6 \text{ km/h}} \right) = 23.61 \text{ m/s}$ , and the acceleration is  $a = 9.80 \text{ m/s}^2$ . The time can be found by solving Eq. 2-11a for the time.

$$v = v_0 + at \rightarrow t = \frac{v - v_0}{a} = \frac{23.61 \text{ m/s} - 0}{9.80 \text{ m/s}^2} = \boxed{2.4 \text{ s}}$$

35. Choose downward to be the positive direction, and take  $y_0 = 0$  to be at the top of the Empire State Building. The initial velocity is  $v_0 = 0$ , and the acceleration is  $a = 9.80 \text{ m/s}^2$ .

(a) The elapsed time can be found from Eq. 2-11b, with  $x$  replaced by  $y$ .

$$y - y_0 = v_0 t + \frac{1}{2} a t^2 \rightarrow t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(380 \text{ m})}{9.80 \text{ m/s}^2}} = 8.806 \text{ s} \approx \boxed{8.8 \text{ s}}$$

(b) The final velocity can be found from equation (2-11a).

$$v = v_0 + at = 0 + (9.80 \text{ m/s}^2)(8.806 \text{ s}) = \boxed{86 \text{ m/s}}$$

- 36.** Choose upward to be the positive direction, and take  $y_0 = 0$  to be at the height where the ball was hit. For the upward path,  $v_0 = 22 \text{ m/s}$ ,  $v = 0$  at the top of the path, and  $a = -9.80 \text{ m/s}^2$ .

(a) The displacement can be found from Eq. 2-11c, with  $x$  replaced by  $y$ .

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (22 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = \boxed{25 \text{ m}}$$

(b) The time of flight can be found from Eq. 2-11b, with  $x$  replaced by  $y$ , using a displacement of 0 for the displacement of the ball returning to the height from which it was hit.

$$y = y_0 + v_0 t + \frac{1}{2} a t^2 = 0 \rightarrow t(v_0 + \frac{1}{2} a t) = 0 \rightarrow t = 0, t = \frac{2v_0}{-a} = \frac{2(22 \text{ m/s})}{-9.80 \text{ m/s}^2} = \boxed{4.5 \text{ s}}$$

The result of  $t = 0 \text{ s}$  is the time for the original displacement of zero (when the ball was hit), and the result of  $t = 4.5 \text{ s}$  is the time to return to the original displacement. Thus the answer is  $t = 4.5 \text{ seconds}$ .

37. Choose upward to be the positive direction, and take  $y_0 = 0$  to be the height from which the ball was thrown. The acceleration is  $a = -9.80 \text{ m/s}^2$ . The displacement upon catching the ball is 0, assuming it was caught at the same height from which it was thrown. The starting speed can be found from Eq. 2-11b, with  $x$  replaced by  $y$ .

$$y = y_0 + v_0 t + \frac{1}{2} a t^2 = 0 \rightarrow$$

$$v_0 = \frac{y - y_0 - \frac{1}{2} a t^2}{t} = -\frac{1}{2} a t = -\frac{1}{2} (-9.80 \text{ m/s}^2) (3.0 \text{ s}) = 14.7 \text{ m/s} \approx \boxed{15 \text{ m/s}}$$

The height can be calculated from Eq. 2-11c, with a final velocity of  $v = 0$  at the top of the path.

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (14.7 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)} = \boxed{11 \text{ m}}$$

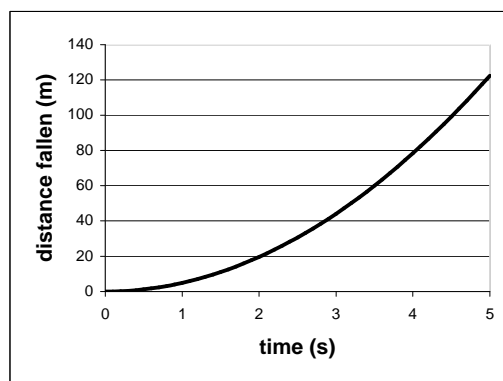
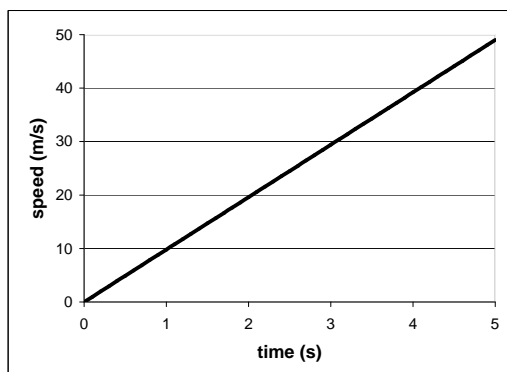
38. Choose downward to be the positive direction, and take  $y_0 = 0$  to be at the height where the object was released. The initial velocity is  $v_0 = 0$ , and the acceleration is  $a = 9.80 \text{ m/s}^2$ .

(a) The speed of the object will be given by Eq. 2-11a with  $v_0 = 0$ , and so  $v = at = (9.80 \text{ m/s}^2)t$ .

This is the equation of a straight line passing through the origin with a slope of  $9.80 \text{ m/s}^2$ .

(b) The distance fallen will be given by equation (2-11b) with  $v_0 = 0$ , and so

$y = y_0 + v_0t + \frac{1}{2}at^2 = 0 + 0 + (4.90 \text{ m/s}^2)t^2$ . This is the equation of a parabola, centered on the t-axis, opening upward.



39. Choose downward to be the positive direction, and take  $y_0 = 0$  to be the height where the object was released. The initial velocity is  $v_0 = -5.20 \text{ m/s}$ , the acceleration is  $a = 9.80 \text{ m/s}^2$ , and the displacement of the package will be  $y = 125 \text{ m}$ . The time to reach the ground can be found from Eq. 2-11b, with  $x$  replaced by  $y$ .

$$y = y_0 + v_0t + \frac{1}{2}at^2 \rightarrow t^2 + \frac{2v_0}{a}t - \frac{2y}{a} = 0 \rightarrow t^2 + \frac{2(-5.2 \text{ m/s})}{9.80 \text{ m/s}^2}t - \frac{2(125 \text{ m})}{9.80 \text{ m/s}^2} = 0 \rightarrow$$

$$t = 5.61 \text{ s}, -4.55 \text{ s}$$

The correct time is the positive answer,  $t = 5.61 \text{ s}$ .

40. Choose downward to be the positive direction, and take  $y_0 = 0$  to be the height from which the object is released. The initial velocity is  $v_0 = 0$ , the acceleration is  $a = g$ . Then we can calculate the position as a function of time from Eq. 2-11b, with  $x$  replaced by  $y$ , as  $y(t) = \frac{1}{2}gt^2$ . At the end of each second, the position would be as follows:

$$y(0) = 0; \quad y(1) = \frac{1}{2}g; \quad y(2) = \frac{1}{2}g(2)^2 = 4y(1); \quad y(3) = \frac{1}{2}g(3)^2 = 9y(1)$$

The distance traveled during each second can be found by subtracting two adjacent position values from the above list.

$$d(1) = y(1) - y(0) = y(1); \quad d(2) = y(2) - y(1) = 3y(1); \quad d(3) = y(3) - y(2) = 5y(1)$$

We could do this in general.

$$y(n) = \frac{1}{2}gn^2 \quad y(n+1) = \frac{1}{2}g(n+1)^2$$

$$d(n+1) = y(n+1) - y(n) = \frac{1}{2}g(n+1)^2 - \frac{1}{2}gn^2 = \frac{1}{2}g((n+1)^2 - n^2)$$

$$= \frac{1}{2}g(n^2 + 2n + 1 - n^2) = \frac{1}{2}g(2n+1)$$

The value of  $(2n+1)$  is always odd, in the sequence  $\boxed{1, 3, 5, 7, \dots}$

41. Choose upward to be the positive direction, and take  $y_0 = 0$  to be the height from which the ball is thrown. The initial velocity is  $v_0$ , the acceleration is  $a = -g$ , and the final location for the round trip is  $y = 0$ . The velocity under those conditions can be found from Eq. 2-11c, with  $x$  replaced by  $y$ .

$$v^2 - v_0^2 = 2ay = 0 \quad \rightarrow \quad v^2 = v_0^2 \quad \rightarrow \quad \boxed{v = \pm v_0}$$

The two results represent two different velocities for the same displacement of 0. The positive sign ( $v = v_0$ ) is the initial velocity, when the ball is moving upwards, and the negative sign ( $v = -v_0$ ) is the final velocity, when the ball is moving downwards. Both of these velocities have the same magnitude, and so the ball has the same speed at the end of its flight as at the beginning.

42. Choose upward to be the positive direction, and  $y_0 = 0$  to be the height from which the stone is thrown. We have  $v_0 = 18.0 \text{ m/s}$ ,  $a = -9.80 \text{ m/s}^2$ , and  $y - y_0 = 11.0 \text{ m}$ .

(a) The velocity can be found from Eq. 2-11c, with  $x$  replaced by  $y$ .

$$v^2 = v_0^2 + 2a(y - y_0) = 0 \quad \rightarrow$$

$$v = \pm\sqrt{v_0^2 + 2ay} = \pm\sqrt{(18.0 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)(11.0 \text{ m})} = \pm 10.4 \text{ m/s}$$

Thus the speed is  $\boxed{|v| = 10.4 \text{ m/s}}$

(b) The time to reach that height can be found from equation (2-11b).

$$y = y_0 + v_0t + \frac{1}{2}at^2 \quad \rightarrow \quad t^2 + \frac{2(18.0 \text{ m/s})}{-9.80 \text{ m/s}^2}t + \frac{2(-11.0 \text{ m})}{-9.80 \text{ m/s}^2} = 0 \quad \rightarrow$$

$$t^2 - 3.673t + 2.245 = 0 \quad \rightarrow \quad \boxed{t = 2.90 \text{ s}, 0.775 \text{ s}}$$

(c)  $\boxed{\text{There are two times at which the object reaches that height}} - \text{once on the way up } (t = 0.775 \text{ s}), \text{ and once on the way down } (t = 2.90 \text{ s}).$

43. The 10-cm (100 mm) apple has a diameter of about 6 mm as measured in the photograph. Thus any distances measured from the picture need to be multiplied by  $100/6$ . Choose the downward direction to be positive. Choose  $y_0 = 0$  to be stem of the apple on the THIRD image from the top of the picture. It is the first picture in which the stem of the apple is visible. The velocity of the apple at that position is not 0, but it is not known either. Call it  $v_0$ . We will choose that the time at that point is  $t = 0$ , and we call the time interval from one picture to the next to be  $T$ . The acceleration of the apple is  $a = g = 9.8 \text{ m/s}^2$ .

The 3<sup>rd</sup> picture after the  $t = 0$  picture (the first one that is not overlapping with another image) has the stem 16.5 mm from the origin of coordinates, at a time of  $t = 3T$ . The actual position would be found by

$$y_1 = (16.5 \text{ mm})(100/6) = 275 \text{ mm} = 0.275 \text{ m}.$$

The 6<sup>th</sup> picture after the  $t = 0$  picture (the next to last one in the picture) has the stem 42 mm from the origin of coordinates, at a time of  $t = 6T$ . The actual position would be found by

$$y_2 = (42 \text{ mm})(100/6) = 700 \text{ mm} = 0.70 \text{ m}.$$

Now we have two sets of position-time data, relative to the origin. Both of those sets of position-time data must satisfy equation Eq. 2-11b.

$$y_1 = y_0 + v_0 t_1 + \frac{1}{2} a t_1^2 \quad \rightarrow \quad 0.275 = 3v_0 T + \frac{1}{2} g (3T)^2$$

$$y_2 = y_0 + v_0 t_2 + \frac{1}{2} a t_2^2 \quad \rightarrow \quad 0.70 = 6v_0 T + \frac{1}{2} g (6T)^2$$

Multiply the first equation by 2, and then subtract it from the second equation to eliminate the dependence on  $v_0$ . The resulting equation can be solved for  $T$ .

$$\left. \begin{array}{l} 0.55 \text{ m} = 6v_0 T + 9gT^2 \\ 0.70 \text{ m} = 6v_0 T + 18gT^2 \end{array} \right\} \rightarrow 0.15 \text{ m} = 9gT^2 \rightarrow T = \sqrt{\frac{0.15 \text{ m}}{9(9.8 \text{ m/s}^2)}} = \boxed{4.1 \times 10^{-2} \text{ s}}$$

This is equivalent to  $\frac{1 \text{ flash}}{T} = \frac{1 \text{ flash}}{4.1 \times 10^{-2} \text{ s}} = \boxed{24 \text{ flashes per second}}$ .

44. Choose downward to be the positive direction, and  $y_0 = 0$  to be the height from which the stone is dropped. Call the location of the top of the window  $y_w$ , and the time for the stone to fall from release to the top of the window is  $t_w$ . Since the stone is dropped from rest, using Eq. 2-11b with  $y$  substituting for  $x$ , we have  $y_w = y_0 + v_0 t + \frac{1}{2} a t^2 = 0 + 0 + \frac{1}{2} g t_w^2$ . The location of the bottom of the window is  $y_w + 2.2 \text{ m}$ , and the time for the stone to fall from release to the bottom of the window is  $t_w + 0.28 \text{ s}$ . Since the stone is dropped from rest, using Eq. 2-11b, we have
- $$y_w + 2.2 \text{ m} = y_0 + v_0 + \frac{1}{2} a t^2 = 0 + 0 + \frac{1}{2} g (t_w + 0.28 \text{ s})^2.$$
- Substituting the first expression for  $y_w$  into the second one.

$$\frac{1}{2} g t_w^2 + 2.2 \text{ m} = \frac{1}{2} g (t_w + 0.28 \text{ s})^2 \quad \rightarrow \quad t_w = 0.662 \text{ s}$$

Use this time in the first equation.

$$y_w = \frac{1}{2} g t_w^2 = \frac{1}{2} (9.8 \text{ m/s}^2) (0.662 \text{ s})^2 = \boxed{2.1 \text{ m}}.$$

45. For the falling rock, choose downward to be the positive direction, and  $y_0 = 0$  to be the height from which the stone is dropped. The initial velocity is  $v_0 = 0 \text{ m/s}$ , the acceleration is  $a = g$ , the displacement is  $y = H$ , and the time of fall is  $t_1$ . Using Eq. 2-11b with  $y$  substituting for  $x$ , we have  $H = y_0 + v_0 t + \frac{1}{2} a t^2 = 0 + 0 + \frac{1}{2} g t_1^2$ .

For the sound wave, use the constant speed equation that  $v_s = \frac{d}{\Delta t} = \frac{H}{T - t_1}$ , which can be rearranged

to give  $t_1 = T - \frac{H}{v_s}$ , where  $T = 3.2$  s is the total time elapsed from dropping the rock to hearing the sound. Insert this expression for  $t_1$  into the equation for  $H$ , and solve for  $H$ .

$$H = \frac{1}{2}g \left( T - \frac{H}{v_s} \right)^2 \rightarrow \frac{g}{2v_s^2} H^2 - \left( \frac{gT}{v_s} + 1 \right) H + \frac{1}{2}gT^2 = 0 \rightarrow$$

$$4.239 \times 10^{-5} H^2 - 1.092H + 50.18 = 0 \rightarrow H = 46.0 \text{ m}, 2.57 \times 10^4 \text{ m}$$

If the larger answer is used in  $t_1 = T - \frac{H}{v_s}$ , a negative time of fall results, and so the physically correct answer is  $\boxed{H = 46 \text{ m}}$ .

46. Choose upward to be the positive direction, and  $y_0 = 0$  to be the location of the nozzle. The initial velocity is  $v_0$ , the acceleration is  $a = -9.8 \text{ m/s}^2$ , the final location is  $y = -1.5$  m, and the time of flight is  $t = 2.0$  s. Using Eq. 2-11b and substituting  $y$  for  $x$  gives the following.

$$y = y_0 + v_0 t + \frac{1}{2} a t^2 \rightarrow v_0 = \frac{y - \frac{1}{2} a t^2}{t} = \frac{-1.5 \text{ m} - \frac{1}{2} (-9.8 \text{ m/s}^2) (2.0 \text{ s})^2}{2.0 \text{ s}} = \boxed{9.1 \text{ m/s}}$$

47. Choose downward to be the positive direction, and  $y_0 = 0$  to be at the top of the cliff. The initial velocity is  $v_0 = -12.0 \text{ m/s}$ , the acceleration is  $a = 9.80 \text{ m/s}^2$ , and the final location is  $y = 70.0$  m.

(a) Using Eq. 2-11b and substituting  $y$  for  $x$ , we have

$$y = y_0 + v_0 t + \frac{1}{2} a t^2 \rightarrow (4.9 \text{ m/s}^2) t^2 - (12.0 \text{ m/s}) t - 70 \text{ m} = 0 \rightarrow t = -2.749 \text{ s}, 5.198 \text{ s}.$$

The positive answer is the physical answer:  $\boxed{t = 5.20 \text{ s}}$ .

(b) Using Eq. 2-11a, we have  $v = v_0 + at = -12.0 \text{ m/s} + (9.80 \text{ m/s}^2)(5.198 \text{ s}) = \boxed{38.9 \text{ m/s}}$ .

(c) The total distance traveled will be the distance up plus the distance down. The distance down will be 70 m more than the distance up. To find the distance up, use the fact that the speed at the top of the path will be 0. Then using Eq. 2-11c:

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (-12.0 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = -7.35 \text{ m}.$$

Thus the distance up is 7.35 m, the distance down is 77.35 m, and the total distance traveled is  $\boxed{84.7 \text{ m}}$ .

48. Choose upward to be the positive direction, and  $y_0 = 0$  to be the level from which the ball was thrown. The initial velocity is  $v_0$ , the instantaneous velocity is  $v = 13 \text{ m/s}$ , the acceleration is  $a = -9.80 \text{ m/s}^2$ , and the location of the window is  $y = 28$  m.

(a) Using Eq. 2-11c and substituting  $y$  for  $x$ , we have

$$v^2 = v_0^2 + 2a(y - y_0) \rightarrow$$

$$v_0 = \pm \sqrt{v^2 - 2a(y - y_0)} = \pm \sqrt{(13 \text{ m/s})^2 - 2(-9.8 \text{ m/s}^2)(28 \text{ m})} = \boxed{27 \text{ m/s}}$$

Choose the positive value because the initial direction is upward.