# 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

$\boxed{1.}$ (*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.

$\boxed{4.}$ 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.

$$\left(1\times10^{6}\,\text{people}\right)\left(\frac{1\text{ car}}{2\text{ people}}\right)\left(\frac{2\dfrac{\text{repairs}}{\text{year}}}{1\text{ car}}\right)\left(\frac{1\text{ yr}}{250\text{ workdays}}\right)\left(\frac{1\text{ mechanic}}{3\dfrac{\text{repairs}}{\text{workday}}}\right)=\boxed{1300\text{ mechanics}}$$

    (*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

$\boxed{1.}$ (*a*) 14 billion years = $\boxed{1.4\times10^{10}\text{ years}}$

(*b*) $\left(1.4\times10^{10}\text{ y}\right)\left(3.156\times10^{7}\text{s}/1\text{ y}\right)=\boxed{4.4\times10^{17}\text{s}}$

2. (*a*) 214 $\boxed{\text{3 significant figures}}$

(*b*) 81.60 $\boxed{\text{4 significant figures}}$

(*c*) 7.03 $\boxed{\text{3 significant figures}}$

(*d*) 0.03 $\boxed{\text{1 significant figure}}$

(*e*) 0.0086 $\boxed{\text{2 significant figures}}$

(*f*) 3236 $\boxed{\text{4 significant figures}}$

(*g*) 8700 $\boxed{\text{2 significant figures}}$

3. (*a*) $1.156 = \boxed{1.156\times10^{0}}$

   (*b*) $21.8 = \boxed{2.18\times10^{1}}$

   (*c*) $0.0068 = \boxed{6.8\times10^{-3}}$

   (*d*) $27.635 = \boxed{2.7635\times10^{1}}$

   (*e*) $0.219 = \boxed{2.19\times10^{-1}}$

   (*f*) $444 = \boxed{4.44\times10^{2}}$

4. (*a*) $8.69\times10^{4} = \boxed{86{,}900}$

   (*b*) $9.1\times10^{3} = \boxed{9{,}100}$

   (*c*) $8.8\times10^{-1} = \boxed{0.88}$

   (*d*) $4.76\times10^{2} = \boxed{476}$

   (*e*) $3.62\times10^{-5} = \boxed{0.0000362}$

5. The uncertainty is taken to be 0.01 m.

$$\%\ \text{uncertainty} = \frac{0.01\ \text{m}}{1.57\ \text{m}}\times100\% = \boxed{1\%}$$

$\boxed{6.}$ $$\%\ \text{uncertainty} = \frac{0.25\ \text{m}}{3.76\ \text{m}}\times100\% = \boxed{6.6\%}$$

7. (*a*) $\%\ \text{uncertainty} = \dfrac{0.2\ \text{s}}{5\ \text{s}}\times100\% = \boxed{4\%}$

   (*b*) $\%\ \text{uncertainty} = \dfrac{0.2\ \text{s}}{50\ \text{s}}\times100\% = \boxed{0.4\%}$

   (*c*) $\%\ \text{uncertainty} = \dfrac{0.2\ \text{s}}{300\ \text{s}}\times100\% = \boxed{0.07\%}$

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

$$9.2\times10^{3}\,\text{s} + 8.3\times10^{4}\,\text{s} + 0.008\times10^{6}\,\text{s} = 9.2\times10^{3}\,\text{s} + 83\times10^{3}\,\text{s} + 8\times10^{3}\,\text{s} = \left(9.2+83+8\right)\times10^{3}\,\text{s}$$

$$= 100\times10^{3}\,\text{s} = \boxed{1.00\times10^{5}\,\text{s}}$$

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

9. $\left(2.079\times10^{2}\,\text{m}\right)\left(0.082\times10^{-1}\right) = \boxed{1.7\ \text{m}}$. 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 $0.1\times10^{4}\,\text{cm}$.

$$A_{\text{specified}} = \pi r_{\text{specified}}^2 = \pi\left(3.8\times10^4\,\text{cm}\right)^2 = 4.5\times10^9\,\text{cm}^2$$

$$A_{\text{min}} = \pi r_{\text{min}}^2 = \pi\left(3.7\times10^4\,\text{cm}\right)^2 = 4.30\times10^9\,\text{cm}^2$$

$$A_{\text{max}} = \pi r_{\text{max}}^2 = \pi\left(3.9\times10^4\,\text{cm}\right)^2 = 4.78\times10^9\,\text{cm}^2$$

$$\Delta A = \tfrac{1}{2}\left(A_{\text{max}} - A_{\text{min}}\right) = \tfrac{1}{2}\left(4.78\times10^9\,\text{cm}^2 - 4.30\times10^9\,\text{cm}^2\right) = 0.24\times10^9\,\text{cm}^2$$

Thus the area should be quoted as $\boxed{A = \left(4.5\pm0.2\right)\times10^9\,\text{cm}^2}$

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.

$$V_{\text{specified}} = \tfrac{4}{3}\pi r_{\text{specified}}^3 = \tfrac{4}{3}\pi\left(2.86\text{ m}\right)^3 = 9.80\times10^1\,\text{m}^3$$

$$V_{\text{min}} = \tfrac{4}{3}\pi r_{\text{min}}^3 = \tfrac{4}{3}\pi\left(2.77\text{ m}\right)^3 = 8.903\times10^1\,\text{m}^3$$

$$V_{\text{max}} = \tfrac{4}{3}\pi r_{\text{max}}^3 = \tfrac{4}{3}\pi\left(2.95\text{ m}\right)^3 = 10.754\times10^1\,\text{m}^3$$

$$\Delta V = \tfrac{1}{2}\left(V_{\text{max}} - V_{\text{min}}\right) = \tfrac{1}{2}\left(10.754\times10^1\,\text{m}^3 - 8.903\times10^1\,\text{m}^3\right) = 0.926\times10^1\,\text{m}^3$$

The percent uncertainty is $\dfrac{\Delta V}{V_{\text{specified}}} = \dfrac{0.923\times10^1\,\text{m}^3}{9.80\times10^1\,\text{m}^3}\times100 = 0.09444 = \boxed{9\,\%}$

12.
(*a*) 286.6 mm — $286.6\times10^{-3}\,\text{m}$ — $\boxed{0.286\ 6\text{ m}}$

(*b*) 85 $\mu$V — $85\times10^{-6}\,\text{V}$ — $\boxed{0.000\ 085\text{ V}}$

(*c*) 760 mg — $760\times10^{-6}\,\text{kg}$ — $\boxed{0.000\ 760\text{ kg}}$ (if last zero is significant)

(*d*) 60.0 ps — $60.0\times10^{-12}\,\text{s}$ — $\boxed{0.000\ 000\ 000\ 0600\text{ s}}$

(*e*) 22.5 fm — $22.5\times10^{-15}\,\text{m}$ — $\boxed{0.000\ 000\ 000\ 000\ 022\ 5\text{ m}}$

(*f*) 2.50 gigavolts — $2.5\times10^9$ volts — $\boxed{2{,}500{,}000{,}000\text{ volts}}$

13.
(*a*) $1\times10^6$ volts — $\boxed{\text{1 megavolt}}$ = 1 Mvolt

(*b*) $2\times10^{-6}$ meters — $\boxed{\text{2 micrometers}}$ = 2 $\mu$m

(*c*) $6\times10^3$ days — $\boxed{\text{6 kilodays}}$ = 6 kdays

(*d*) $18\times10^2$ bucks — $\boxed{\text{18 hectobucks}}$ = 18 hbucks

(*e*) $8\times10^{-9}$ pieces — $\boxed{\text{8 nanopieces}}$ = 8 npieces

14. (*a*) Assuming a height of 5 feet 10 inches, then $5'10'' = \left(70\text{ in}\right)\left(1\text{ m}/39.37\text{ in}\right) = \boxed{1.8\text{ m}}$

(*b*) Assuming a weight of 165 lbs, then $\left(165\text{ lbs}\right)\left(0.456\text{ kg}/1\text{ lb}\right) = \boxed{75.2\text{ kg}}$

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 m/s$^2$.

15. (*a*) 93 million miles $= \left(93\times10^{6}\,\text{miles}\right)\left(1610\text{ m}/1\text{ mile}\right) = \boxed{1.5\times10^{11}\,\text{m}}$

(*b*) $1.5\times10^{11}\,\text{m} = 150\times10^{9}\,\text{m} = \boxed{150\text{ gigameters}}$ or $1.5\times10^{11}\,\text{m} = 0.15\times10^{12}\,\text{m} = \boxed{0.15\text{ terameters}}$

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

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

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*) $1.0\times10^{-10}\,\text{m} = \left(1.0\times10^{-10}\,\text{m}\right)\left(39.37\text{ in}/1\text{ m}\right) = \boxed{3.9\times10^{-9}\,\text{in}}$

(*b*) $\left(1.0\text{ cm}\right)\left(\frac{1\text{ m}}{100\text{ cm}}\right)\left(\frac{1\text{ atom}}{1.0\times10^{-10}\,\text{m}}\right) = \boxed{1.0\times10^{8}\,\text{atoms}}$

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

$$1.80\text{ m} + 142.5\text{ cm} + 5.34\times10^{5}\,\mu\text{m} = 1.80\text{ m} + 1.425\text{ m} + 0.534\text{ m} = 3.759\text{ m} = \boxed{3.76\text{ m}}$$

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*) $\left(1\text{k}/\text{h}\right)\left(\frac{0.621\text{ mi}}{1\text{ km}}\right) = \boxed{0.621\,\text{mi}/\text{h}}$

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

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

21. One mile is $1.61\times10^{3}\,\text{m}$. It is 110 m longer than a 1500-m race. The percentage difference is

$$\frac{110\text{ m}}{1500\text{ m}}\times100\% = \boxed{7.3\%}$$

22. (*a*) $1.00\text{ ly} = \left(2.998\times10^{8}\text{ m}/\text{s}\right)\left(3.156\times10^{7}\,\text{s}\right) = \boxed{9.46\times10^{15}\,\text{m}}$

(*b*) $\left(1.00\text{ ly}\right)\left(\frac{9.462\times10^{15}\,\text{m}}{1.00\text{ ly}}\right)\left(\frac{1\text{ AU}}{1.50\times10^{11}\text{m}}\right) = \boxed{6.31\times10^{4}\,\text{AU}}$

(*c*) $\left(2.998\times10^{8}\text{ m}/\text{s}\right)\left(\frac{1\text{ AU}}{1.50\times10^{11}\,\text{m}}\right)\left(\frac{3600\text{ s}}{1\text{ hr}}\right) = \boxed{7.20\,\text{AU}/\text{h}}$

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

(*a*) $A_{\text{Moon}} = \pi D_{\text{Moon}}^2 = \pi\left(3.48\times10^6\,\text{m}\right)^2 = \boxed{3.80\times10^{13}\,\text{m}^2}$

(*b*) $\dfrac{A_{\text{Earth}}}{A_{\text{Moon}}} = \dfrac{\pi D_{\text{Earth}}^2}{\pi D_{\text{Moon}}^2} = \left(\dfrac{D_{\text{Earth}}}{D_{\text{Moon}}}\right)^2 = \left(\dfrac{R_{\text{Earth}}}{R_{\text{Moon}}}\right)^2 = \left(\dfrac{6.38\times10^6\,\text{m}}{1.74\times10^6\,\text{m}}\right)^2 = \boxed{13.4}$

24. (*a*) $2800 = 2.8\times10^3 \approx 1\times10^3 = \boxed{10^3}$

(*b*) $86.30\times10^2 = 8.630\times10^3 \approx 10\times10^3 = \boxed{10^4}$

(*c*) $0.0076 = 7.6\times10^{-3} \approx 10\times10^{-3} = \boxed{10^{-2}}$

(*d*) $15.0\times10^8 = 1.5\times10^9 \approx 1\times10^9 = \boxed{10^9}$

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 $\frac{1}{4}\left(3500\,\text{m}^2\right)\left(\dfrac{1\text{ book}}{\left(0.25\text{ m}\right)\left(0.04\text{ m}\right)}\right) = 8.75\times10^4\,\text{books}$. With 8 shelves of books, the total number of books stored is as follows.

$$\left(8.75\times10^4\,\frac{\text{books}}{\text{shelf level}}\right)\left(8\text{ shelves}\right) \approx \boxed{7\times10^5\text{ books}}.$$

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

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

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.

$\boxed{27.}$ 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.

$$\left(70\text{ y}\right)\left(365\text{ d}/1\text{ y}\right)\left(2\text{ L}/1\text{ d}\right) \approx \boxed{5\times10^4\,\text{L}}$$

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.

$$V = \pi r^2 h = \pi\left(12\text{ cm}\right)^2\left(170\text{ cm}\right) = 9\times10^4\,\text{cm}^3 \approx \boxed{8\times10^4\,\text{cm}^3}$$

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 $ft^2$. There would perhaps be 4 windows in that wall, each about 3 ft wide and 4 feet tall, so 12 $ft^2$ per window, or about 50 $ft^2$ 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 cm/year. Assume the average tire has a radius of 40 cm, and a width of 10 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

$$\left(\frac{\text{Mass}}{\text{year}}\right) = \left(\frac{\text{Surface area}}{\text{tire}}\right)\left(\frac{\text{Thickness wear}}{\text{year}}\right)(\text{density of rubber})(\#\text{ of tires})$$

$$= \left[2\pi(0.4\text{ m})(0.1\text{ m})\right](0.002\ \text{m/y})(1200\,\text{kg/m}^3)(600{,}000{,}000\text{ tires})$$

$$= \boxed{4\times 10^8\ \text{kg/y}}$$

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 $(\text{m/s})(\text{s}^2) = \text{m}\bullet\text{s}$, 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 m needs to be distinguishable from 20,000,002 m, which means that $\boxed{\text{8 significant figures}}$ are needed in the distance measurements.

35. Multiply the number of chips per wafer times the number of wafers that can be made fro 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: $1.00\text{ y} = (1.00\text{ y})\left(\dfrac{3.156\times10^7\text{s}}{1\text{ y}}\right) = \boxed{3.16\times10^7\text{s}}$

(*b*) # of nanoseconds in 1.00 y: $1.00\text{ y} = (1.00\text{ y})\left(\dfrac{3.156\times10^7\text{s}}{1\text{ y}}\right)\left(\dfrac{1\times10^9\text{ns}}{1\text{ s}}\right) = \boxed{3.16\times10^{16}\text{ns}}$

(*c*) # of years in 1.00 s: $1.00\text{ s} = (1.00\text{ s})\left(\dfrac{1\text{ y}}{3.156\times10^7\text{s}}\right) = \boxed{3.17\times10^{-8}\text{y}}$

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

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

$$\left(3\times10^8\right)\pi\frac{d^3}{6} = 2\times10^{-3}\text{m}^3 \quad\to\quad d = \left[\frac{6\left(2\times10^{-3}\right)}{3\times10^8\pi}\text{m}^3\right]^{1/3} = \boxed{2\times10^{-4}\text{m}}.$$

38. $1\text{ hectare} = (1\text{ hectare})\left(\dfrac{10^4\text{ m}^2}{1\text{ hectare}}\right)\left(\dfrac{3.28\text{ ft}}{1\text{ m}}\right)^2\left(\dfrac{1\text{ acre}}{4\times10^4\text{ft}^2}\right) = \boxed{2.69\text{ acres}}$

39. (*a*) $\left(\dfrac{10^{-15}\text{kg}}{1\text{ bacterium}}\right)\left(\dfrac{1\text{ proton or neutron}}{10^{-27}\text{kg}}\right) = \boxed{10^{12}\text{ protons or neutrons}}$

(*b*) $\left(\dfrac{10^{-17}\text{kg}}{1\text{ DNA molecule}}\right)\left(\dfrac{1\text{ proton or neutron}}{10^{-27}\text{kg}}\right) = \boxed{10^{10}\text{ protons or neutrons}}$

(*c*) $\left(\dfrac{10^{2}\text{kg}}{1\text{ human}}\right)\left(\dfrac{1\text{ proton or neutron}}{10^{-27}\text{kg}}\right) = \boxed{10^{29}\text{ protons or neutrons}}$

(*d*) $\left(\dfrac{10^{41}\text{kg}}{1\text{ galaxy}}\right)\left(\dfrac{1\text{ proton or neutron}}{10^{-27}\text{kg}}\right) = \boxed{10^{68}\text{ protons or neutrons}}$

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.

$$\left(3\times10^8\text{people}\right)\left(\frac{1\text{ automobile}}{2\text{ people}}\right)\left(\frac{12{,}000\text{ mi}}{1\text{ y}}\right)\left(\frac{1\text{ gallon}}{20\text{ mi}}\right) \approx \boxed{1\times10^{11}\text{ gallons}/\text{y}}$$

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 bout 15 rows. Thus we estimate that there are about $\boxed{\text{1500 gumballs}}$ in the machine.

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

$$\left(4\times10^4\text{people}\right)\left(\frac{1200\text{ L/day}}{4\text{ people}}\right)\left(\frac{365\text{ day}}{1\text{ y}}\right)\left(\frac{1000\text{ cm}^3}{1\text{ L}}\right)\left(\frac{1\text{ km}}{10^5\text{ cm}}\right)^3 = 4.4\times10^{-3}\text{ km}^3/\text{y}$$

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

$$d=\frac{V}{A}=\frac{4.4\times10^{-3}\ \text{km}^3/\text{y}}{50\ \text{km}^2}=\left(8.76\times10^{-5}\ \frac{\text{km}}{\text{y}}\right)\left(\frac{10^5\ \text{cm}}{1\ \text{km}}\right)=8.76\ \text{cm/y}\approx\boxed{9\ \text{cm/y}}$$

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

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

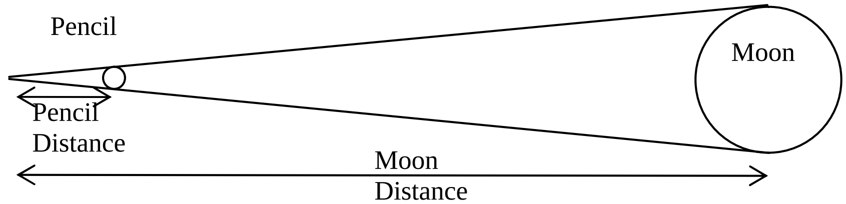
44. To calculate the mass of water, we need to find the volume of water, and then convert the volume to mass.

$$\left[\left(4\times10^1\ \text{km}^2\right)\left(\frac{10^5\text{cm}}{1\ \text{km}}\right)^2\right](1.0\ \text{cm})\left(\frac{10^{-3}\text{kg}}{1\ \text{cm}^3}\right)\left(\frac{1\ \text{ton}}{10^3\text{kg}}\right)=\boxed{4\times10^5\ \text{ton}}$$

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

$$\left[\left(4\times10^1\ \text{km}^2\right)\left(\frac{10^5\text{cm}}{1\ \text{km}}\right)^2\right](1.0\ \text{cm})\left(\frac{1\ \text{L}}{1\times10^3\text{cm}^3}\right)\left(\frac{1\ \text{gal}}{3.78\ \text{L}}\right)=\boxed{1\times10^8\ \text{gal}}$$

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.




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

$$\text{Moon diameter}=\frac{\text{pencil diameter}}{\text{pencil distance}}(\text{Moon distance})=\frac{7\times10^{-3}\text{m}}{0.75\ \text{m}}\left(3.8\times10^5\text{km}\right)\approx\boxed{3500\ \text{km}}$$

46. The person walks $4\ \text{km/h}$, 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.

$$2\pi(6380\ \text{km})\left(\frac{1\ \text{h}}{4\ \text{km}}\right)\left(\frac{1\ \text{d}}{10\ \text{h}}\right)=\boxed{1\times10^3\ \text{d}}$$

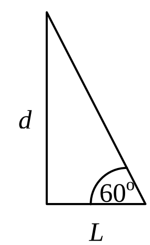
47. A cubit is about a half of a meter, by measuring several people's forearms. Thus the dimensions of Noah's ark would be $\boxed{150\text{ m long , 25 m wide, 15 m high}}$. The volume of the ark is found by multiplying the three dimensions.

$$V = (150\text{ m})(25\text{ m})(15\text{ m}) = 5.625\times10^4\text{ m}^3 \approx \boxed{6\times10^4\text{ m}^3}$$

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

$$V = \pi(d/2)^2 t \quad\to\quad d = 2\sqrt{\frac{V}{\pi t}} = 2\sqrt{\frac{1000\text{cm}^3\left(\frac{1\text{ m}}{100\text{ cm}}\right)^3}{\pi\left(2\times10^{-10}\text{m}\right)}} = \boxed{3\times10^3\text{ m}}.$$

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.




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

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

50. $\left(\dfrac{8\text{ s}}{1\text{ y}}\right)\left(\dfrac{1\text{ y}}{3.156\times10^7\text{s}}\right)\times100\% = \boxed{3\times10^{-5}\%}$

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

$$V_{\text{Moon}} = \tfrac{4}{3}\pi R_{\text{Moon}}^3 = \tfrac{4}{3}\pi\left(1.74\times10^6\text{m}\right)^3 = \boxed{2.21\times10^{19}\text{m}^3}$$

$$\frac{V_{\text{Earth}}}{V_{\text{Moon}}} = \frac{\frac{4}{3}\pi R_{\text{Earth}}^3}{\frac{4}{3}\pi R_{\text{Moon}}^3} = \left(\frac{R_{\text{Earth}}}{R_{\text{Moon}}}\right)^3 = \left(\frac{6.38\times10^6\text{m}}{1.74\times10^6\text{m}}\right)^3 = 49.3.$$

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

52. (*a*) $1.0\,\text{Å} = (1.0\,\text{Å})\left(\dfrac{10^{-10}\text{m}}{1\text{Å}}\right)\left(\dfrac{1\text{ nm}}{10^{-9}\text{m}}\right) = \boxed{0.10\text{ nm}}$

(*b*) $1.0\,\text{Å} = (1.0\,\text{Å})\left(\dfrac{10^{-10}\text{m}}{1\text{Å}}\right)\left(\dfrac{1\text{ fm}}{10^{-15}\text{m}}\right) = \boxed{1.0\times10^5\text{fm}}$

(*c*) $1.0\text{ m} = (1.0\text{ m})\left(\dfrac{1\text{Å}}{10^{-10}\text{m}}\right) = \boxed{1.0\times10^{10}\text{ Å}}$

(*d*) $1.0\text{ ly} = (1.0\text{ ly})\left(\dfrac{9.46\times10^{15}\text{m}}{1\text{ ly}}\right)\left(\dfrac{1\text{Å}}{10^{-10}\text{m}}\right) = \boxed{9.5\times10^{25}\text{ Å}}$

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

$$\left(\frac{\Delta\theta}{\theta}\right)100 = \left(\frac{0.5^\circ}{15.0^\circ}\right)100 = \boxed{3\%} \qquad \left(\frac{\Delta\sin\theta}{\sin\theta}\right)100 = \left(\frac{8\times10^{-3}}{0.259}\right)100 = \boxed{3\%}$$

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

$$\left(\frac{\Delta\theta}{\theta}\right)100 = \left(\frac{0.5^\circ}{75.0^\circ}\right)100 = \boxed{0.7\%} \qquad \left(\frac{\Delta\sin\theta}{\sin\theta}\right)100 = \left(\frac{2\times10^{-3}}{0.966}\right)100 = \boxed{0.2\%}$$

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.

$$(1\text{ minute})\left(\frac{1^\circ}{60\text{ minute}}\right)\left(\frac{2\pi\left(6.38\times10^3\text{km}\right)}{360^\circ}\right)\left(\frac{0.621\text{ m}}{1\text{ km}}\right) = \boxed{1.15\text{ mi}}$$

# CHAPTER 2: Describing Motion: Kinematics in One Dimension

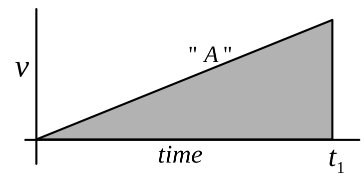
## Answers to Questions

$\boxed{1.}$ A car speedometer measures only speed. It does not give any information about the direction, and so does not measure velocity.

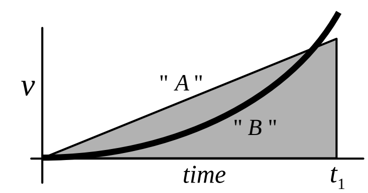
2. By definition, if an object has a constant velocity, then both the object's speed and its direction of motion are constant. Therefore the object CANNOT have a varying speed if its velocity is constant.

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

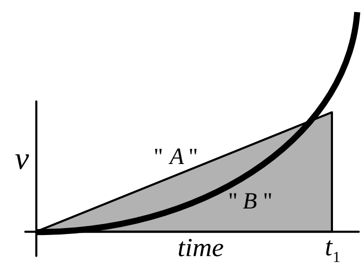
4. For both cars, the time elapsed is the distance traveled divided by the average velocity. Since both cars travel the same distance, the car with the larger average velocity will have the smaller elapsed time. Consider this scenario. Assume that one car has a constant acceleration down the track. Then 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 $m/s^2$.

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 $v = v_0 + at \quad \to \quad 0 = v_0 - gt \quad \to \quad v_0 = gt$ 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 $t = d / v$.

$$\bar{v} = \frac{d_{AB} + d_{BC}}{t_{AB} + t_{BC}} = \frac{(d\ \text{km}) + (d\ \text{km})}{\dfrac{d\ \text{km}}{70\,\text{km/h}} + \dfrac{d\ \text{km}}{90\,\text{km/h}}} = 78.75\,\text{km/h}$$ . The average speed is 78.75 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 $t_2 = 2t_1$, $t_3 = 3t_1$, $t_4 = 4t_1$, $\cdots$, 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 $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{-4.2\,\text{cm} - 3.4\,\text{cm}}{6.1\,\text{s} - 3.0\,\text{s}} = \dfrac{-7.6\,\text{cm}}{3.1\,\text{s}} = \boxed{-2.5\,\text{cm/s}}$.

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

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

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

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.

$$\text{ave speed}_2 = v_2 = \frac{d_2}{\Delta t_2} \rightarrow d_2 = v_2\Delta t_2 = (65\,\text{km/h})(1.96\,\text{h}) = 127.5 \text{ km} = 1.3\times10^2\,\text{km}$$

(*a*) The total distance is then $d_{total} = d_1 + d_2 = 130 \text{ km} + 127.5 \text{ km} = 257.5 \text{ km} \approx \boxed{2.6\times10^2 \text{ km}}$

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

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

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.

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

(*a*) 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*) 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 s + 4.8 s = 18.8 s.

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

(*b*) 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.

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

Solving for $d_{\text{truck}}$ 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

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

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 $\bar{v} = \dfrac{d}{\Delta t}$, so $\Delta t = \dfrac{d}{\bar{v}}$ for each segment.

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

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

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, $\bar{v}_1 = \dfrac{d_1}{\Delta t_1}$ and so $\Delta t_1 = \dfrac{d_1}{\bar{v}_1} = \dfrac{250\ \text{km}}{95\,\text{km/h}} = 2.632\ \text{h}$. During the return portion, $\bar{v}_2 = \dfrac{d_2}{\Delta t_2}$, and so $\Delta t_2 = \dfrac{d_2}{\bar{v}_2} = \dfrac{250\ \text{km}}{55\,\text{km/h}} = 4.545\ \text{h}$. Thus the total time, including lunch, is $\Delta t_{\text{total}} = \Delta t_1 + \Delta t_{\text{lunch}} + \Delta t_2 = 8.177\ \text{h}$. Average speed $= \dfrac{d_{total}}{\Delta t_{total}} = \dfrac{500\ \text{km}}{8.177\ \text{h}} = \boxed{61\,\text{km/h}}$.
(*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 $\Delta t_{\text{sound}} = \dfrac{d}{\bar{v}_{\text{sound}}} = \dfrac{16.5\ \text{m}}{340\ \text{m/s}} = 4.85\times 10^{-2}\,\text{s}$. 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

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

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

(*b*) $\bar{a} = \left(7.41\,\mathrm{m/s^2}\right)\left(\dfrac{1\ \mathrm{km}}{1000\ \mathrm{m}}\right)\left(\dfrac{3600\ \mathrm{s}}{1\ \mathrm{h}}\right)^2 = \boxed{9.60\times10^4\ \mathrm{km/h^2}}$

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

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

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

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

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

$$v = v_0 + at \quad \rightarrow$$

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

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:

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

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

From 2.25 s to 2.75 s, for average acceleration:

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

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

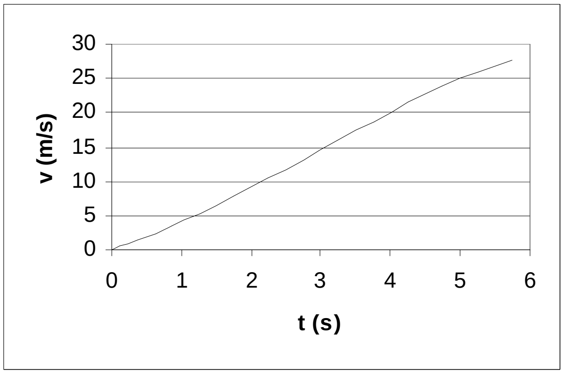
Table of Calculations

| $t$ (s) | $x$ (m) |
|---|---|
| 0.00 | 0.00 |
| 0.25 | 0.11 |
| 0.50 | 0.46 |
| 0.75 | 1.06 |
| 1.00 | 1.94 |
| 1.50 | 4.62 |
| 2.00 | 8.55 |
| 2.50 | 13.79 |
| 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 |

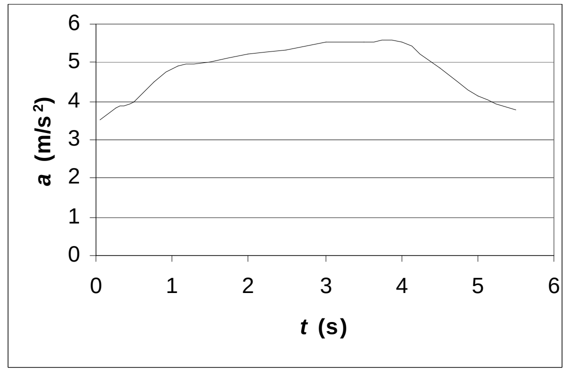
| $t$ (s) | $v$ (m/s) |
|---|---|
| 0.00 | 0.00 |
| 0.125 | 0.44 |
| 0.375 | 1.40 |
| 0.625 | 2.40 |
| 0.875 | 3.52 |
| 1.25 | 5.36 |
| 1.75 | 7.86 |
| 2.25 | 10.48 |
| 2.75 | 13.14 |
| 3.25 | 15.90 |
| 3.75 | 18.68 |
| 4.25 | 21.44 |
| 4.75 | 23.86 |
| 5.25 | 25.92 |
| 5.75 | 27.80 |

| $t$ (s) | $a$ (m/s$^2$) |
|---|---|
| 0.063 | 3.52 |
| 0.25 | 3.84 |
| 0.50 | 4.00 |
| 0.75 | 4.48 |
| 1.06 | 4.91 |
| 1.50 | 5.00 |
| 2.00 | 5.24 |
| 2.50 | 5.32 |
| 3.00 | 5.52 |
| 3.50 | 5.56 |
| 4.00 | 5.52 |
| 4.50 | 4.84 |
| 5.00 | 4.12 |
| 5.50 | 3.76 |

Graph of the velocity




Graph of the acceleration




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

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

$$x-x_0=v_0t+\tfrac{1}{2}at^2=(13\,\text{m/s})(6.0\text{ s})+\tfrac{1}{2}(2.0\,\text{m/s}^2)(6.0\text{ s})^2=\boxed{114\text{ m}}$$

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 $x-x_0$.

$$v^2=v_0^2+2a(x-x_0)\ \rightarrow\ x-x_0=\frac{v^2-v_0^2}{2a}=\frac{(33\,\text{m/s})^2-0}{2(3.0\,\text{m/s}^2)}=\boxed{1.8\times10^2\,\text{m}}$$

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 form combining Eqs. 2-7 and 2-8.

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

$\boxed{26.}$ 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": $a = \dfrac{-3.484\times 10^2\ \text{m/s}^2}{(9.8\,\text{m/s}^2)/g} = \boxed{-36\,g\text{'s}}$.

28. The origin is the location of the car at the beginning of the reaction time. The initial speed of the car is $(95\,\text{km/h})\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 26.39\,\text{m/s}$. 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.

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

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

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 $\Delta x_{\substack{\text{passing}\\\text{car}}}$ from Eq. 2-11b.

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

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

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

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

Calculate the displacements of the two cars during this time.

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

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

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

$\boxed{\text{The car should not pass.}}$

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:

$$v = v_o + at \qquad d_1 = v_o t + \tfrac{1}{2}at^2 \qquad d_2 = v(180-t) = (v_0 + at)(180-t)$$

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

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

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

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

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

Case I: trying to stop. The constraint is, with the braking deceleration of the car $\left(a = -5.8\text{ m/s}^2\right)$, 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 $\left[a = \left(\frac{65\text{ km/h} - 45\text{ km/h}}{6.0\text{ s}}\right)\left(\frac{1\text{ m/s}}{3.6\text{ km/h}}\right) = 0.9259\text{ m/s}^2\right]$, 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

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

$\boxed{\text{She should stop.}}$

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*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \quad \rightarrow \quad y - 0 = 0 + \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)\left(3.25\text{ s}\right)^2 \quad \rightarrow \quad y = \boxed{51.8\text{ m}}$$

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

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

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*.

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

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

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

$\boxed{36.}$ 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 $y$.

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

(*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.

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

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

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 = 0 \quad \rightarrow$$

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

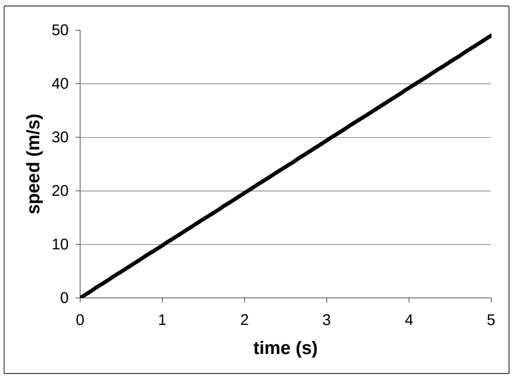
The height can be calculated from Eq. 2-11c, with a final velocity of $v = 0$ at the top of the path.

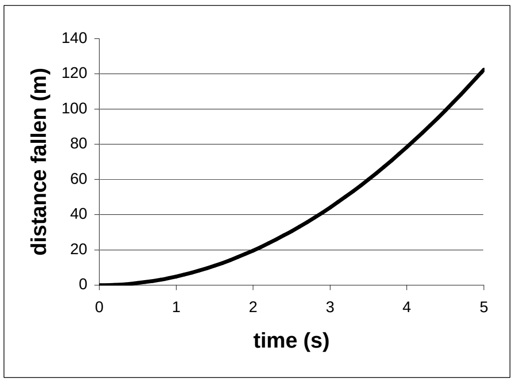
$$v^2 = v_0^2 + 2a(y - y_0) \quad \rightarrow \quad y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - (14.7\,\text{m/s})^2}{2(-9.8\,\text{m/s}^2)} = \boxed{11\text{ m}}$$

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 $y = y_0 + v_0 t + \frac{1}{2}at^2 = 0 + 0 + (4.90\,\text{m/s}^2)t^2$. 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 $v_0 = -5.20\,\text{m/s}^2$, 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*.

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

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

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

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:

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

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.

$$y(n) = \tfrac{1}{2}gn^2 \qquad y(n+1) = \tfrac{1}{2}g(n+1)^2$$

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

$$= \tfrac{1}{2}g\left(n^2 + 2n + 1 - n^2\right) = \tfrac{1}{2}g(2n+1)$$

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

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).

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \quad \rightarrow \quad t^2 + \frac{2(18.0\,\text{m/s})}{-9.80\,\text{m/s}^2}t + \frac{2(-11.0\ \text{m})}{-9.80\,\text{m/s}^2} = 0 \quad \rightarrow$$

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

(*c*) $\boxed{\text{There are two times at which the object reaches that height}}$ – once on the way up $(t = 0.775\ \text{s})$, 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 3rd 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 6th 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.

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

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

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 $T$.

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

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

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 $y_w = y_0 + v_0 t + \tfrac{1}{2} a t^2 = 0 + 0 + \tfrac{1}{2} g t_w^2$. 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 $y_w + 2.2 \text{ m} = y_0 + v_0 + \tfrac{1}{2} a t^2 = 0 + 0 + \tfrac{1}{2} g \left(t_w + 0.28 \text{ s}\right)^2$. Substituting the first expression for $y_w$ into the second one.

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

Use this time in the first equation.

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

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 $H = y_0 + v_0 t + \tfrac{1}{2} t^2 = 0 + 0 + \tfrac{1}{2} g t_1^2$.

For the sound wave, use the constant speed equation that $v_s = \dfrac{d}{\Delta t} = \dfrac{H}{T - t_1}$, which can be rearranged to give $t_1 = T - \frac{H}{v_s}$, where $T = 3.2\ \text{s}$ 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*.

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

$$4.239\times10^{-5}H^2 - 1.092H + 50.18 = 0 \quad \rightarrow \quad H = 46.0\ \text{m},\ 2.57\times10^4\ \text{m}$$

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 $y = -1.5\ \text{m}$, and the time of flight is $t = 2.0\ \text{s}$. Using Eq. 2-11b and substituting *y* for *x* gives the following.

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

$\boxed{47.}$ 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 $y = 70.0\ \text{m}$.

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

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

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

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

(*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:

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

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 $y = 28\ \text{m}$.

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

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

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

Choose the positive value because the initial direction is upward.

(*b*) At the top of its path, the velocity will be 0, and so we can use the initial velocity as found above, along with Eq. 2-11c.

$$v^2 = v_0^2 + 2a\left(y - y_0\right) \quad\rightarrow\quad y = y_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - \left(27\,\text{m/s}\right)^2}{2\left(-9.8\,\text{m/s}^2\right)} = \boxed{37\ \text{m}}$$

(*c*) We want the time elapsed from throwing (speed $v_0 = 27\,\text{m/s}$) to reaching the window (speed $v = 13\,\text{m/s}$). Using Eq. 2-11a, we have:

$$v = v_0 + at \quad\rightarrow\quad t = \frac{v - v_0}{a} = \frac{13\,\text{m/s} - 27\,\text{m/s}}{-9.80\,\text{m/s}^2} = \boxed{1.4\ \text{s}}.$$

(*d*) We want the time elapsed from the window (speed $v_0 = 13\,\text{m/s}$) to reaching the street (speed $v = -27\,\text{m/s}$). Using Eq. 2-11a, we have:

$$v = v_0 + at \quad\rightarrow\quad t = \frac{v - v_0}{a} = \frac{-27\,\text{m/s} - 13\,\text{m/s}}{-9.80\,\text{m/s}^2} = \boxed{4.1\ \text{s}}.$$

49. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) The greatest velocity is found at the highest point on the graph, which is at $\boxed{t \approx 48\ \text{s}}$.

(*b*) The indication of a constant velocity on a velocity-time graph is a slope of 0, which occurs from $\boxed{t = 90\ \text{s}\ \text{to}\ t \approx 108\ \text{s}}$.

(*c*) The indication of a constant acceleration on a velocity-time graph is a constant slope, which occurs from $\boxed{t = 0\ \text{s}\ \text{to}\ t \approx 38\ \text{s}}$, again from $\boxed{t \approx 65\ \text{s}\ \text{to}\ t \approx 83\ \text{s}}$, and again from $\boxed{t = 90\ \text{s}\ \text{to}\ t \approx 108\ \text{s}}$.

(*d*) The magnitude of the acceleration is greatest when the magnitude of the slope is greatest, which occurs from $\boxed{t \approx 65\ \text{s}\ \text{to}\ t \approx 83\ \text{s}}$.

50. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) The instantaneous velocity is given by the slope of the tangent line to the curve. At $t = 10.0\ \text{s}$, the slope is approximately $v\left(10\right) \approx \dfrac{3\,\text{m} - 0}{10.0\ \text{s} - 0} = \boxed{0.3\,\text{m/s}}$.

(*b*) At $t = 30.0\ \text{s}$, the slope of the tangent line to the curve, and thus the instantaneous velocity, is approximately $v\left(30\right) \approx \dfrac{22\ \text{m} - 8\ \text{m}}{35\ \text{s} - 25\ \text{s}} = \boxed{1.4\,\text{m/s}}$.

(*c*) The average velocity is given by $\bar{v} = \dfrac{x\left(5\right)\text{m} - x\left(0\right)\text{m}}{5.0\ \text{s} - 0\ \text{s}} = \dfrac{1.5\ \text{m} - 0}{5.0\ \text{s}} = \boxed{.30\,\text{m/s}}$.

(*d*) The average velocity is given by $\bar{v} = \dfrac{x\left(30\right)\text{m} - x\left(25\right)\text{m}}{30.0\ \text{s} - 25.0\ \text{s}} = \dfrac{16\ \text{m} - 9\ \text{m}}{5.0\ \text{s}} = \boxed{1.4\,\text{m/s}}$.

(*e*) The average velocity is given by $\bar{v} = \dfrac{x\left(50\right)\text{m} - x\left(40\right)\text{m}}{50.0\ \text{s} - 40.0\ \text{s}} = \dfrac{10\ \text{m} - 19.5\ \text{m}}{10.0\ \text{s}} = \boxed{-0.95\,\text{m/s}}$.

51. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) The indication of a constant velocity on a position-time graph is a constant slope, which occurs from $\boxed{t = 0\ \text{s}\ \text{to}\ t \approx 18\ \text{s}}$.

(*b*) The greatest velocity will occur when the slope is the highest positive value, which occurs at about $\boxed{t = 27\text{ s}}$.

(*c*) The indication of a 0 velocity on a position-time graph is a slope of 0, which occurs at about from $\boxed{t = 38\text{ s}}$.

(*d*) $\boxed{\text{The object moves in both directions.}}$ When the slope is positive, from $t = 0\text{ s}$ to $t = 38\text{ s}$, the object is moving in the positive direction. When the slope is negative, from $t = 38\text{ s}$ to $t = 50\text{ s}$, the object is moving in the negative direction.

52. Slightly different answers may be obtained since the data comes from reading the graph. We assume that the short, nearly horizontal portions of the graph are the times that shifting is occurring, and those times are not counted as being "in" a certain gear.

(*a*) The average acceleration in 2nd gear is given by $\overline{a}_2 = \dfrac{\Delta v_2}{\Delta t_2} = \dfrac{24\text{ m/s} - 14\text{ m/s}}{8\text{ s} - 4\text{ s}} = \boxed{2.5\text{ m/s}^2}$.

The average acceleration in 4th gear is given by $\overline{a}_4 = \dfrac{\Delta v_4}{\Delta t_4} = \dfrac{44\text{ m/s} - 37\text{ m/s}}{27\text{ s} - 16\text{ s}} = \boxed{0.64\text{ m/s}^2}$.

(*b*) The distance traveled can be determined from a velocity-time graph by calculating the area between the graph and the $v = 0$ axis, bounded by the times under consideration. For this case, we will approximate the area as a rectangle.

$$\text{height} = \overline{v} = \frac{v_f + v_0}{2} = \frac{44\text{ m/s} + 37\text{ m/s}}{2} = 40.5\text{ m/s} \qquad \text{width} = \Delta t = 27\text{ s} - 16\text{ s} = 11\text{ s}$$

Thus the distance traveled is $d = \overline{v}\Delta t = (40.5\text{ m/s})(11\text{ s}) = \boxed{450\text{ m}}$.

53. Slightly different answers may be obtained since the data comes from reading the graph. We assume that the short, nearly horizontal portions of the graph are the times that shifting is occurring, and those times are not counted as being "in" a certain gear.

(*a*) The average acceleration in first gear is given by $\overline{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{14\text{ m/s} - 0\text{ m/s}}{4\text{ s} - 0\text{ s}} = \boxed{4\text{ m/s}^2}$.

(*b*) The average acceleration in third gear is given by $\overline{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{37\text{ m/s} - 24\text{ m/s}}{14\text{ s} - 9\text{ s}} = \boxed{3\text{ m/s}^2}$.

(*c*) The average acceleration in fifth gear is given by $\overline{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{52\text{ m/s} - 44\text{ m/s}}{50\text{ s} - 27\text{ s}} = \boxed{0.35\text{ m/s}^2}$.

(*d*) The average acceleration through the first four gears is given by

$$\overline{a} = \frac{\Delta v}{\Delta t} = \frac{44\text{ m/s} - 0\text{ m/s}}{27\text{ s} - 0\text{ s}} = \boxed{1.6\text{ m/s}^2}.$$

54. Slightly different answers may be obtained since the data comes from reading the graph.

(*a*) To estimate the distance the object traveled during the first minute, we need to find the area under the graph, from $t = 0$ s to $t = 60$ s. Each "block" of the graph represents an "area" of $\Delta x = (10\text{ m/s})(10\text{ s}) = 100\text{ m}$. By counting and estimating, there are about 17.5 blocks under the 1st minute of the graph, and so the distance traveled during the 1st minute is about $\boxed{1750\text{ m}}$.

(*b*) For the second minute, there are about 5 blocks under the graph, and so the distance traveled during the second minute is about $\boxed{500\text{ m}}$.

Alternatively, average accelerations can be estimated for various portions of the graph, and then the uniform acceleration equations may be applied. For instance, for part (*a*), break the motion up into two segments, from 0 to 50 seconds and then from 50 to 60 seconds.

(*a*) t = 0 to 50: $\overline{a}_1 = \dfrac{\Delta v}{\Delta t} = \dfrac{38\,\text{m/s} - 14\,\text{m/s}}{50\text{ s} - 0\text{ s}} = 0.48\,\text{m/s}^2$

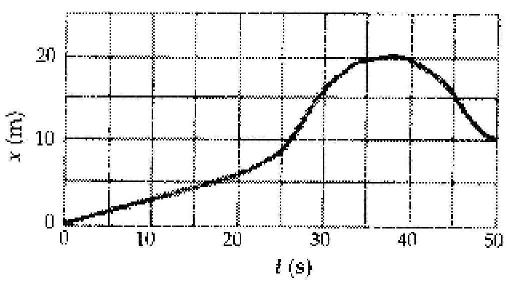
$$d_1 = v_{o1}t_1 + \tfrac{1}{2}\overline{a}_1 t_1^2 = (14\,\text{m/s})(50\text{ s}) + \tfrac{1}{2}(0.48\,\text{m/s}^2)(50\text{ s})^2 = 1300\text{ m}$$

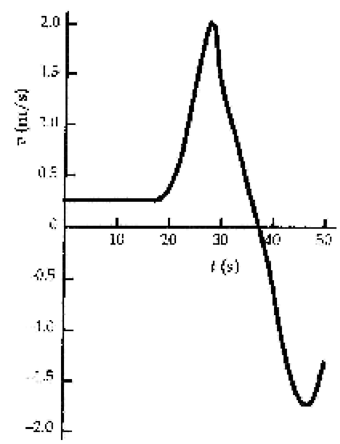
$$\overline{a}_2 = \frac{\Delta v}{\Delta t} = \frac{31\,\text{m/s} - 38\,\text{m/s}}{60\text{ s} - 50\text{ s}} = -0.70\,\text{m/s}^2$$

$$d_2 = v_{o2}t_2 + \tfrac{1}{2}\overline{a}_2 t_2^2 = (38\,\text{m/s})(10\text{ s}) + \tfrac{1}{2}(-0.70\,\text{m/s}^2)(10\text{ s})^2 = 345\text{ m}$$

$$d_1 + d_2 = 1645\text{ m}$$

55. The $v$ vs. $t$ graph is found by taking the slope of the $x$ vs. $t$ graph. Both graphs are shown here.




56. (*a*) During the interval from A to B, it is $\boxed{\text{moving in the negative direction}}$, because its displacement is negative.

(*b*) During the interval from A to B, it is $\boxed{\text{speeding up}}$, because the magnitude of its slope is increasing (changing from less steep to more steep).

(*c*) During the interval from A to B, $\boxed{\text{the acceleration is negative}}$, because the graph is concave downward, indicating that the slope is getting more negative, and thus the acceleration is negative.

(*d*) During the interval from D to E, it is $\boxed{\text{moving in the positive direction}}$, because the displacement is positive.

(*e*) During the interval from D to E, it is $\boxed{\text{speeding up}}$, because the magnitude of its slope is increasing (changing from less steep to more steep).

(*f*) During the interval from D to E, $\boxed{\text{the acceleration is positive}}$, because the graph is concave upward, indicating the slope is getting more positive, and thus the acceleration is positive.

(*g*) During the interval from C to D, $\boxed{\text{the object is not moving in either direction}}$.

$\boxed{\text{The velocity and acceleration are both 0.}}$

57. (*a*) For the free-falling part of the motion, choose downward to be the positive direction, and $y_0 = 0$ to be the height from which the person jumped. The initial velocity is $v_0 = 0$, acceleration is $a = 9.80\,\mathrm{m/s^2}$, and the location of the net is $y = 15.0\ \mathrm{m}$. Find the speed upon reaching the net from Eq. (2-11c) with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a\left(y - y_{(\,)}\right) \;\rightarrow\; v = \pm\sqrt{0 + 2a\left(y - 0\right)} = \pm\sqrt{2\left(9.80\,\mathrm{m/s^2}\right)\left(15.0\ \mathrm{m}\right)} = 17.1\,\mathrm{m/s}$$

The positive root is selected since the person is moving downward.
For the net-stretching part of the motion, choose downward to be the positive direction, and $y_0 = 15.0\ \mathrm{m}$ to be the height at which the person first contacts the net. The initial velocity is $v_0 = 17.1\,\mathrm{m/s}$, the final velocity is $v = 0$, and the location at the stretched position is $y = 16.0\ \mathrm{m}$. Find the acceleration from Eq. (2-11c) with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a\left(y - y_0\right) \;\rightarrow\; a = \frac{v^2 - v_0^2}{2\left(y - y_0\right)} = \frac{0^2 - \left(17.1\,\mathrm{m/s}\right)^2}{2\left(1.0\ \mathrm{m}\right)} = \boxed{-150\,\mathrm{m/s^2}}$$

(*b*) For the acceleration to be smaller, in the above equation we see that the displacement would have to be larger. This means that the net should be $\boxed{\text{"loosened"}}$.

58. Choose the upward direction to be positive, and $y_0 = 0$ to be the level from which the object was thrown. The initial velocity is $v_0$ and the velocity at the top of the path is $v = 0\,\mathrm{m/s}$. The height at the top of the path can be found from Eq. (2-11c) with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a\left(y - y_0\right) \;\rightarrow\; y - y_0 = \frac{-v_0^2}{2a}.$$

From this we see that the displacement is inversely proportional to the acceleration, and so if the acceleration is reduced by a factor of 6 by going to the Moon, and the initial velocity is unchanged, the $\boxed{\text{displacement increases by a factor of 6}}$.

59. The initial velocity of the car is $v_0 = \left(100\,\mathrm{km/h}\right)\left(\dfrac{1\,\mathrm{m/s}}{3.6\,\mathrm{km/h}}\right) = 27.8\,\mathrm{m/s}$. Choose $x_0 = 0$ to be location at which the deceleration begins. We have $v = 0\,\mathrm{m/s}$ and $a = -30g = -294\,\mathrm{m/s^2}$. Find the displacement from Eq. (2-11c).

$$v^2 = v_0^2 + 2a\left(x - x_0\right) \;\rightarrow\; x = x_0 + \frac{v^2 - v_0^2}{2a} = 0 + \frac{0 - \left(27.8\,\mathrm{m/s}\right)^2}{2\left(-2.94\times10^2\ \mathrm{m/s^2}\right)} = 1.31\,\mathrm{m} \approx \boxed{1.3\ \mathrm{m}}$$

60. Choose downward to be the positive direction, and $y_0 = 0$ to be at the height of the bridge. Agent Bond has an initial velocity of $v_0 = 0$, an acceleration of $a = g$, and will have a displacement of $y = 12\ \mathrm{m} - 1.5\ \mathrm{m} = 11.5\ \mathrm{m}$. Find the time of fall from Eq. 2-11b with *x* replaced by *y*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \;\rightarrow\; t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2\left(11.5\ \mathrm{m}\right)}{9.80\,\mathrm{m/s^2}}} = 1.532\ \mathrm{s}$$

If the truck is approaching with $v = 25\,\mathrm{m/s}$, then he needs to jump when the truck is a distance away given by $d = vt = \left(25\,\mathrm{m/s}\right)\left(1.532\ \mathrm{s}\right) = 38.30\ \mathrm{m}$. Convert this distance into "poles".

$$d = \left(38.30\ \mathrm{m}\right)\left(1\ \mathrm{pole}/25\ \mathrm{m}\right) = 1.53\ \mathrm{poles}$$

So he should jump when the truck is about $\boxed{1.5 \text{ poles}}$ away from the bridge.

61. (*a*) Choose downward to be the positive direction, and $y_0 = 0$ to be the level from which the car was dropped. The initial velocity is $v_0 = 0$, the final location is $y = H$, and the acceleration is $a = g$. Find the final velocity from Eq. 2-11c, replacing *x* with *y*.

$$v^2 = v_0^2 + 2a(y - y_0) \quad \rightarrow \quad v = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \pm\sqrt{2gH}\ .$$

The speed is the magnitude of the velocity, $\boxed{v = \sqrt{2gH}}$.

(*b*) Solving the above equation for the height, we have that $H = \dfrac{v^2}{2g}$. Thus for a collision of

$$v = (60\,\text{km/h})\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 16.67\,\text{m/s}$$, the corresponding height is:

$$H = \frac{v^2}{2g} = \frac{(16.67\,\text{m/s})^2}{2(9.80\,\text{m/s}^2)} = 14.17\,\text{m} \approx \boxed{14\text{ m}}.$$

(*c*) For a collision of $v = (100\,\text{km/h})\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 27.78\,\text{m/s}$, the corresponding height is:

$$H = \frac{v^2}{2g} = \frac{(27.78\,\text{m/s})^2}{2(9.80\,\text{m/s}^2)} = 39.37\,\text{m} \approx \boxed{39\text{ m}}.$$

62. The average speed is the distance divided by the time.

$$\bar{v} = \frac{d}{t} = \left(\frac{1\times10^9\ \text{km}}{1\ \text{y}}\right)\left(\frac{1\ \text{y}}{365\ \text{d}}\right)\left(\frac{1\ \text{d}}{24\ \text{h}}\right) = 1.142\times10^5\ \text{km/h} \approx \boxed{1\times10^5\ \text{km/h}}$$

63. Use the information for the first 180 m to find the acceleration, and the information for the full motion to find the final velocity. For the first segment, the train has $v_0 = 0\,\text{m/s}$, $v_1 = 25\,\text{m/s}$, and a displacement of $x_1 - x_0 = 180\ \text{m}$. Find the acceleration from Eq. 2-11c.

$$v_1^2 = v_0^2 + 2a(x_1 - x_0) \quad \rightarrow \quad a = \frac{v_1^2 - v_0^2}{2(x_1 - x_0)} = \frac{(25\,\text{m/s})^2 - 0}{2(180\ \text{m})} = 1.736\,\text{m/s}^2$$

Find the speed of the train after it has traveled the total distance (total displacement of $x_2 - x_0 = 275\ \text{m}$) using Eq. 2-11c.

$$v_2^2 = v_0^2 + 2a(x_2 - x_0) \quad \rightarrow \quad v_2 = \sqrt{v_0^2 + 2a(x_2 - x_0)} = \sqrt{2(1.736\,\text{m/s}^2)(275\ \text{m})} = \boxed{31\,\text{m/s}}.$$

64. For the motion in the air, choose downward to be the positive direction, and $y_0 = 0$ to be at the height of the diving board. Then diver has $v_0 = 0$, (assuming the diver does not jump upward or downward), $a = g = 9.8\,\text{m/s}^2$, and $y = 4.0\ \text{m}$ when reaching the surface of the water. Find the diver's speed at the water's surface from Eq. 2-11c, with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a(y - y_0)x \quad \rightarrow \quad v = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \sqrt{0 + 2(9.8\,\text{m/s}^2)(4.0\ \text{m})} = 8.85\,\text{m/s}$$

For the motion in the water, again choose down to be positive, but redefine $y_0 = 0$ to be at the surface of the water. For this motion, $v_0 = 8.85\,\text{m/s}$, $v = 0$, and $y - y_0 = 2.0\text{ m}$. Find the acceleration from Eq. 2-11c, with *x* replaced by *y*.

$$v^2 = v_0^2 + 2a(y - y_0) \;\rightarrow\; a = \frac{v^2 - v_0^2}{2(y - y_0)x} = \frac{0 - (8.85\,\text{m/s})^2}{2(2.0\text{ m})} = -19.6\,\text{m/s}^2 \approx \boxed{-20\,\text{m/s}^2}$$

The negative sign indicates that the acceleration is directed upwards.

65. This problem can be analyzed as a series of three one-dimensional motions: the acceleration phase, the constant speed phase, and the deceleration phase. The maximum speed of the train is:

$$(90\,\text{km/h})\left(\frac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 25\,\text{m/s}.$$

In the acceleration phase, the initial velocity is $v_0 = 0\,\text{m/s}$, the acceleration is $a = 1.1\,\text{m/s}^2$, and the final velocity is $v = 25\,\text{m/s}$. Find the elapsed time for the acceleration phase from Eq. 2-11a.

$$v = v_0 + at \;\rightarrow\; t_{\text{acc}} = \frac{v - v_0}{a} = \frac{25\,\text{m/s} - 0}{1.1\,\text{m/s}^2} = 22.73\text{ s}.$$

Find the displacement during the acceleration phase from Eq. 2-11b.

$$(x - x_0)_{\text{acc}} = v_0 t + \tfrac{1}{2}at^2 = 0 + \tfrac{1}{2}(1.1\,\text{m/s}^2)(22.73\text{ s})^2 = 284\text{ m}.$$

In the deceleration phase, the initial velocity is $v_0 = 25\,\text{m/s}$, the acceleration is $a = -2.0\,\text{m/s}^2$, and the final velocity is $v = 0\,\text{m/s}$. Find the elapsed time for the deceleration phase from equation Eq. 2-11a.

$$v = v_0 + at \;\rightarrow\; t_{\text{dec}} = \frac{v - v_0}{a} = \frac{0 - 25\,\text{m/s}}{-2.0\,\text{m/s}^2} = 12.5\text{ s}.$$

Find the distance traveled during the deceleration phase from Eq. 2-11b.

$$(x - x_0)_{\text{dec}} = v_0 t + \tfrac{1}{2}at^2 = (25\,\text{m/s})(12.5\text{ s}) + \tfrac{1}{2}(-2.0\,\text{m/s}^2)(12.5\text{ s})^2 = 156\text{ m}.$$

The total elapsed time and distance traveled for the acceleration / deceleration phases are:

$$\begin{aligned} t_{\text{acc}} + t_{\text{dec}} &= 22.7\text{ s} + 12.5\text{ s} = 35.2\text{ s} \\ (x - x_0)_{\text{acc}} + (x - x_0)_{\text{dec}} &= 284\text{ m} + 156\text{ m} = 440\text{ m} \end{aligned}.$$

(*a*) If the stations are spaced 1.80 km = 1800 m apart, then there is a total of $\dfrac{9000\text{ m}}{1800\text{ m}} = 5$ inter-station segments. A train making the entire trip would thus have a total of 5 inter-station segments and 4 stops of 20 s each at the intermediate stations. Since 440 m is traveled during acceleration and deceleration, 1360 m of each segment is traveled at an average speed of $\bar{v} = 25\,\text{m/s}$. The time for that 1360 m is given by

$d = \bar{v}t \;\rightarrow\; t_{\substack{\text{constant}\\\text{speed}}} = \dfrac{d}{\bar{v}} = \dfrac{1360\text{ m}}{25\,\text{m/s}} = 54.4\text{ s}$. Thus a total inter-station segment will take 35.2 s + 54.4 s = 89.6 s. With 5 inter-station segments of 89.6 s each, and 4 stops of 20 s each, the total time is given by:

$$t_{0.8\text{ km}} = 5(89.6\,\text{s}) + 4(20\,\text{s}) = 528\text{ s} = \boxed{8.8\text{ min}}.$$

(*b*) If the stations are spaced 3.0 km =3000 m apart, then there is a total of $\frac{9000\text{ m}}{3000\text{ m}} = 3$ inter-station segments. A train making the entire trip would thus have a total of 3 inter-station segments and 2 stops of 20 s each at the intermediate stations. Since 440 m is traveled during acceleration and deceleration, 2560 m of each segment is traveled at an average speed of $\bar{v} = 25\,\text{m/s}$. The time for that 2560 m is given by $d = \bar{v}t \;\rightarrow\; t = \frac{d}{\bar{v}} = \frac{2560\text{ m}}{25\,\text{m/s}} = 102.4\text{ s}$.

Thus a total inter-station segment will take 35.2 s + 102.4 s = 137.6 s. With 3 inter-station segments of 137.6 s each, and 2 stops of 20 s each, the total time is

$$t_{3.0\text{ km}} = 3(137.6\,\text{s}) + 2(20\,\text{s}) = 453\text{ s} = \boxed{7.5\text{ min}}.$$

66. Choose downward to be the positive direction, and $y_0 = 0$ to be at the start of the pelican's dive. The pelican has an initial velocity is $v_0 = 0$ and an acceleration of $a = g$, and a final location of $y = 16.0\text{ m}$. Find the total time of the pelican's dive from Eq. 2-11b, with *x* replaced by *y*.

$$y = y_0 + v_0t + \tfrac{1}{2}at^2 \;\rightarrow\; y = 0 + 0 + \tfrac{1}{2}at^2 \;\rightarrow\; t_{\text{dive}} = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(16.0\text{ m})}{9.80\,\text{m/s}^2}} = 1.81\text{ s}.$$

The fish can take evasive action if he sees the pelican at a time of 1.81 s – 0.20 s = 1.61 s into the dive. Find the location of the pelican at that time from Eq. 2-11b.

$$y = y_0 + v_0t + \tfrac{1}{2}at = 0 + 0 + \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)(1.61\text{ s})^2 = 12.7\text{ m}$$

Thus the fish must spot the pelican at a minimum height from the surface of the water of $16.0\text{ m} - 12.7\text{ m} = \boxed{3.3\text{ m}}$.

67. First consider the "uphill lie", in which the ball is being putted down the hill. Choose $x_0 = 0$ to be the ball's original location, and the direction of the ball's travel as the positive direction. The final velocity of the ball is $v = 0\,\text{m/s}$, the acceleration of the ball is $a = -2.0\,\text{m/s}^2$, and the displacement of the ball will be $x - x_0 = 6.0\text{ m}$ for the first case, and $x - x_0 = 8.0\text{ m}$ for the second case. Find the initial velocity of the ball from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; v_0 = \sqrt{v^2 - 2a(x - x_0)} = \begin{cases} \sqrt{0 - 2\left(-2.0\,\text{m/s}^2\right)(6.0\text{ m})} = 4.9\,\text{m/s} \\ \sqrt{0 - 2\left(-2.0\,\text{m/s}^2\right)(8.0\text{ m})} = 5.7\,\text{m/s} \end{cases}$$

The range of acceptable velocities for the uphill lie is $\boxed{4.9\,\text{m/s} \text{ to } 5.7\,\text{m/s}}$, with a spread of 0.8 m/s.

Now consider the "downhill lie", in which the ball is being putted up the hill. Use a very similar set-up for the problem, with the basic difference being that the acceleration of the ball is now $a = -3.0\,\text{m/s}^2$. Find the initial velocity of the ball from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \;\rightarrow\; v_0 = \sqrt{v^2 - 2a(x - x_0)} = \begin{cases} \sqrt{0 - 2\left(-3.0\,\text{m/s}^2\right)(6.0\text{ m})} = 6.0\,\text{m/s} \\ \sqrt{0 - 2\left(-3.0\,\text{m/s}^2\right)(8.0\text{ m})} = 6.9\,\text{m/s} \end{cases}$$

The range of acceptable velocities for the downhill lie is $\boxed{6.0\,\text{m/s} \text{ to } 6.9\,\text{m/s}}$, with a spread of 0.9 m/s.

Because the range of acceptable velocities is smaller for putting down the hill, more control in putting is necessary, and so the downhill putt is more difficult.

68. (*a*) The train's constant speed is $v_{\text{train}} = 6.0\,\text{m/s}$, and the location of the empty box car as a function of time is given by $x_{\text{train}} = v_{\text{train}}t = (6.0\,\text{m/s})t$. The fugitive has $v_0 = 0\,\text{m/s}$ and $a = 4.0\,\text{m/s}^2$ until his final speed is $8.0\,\text{m/s}$. The elapsed time during acceleration is $t_{\text{acc}} = \dfrac{v - v_0}{a} = \dfrac{8.0\,\text{m/s}}{4.0\,\text{m/s}^2} = 2.0\ \text{s}$. Let the origin be the location of the fugitive when he starts to run. The first possibility to consider is, "Can the fugitive catch the train before he reaches his maximum speed?" During the fugitive's acceleration, his location as a function of time is given by $x_{\text{fugitive}} = x_0 + v_0t + \frac{1}{2}at^2 = 0 + 0 + \frac{1}{2}(4.0\,\text{m/s}^2)t^2$. For him to catch the train, we must have $x_{\text{train}} = x_{\text{fugitive}} \;\rightarrow\; (6.0\,\text{m/s})t = \frac{1}{2}(4.0\,\text{m/s}^2)t^2$. The solutions of this are $t = 0\ \text{s}, 3\ \text{s}$. Thus the fugitive cannot catch the car during his 2.0 s of acceleration.

Now the equation of motion of the fugitive changes. After the 2.0 s acceleration, he runs with a constant speed of $8.0\,\text{m/s}$. Thus his location is now given (for times $t > 2\ \text{s}$) by the following.

$$x_{\text{fugitive}} = \tfrac{1}{2}(4.0\,\text{m/s}^2)(2.0\ \text{s})^2 + (8.0\,\text{m/s})(t - 2.0\ \text{s}) = (8.0\,\text{m/s})t - 8.0\ \text{m}.$$

So now, for the fugitive to catch the train, we again set the locations equal.

$$x_{\text{train}} = x_{\text{fugitive}} \;\rightarrow\; (6.0\,\text{m/s})t = (8.0\,\text{m/s})t - 8.0\ \text{m} \;\rightarrow\; t = \boxed{4.0\ \text{s}}$$

(*b*) The distance traveled to reach the box car is given by

$$x_{\text{fugitive}}(t = 4.0\ \text{s}) = (8.0\,\text{m/s})(4.0\ \text{s}) - 8.0\ \text{m} = \boxed{24\ \text{m}}.$$

69. Choose downward to be the positive direction, and $y_0 = 0$ to be at the roof from which the stones are dropped. The first stone has an initial velocity of $v_0 = 0$ and an acceleration of $a = g$. Eqs. 2-11a and 2-11b (with *x* replaced by *y*) give the velocity and location, respectively, of the first stone as a function of time.

$$v = v_0 + at \;\rightarrow\; v_1 = gt_1 \qquad y = y_0 + v_0t + \tfrac{1}{2}at^2 \;\rightarrow\; y_1 = \tfrac{1}{2}gt_1^2.$$

The second stone has the same initial conditions, but its elapsed time $t - 1.50\ \text{s}$, and so has velocity and location equations as follows.

$$v_2 = g(t_1 - 1.50\ \text{s}) \qquad y_2 = \tfrac{1}{2}g(t_1 - 1.50\ \text{s})^2$$

The second stone reaches a speed of $v_2 = 12.0\,\text{m/s}$ at a time given by

$$t_1 = 1.50\ \text{s} + \frac{v_2}{g} = 1.50\ \text{s} + \frac{12.0\,\text{m/s}}{9.80\,\text{m/s}^2} = 2.72\ \text{s}.$$

The location of the first stone at that time is

$$y_1 = \tfrac{1}{2}gt_1^2 = \tfrac{1}{2}(9.80\,\text{m/s}^2)(2.72\ \text{s})^2 = 36.4\ \text{m}.$$

The location of the second stone at that time is

$$y_2 = \tfrac{1}{2}g(t_1 - 1.50\ \text{s})^2 = \tfrac{1}{2}(9.80\,\text{m/s}^2)(2.72 - 1.50\ \text{s})^2 = 7.35\ \text{m}.$$

Thus the distance between the two stones is $y_1 - y_2 = 36.4\ \text{m} - 7.35\ \text{m} = \boxed{29.0\ \text{m}}$.

70. To find the average speed for the entire race, we must take the total distance divided by the total time. If one lap is a distance of $L$, then the total distance will be $10L$. The time elapsed at a given constant speed is given by $t = d/v$, so the time for the first 9 laps would be $t_1 = \dfrac{9L}{198.0\text{ km/h}}$, and the time for the last lap would be $t_2 = L/v_2$, where $v_2$ is the average speed for the last lap. Write an expression for the average speed for the entire race, and then solve for $v_2$.

$$\overline{v} = \frac{d_{\text{total}}}{t_1 + t_2} = \frac{10L}{\dfrac{9L}{198.0\text{ km/h}} + \dfrac{L}{v_2}} = 200.0\text{ km/h} \quad \rightarrow$$

$$v_2 = \frac{1}{\dfrac{10}{200.0\text{ km/h}} - \dfrac{9}{198.0\text{ km/h}}} = \boxed{220.0\text{ km/h}}$$

71. The initial velocity is $v_0 = (18\text{ km/h})\left(\dfrac{1\text{ m/s}}{3.6\text{ km/h}}\right) = 5.0\text{ m/s}$. The final velocity is $v_0 = (75\text{ km/h})\left(\dfrac{1\text{ m/s}}{3.6\text{ km/h}}\right) = 20.83\text{ m/s}$. The displacement is $x - x_0 = 4.0\text{ km} = 4000\text{ m}$. Find the average acceleration from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \quad \rightarrow \quad a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(20.83\text{ m/s})^2 - (5.0\text{ m/s})^2}{2(4000\text{ m})} = \boxed{5.1\times10^{-2}\text{ m/s}^2}$$

72. Assume that $y_0 = 0$ for each child is the level at which the child loses contact with the trampoline surface. Choose upward to be the positive direction.

(*a*) The second child has $v_{02} = 5.0\text{ m/s}$, $a = -g = -9.8\text{ m/s}^2$, and $v = 0\text{ m/s}$ at the maximum height position. Find the child's maximum height from Eq. 2-11c, with *x* replaced by *y*.

$$v^2 = v_{02}^2 + 2a(y_2 - y_0) \quad \rightarrow \quad y_2 = y_0 + \frac{v^2 - v_{02}^2}{2a} = 0 + \frac{0 - (5.0\text{ m/s})^2}{2(-9.8\text{ m/s}^2)} = 1.276\text{ m} \approx \boxed{1.3\text{ m}}$$

(*b*) Since the first child can bounce up to one-and-a-half times higher than the second child, the first child can bounce up to a height of $1.5(1.276\text{ m}) = 1.913\text{ m} = y_1 - y_0$. Eq. 2-11c is again used to find the initial speed of the first child.

$$v^2 = v_{01}^2 + 2a(y_1 - y_0) \quad \rightarrow$$

$$v_{01} = \pm\sqrt{v^2 - 2a(y_1 - y_0)} = \sqrt{0 - 2(-9.8\text{ m/s}^2)(1.913\text{ m})} = 6.124\text{ m/s} \approx \boxed{6.1\text{ m/s}}$$

The positive root was chosen since the child was initially moving upward.

(*c*) To find the time that the first child was in the air, use Eq. 2-11b with a total displacement of 0, since the child returns to the original position.

$$y = y_0 + v_{01}t_1 + \tfrac{1}{2}at_1^2 \quad \rightarrow \quad 0 = (6.124\text{ m/s})t_1 + \tfrac{1}{2}(-9.8\text{ m/s}^2)t_1^2 \quad \rightarrow \quad t_1 = 0\text{ s},\ 1.2497\text{ s}$$

The time of 0 s corresponds to the time the child started the jump, so the correct answer is $\boxed{1.2\text{ s}}$.

73. For the car to pass the train, the car must travel the length of the train AND the distance the train travels. The distance the car travels can thus be written as either $d_{car} = v_{car}t = (95\,\text{km/h})t$ or $d_{car} = L_{train} + v_{train}t = 1.10\text{ km} + (75\,\text{km/h})t$. To solve for the time, equate these two expressions for the distance the car travels.

$$(95\,\text{km/h})t = 1.10\text{ km} + (75\,\text{km/h})t \quad \rightarrow \quad t = \frac{1.10\text{ km}}{20\,\text{km/h}} = 0.055\text{ h} = \boxed{3.3\text{ min}}$$

The distance the car travels during this time is $d = (95\,\text{km/h})(0.055\text{ h}) = 5.225\,\text{km} \approx \boxed{5.2\text{ km}}$.

If the train is traveling the opposite direction from the car, then the car must travel the length of the train MINUS the distance the train travels. Thus the distance the car travels can be written as either $d_{car} = (95\,\text{km/h})t$ or $d_{car} = 1.10\text{ km} - (75\,\text{km/h})t$. To solve for the time, equate these two expressions for the distance the car travels.

$$(95\,\text{km/h})t = 1.10\text{ km} - (75\,\text{km/h})t \quad \rightarrow \quad t = \frac{1.10\text{ km}}{170\,\text{km/h}} = 6.47\times10^{-3}\text{ h} = \boxed{23.3\text{ s}}$$

The distance the car travels during this time is $d = (95\,\text{km/h})(6.47\times10^{-3}\text{ h}) = \boxed{0.61\text{ km}}$.

74. For the baseball, $v_0 = 0$, $x - x_0 = 3.5\text{ m}$, and the final speed of the baseball (during the throwing motion ) is $v = 44\,\text{m/s}$. The acceleration is found from Eq. 2-11c.

$$v^2 = v_0^2 + 2a(x - x_0) \quad \rightarrow \quad a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(44\,\text{m/s})^2 - 0}{2(3.5\text{ m})} = \boxed{280\,\text{m/s}^2}$$

75. (*a*) Choose upward to be the positive direction, and $y_0 = 0$ at the ground. The rocket has $v_0 = 0$, $a = 3.2\,\text{m/s}^2$, and $y = 1200\text{ m}$ when it runs out of fuel. Find the velocity of the rocket when it runs out of fuel from Eq 2-11c, with *x* replaced by *y*.

$$v_{1200\text{ m}}^2 = v_0^2 + 2a(y - y_0) \quad \rightarrow$$

$$v_{1200\text{ m}} = \pm\sqrt{v_0^2 + 2a(y - y_0)} = \pm\sqrt{0 + 2(3.2\,\text{m/s}^2)(1200\text{ m})} = 87.64\,\text{m/s} \approx \boxed{88\,\text{m/s}}$$

The positive root is chosen since the rocket is moving upwards when it runs out of fuel.

(*b*) The time to reach the 1200 m location can be found from equation (2-11a).

$$v_{1200\text{ m}} = v_0 + at_{1200\text{ m}} \quad \rightarrow \quad t_{1200\text{ m}} = \frac{v_{1200\text{ m}} - v_0}{a} = \frac{87.64\,\text{m/s} - 0}{3.2\,\text{m/s}^2} = 27.39\text{ s} \approx \boxed{27\text{ s}}$$

(*c*) For this part of the problem, the rocket will have an initial velocity $v_0 = 87.64\,\text{m/s}$, an acceleration of $a = -9.8\,\text{m/s}^2$, and a final velocity of $v = 0$ at its maximum altitude. The altitude reached from the out-of-fuel point can be found from equation (2-11c).

$$v^2 = v_{1200\text{ m}}^2 + 2a(y - 1200\text{ m}) \quad \rightarrow$$

$$y_{max} = 1200\text{ m} + \frac{0 - v_{1200\text{ m}}^2}{2a} = 1200\text{ m} + \frac{-(87.64\,\text{m/s})^2}{2(-9.8\,\text{m/s}^2)} = 1200\text{ m} + 390\text{ m} = \boxed{1590\text{ m}}$$

(*d*) The time for the "coasting" portion of the flight can be found from Eq. 2-11a.

$$v = v_{1200\text{ m}} + at_{coast} \quad \rightarrow \quad t_{coast} = \frac{v - v_0}{a} = \frac{0 - 87.64\,\text{m/s}}{-9.8\,\text{m/s}^2} = 8.94\text{ s}$$

Thus the total time to reach the maximum altitude is $t = 27\text{ s} + 8.94\text{ s} \approx \boxed{36\text{ s}}$.

(*e*) For this part of the problem, the rocket has $v_0 = 0\,\text{m/s}$, $a = -9.8\,\text{m/s}^2$, and a displacement of $-1600\text{ m}$ (it falls from a height of 1600 m to the ground). Find the velocity upon reaching the Earth from Eq. 2-11c.

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

$$v = \pm\sqrt{v_0^2 + 2a\left(y - y_0\right)} = \pm\sqrt{0 + 2\left(-9.80\,\text{m/s}^2\right)\left(-1600\text{ m}\right)} = \boxed{-177\,\text{m/s}}$$

The negative root was chosen because the rocket is moving downward, which is the negative direction.

(*f*) The time for the rocket to fall back to the Earth is found from Eq. 2-11a.

$$v = v_0 + at \quad \rightarrow \quad t_{\text{fall}} = \frac{v - v_0}{a} = \frac{-177\,\text{m/s} - 0}{-9.80\,\text{m/s}^2} = 18.1\text{ s}$$

Thus the total time for the entire flight is $t = 36\text{ s} + 18.1\text{ s} = \boxed{54\text{ s}}$.

76. The speed limit is $50\,\text{km/h}\left(\dfrac{1\,\text{m/s}}{3.6\,\text{km/h}}\right) = 13.89\,\text{m/s}$.

(*a*) For your motion, you would need to travel $\left(10 + 15 + 50 + 15 + 70\right)\text{m} = 160\text{ m}$ to get through the third light. The time to travel the 160 m is found using the distance and the constant speed.

$$d = \overline{v}\,t \quad \rightarrow \quad t = \frac{d}{\overline{v}} = \frac{160\text{ m}}{13.89\,\text{m/s}} = 11.52\text{ s}$$

$\boxed{\text{Yes}}$, you can make it through all three lights without stopping.

(*b*) The second car needs to travel 150 m before the third light turns red. This car accelerates from $v_0 = 0\,\text{m/s}$ to a maximum of $v = 13.89\,\text{m/s}$ with $a = 2.0\,\text{m/s}^2$. Use Eq. 2-11a to determine the duration of that acceleration.

$$v = v_0 + at \quad \rightarrow \quad t_{\text{acc}} = \frac{v - v_0}{a} = \frac{13.89\,\text{m/s} - 0\,\text{m/s}}{2.0\,\text{m/s}^2} = 6.94\text{ s}$$

The distance traveled during that time is found from Eq. 2-11b.

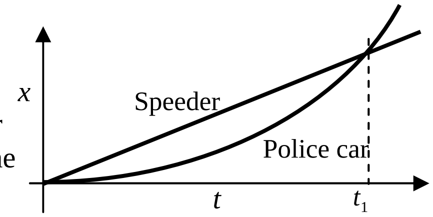
$$\left(x - x_0\right)_{\text{acc}} = v_0 t_{\text{acc}} + \tfrac{1}{2}at_{\text{acc}}^2 = 0 + \tfrac{1}{2}\left(2.0\,\text{m/s}^2\right)\left(6.94\text{ s}\right)^2 = 48.2\text{ m}.$$

Since 6.94 sec have elapsed, there are 13 – 6.94 = 6.06 sec remaining to clear the intersection. The car travels another 6 seconds at a speed of 13.89 m/s, covering a distance of $d_{\substack{\text{constant}\\ \text{speed}}} = \overline{v}\,t = \left(13.89\,\text{m/s}\right)\left(6.06\text{ s}\right) = 84.2\text{ m}$. Thus the total distance is 48.2 m + 84.2 m = 132.4 m. $\boxed{\text{No}}$, the car cannot make it through all three lights without stopping.

77. Take the origin to be the location where the speeder passes the police car. The speeder's constant speed is $v_{\text{speeder}} = \left(120\,\text{km/h}\right)\left(\dfrac{1\,\text{m/s}}{3.6\text{ km/h}}\right) = 33.3\,\text{m/s}$, and the location of the speeder as a function of time is given by $x_{\text{speeder}} = v_{\text{speeder}}t_{\text{speeder}} = \left(33.3\,\text{m/s}\right)t_{\text{speeder}}$. The police car has an initial velocity of $v_0 = 0\,\text{m/s}$ and a constant acceleration of $a_{\text{police}}$. The location of the police car as a function of time is given by Eq. 2-11b.

$$x_{\text{police}} = v_0 t + \tfrac{1}{2}at^2 = \tfrac{1}{2}a_{\text{police}}t_{\text{police}}^2.$$

(*a*) The position vs. time graphs would qualitatively look like the graph shown here.




(*b*) The time to overtake the speeder occurs when the speeder has gone a distance of 750 m. The time is found using the speeder's equation from above.

$$750\text{ m} = \left(33.3\,\text{m/s}\right)t_{\text{speeder}} \quad\to\quad t_{\text{speeder}} = \frac{750\text{ m}}{33.3\,\text{m/s}} = 22.5\text{ s} \approx \boxed{23\text{ s}}$$

(*c*) The police car's acceleration can be calculated knowing that the police car also had gone a distance of 750 m in a time of 22.5 s.

$$750\text{ m} = \tfrac{1}{2}a_p\left(22.5\text{ s}\right)^2 \quad\to\quad a_p = \frac{2\left(750\text{ m}\right)}{\left(22.5\text{ s}\right)^2} = 2.96\,\text{m/s}^2 \approx \boxed{3.0\,\text{m/s}^2}$$

(*d*) The speed of the police car at the overtaking point can be found from Eq. 2-11a.

$$v = v_0 + at = 0 + \left(2.96\,\text{m/s}^2\right)\left(22.5\text{ s}\right) = 66.67\,\text{m/s} \approx \boxed{67\,\text{m/s}}$$

Note that this is exactly twice the speed of the speeder.

78. Choose downward to be the positive direction, and the origin to be at the roof of the building from which the stones were dropped. The first stone has $y_0 = 0$, $v_0 = 0$, a final location of $y = H$ (as yet unknown), and $a = g$. If the time for the first stone to reach the ground is $t_1$, then Eq. 2-11c gives the following, replacing *x* with *y*:

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \quad\to\quad H = \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)t_1^2 .$$

The second stone has $v_0 = 25.0\,\text{m/s}$, $y_0 = 0$, a final location of $y = H$, and $a = g$. The time for the second stone to reach the ground is $t_1 - 2.00\text{ s}$, and so Eq. 2-11c for the second stone is

$$H = \left(25.0\,\text{m/s}\right)\left(t_1 - 2.00\right) + \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)\left(t_1 - 2.00\right)^2 .$$

(*a*) Set the two expressions for $H$ equal to each other, and solve for $t_1$.

$$\tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)t_1^2 = \left(25.0\,\text{m/s}\right)\left(t_1 - 2\right) + \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)\left(t_1 - 2\right)^2 \quad\to\quad t_1 = \boxed{5.63\text{ s}}$$

(*b*) The building height is given by $H = \tfrac{1}{2}gt_1^2 = \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)\left(5.63\text{ s}\right)^2 = \boxed{155\text{ m}}$.

(*c*) The speed of the stones is found using Eq. 2-11a.

$$\#1: \quad v = v_0 + at = gt_1 = \left(9.80\,\text{m/s}^2\right)\left(5.63\text{ s}\right) = \boxed{55.2\,\text{m/s}}$$

$$\#2: \quad v = v_0 + at = v_0 + g\left(t_1 - 2\right) = 25.0\,\text{m/s} + \left(9.80\,\text{m/s}^2\right)\left(3.63\text{ s}\right) = \boxed{60.6\,\text{m/s}}$$

79. Choose upward to be the positive direction, and the origin to be at ground level. The initial velocity of the first stone is $v_{0A} = 11.0\,\text{m/s}$, and the acceleration of both stones is $a = -9.80\,\text{m/s}^2$. The starting location is $y_{0A} = H_A$, and it takes 4.5 s for the stone to reach the final location $y = 0$. Use Eq. 2-11b (with *x* replaced by *y*) to find a value for $H_A$.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \quad\to\quad 0 = H_A + \left(11.0\,\text{m/s}\right)\left(4.5\text{ s}\right) - \tfrac{1}{2}\left(9.80\,\text{m/s}^2\right)\left(4.5\text{ s}\right)^2 \quad\to$$

$$H_A = 49.7\text{ m}$$

Assume that the 12$^{\text{th}}$ floor balcony is three times higher above the ground than the 4$^{\text{th}}$ floor balcony. Thus the height of 4$^{\text{th}}$ floor balcony is $\tfrac{1}{3}\left(49.7\text{ m}\right) = 16.6\text{ m}$. So for the second stone, $y_{0B} = 16.6\text{ m}$, and it takes 4.5 s for the stone to reach the final location $y = 0$. Use Eq. 2-11b to find the starting velocity, $v_{0B}$.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \quad \rightarrow \quad 0 = 16.6\text{ m} + v_{0B}(4.5\text{ s}) - \tfrac{1}{2}(9.80\text{ m/s}^2)(4.5\text{ s})^2 \quad \rightarrow$$

$$v_{0B} = \boxed{18\text{ m/s}}$$

80. Choose downward to be the positive direction, and the origin to be at the location of the plane. The parachutist has $v_0 = 0$, $a = g = 9.8\text{ m/s}^2$, and will have $y - y_0 = 2850\text{ m}$ when she pulls the ripcord. Eq. 2-11b, with *x* replaced by *y*, is used to find the time when she pulls the ripcord.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 \quad \rightarrow \quad t = \sqrt{2(y - y_0)/a} = \sqrt{2(2850\text{ m})/(9.80\text{ m/s}^2)} = \boxed{24.1\text{ s}}$$

The speed is found from Eq. 2-11a.

$$v = v_0 + at = 0 + (9.80\text{ m/s}^2)(24.1\text{ s}) = 236\text{ m/s} \cong \boxed{2.3\times10^2\text{ m/s}} = 850\text{ km/h}$$

81. The speed of the conveyor belt is given by $d = \bar{v}\Delta t \rightarrow \bar{v} = \dfrac{d}{\Delta t} = \dfrac{1.1\text{ m}}{2.5\text{ min}} = \boxed{0.44\text{ m/min}}$. The rate of burger production, assuming the spacing given is center to center, can be found as

$$\left(\frac{1\text{ burger}}{0.15\text{ m}}\right)\left(\frac{0.44\text{ m}}{1\text{ min}}\right) = \boxed{2.9\,\frac{\text{burgers}}{\text{min}}}.$$

82. Choose upward to be the positive direction, and the origin to be at the level where the ball was thrown. The velocity at the top of the ball's path will be $v = 0$, and the ball will have an acceleration of $a = -g$. If the maximum height that the ball reaches is $y = H$, then the relationship between the initial velocity and the maximum height can be found from Eq. 2-11c, with *x* replaced by *y*.

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

We are told that $v_{0\text{ Bill}} = 1.5 v_{0\text{ Joe}}$, so $\dfrac{H_{\text{Bill}}}{H_{\text{Joe}}} = \dfrac{(v_{0\text{ Bill}})^2/2g}{(v_{0\text{ Joe}})^2/2g} = \dfrac{(v_{0\text{ Bill}})^2}{(v_{0\text{ Joe}})^2} = 1.5^2 = 2.25 \approx \boxed{2.3}$.

83. As shown in problem 41, the speed with which the ball was thrown upward is the same as its speed on returning to the ground. From the symmetry of the two motions (both motions have speed = 0 at top, have same distance traveled and have same acceleration), the time for the ball to rise is 1.2 s. Choose upward to be the positive direction, and the origin to be at the level where the ball was thrown. For the ball, $v = 0$ at the top of the motion, and $a = -g$. Find the initial velocity from Eq. 2-11a.

$$v = v_0 + at \quad \rightarrow \quad v_0 = v - at = 0 - (-9.80\text{ m/s}^2)(1.2\text{ s}) = \boxed{12\text{ m/s}}$$

84. Choose downward to be the positive direction, and the origin to be at the top of the building. The barometer has $y_0 = 0$, $v_0 = 0$, and $a = g = 9.8\text{ m/s}^2$. Use Eq. 2-11b to find the height of the building, with *x* replaced by *y*.

$$y = y_0 + v_0 t + \tfrac{1}{2}at^2 = 0 + 0 + \tfrac{1}{2}(9.8\text{ m/s}^2)t^2$$

$$y_{t=2.0} = \tfrac{1}{2}(9.8\text{ m/s}^2)(2.0\text{ s})^2 = 20\text{ m} \qquad y_{t=2.3} = \tfrac{1}{2}(9.8\text{ m/s}^2)(2.3\text{ s})^2 = 26\text{ m}$$

The difference in the estimates is $\boxed{6\text{ m}}$.