CHAPTER 2

Describing Motion: Kinematics in One Dimension

Windows OS

Problems

[The Problems at the end of each Chapter are ranked I, II, or III according to estimated difficulty, with (I) Problems being easiest. Level III are meant as challenges for the best students. The Problems are arranged by Section, meaning that the reader should have read up to and including that Section, but not only that Section—Problems often depend on earlier material. Finally, there is a set of unranked "General Problems" not arranged by Section number.]

2–1 to 2–3 Speed and Velocity

1. (I) If you are driving 110 km / h along a straight road and you look to the side for 2.0 s, how far do you travel during this inattentive period?
2. (I) What must your car's average speed be in order to travel 235 km in 3.25 h?
3. (I) A particle at $t_1 = 2\ 2.0\,\mathrm{s}$ is at $x_1 = 4.3\,\mathrm{cm}$ and at $t_2 = 4.5\,\mathrm{s}$ is at $x_2 = 8.5\,\mathrm{cm}.$ What is its average velocity? Can you calculate its average speed from these data?
4. (I) A rolling ball moves from $x_1 = 3.4\,\mathrm{cm}$ to $x_2 = 2\ 4.2\,\mathrm{cm}$ during the time from $t_1 = 3.0\,\mathrm{s}$ to $t_2 = 5.1\,\mathrm{s}.$ What is its average velocity?
5. (II) According to a rule-of-thumb, every five seconds between a lightning flash and the following thunder gives the distance to the flash in miles. Assuming that the flash of light arrives in essentially no time at all, estimate the speed of sound in m / s from this rule. What would be the rule for kilometers?
6. (II) You are driving home from school steadily at 95 km / h for 130 km. It then begins to rain and you slow to 65 km / h. You arrive home after driving 3 hours and 20 minutes. (*a*) How far is your hometown from school? (*b*) What was your average speed?
7. (II) A horse canters away from its trainer in a straight line, moving 116 m away in 14.0 s. It then turns abruptly and gallops halfway back in 4.8 s. Calculate (*a*) its average speed and (*b*) its average velocity for the entire trip, using "away from the trainer" as the positive direction.

8. (II) The position of a small object is given by $x = 34 + 10t - 2t^3$, where t is in seconds and x in meters. (*a*) Plot x as a function of t from $t = 0$ to $t = 3.0\,\text{s}$. (*b*) Find the average velocity of the object between 0 and 3.0 s. (*c*) At what time between 0 and 3.0 s is the -instantaneous velocity zero?

9. (II) The position of a rabbit along a straight tunnel as a function of time is plotted in Fig. 2–36. What is its instantaneous velocity (*a*) at $t = 10.0\,\text{s}$ and (*b*) at $t = 30.0\,\text{s}$? What is its average velocity (*c*) between $t = 0$ and $t = 5.0\,\text{s}$, (*d*) between $t = 25.0\,\text{s}$ and $t = 30.0\,\text{s}$, and (*e*) between $t = 40.0\,\text{s}$ and $t = 50.0\,\text{s}$?

10. (II) On an audio compact disc (CD), digital bits of information are encoded sequentially along a spiral path. Each bit occupies about $0.28\,\mu\text{m}$. A CD player's readout laser scans along the spiral's sequence of bits at a constant speed of about $1.2\ \text{m/s}$ as the CD spins. (*a*) Determine the number *N* of digital bits that a CD player reads every second. (*b*) The audio information is sent to each of the two loudspeakers 44,100 times per second. Each of these samplings requires 16 bits and so one would (at first glance) think the required bit rate for a CD player is

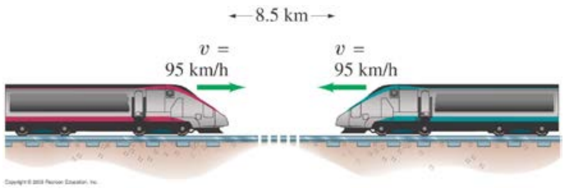
$$N_0 = 2\left(44{,}100\ \frac{\text{samplings}}{\text{second}}\right)\left(16\ \frac{\text{bits}}{\text{sampling}}\right) = 1.43\ 10^6\ \frac{\text{bits}}{\text{second}},$$

where the 2 is for the 2 loudspeakers (the 2 stereo channels).

Note that N_0 is less than the number *N* of bits actually read per second by a CD player. The excess number of bits $(@N - N_0)$ is needed for encoding and error-correction. What percentage of the bits on a CD are dedicated to encoding and error-correction?

11. (II) A car traveling $95\ \text{km/h}$ is 110 m behind a truck traveling $75\ \text{km/h}$. How long will it take the car to reach the truck?

12. (II) Two locomotives approach each other on parallel tracks. Each has a speed of $95\ \text{km/h}$ with respect to the ground. If they are initially 8.5 km apart, how long will it be before they reach each other? (See Fig. 2–38).



13. (II) Digital bits on a 12.0-cm diameter audio CD are encoded along an outward spiraling path that starts at radius $R_1 = 2.5\ \text{cm}$ and finishes at radius $R_2 = 5.8\ \text{cm}$. The distance between the centers of neighboring spiral-windings is $1.6\ \mu\text{m}\ \left(\approx 1.6 \times 10^{-6}\ \text{m}\right)$. (*a*) Determine the total length of the spiraling path. [*Hint*: Imagine "unwinding" the spiral into a straight path of width $1.6\ \mu\text{m}$, and note that the original spiral and the straight path both occupy the same area.] (*b*) To read information, a CD player adjusts the rotation of the CD so that the player's readout laser moves along the spiral path at a constant speed of 1.25 m / s. Estimate the maximum playing time of such a CD.

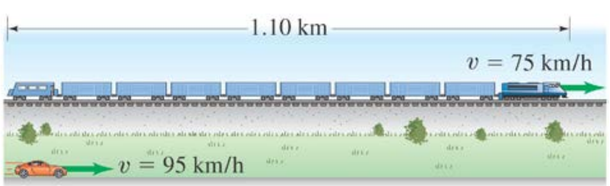
14. (II) An airplane travels 3100 km at a speed of 720 km / h, and then encounters a tailwind that boosts its speed to 990 km / h for the next 2800 km. What was the total time for the trip? What was the average speed of the plane for this trip? [*Hint*: Does Eq. 2–12d apply, or not?]

15. (II) Calculate the average speed and average velocity of a complete round trip in which the outgoing 250 km is covered at 95 km / h, followed by a 1.0-h lunch break, and the return 250 km is covered at 55 km / h.

16. (II) The position of a ball rolling in a straight line is given by $x = 2.0 - 3.6\,t + 1.1\,t^2$, where x is in meters and t in seconds. (*a*) Determine the position of the ball at $t = 1.0\ \text{s}$, 2.0 s, and 3.0 s. (*b*) What is the average velocity over the interval $t = 1.0\ \text{s}$ to $t = 3.0\ \text{s}$? (*c*) What is its instantaneous velocity at $t = 2.0\ \text{s}$ and at $t = 3.0\ \text{s}$?

17. (II) A dog runs 120 m away from its master in a straight line in 8.4 s, and then runs halfway back in one-third the time. Calculate (*a*) its average speed and (*b*) its average velocity.

18. (III) An automobile traveling 95 km / h overtakes a 1.10-km-long train traveling in the same direction on a track parallel to the road. If the train's speed is 75 km / h, how long does it take the car to pass it, and how far will the car have traveled in this time? See Fig. 2 – 39. What are the results if the car and train are traveling in opposite directions?



19. (III) A bowling ball traveling with constant speed hits the pins at the end of a bowling lane 16.5 m long. The bowler hears the sound of the ball hitting the pins 2.50 s after the ball is released from his hands. What is the speed of the ball, assuming the speed of sound is 340 m / s?

2–4 Acceleration

20. (I) A sports car accelerates from rest to 95 km / h in 4.5 s. What is its average acceleration in $\mathrm{m/s^2}$?

21. (I) At highway speeds, a particular automobile is capable of an acceleration of about $1.8\ \mathrm{m/s^2}$. At this rate, how long does it take to accelerate from 80 km / h to 110 km / h?

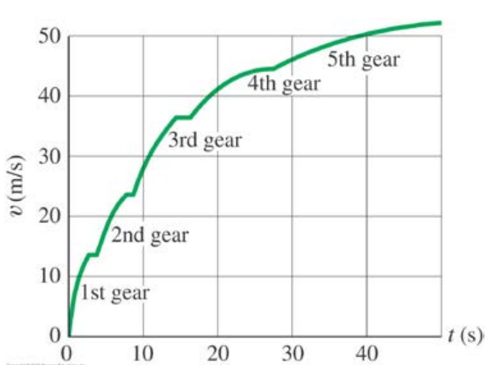
22. (I) A sprinter accelerates from rest to 9.00 m / s in 1.28 s. What is her acceleration in (*a*) $\mathrm{m/s^2}$; (*b*) $\mathrm{km/h^2}$?

23. (I) Figure 2–37 shows the velocity of a train as a function of time. (*a*) At what time was its velocity greatest? (*b*) During what periods, if any, was the velocity constant? (*c*) During what periods, if any, was the acceleration constant? (*d*) When was the magnitude of the acceleration greatest?

24. (II) A sports car moving at constant speed travels 110 m in 5.0 s. If it then brakes and comes to a stop in 4.0 s, what is the magnitude of its acceleration in $\mathrm{m/s^2}$, and in *g*'s $\left(g = 9.80\ \mathrm{m/s^2}\right)$?

25. (II) A car moving in a straight line starts at $x = 0$ at $t = 0$. It passes the point $x = 25.0\ \mathrm{m}$ with a speed of 11.0 m / s at $t = 3.00\ \mathrm{s}$. It passes the point $x = 385\ \mathrm{m}$ with a speed of 45.0 m / s at $t = 20.0\ \mathrm{s}$. Find (*a*) the average velocity and (*b*) the average acceleration between $t = 3.00\ \mathrm{s}$ and $t = 20.0\ \mathrm{s}$.

26. (II) A particular automobile can accelerate approximately as shown in the velocity vs. time graph of Fig. 2–40. (The short flat spots in the curve represent shifting of the gears.) Estimate the average acceleration of the car in (*a*) second gear; and (*b*) fourth gear. (*c*) What is its average acceleration through the first four gears?



27. (II) A particle moves along the x axis. Its position as a function of time is given by $x = 6.8\,t + 8.5\,t^2$, where t is in seconds and x is in meters. What is the acceleration as a function of time?

28. (II) The position of a racing car, which starts from rest at $t = 0$ and moves in a straight line, is given as a function of time in the following Table. Estimate (*a*) its velocity and (*b*) its acceleration as a function of time. Display each in a Table and on a graph.

$t(\mathrm{s})$	0	0.25	0.50	0.75	1.00	1.50	2.00	2.50
$x(\mathrm{m})$	0	0.11	0.46	1.06	1.94	4.62	8.55	13.79
$t(\mathrm{s})$	3.00	3.50	4.00	4.50	5.00	5.50	6.00	
$x(\mathrm{m})$	20.36	28.31	37.65	48.37	60.30	73.26	87.16	

29. (II) The position of an object is given by $x = At + Bt^2$, where x is in meters and t is in seconds. (*a*) What are the units of A and B? (*b*) What is the acceleration as a function of time? (*c*) What are the velocity and acceleration at $t = 5.0\,\mathrm{s}$? (*d*) What is the velocity as a function of time if $x = At + Bt^{2\,3}$?

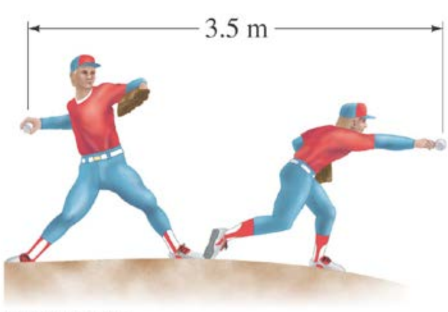
2–5 and 2–6 Motion at Constant Acceleration

30. (I) A car slows down from 25 m / s to rest in a distance of 85 m. What was its acceleration, assumed constant?

31. (I) A car accelerates from 12 m / s to 21 m / s in 6.0 s. What was its acceleration? How far did it travel in this time? Assume constant acceleration.

32. (I) A light plane must reach a speed of 32 m / s for takeoff. How long a runway is needed if the (constant) acceleration is $3.0\ \mathrm{m/s^2}$?

33. (II) A baseball pitcher throws a baseball with a speed of 41 m / s. Estimate the average acceleration of the ball during the throwing motion. In throwing the baseball, the pitcher accelerates the ball through a displacement of about 3.5 m, from behind the body to the point where it is released (Fig. 2–41).



34. (II) Show that $\overline{y} = (y + y_0)/2$ (see Eq. 2–12d) is not valid when the acceleration $a = A + Bt,$ where *A* and *B* are constants.

35. (II) A world-class sprinter can reach a top speed (of about 11.5 m / s) in the first 15.0 m of a race. What is the average acceleration of this sprinter and how long does it take her to reach that speed?

36. (II) An inattentive driver is traveling 18.0 m / s when he notices a red light ahead. His car is capable of decelerating at a rate of $3.65\,\mathrm{m/s^2}$. If it takes him 0.200 s to get the brakes on and he is 20.0 m from the intersection when he sees the light, will he be able to stop in time?

37. (II) A car slows down uniformly from a speed of 18.0 m / s to rest in 5.00 s. How far did it travel in that time?

38. (II) In coming to a stop, a car leaves skid marks 85 m long on the highway. Assuming a deceleration of $4.00\,\mathrm{m/s^2}$, estimate the speed of the car just before braking.

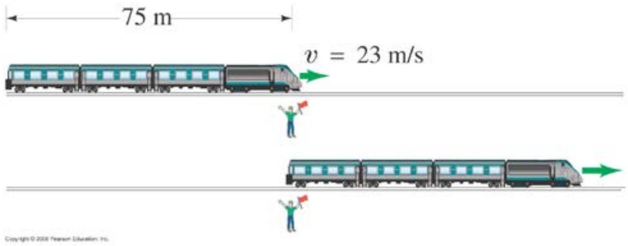
39. (II) A car traveling 85 km / h slows down at a constant $0.50\,\mathrm{m/s^2}$ just by "letting up on the gas." Calculate (*a*) the distance the car coasts before it stops, (*b*) the time it takes to stop, and (*c*) the distance it travels during the first and fifth seconds.

40. (II) A car traveling at 105 km / h strikes a tree. The front end of the car compresses and the driver comes to rest after traveling 0.80 m. What was the magnitude of the average acceleration of the driver during the collision? Express the answer in terms of "*g*'s," where $1.00\ g = 9.80\,\mathrm{m/s^2}$.

41. (II) Determine the stopping distances for an automobile with an initial speed of 95 km / h and human reaction time of 1.0 s: (*a*) for an acceleration $a = -5.0\ \mathrm{m/s^2}$
(*b*) for $a = -7.0\ \mathrm{m/s^2}$.

42. (II) A space vehicle accelerates uniformly from 65 m / s at $t = 0$ to 162 m / s at $t = 10.0\,\mathrm{s}$. How far did it move between $t = 2.0\,\mathrm{s}$ and $t = 6.0\,\mathrm{s}$?

43. (II) A 75-m-long train begins uniform acceleration from rest. The front of the train has a speed of 23 m / s when it passes a railway worker who is standing 180 m from where the front of the train started. What will be the speed of the last car as it passes the worker? (See Fig. 2 – 42.)

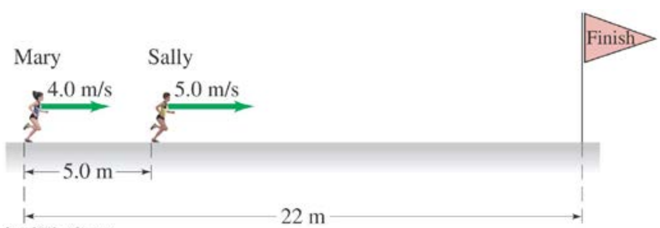


44. (II) An unmarked police car traveling a constant 95 km / h is passed by a speeder traveling 135 km / h. Precisely 1.00 s after the speeder passes, the police officer steps on the accelerator; if the police car's acceleration is $2.00\ \mathrm{m/s^2}$, how much time passes before the police car overtakes the speeder (assumed moving at constant speed)?

45. (III) Assume in Problem 44 that the speeder's speed is not known. If the police car accelerates uniformly as given above and overtakes the speeder after accelerating for 7.00 s, what was the speeder's speed?

46. (III) A runner hopes to complete the 10,000-m run in less than 30.0 min. After running at constant speed for exactly 27.0 min, there are still 1100 m to go. The runner must then accelerate at $0.20\ \mathrm{m/s^2}$ for how many seconds in order to achieve the desired time?

47. (III) Mary and Sally are in a foot race (Fig. 2–43). When Mary is 22 m from the finish line, she has a speed of 4.0 m / s and is 5.0 m behind Sally, who has a speed of 5.0 m / s. Sally thinks she has an easy win and so, during the remaining portion of the race, decelerates at a constant rate of $0.50\ \mathrm{m/s^2}$ to the finish line. What constant acceleration does Mary now need during the remaining portion of the race, if she wishes to cross the finish line side-by-side with Sally?



2–7 Freely Falling Objects

[Neglect air resistance.]

48. (I) A stone is dropped from the top of a cliff. It is seen to hit the ground below after 3.75 s. How high is the cliff?

49. (I) If a car rolls gently $(y_0 = 0)$ off a vertical cliff, how long does it take it to reach 55 km / h?

50. (I) Estimate (*a*) how long it took King Kong to fall straight down from the top of the Empire State Building (380 m high), and (*b*) his velocity just before "landing."

51. (II) A baseball is hit almost straight up into the air with a speed of about 20 m / s. (*a*) How high does it go? (*b*) How long is it in the air?

52. (II) A ball player catches a ball 3.2 s after throwing it vertically upward. With what speed did he throw it, and what height did it reach?

53. (II) A kangaroo jumps to a vertical height of 1.65 m. How long was it in the air before returning to Earth?

54. (II) The best rebounders in basketball have a vertical leap (that is, the vertical movement of a fixed point on their body) of about 120 cm. (*a*) What is their initial "launch" speed off the ground? (*b*) How long are they in the air?

55. (II) A helicopter is ascending vertically with a speed of 5.10 m / s. At a height of 105 m above the Earth, a package is dropped from a window. How much time does it take for the package to reach the ground? [*Hint*: v_0 for the package equals the speed of the helicopter.]

56. (II) For an object falling freely from rest, show that the distance traveled during each successive second increases in the ratio of successive odd integers (1, 3, 5, etc.). (This was first shown by Galileo.) See Figs. 2–26 and 2–29.

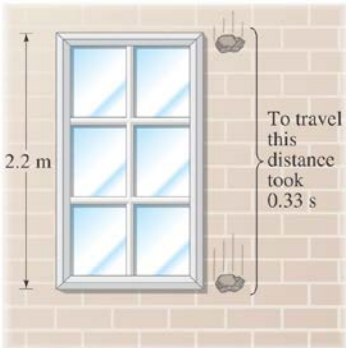
57. (II) A baseball is seen to pass upward by a window 23 m above the street with a vertical speed of 14 m / s. If the ball was thrown from the street, (*a*) what was its initial speed, (*b*) what altitude does it reach, (*c*) when was it thrown, and (*d*) when does it reach the street again?

58. (II) A rocket rises vertically, from rest, with an acceleration of $3.2\ \text{m/s}^2$ until it runs out of fuel at an altitude of 950 m. After this point, its acceleration is that of gravity, downward. (*a*) What is the velocity of the rocket when it runs out of fuel? (*b*) How long does it take to reach this point? (*c*) What maximum altitude does the rocket reach? (*d*) How much time (total) does it take to reach maximum altitude? (*e*) With what velocity does it strike the Earth? (*f*) How long (total) is it in the air?

59. (II) Roger sees water balloons fall past his window. He notices that each balloon strikes the sidewalk 0.83 s after passing his window. Roger's room is on the third floor, 15 m above the sidewalk. (*a*) How fast are the balloons traveling when they pass Roger's window? (*b*) Assuming the balloons are being released from rest, from what floor are they being released? Each floor of the dorm is 5.0 m high.

60. (II) A stone is thrown vertically upward with a speed of 24.0 m / s. (*a*) How fast is it moving when it reaches a height of 13.0 m? (*b*) How much time is required to reach this height? (*c*) Why are there two answers to (*b*)?

61. (II) A falling stone takes 0.33 s to travel past a window 2.2 m tall (Fig. 2–44). From what height above the top of the window did the stone fall?



62. (II) Suppose you adjust your garden hose nozzle for a hard stream of water. You point the nozzle vertically upward at a height of 1.5 m above the ground (Fig. 2–45). When you quickly turn off the nozzle, you hear the water striking the ground next to you for another 2.0 s. What is the water speed as it leaves the nozzle?

63. (III) A toy rocket moving vertically upward passes by a 2.0-m-high window whose sill is 8.0 m above the ground. The rocket takes 0.15 s to travel the 2.0 m height of the window. What was the launch speed of the rocket, and how high will it go? Assume the propellant is burned very quickly at blastoff.

64. (III) A ball is dropped from the top of a 50.0-m-high cliff. At the same time, a carefully aimed stone is thrown straight up from the bottom of the cliff with a speed of 24.0 m / s. The stone and ball collide part way up. How far above the base of the cliff does this happen?

65. (III) A rock is dropped from a sea cliff and the sound of it striking the ocean is heard 3.4 s later. If the speed of sound is 340 m / s, how high is the cliff?

66. (III) A rock is thrown vertically upward with a speed of 12.0 m / s. Exactly 1.00 s later, a ball is thrown up vertically along the same path with a speed of 18.0 m / s. (*a*) At what time will they strike each other? (*b*) At what height will the collision occur? (*c*) Answer (*a*) and (*b*) assuming that the order is reversed: the ball is thrown 1.00 s before the rock.

***2–8 Variable Acceleration; Calculus**

***67.** (II) Given $v(t) = 25 + 18t$, where v is in m / s and t is in s, use calculus to determine the total displacement from $t_1 = 1.5\text{ s}$ to $t_2 = 3.1\text{ s}$.

***68.** (III) The acceleration of a particle is given by $a = A\sqrt{t}$ where $A = 2.0\text{ m/s}^{5/2}$. At $t = 0$, $v = 7.5\text{ m/s}$ and $x = 0$. (*a*) What is the speed as a function of time? (*b*) What is the displacement as a function of time? (*c*) What are the acceleration, speed and displacement at $t = 5.0\text{ s}$?

***69.** (III) Air resistance acting on a falling body can be taken into account by the approximate relation for the acceleration:

$$a = \frac{dv}{dt} = g - kv,$$

where *k* is a constant. (*a*) Derive a formula for the velocity of the body as a function of time assuming it starts from rest ($v = 0$ at $t = 0$). [*Hint*: Change variables by setting $u = g - kv$.] (*b*) Determine an expression for the terminal velocity, which is the maximum value the velocity reaches.

***2–9 Graphical Analysis and Numerical Integration**

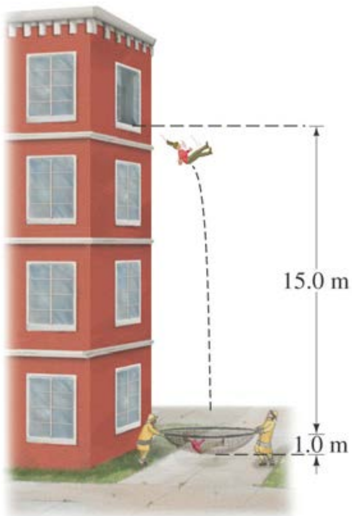
[See Problems 95 – 97 at the end of this Chapter.]

General Problems

70. A fugitive tries to hop on a freight train traveling at a constant speed of 5.0 m / s. Just as an empty box car passes him, the fugitive starts from rest and accelerates at $a = 1.2\text{ m/s}^2$ to his maximum speed of 6.0 m / s. (*a*) How long does it take him to catch up to the empty box car? (*b*) What is the distance traveled to reach the box car?

71. The acceleration due to gravity on the Moon is about one-sixth what it is on Earth. If an object is thrown vertically upward on the Moon, how many times higher will it go than it would on Earth, assuming the same initial velocity?

72. A person jumps from a fourth-story window 15.0 m above a firefighter's safety net. The survivor stretches the net 1.0 m before coming to rest, Fig. 2–46. (*a*) What was the average deceleration experienced by the survivor when she was slowed to rest by the net? (*b*) What would you do to make it "safer" (that is, to generate a smaller deceleration): would you stiffen or loosen the net? Explain.



73. A person who is properly restrained by an over-the-shoulder seat belt has a good chance of surviving a car collision if the deceleration does not exceed 30 "*g*'s" $\left(1.00\ g = 9.80\ \mathrm{m/s^2}\right)$. Assuming uniform deceleration of this value, calculate the distance over which the front end of the car must be designed to collapse if a crash brings the car to rest from 100 km / h.

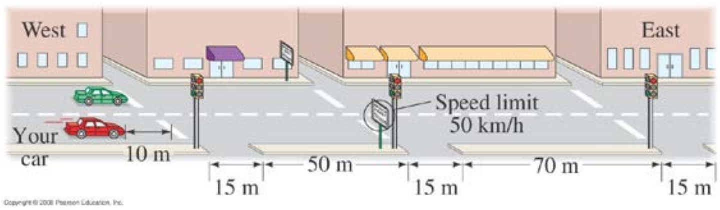
74. Pelicans tuck their wings and free-fall straight down when diving for fish. Suppose a pelican starts its dive from a height of 16.0 m and cannot change its path once committed. If it takes a fish 0.20 s to perform evasive action, at what minimum height must it spot the pelican to escape? Assume the fish is at the surface of the water.

75. Suppose a car manufacturer tested its cars for front-end collisions by hauling them up on a crane and dropping them from a certain height. (*a*) Show that the speed just before a car hits the ground, after falling from rest a vertical distance *H*, is given by $\sqrt{2gH}$ * What height corresponds to a collision at (*b*) 50 km / h? (*c*) 100 km / h?

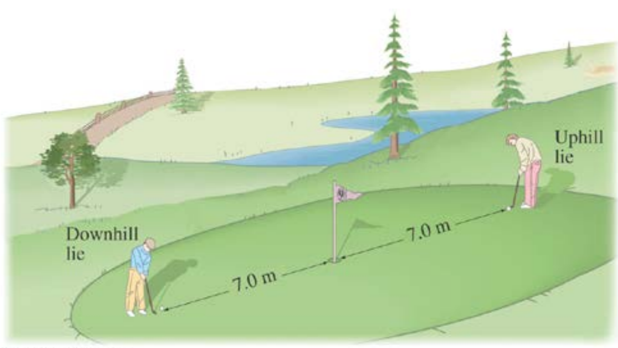
76. A stone is dropped from the roof of a high building. A second stone is dropped 1.50 s later. How far apart are the stones when the second one has reached a speed of 12.0 m / s?

77. A bicyclist in the Tour de France crests a mountain pass as he moves at 15 km / h. At the bottom, 4.0 km farther, his speed is 75 km / h. What was his average acceleration (in $\mathrm{m/s^2}$) while riding down the mountain?

78. Consider the street pattern shown in Fig. 2–47. Each intersection has a traffic signal, and the speed limit is 50 km / h. Suppose you are driving from the west at the speed limit. When you are 10.0 m from the first intersection, all the lights turn green. The lights are green for 13.0 s each. (*a*) Calculate the time needed to reach the third stoplight. Can you make it through all three lights without stopping? (*b*) Another car was stopped at the first light when all the lights turned green. It can accelerate at the rate of $2.00\ \text{m/s}^2$ to the speed limit. Can the second car make it through all three lights without stopping? By how many seconds would it make it or not?

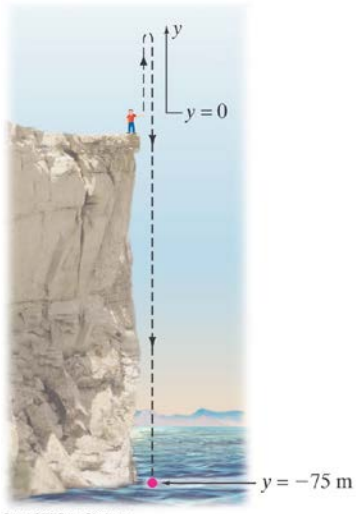


79. In putting, the force with which a golfer strikes a ball is planned so that the ball will stop within some small distance of the cup, say 1.0 m long or short, in case the putt is missed. Accomplishing this from an uphill lie (that is, putting the ball downhill, see Fig. 2–48) is more difficult than from a downhill lie. To see why, assume that on a particular green the ball decelerates constantly at $1.8\ \text{m/s}^2$ going downhill, and constantly at $2.8\ \text{m/s}^2$ going uphill. Suppose we have an uphill lie 7.0 m from the cup. Calculate the allowable range of initial velocities we may impart to the ball so that it stops in the range 1.0 m short to 1.0 m long of the cup. Do the same for a downhill lie 7.0 m from the cup. What in your results suggests that the downhill putt is more difficult?

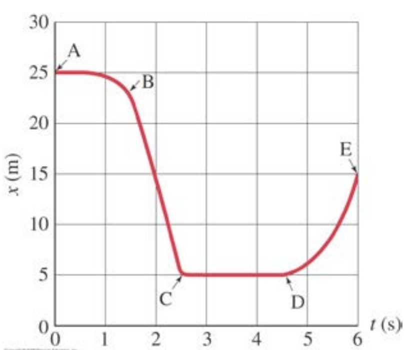


80. A robot used in a pharmacy picks up a medicine bottle at $t = 0.$ It accelerates at $0.20\ \text{m/s}^2$ for 5.0 s, then travels without acceleration for 68 s and finally decelerates at 2 $0.40\ \text{m/s}^2$ for 2.5 s to reach the counter where the pharmacist will take the medicine from the robot. From how far away did the robot fetch the medicine?

81. A stone is thrown vertically upward with a speed of 12.5 m / s from the edge of a cliff 75.0 m high (Fig. 2–49). (*a*) How much later does it reach the bottom of the cliff? (*b*) What is its speed just before hitting? (*c*) What total distance did it travel?



82. Figure 2–50 is a position versus time graph for the motion of an object along the *x* axis. Consider the time interval from A to B. (*a*) Is the object moving in the positive or negative direction? (*b*) Is the object speeding up or slowing down? (*c*) Is the acceleration of the object positive or negative? Next, consider the time interval from D to E. (*d*) Is the object moving in the positive or negative direction? (*e*) Is the object speeding up or slowing down? (*f*) Is the acceleration of the object positive or negative? (*g*) Finally, answer these same three questions for the time interval from C to D.



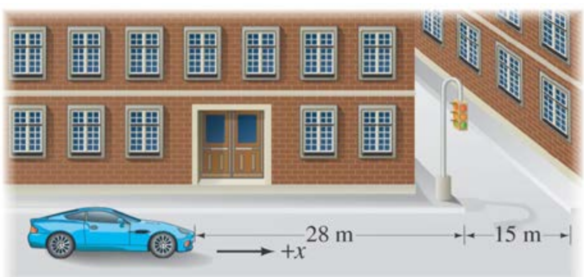
83. In the design of a *rapid transit system*, it is necessary to balance the average speed of a train against the distance between stops. The more stops there are, the slower the train's average speed. To get an idea of this problem, calculate the time it takes a train to make a 9.0-km trip in two situations: (*a*) the stations at which the trains must stop are 1.8 km apart (a total of 6 stations, including those at the ends); and (*b*) the stations are 3.0 km apart (4 stations total). Assume that at each station the train accelerates at a rate of $1.1\ \text{m/s}^2$ until it reaches 95 km / h, then stays at this speed until its brakes are applied for arrival at the next station, at which time it decelerates at 2 $2.0\ \text{m/s}^2$. Assume it stops at each intermediate station for 22 s.

84. A person jumps off a diving board 4.0 m above the water’s surface into a deep pool. The person’s downward motion stops 2.0 m below the surface of the water. Estimate the average deceleration of the person while under the water.

85. Bill can throw a ball vertically at a speed 1.5 times faster than Joe can. How many times higher will Bill’s ball go than Joe’s?

86. Sketch the y vs. t graph for the object whose displacement as a function of time is given by Fig. 2–36.

87. A person driving her car at 45 km / h approaches an intersection just as the traffic light turns yellow. She knows that the yellow light lasts only 2.0 s before turning to red, and she is 28 m away from the near side of the intersection (Fig. 2–51). Should she try to stop, or should she speed up to cross the intersection before the light turns red? The intersection is 15 m wide. Her car’s maximum deceleration is 2 $5.8\ \text{m/s}^2$, whereas it can accelerate from 45 km / h to 65 km / h in 6.0 s. Ignore the length of her car and her reaction time.



88. A car is behind a truck going 25 m / s on the highway. The driver looks for an opportunity to pass, guessing that his car can accelerate at $1.0\ \text{m/s}^2$, and he gauges that he has to cover the 20-m length of the truck, plus 10-m clear room at the rear of the truck and 10 m more at the front of it. In the oncoming lane, he sees a car approaching, probably also traveling at 25 m / s. He estimates that the car is about 400 m away. Should he attempt the pass? Give details.

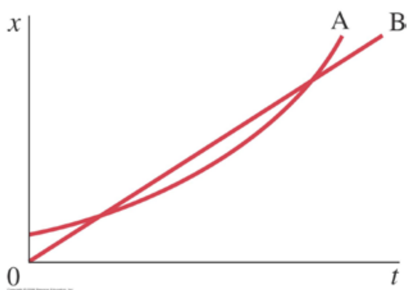
89. Agent Bond is standing on a bridge, 13 m above the road below, and his pursuers are getting too close for comfort. He spots a flatbed truck approaching at 25 m / s, which he measures by knowing that the telephone poles the truck is passing are 25 m apart in this country. The bed of the truck is 1.5 m above the road, and Bond quickly calculates how many poles away the truck should be when he jumps down from the bridge onto the truck, making his getaway. How many poles is it?

90. A police car at rest, passed by a speeder traveling at a constant 130 km / h, takes off in hot pursuit. The police officer catches up to the speeder in 750 m, maintaining a constant acceleration. (*a*) Qualitatively plot the position vs. time graph for both cars from the police car's start to the catch-up point. Calculate (*b*) how long it took the police officer to overtake the speeder, (*c*) the required police car acceleration, and (*d*) the speed of the police car at the overtaking point.

91. A fast-food restaurant uses a conveyor belt to send the burgers through a grilling machine. If the grilling machine is 1.1 m long and the burgers require 2.5 min to cook, how fast must the conveyor belt travel? If the burgers are spaced 15 cm apart, what is the rate of burger production (in burgers / min)?

92. Two students are asked to find the height of a particular building using a barometer. Instead of using the barometer as an altitude-measuring device, they take it to the roof of the building and drop it off, timing its fall. One student reports a fall time of 2.0 s, and the other, 2.3 s. What difference does the 0.3 s make for the estimates of the building's height?

93. Figure 2–52 shows the position vs. time graph for two bicycles, A and B. (*a*) Is there any instant at which the two bicycles have the same velocity? (*b*) Which bicycle has the larger acceleration? (*c*) At which instant(s) are the bicycles passing each other? Which bicycle is passing the other? (*d*) Which bicycle has the highest instantaneous velocity? (*e*) Which bicycle has the higher average velocity?



94. You are traveling at a constant speed y_M, and there is a car in front of you traveling with a speed y_A * You notice that $y_M > y_A$, so you start slowing down with a constant acceleration *a* when the distance between you and the other car is *x*. What relationship between *a* and *x* determines whether or not you run into the car in front of you?

***Numerical/Computer**

***95.** (II) The Table below gives the speed of a particular drag racer as a function of time. (*a*) Calculate the average acceleration $\left(\mathrm{m/s^2}\right)$ during each time interval. (*b*) Using numerical integration (see Section 2–9) estimate the total distance traveled (m) as a function of time. [*Hint*: for $\bar{v}$ in each interval sum the velocities at the beginning and end of the interval and divide by 2; for example, in the second interval use $\bar{v} = (6.0 + 13.2)/2 = 9.6$] (*c*) Graph each of these.

$t\,(\mathrm{s})$	0	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
$v\,(\mathrm{km/h})$	0.0	6.0	13.2	22.3	32.2	43.0	53.5	62.6	70.6	78.4	85.1

***96.** (III) The acceleration of an object (in $\mathrm{m/s^2}$) is measured at 1.00-s intervals starting at $t = 0$ to be as follows: 1.25, 1.58, 1.96, 2.40, 2.66, 2.70, 2.74, 2.72, 2.60, 2.30, 2.04, 1.76, 1.41, 1.09, 0.86, 0.51, 0.28, 0.10. Use numerical integration (see Section 2–9) to estimate (*a*) the velocity (assume that $v = 0$ at $t = 0$) and (*b*) the displacement at $t = 17.00\ \mathrm{s}$.

97. (III) A lifeguard standing at the side of a swimming pool spots a child in distress, Fig. 2–53. The lifeguard runs with average speed v_R along the pool's edge for a distance *x*, then jumps into the pool and swims with average speed v_S on a straight path to the child. (*a*) Show that the total time t it takes the lifeguard to get to the child is given by

$$t = \frac{x}{v_R} + \frac{\sqrt{D^2 + (d - x)^2}}{v_S}.$$

(*b*) Assume $v_R = 4.0\ \mathrm{m/s}$ and $v_S = 1.5\ \mathrm{m/s}$. Use a graphing calculator or computer to plot t vs. *x* in part (*a*), and from this plot determine the optimal distance *x* the lifeguard should run before jumping into the pool (that is, find the value of *x* that minimizes the time t to get to the child).