Ch 2 6th

Summary

[The Summary that appears at the end of each Chapter in this book gives a brief overview of the main ideas of the Chapter. The Summary *cannot* serve to give an understanding of the material, which can be accomplished only by a detailed reading of the Chapter.]

Kinematics deals with the description of how objects move. The description of the motion of any object must always be given relative to some particular **reference frame.**

The **displacement** of an object is the change in position of the object.

Average speed is the distance traveled divided by the elapsed time or time interval, Δt, the time period over which we choose to make our observations. An object's **average velocity** over a particular time interval Δt is its displacement Δx during that time interval, divided by Δt:

$$\bar{v} = \frac{\Delta x}{\Delta t}. \qquad (2\text{–}2)$$

The **instantaneous velocity**, whose magnitude is the same as the *instantaneous speed*, is defined as the average velocity taken over an infinitesimally short time interval.

Acceleration is the change of velocity per unit time. An object's **average acceleration** over a time interval Δt is

$$\bar{a} = \frac{\Delta v}{\Delta t}, \qquad (2\text{–}4)$$

where Δv is the change of velocity during the time interval **Instantaneous acceleration** is the average acceleration ta over an infinitesimally short time interval.

If an object has position x_0 and velocity v_0 at time t and moves in a straight line with constant acceleration, velocity v and position x at a later time t are related to acceleration a, the initial position x_0, and the initial velo v_0 by Eqs. 2–11:

$$v = v_0 + at, \qquad x = x_0 + v_0 t + \tfrac{1}{2}at^2,$$

$$v^2 = v_0^2 + 2a(x - x_0), \qquad \bar{v} = \frac{v + v_0}{2}. \qquad (2\text{–}$$

Objects that move vertically near the surface of t Earth, either falling or having been projected vertically up down, move with the constant downward **acceleration due gravity**, whose magnitude is $g = 9.80\,\mathrm{m/s^2}$ if air resistan can be ignored. We can apply Eqs. 2–11 for constant accele tion to objects that move up or down freely near the Eartl surface.

[*The slope of a curve at any point on a graph is t slope of the tangent to the curve at that point. If the graph x vs. t, the slope is $\Delta x/\Delta t$ and equals the velocity at that poi The area under a v vs. t graph equals the displaceme between any two chosen times.]

Questions

1-2, 10

1. Does a car speedometer measure speed, velocity, or both?
2. Can an object have a varying speed if its velocity is constant? If yes, give examples.
3. When an object moves with constant velocity, does its average velocity during any time interval differ from its instantaneous velocity at any instant?
4. In drag racing, is it possible for the car with the greatest speed crossing the finish line to lose the race? Explain.
5. If one object has a greater speed than a second object, does the first necessarily have a greater acceleration? Explain, using examples.
6. Compare the acceleration of a motorcycle that accelerates from 80 km/h to 90 km/h with the acceleration of a bicycle that accelerates from rest to 10 km/h in the same time.
7. Can an object have a northward velocity and a southward acceleration? Explain.
8. Can the velocity of an object be negative when its acceleration is positive? What about vice versa?
9. Give an example where both the velocity and acceleration are negative.
10. Two cars emerge side by side from a tunnel. Car A is traveling with a speed of 60 km/h and has an acceleration of 40 km/h/min. Car B has a speed of 40 km/h and has an acceleration of 60 km/h/min. Which car is passing the other as they come out of the tunnel? Explain your reasoning.
11. Can an object be increasing in speed as its acceleration decreases? If so, give an example. If not, explain.
12. A baseball player hits a foul ball straight up into the air. It leaves the bat with a speed of 120 km/h. In the absence of air resistance, how fast will the ball be traveling when the catcher catches it?
13. As a freely falling object speeds up, what is happening t its acceleration due to gravity—does it increase, decreas or stay the same?
14. How would you estimate the maximum height you coul throw a ball vertically upward? How would you estimat the maximum speed you could give it?
15. You travel from point A to point B in a car moving at constant speed of 70 km/h. Then you travel the sam distance from point B to another point C, moving at constant speed of 90 km/h. Is your average speed for th entire trip from A to C 80 km/h? Explain why or why not
16. In a lecture demonstration, a 3.0-m-long vertical strin with ten bolts tied to it at equal intervals is dropped fron the ceiling of the lecture hall. The string falls on a ti plate, and the class hears the clink of each bolt as it hit the plate. The sounds will not occur at equal time intervals. Why? Will the time between clinks increase o decrease near the end of the fall? How could the bolts be tied so that the clinks occur at equal intervals?
17. Which one of these motions is *not* at constant acceleration: a rock falling from a cliff, an elevator moving from the second floor to the fifth floor making stops along the way, a dish resting on a table?
18. An object that is thrown vertically upward will return to its original position with the same speed as it had initially if air resistance is negligible. If air resistance is appreciable, will this result be altered, and if so, how? [*Hint:* The acceleration due to air resistance is always in a direction opposite to the motion.]
19. Can an object have zero velocity and nonzero acceleration at the same time? Give examples.
20. Can an object have zero acceleration and nonzero velocity at the same time? Give examples.

*21. Describe in words the motion plotted in Fig. 2–28 in terms of v, a, etc. [*Hint*: First try to duplicate the motion plotted by walking or moving your hand.]

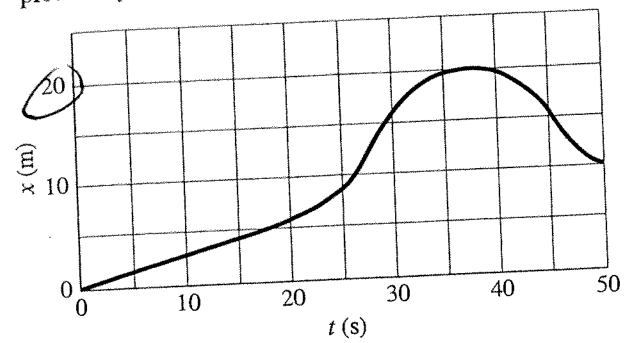

FIGURE 2–28 Question 21, Problems 50, 51, and 55.

*22. Describe in words the motion of the object graphed in Fig. 2–29.

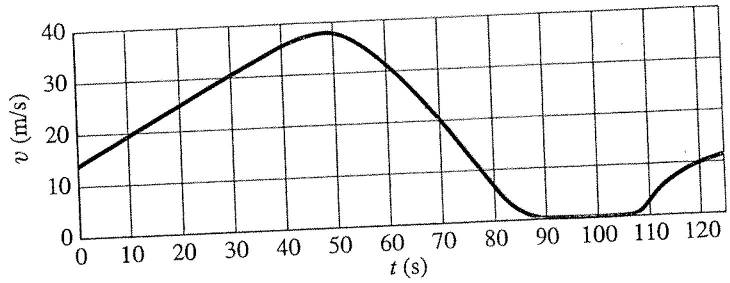

FIGURE 2–29 Question 22, Problems 49 and 54.

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) What must be your car's average speed in order to travel 235 km in 3.25 h?
2. (I) A bird can fly 25 km/h. How long does it take to fly 15 km?
3. (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?
4. (I) Convert 35 mi/h to (*a*) km/h, (*b*) m/s, and (*c*) ft/s.
5. (I) A rolling ball moves from $x_1 = 3.4$ cm to $x_2 = -4.2$ cm during the time from $t_1 = 3.0$ s to $t_2 = 6.1$ s. What is its average velocity?
6. (II) A particle at $t_1 = -2.0$ s is at $x_1 = 3.4$ cm and at $t_2 = 4.5$ s is at $x_2 = 8.5$ cm. What is its average velocity? Can you calculate its average speed from these data?
7. (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?
8. (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.
9. (II) A person jogs eight complete laps around a quarter-mile track in a total time of 12.5 min. Calculate (*a*) the average speed and (*b*) the average velocity, in m/s.
10. (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.
11. (II) Two locomotives approach each other on parallel tracks. Each has a speed of 95 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. 2–30).

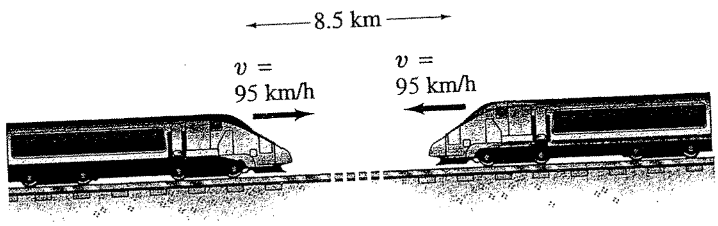

FIGURE 2–30 Problem 11.

12. (II) A car traveling 88 km/h is 110 m behind a truck traveling 75 km/h. How long will it take the car to reach the truck?
13. (II) An airplane travels 3100 km at a speed of 790 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*: Think carefully before using Eq. 2–11d.]
14. (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-hour lunch break, and the return 250 km is covered at 55 km/h.
15. (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? The speed of sound is 340 m/s.

2–4 Acceleration

16. (I) A sports car accelerates from rest to 95 km/h in 6.2 s. What is its average acceleration in m/s^2?
17. (I) A sprinter accelerates from rest to 10.0 m/s in 1.35 s. What is her acceleration (*a*) in m/s^2, and (*b*) in km/h^2?

18. (II) At highway speeds, a particular automobile is capable of an acceleration of about $1.6\ m/s^2$. At this rate, how long does it take to accelerate from 80 km/h to 110 km/h?

19. (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 its acceleration in m/s^2? Express the answer in terms of "g's," where $1.00\ g = 9.80\ m/s^2$.

20. (III) 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 (s)	0	0.25	0.50	0.75	1.00	1.50	2.00	2.50
x (m)	0	0.11	0.46	1.06	1.94	4.62	8.55	13.79

t (s)	3.00	3.50	4.00	4.50	5.00	5.50	6.00
x (m)	20.36	28.31	37.65	48.37	60.30	73.26	87.16

2–5 and 2–6 Motion at Constant Acceleration

21. (I) A car accelerates from 13 m/s to 25 m/s in 6.0 s. What was its acceleration? How far did it travel in this time? Assume constant acceleration.

22. (I) A car slows down from 23 m/s to rest in a distance of 85 m. What was its acceleration, assumed constant?

23. (I) A light plane must reach a speed of 33 m/s for takeoff. How long a runway is needed if the (constant) acceleration is $3.0\ m/s^2$?

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

25. (II) A car slows down uniformly from a speed of 21.0 m/s to rest in 6.00 s. How far did it travel in that time?

26. (II) In coming to a stop, a car leaves skid marks 92 m long on the highway. Assuming a deceleration of $7.00\ m/s^2$, estimate the speed of the car just before braking.

27. (II) A car traveling 85 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 average acceleration of the driver during the collision? Express the answer in terms of "g's," where $1.00\ g = 9.80\ m/s^2$.

28. (II) Determine the stopping distances for a car with an initial speed of 95 km/h and human reaction time of 1.0 s, for an acceleration (*a*) $a = -4.0\ m/s^2$; (*b*) $a = -8.0\ m/s^2$.

29. (III) Show that the equation for the stopping distance of a car is $d_S = v_0 t_R - v_0^2/(2a)$, where v_0 is the initial speed of the car, t_R is the driver's reaction time, and a is the constant acceleration (and is negative).

30. (III) A car is behind a truck going 25 m/s on the highway. The car's driver looks for an opportunity to pass, guessing that his car can accelerate at $1.0\ m/s^2$. 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.

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

32. (III) A person driving her car at 45 km/h approaches intersection just as the traffic light turns yellow. S knows that the yellow light lasts only 2.0 s before turni red, and she is 28 m away from the near side of the inte section (Fig. 2–31). Should she try to stop, or should sl speed up to cross the intersection before the light tur red? The intersection is 15 m wide. Her car's maximu deceleration is $-5.8\ m/s^2$, whereas it can accelerate fro 45 km/h to 65 km/h in 6.0 s. Ignore the length of her c and her reaction time.

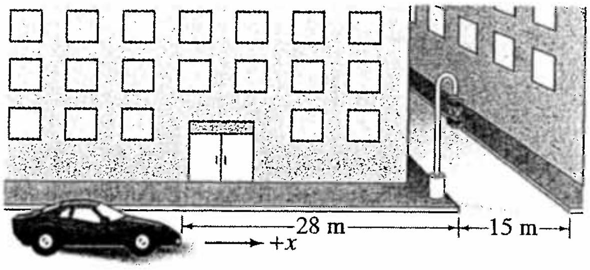

FIGURE 2–31 Problem 32.

2–7 Falling Objects [neglect air resistance]

33. (I) A stone is dropped from the top of a cliff. It hits th ground below after 3.25 s. How high is the cliff?

34. (I) If a car rolls gently ($v_0 = 0$) off a vertical cliff, hov long does it take it to reach 85 km/h?

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

36. (II) A baseball is hit nearly straight up into the air with speed of 22 m/s. (*a*) How high does it go? (*b*) How long i it in the air?

37. (II) A ballplayer catches a ball 3.0 s after throwing i vertically upward. With what speed did he throw it, an what height did it reach?

38. (II) An object starts from rest and falls under the influ ence of gravity. Draw graphs of (*a*) its speed and (*b*) th distance it has fallen, as a function of time from $t = 0$ t $t = 5.00$ s. Ignore air resistance.

39. (II) A helicopter is ascending vertically with a speed o 5.20 m/s. At a height of 125 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*: The package's initial speed equals the helicopter's.]

40. (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. 2–18 and 2–21.

41. (II) If air resistance is neglected, show (algebraically) that a ball thrown vertically upward with a speed v_0 will have the same speed, v_0, when it comes back down to the starting point.

42. (II) A stone is thrown vertically upward with a speed of 18.0 m/s. (*a*) How fast is it moving when it reaches a height of 11.0 m? (*b*) How long is required to reach this height? (*c*) Why are there two answers to (*b*)?

43. (III) Estimate the time between each photoflash of the apple in Fig. 2–18 (or number of photoflashes per second). Assume the apple is about 10 cm in diameter. [*Hint*: Use two apple positions, but not the unclear ones at the top.]

44. (III) A falling stone takes 0.28 s to travel past a window 2.2 m tall (Fig. 2–32). From what height above the top of the window did the stone fall?

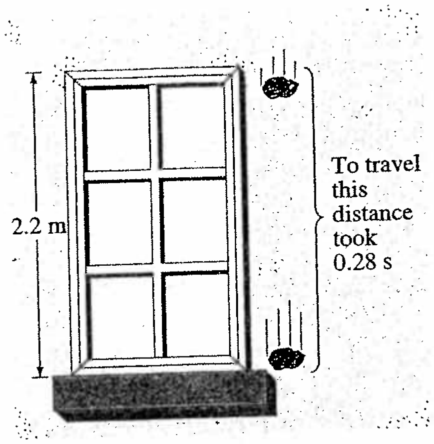

FIGURE 2–32 Problem 44.

45. (III) A rock is dropped from a sea cliff, and the sound of it striking the ocean is heard 3.2 s later. If the speed of sound is 340 m/s, how high is the cliff?

46. (III) 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. 2–33). When you quickly move the nozzle away from the vertical, 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?

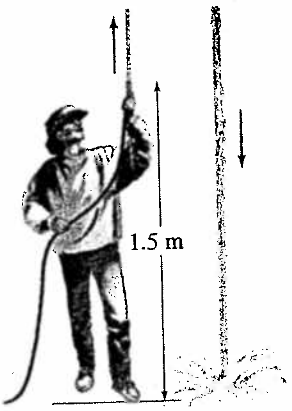

FIGURE 2–33 Problem 46.

47. (III) A stone is thrown vertically upward with a speed of 12.0 m/s from the edge of a cliff 70.0 m high (Fig. 2–34). (*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?

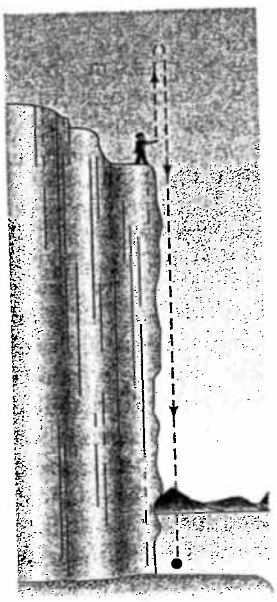

FIGURE 2–34 Problem 47.

48. (III) A baseball is seen to pass upward by a window 28 m above the street with a vertical speed of 13 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?

* 2–8 Graphical Analysis

* 49. (I) Figure 2–29 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?

* 50. (II) The position of a rabbit along a straight tunnel as a function of time is plotted in Fig. 2–28. What is its instantaneous velocity (*a*) at $t = 10.0$ s and (*b*) at $t = 30.0$ s? What is its average velocity (*c*) between $t = 0$ and $t = 5.0$ s, (*d*) between $t = 25.0$ s and $t = 30.0$ s, and (*e*) between $t = 40.0$ s and $t = 50.0$ s?

* 51. (II) In Fig. 2–28, (*a*) during what time periods, if any, is the velocity constant? (*b*) At what time is the velocity greatest? (*c*) At what time, if any, is the velocity zero? (*d*) Does the object move in one direction or in both directions during the time shown?

* 52. (II) A certain type of automobile can accelerate approximately as shown in the velocity–time graph of Fig. 2–35. (The short flat spots in the curve represent shifting of the gears.) (*a*) Estimate the average acceleration of the car in second gear and in fourth gear. (*b*) Estimate how far the car traveled while in fourth gear.

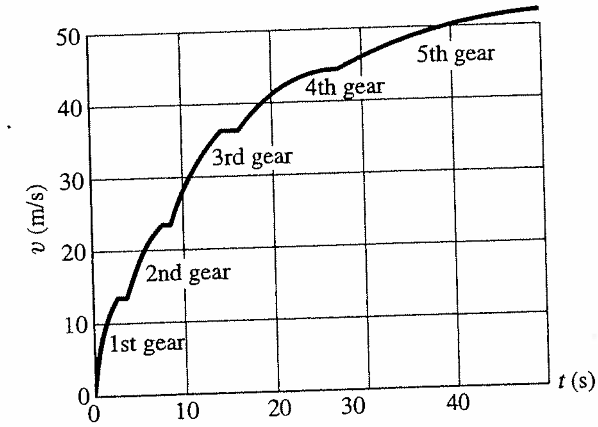

FIGURE 2–35 Problems 52 and 53. The velocity of an automobile as a function of time, starting from a dead stop. The jumps in the curve represent gear shifts.

* 53. (II) Estimate the average acceleration of the car in the previous Problem (Fig. 2–35) when it is in (*a*) first, (*b*) third, and (*c*) fifth gear. (*d*) What is its average acceleration through the first four gears?

* 54. (II) In Fig. 2–29, estimate the distance the object traveled during (*a*) the first minute, and (*b*) the second minute.

* 55. (II) Construct the v vs. t graph for the object whose displacement as a function of time is given by Fig. 2–28.

* **56.** (II) Figure 2–36 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? Now 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.

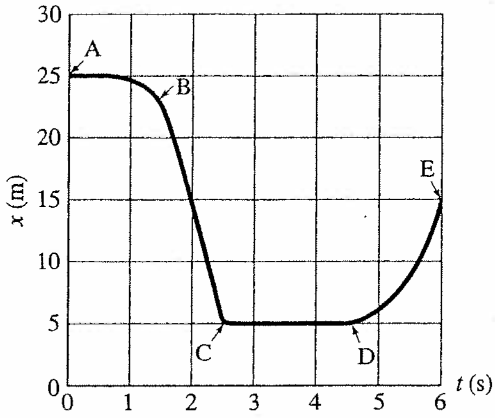

FIGURE 2–36 Problem 56.

General Problems

57. 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. 2–37. (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.

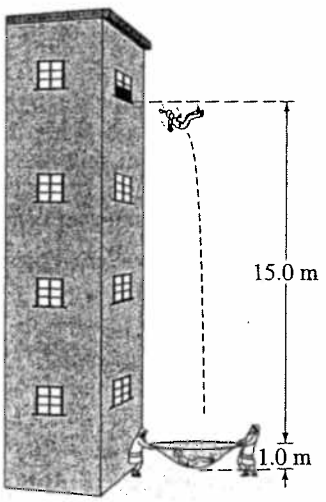

FIGURE 2–37 Problem 57.

58. 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?

59. A person who is properly constrained by an over-the-shoulder seat belt has a good chance of surviving a car collision if the deceleration does not exceed about 30 "g's" $(1.0\,g = 9.8\,\mathrm{m/s^2})$. 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.

60. Agent Bond is standing on a bridge, 12 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 to make his getaway. How many poles is it?

61. 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) 60 km/h? (c) 100 km/h?

62. Every year the Earth travels about 10^9 km as it orbits the Sun. What is Earth's average speed in km/h?

63. A 95-m-long train begins uniform acceleration from rest. The front of the train has a speed of 25 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. 2–38.)

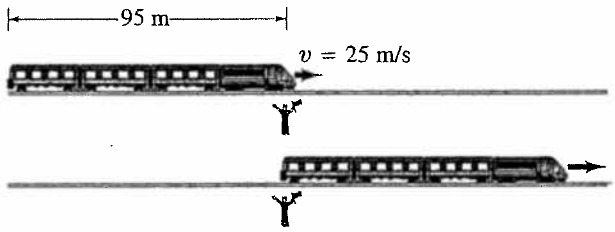

FIGURE 2–38 Problem 63.

64. 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.

65. 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 $1.1\,\mathrm{m/s^2}$ until it reaches 90 km/h, then stays at this speed until its brakes are applied for arrival at the next station, at which time it decelerates at $-2.0\,\mathrm{m/s^2}$. Assume it stops at each intermediate station for 20 s.

66. 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.

67. 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 downhill, see Fig. 2–39) is more difficult than from a downhill lie. To see why, assume that on a particular green the ball decelerates constantly at $2.0\,m/s^2$ going downhill, and constantly at $3.0\,m/s^2$ 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?

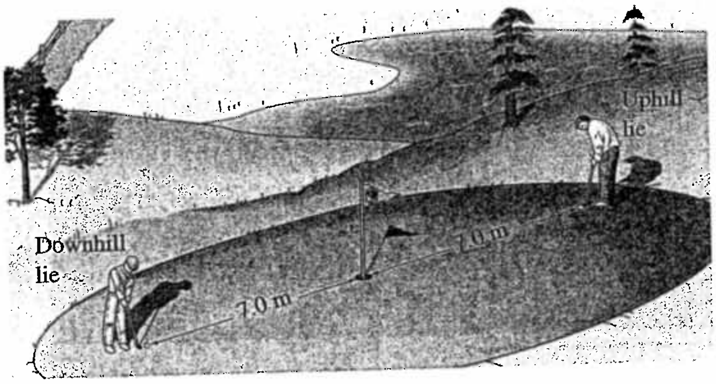

FIGURE 2–39 Problem 67. Golf on Wednesday morning.

68. A fugitive tries to hop on a freight train traveling at a constant speed of 6.0 m/s. Just as an empty box car passes him, the fugitive starts from rest and accelerates at $a = 4.0\,m/s^2$ to his maximum speed of 8.0 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?

69. 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?

70. A race car driver must average 200.0 km/h over the course of a time trial lasting ten laps. If the first nine laps were done at 198.0 km/h, what average speed must be maintained for the last lap?

71. A bicyclist in the Tour de France crests a mountain pass as he moves at 18 km/h. At the bottom, 4.0 km farther, his speed is 75 km/h. What was his average acceleration (in m/s^2) while riding down the mountain?

72. Two children are playing on two trampolines. The first child can bounce up one-and-a-half times higher than the second child. The initial speed up of the second child is 5.0 m/s. (*a*) Find the maximum height the second child reaches. (*b*) What is the initial speed of the first child? (*c*) How long was the first child in the air?

73. 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. 2–40. What are the results if the car and train are traveling in opposite directions?

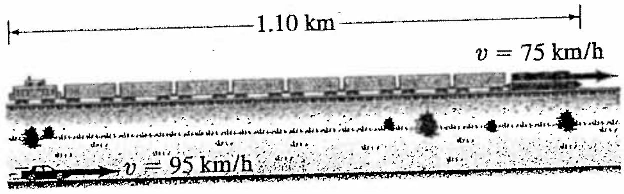

FIGURE 2–40 Problem 73.

74. A baseball pitcher throws a baseball with a speed of 44 m/s. 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). Estimate the average acceleration of the ball during the throwing motion.

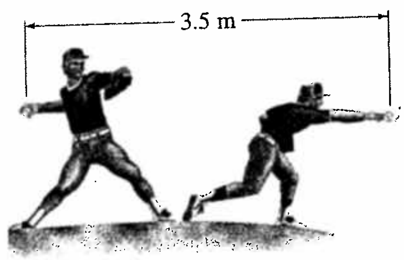

FIGURE 2–41 Problem 74.

75. A rocket rises vertically, from rest, with an acceleration of $3.2\,m/s^2$ until it runs out of fuel at an altitude of 1200 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 the rocket strike the Earth? (*f*) How long (total) is it in the air?

76. Consider the street pattern shown in Fig. 2–42. 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 m from the first intersection, all the lights turn green. The lights are green for 13 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 $2.0\,m/s^2$ to the speed limit. Can the second car make it through all three lights without stopping?

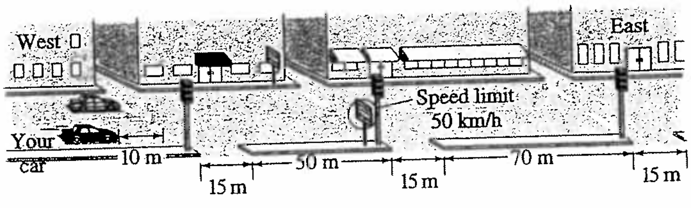

FIGURE 2–42 Problem 76.

77. A police car at rest, passed by a speeder traveling at a constant 120 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.

78. A stone is dropped from the roof of a building; 2.00 s after that, a second stone is thrown straight down with an initial speed of 25.0 m/s, and the two stones land at the same time. (*a*) How long did it take the first stone to reach the ground? (*b*) How high is the building? (*c*) What are the speeds of the two stones just before they hit the ground?

79. Two stones are thrown vertically up at the same time. The first stone is thrown with an initial velocity of 11.0 m/s from a 12th-floor balcony of a building and hits the ground after 4.5 s. With what initial velocity should the second stone be thrown from a 4^{th}-floor balcony so that it hits the ground at the same time as the first stone? Make simple assumptions, like equal-height floors.

80. If there were no air resistance, how long would it take a free-falling parachutist to fall from a plane at 3200 m to an altitude of 350 m, where she will pull her ripcord? What would her speed be at 350 m? (In reality, the air resistance will restrict her speed to perhaps 150 km/h.)

81. 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)?

82. 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?

83. You stand at the top of a cliff while your friend stands on the ground below you. You drop a ball from rest and see that it takes 1.2 s for the ball to hit the ground below. Your friend then picks up the ball and throws it up to you, such that it just comes to rest in your hand. What is the speed with which your friend threw the ball?

84. 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. How much difference does the 0.3 s make for the estimates of the building's height?

* 85. Figure 2–43 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?

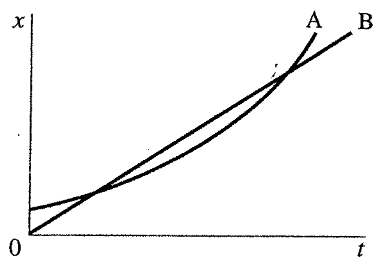

FIGURE 2–43 Problem 85.

Answers to Exercises

A: (*b*).
B: (*a*) +; (*b*) −; (*c*) −; (*d*) +.
C: (*c*).
D: $4.9\ m/s^2$.
E: That plane on which a smooth ball will not roll; or perpendicular to vertical.

Ch 3 6th Ed

Questions

1. One car travels due east at 40 km/h, and a second car travels north at 40 km/h. Are their velocities equal? Explain.
2. Can you give several examples of an object's motion in which a great distance is traveled but the displacement is zero?
3. Can the displacement vector for a particle moving in two dimensions ever be longer than the length of path traveled by the particle over the same time interval? Can it ever be less? Discuss.
4. During baseball practice, a batter hits a very high fly ball and then runs in a straight line and catches it. Which had the greater displacement, the batter or the ball?
5. If $\vec{V} = \vec{V}_1 + \vec{V}_2$, is V necessarily greater than V_1 and/or V_2? Discuss.
6. Two vectors have length $V_1 = 3.5\,\text{km}$ and $V_2 = 4.0\,\text{km}$. What are the maximum and minimum magnitudes of their vector sum?
7. Can two vectors of unequal magnitude add up to give the zero vector? Can *three* unequal vectors? Under what conditions?
8. Can the magnitude of a vector ever (*a*) be equal to one of its components, or (*b*) be less than one of its components?
9. Can a particle with constant speed be accelerating? What if it has constant velocity?
10. A child wishes to determine the speed a slingshot imparts to a rock. How can this be done using only a meter stick, a rock, and the slingshot?
11. It was reported in World War I that a pilot flying at an altitude of 2 km caught in his bare hands a bullet fired at the plane! Using the fact that a bullet slows down considerably due to air resistance, explain how this incident occurred.
12. At some amusement parks, to get on a moving "car" the riders first hop onto a moving walkway and then onto the cars themselves. Why is this done?
13. If you are riding on a train that speeds past another train moving in the same direction on an adjacent track, it appears that the other train is moving backward. Why?
14. If you stand motionless under an umbrella in a rainstorm where the drops fall vertically, you remain relatively dry. However, if you start running, the rain begins to hit your legs even if they remain under the umbrella. Why?
15. A person sitting in an enclosed train car, moving at constant velocity, throws a ball straight up into the air in her reference frame. (*a*) Where does the ball land? What is your answer if the car (*b*) accelerates, (*c*) decelerates, (*d*) rounds a curve, (*e*) moves with constant velocity but is open to the air?
16. Two rowers, who can row at the same speed in still water, set off across a river at the same time. One heads straight across and is pulled downstream somewhat by the current. The other one heads upstream at an angle so as to arrive at a point opposite the starting point. Which rower reaches the opposite side first?
17. How do you think a baseball player "judges" the flight of a fly ball? Which equation in this Chapter becomes part of the player's intuition?
18. In archery, should the arrow be aimed directly at the target? How should your angle of aim depend on the distance to the target?
19. A projectile is launched at an angle of 30° to the horizontal with a speed of 30 m/s. How does the horizontal component of its velocity 1.0 s after launch compare with its horizontal component of velocity 2.0 s after launch?
20. Two cannonballs, A and B, are fired from the ground with identical initial speeds, but with θ_A larger than θ_B. (*a*) Which cannonball reaches a higher elevation? (*b*) Which stays longer in the air? (*c*) Which travels farther?

Problems

3–2 to 3–4 Vector Addition

1. (I) A car is driven 215 km west and then 85 km southwest. What is the displacement of the car from the point of origin (magnitude and direction)? Draw a diagram.
2. (I) A delivery truck travels 18 blocks north, 10 blocks east, and 16 blocks south. What is its final displacement from the origin? Assume the blocks are equal length.
3. (I) Show that the vector labeled "incorrect" in Fig. 3–6c is actually the difference of the two vectors. Is it $\vec{V}_2 - \vec{V}_1$, or $\vec{V}_1 - \vec{V}_2$?
4. (I) If $V_x = 6.80$ units and $V_y = -7.40$ units, determine the magnitude and direction of $\vec{V}$.
5. (II) Graphically determine the resultant of the following three vector displacements: (1) 34 m, 25° north of east; (2) 48 m, 33° east of north; and (3) 22 m, 56° west of south.
6. (II) The components of a vector $\vec{V}$ can be written (V_x, V_y, V_z). What are the components and length of a vector which is the sum of the two vectors, $\vec{V}_1$ and $\vec{V}_2$, whose components are (8.0, −3.7, 0.0) and (3.9, −8.1, −4.4)?
7. (II) $\vec{V}$ is a vector 14.3 units in magnitude and points at an angle of 34.8° above the negative x axis. (*a*) Sketch this vector. (*b*) Find V_x and V_y. (*c*) Use V_x and V_y to obtain (again) the magnitude and direction of $\vec{V}$. [*Note*: Part (*c*) is a good way to check if you've resolved your vector correctly.]
8. (II) Vector $\vec{V}_1$ is 6.6 units long and points along the negative x axis. Vector $\vec{V}_2$ is 8.5 units long and points at +45° to the positive x axis. (*a*) What are the x and y components of each vector? (*b*) Determine the sum $\vec{V}_1 + \vec{V}_2$ (magnitude and angle).

9. (II) An airplane is traveling 735 km/h in a direction 41.5° west of north (Fig. 3–31). (*a*) Find the components of the velocity vector in the northerly and westerly directions. (*b*) How far north and how far west has the plane traveled after 3.00 h?

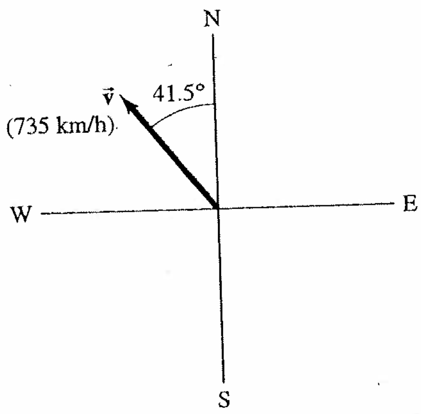

FIGURE 3–31 Problem 9.

10. (II) Three vectors are shown in Fig. 3–32. Their magnitudes are given in arbitrary units. Determine the sum of the three vectors. Give the resultant in terms of (*a*) components, (*b*) magnitude and angle with the *x* axis.

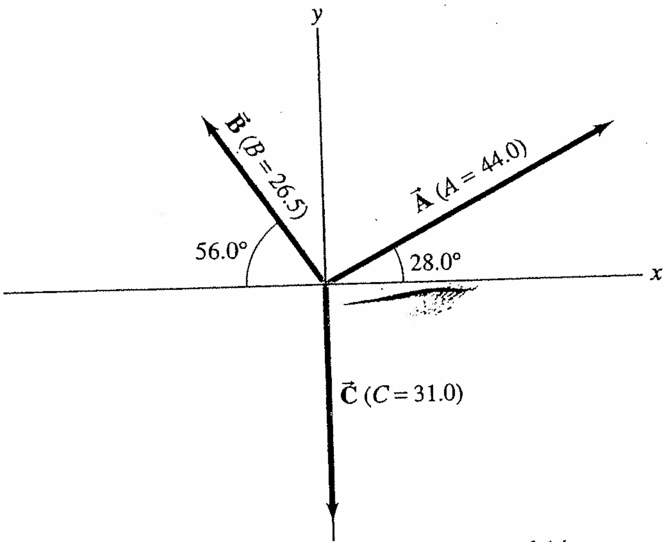

FIGURE 3–32 Problems 10, 11, 12, 13, and 14. Vector magnitudes are given in arbitrary units.

11. (II) Determine the vector $\vec{A} - \vec{C}$, given the vectors $\vec{A}$ and $\vec{C}$ in Fig. 3–32.

12. (II) (*a*) Given the vectors $\vec{A}$ and $\vec{B}$ shown in Fig. 3–32, determine $\vec{B} - \vec{A}$. (*b*) Determine $\vec{A} - \vec{B}$ without using your answer in (*a*). Then compare your results and see if they are opposite.

13. (II) For the vectors given in Fig. 3–32, determine (*a*) $\vec{A} - \vec{B} + \vec{C}$, (*b*) $\vec{A} + \vec{B} - \vec{C}$, and (*c*) $\vec{C} - \vec{A} - \vec{B}$.

14. (II) For the vectors shown in Fig. 3–32, determine (*a*) $\vec{B} - 2\vec{A}$, (*b*) $2\vec{A} - 3\vec{B} + 2\vec{C}$.

15. (II) The summit of a mountain, 2450 m above base camp, is measured on a map to be 4580 m horizontally from the camp in a direction 32.4° west of north. What are the components of the displacement vector from camp to summit? What is its magnitude? Choose the *x* axis east, *y* axis north, and *z* axis up.

16. (II) You are given a vector in the *xy* plane that ha magnitude of 70.0 units and a *y* component of −55.0 ur What are the two possibilities for its *x* component?

3–5 and 3–6 Projectile Motion (neglect air resistance)

17. (I) A tiger leaps horizontally from a 6.5-m-high rock v a speed of 3.5 m/s. How far from the base of the rock she land?

18. (I) A diver running 1.8 m/s dives out horizontally f the edge of a vertical cliff and 3.0 s later reaches the w below. How high was the cliff, and how far from its l did the diver hit the water?

19. (II) A fire hose held near the ground shoots water speed of 6.8 m/s. At what angle(s) should the nozzle p in order that the water land 2.0 m away (Fig. 3–33)? are there two different angles? Sketch the two trajecto

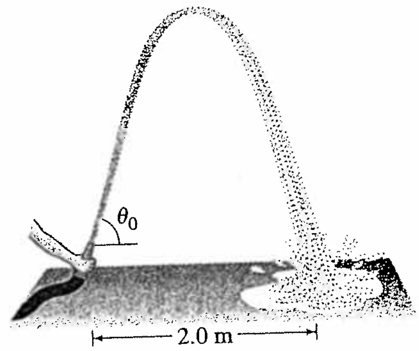

FIGURE 3–33 Problem 19.

20. (II) Romeo is chucking pebbles gently up to J window, and he wants the pebbles to hit the windo only a horizontal component of velocity. He is stanc the edge of a rose garden 4.5 m below her windo 5.0 m from the base of the wall (Fig. 3–34). How fa the pebbles going when they hit her window?

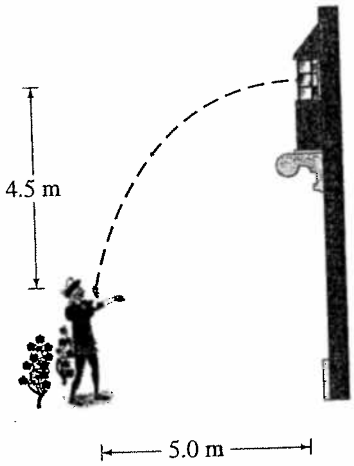

FIGURE 3–34 Problem 20.

21. (II) A ball is thrown horizontally from the ro building 45.0 m tall and lands 24.0 m from the ba was the ball's initial speed?

22. (II) A football is kicked at ground level with a s 18.0 m/s at an angle of 35.0° to the horizontal. Ho later does it hit the ground?

23. (II) A ball thrown horizontally at 22.2 m/s from of a building lands 36.0 m from the base of the How tall is the building?

24. (II) An athlete executing a long jump leaves the ground at a 28.0° angle and travels 7.80 m. (*a*) What was the takeoff speed? (*b*) If this speed were increased by just 5.0%, how much longer would the jump be?

25. (II) Determine how much farther a person can jump on the Moon as compared to the Earth if the takeoff speed and angle are the same. The acceleration due to gravity on the Moon is one-sixth what it is on Earth.

26. (II) A hunter aims directly at a target (on the same level) 75.0 m away. (*a*) If the bullet leaves the gun at a speed of 180 m/s, by how much will it miss the target? (*b*) At what angle should the gun be aimed so as to hit the target?

27. (II) The pilot of an airplane traveling 180 km/h wants to drop supplies to flood victims isolated on a patch of land 160 m below. The supplies should be dropped how many seconds before the plane is directly overhead?

28. (II) Show that the speed with which a projectile leaves the ground is equal to its speed just before it strikes the ground at the end of its journey, assuming the firing level equals the landing level.

29. (II) Suppose the kick in Example 3–5 is attempted 36.0 m from the goalposts, whose crossbar is 3.00 m above the ground. If the football is directed correctly between the goalposts, will it pass over the bar and be a field goal? Show why or why not.

30. (II) A projectile is fired with an initial speed of 65.2 m/s at an angle of 34.5° above the horizontal on a long flat firing range. Determine (*a*) the maximum height reached by the projectile, (*b*) the total time in the air, (*c*) the total horizontal distance covered (that is, the range), and (*d*) the velocity of the projectile 1.50 s after firing.

31. (II) A projectile is shot from the edge of a cliff 125 m above ground level with an initial speed of 65.0 m/s at an angle of 37.0° with the horizontal, as shown in Fig. 3–35. (*a*) Determine the time taken by the projectile to hit point P at ground level. (*b*) Determine the range X of the projectile as measured from the base of the cliff. At the instant just before the projectile hits point P, find (*c*) the horizontal and the vertical components of its velocity, (*d*) the magnitude of the velocity, and (*e*) the angle made by the velocity vector with the horizontal. (*f*) Find the maximum height above the cliff top reached by the projectile.

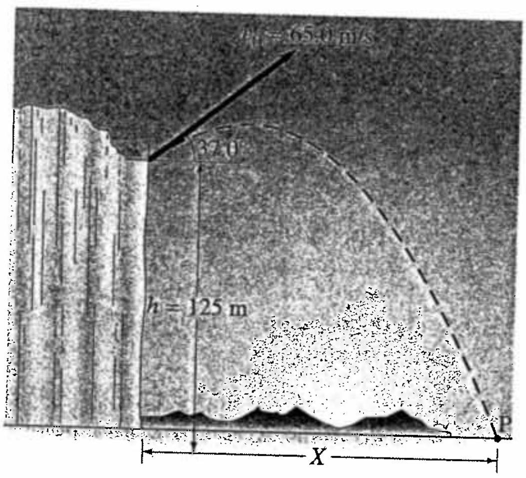

FIGURE 3–35 Problem 31.

32. (II) A shotputter throws the shot with an initial speed of 15.5 m/s at a 34.0° angle to the horizontal. Calculate the horizontal distance traveled by the shot if it leaves the athlete's hand at a height of 2.20 m above the ground.

33. (II) At what projection angle will the range of a projectile equal its maximum height?

34. (III) Revisit Conceptual Example 3–7, and assume that the boy with the slingshot is *below* the boy in the tree (Fig. 3–36), and so aims *upward*, directly at the boy in the tree. Show that again the boy in the tree makes the wrong move by letting go at the moment the water balloon is shot.

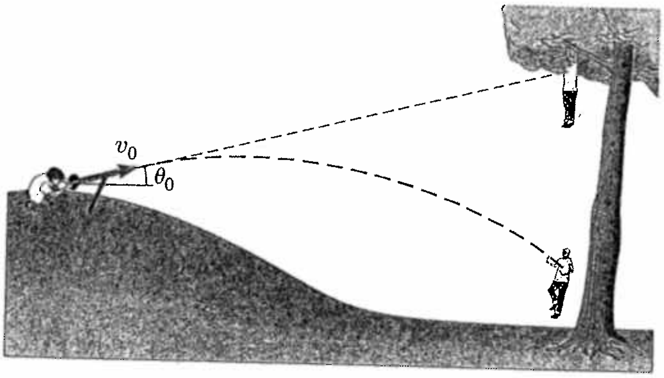

FIGURE 3–36 Problem 34.

35. (III) A rescue plane wants to drop supplies to isolated mountain climbers on a rocky ridge 235 m below. If the plane is traveling horizontally with a speed of 250 km/h (69.4 m/s), (*a*) how far in advance of the recipients (horizontal distance) must the goods be dropped (Fig. 3–37a)? (*b*) Suppose, instead, that the plane releases the supplies a horizontal distance of 425 m in advance of the mountain climbers. What vertical velocity (up or down) should the supplies be given so that they arrive precisely at the climbers' position (Fig. 3–37b)? (*c*) With what speed do the supplies land in the latter case?

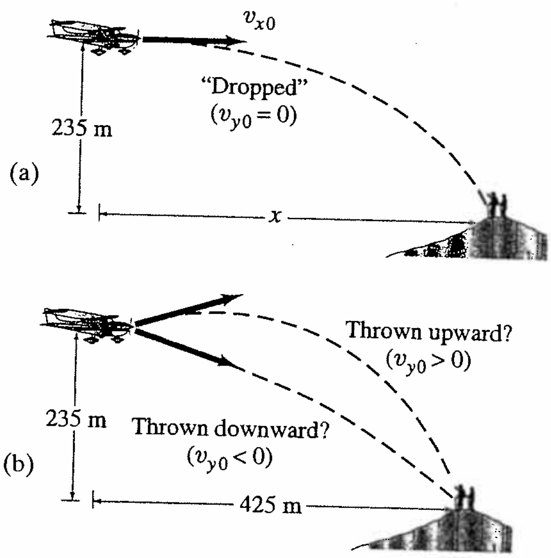

FIGURE 3–37 Problem 35.

* 3–8 Relative Velocity

*** 36.** (I) A person going for a morning jog on the deck of a cruise ship is running toward the bow (front) of the ship at 2.2 m/s while the ship is moving ahead at 7.5 m/s. What is the velocity of the jogger relative to the water? Later, the jogger is moving toward the stern (rear) of the ship. What is the jogger's velocity relative to the water now?

*** 37.** (II) Huck Finn walks at a speed of 0.60 m/s across his raft (that is, he walks perpendicular to the raft's motion relative to the shore). The raft is traveling down the Mississippi River at a speed of 1.70 m/s relative to the river bank (Fig. 3–38). What is Huck's velocity (speed and direction) relative to the river bank?

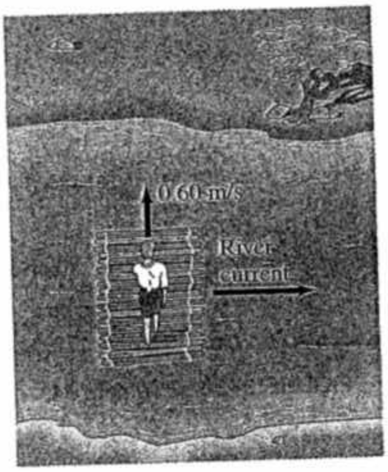

FIGURE 3–38 Problem 37.

*** 38.** (II) You are driving south on a highway at 25 m/s (approximately 55 mi/h) in a snowstorm. When you last stopped, you noticed that the snow was coming down vertically, but it is passing the windows of the moving car at an angle of 30° to the horizontal. Estimate the speed of the snowflakes relative to the car and relative to the ground.

*** 39.** (II) A boat can travel 2.30 m/s in still water. (*a*) If the boat points its prow directly across a stream whose current is 1.20 m/s, what is the velocity (magnitude and direction) of the boat relative to the shore? (*b*) What will be the position of the boat, relative to its point of origin, after 3.00 s? (See Fig. 3–30.)

*** 40.** (II) Two planes approach each other head-on. Each has a speed of 785 km/h, and they spot each other when they are initially 11.0 km apart. How much time do the pilots have to take evasive action?

*** 41.** (II) An airplane is heading due south at a speed of 600 km/h. If a wind begins blowing from the southwest at a speed of 100 km/h (average), calculate: (*a*) the velocity (magnitude and direction) of the plane relative to the ground, and (*b*) how far from its intended position will it be after 10 min if the pilot takes no corrective action. [*Hint*: First draw a diagram.]

*** 42.** (II) In what direction should the pilot aim the plane in Problem 41 so that it will fly due south?

*** 43.** (II) Determine the speed of the boat with respect to t shore in Example 3–11.

*** 44.** (II) A passenger on a boat moving at 1.50 m/s on a s lake walks up a flight of stairs at a speed of 0.50 n (Fig. 3–39). The stairs are angled at 45° pointing in direction of motion as shown. What is the velocity of passenger relative to the water?

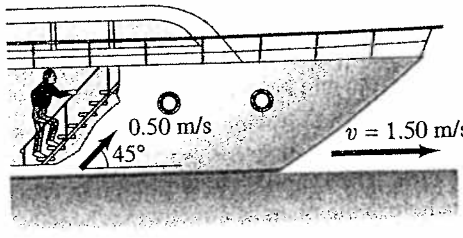

FIGURE 3–39 Problem 44.

*** 45.** (II) A motorboat whose speed in still water is 2.60 must aim upstream at an angle of 28.5° (with respect line perpendicular to the shore) in order to travel dir across the stream. (*a*) What is the speed of the curı (*b*) What is the resultant speed of the boat with respe the shore? (See Fig. 3–28.)

*** 46.** (II) A boat, whose speed in still water is 1.70 m/s, cross a 260-m-wide river and arrive at a point 1 upstream from where it starts (Fig. 3–40). To do s pilot must head the boat at a 45° upstream angle. W the speed of the river's current?

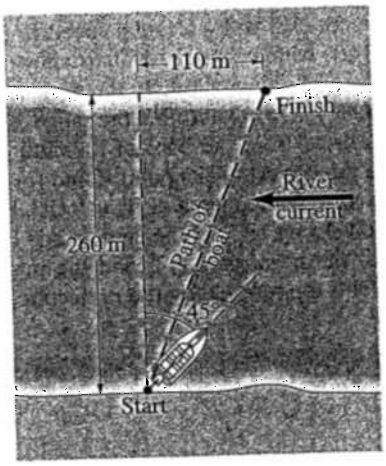

FIGURE 3–40 Problem 46.

*** 47.** (II) A swimmer is capable of swimming 0.45 m/s water. (*a*) If she aims her body directly across a wide river whose current is 0.40 m/s, how far dowı (from a point opposite her starting point) will sh (*b*) How long will it take her to reach the other si

*** 48.** (II) (*a*) At what upstream angle must the swim Problem 47 aim, if she is to arrive at a point across the stream? (*b*) How long would it take he

Ch 4

Newton's third law states that whenever one object exerts a force on a second object, the second object always exerts a force on the first object which is equal in magnitude but opposite in direction:

$$\vec{F}_{AB} = -\vec{F}_{BA} \quad (4\text{–}2)$$

where $\vec{F}_{BA}$ is the force on object B exerted by object A.

The tendency of an object to resist a change in its motion is called **inertia**. **Mass** is a measure of the inertia of an object.

Weight refers to the **gravitational force** on an object, and is equal to the product of the object's mass m and the acceleration of gravity $\vec{g}$:

$$\vec{F}_G = m\vec{g}. \quad (4\text{–}3)$$

Force, which is a vector, can be considered as a push or pull; or, from Newton's second law, force can be defined as an action capable of giving rise to acceleration. The **net force** on an object is the vector sum of all forces acting on it.

When two objects slide over one another, the force of friction that each object exerts on the other can be written approximately as $F_{fr} = \mu_k F_N$, where F_N is the **normal force** (the force each object exerts on the other perpendicular to their contact surfaces), and μ_k is the coefficient of **kinetic friction**. If the objects are at rest relative to each other, then F_{fr} is just large enough to hold them at rest and satisfies the inequality $F_{fr} < \mu_s F_N$, where μ_s is the coefficient of **static friction**.

For solving problems involving the forces on one or more objects, it is essential to draw a **free-body diagram** for each object, showing all the forces acting on only that object. Newton's second law can be applied to the vector components for each object.

Questions

1. Why does a child in a wagon seem to fall backward when you give the wagon a sharp pull forward?
2. A box rests on the (frictionless) bed of a truck. The truck driver starts the truck and accelerates forward. The box immediately starts to slide toward the rear of the truck bed. Discuss the motion of the box, in terms of Newton's laws, as seen (*a*) by Mary standing on the ground beside the truck, and (*b*) by Chris who is riding on the truck (Fig. 4–35).

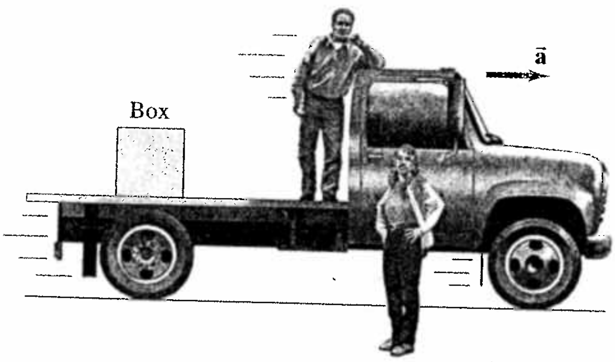

FIGURE 4–35 Question 2.

3. If the acceleration of an object is zero, are no forces acting on it? Explain.
4. Only one force acts on an object. Can the object have zero acceleration? Can it have zero velocity? Explain.
5. When a golf ball is dropped to the pavement, it bounces back up. (*a*) Is a force needed to make it bounce back up? (*b*) If so, what exerts the force?
6. If you walk along a log floating on a lake, why does the log move in the opposite direction?
7. Why might your foot hurt if you kick a heavy desk or a wall?
8. When you are running and want to stop quickly, you must decelerate quickly. (*a*) What is the origin of the force that causes you to stop? (*b*) Estimate (using your own experience) the maximum rate of deceleration of a person running at top speed to come to rest.
9. A stone hangs by a fine thread from the ceiling, and a section of the same thread dangles from the bottom of the stone (Fig. 4–36). If a person gives a sharp pull on the dangling thread, where is the thread likely to break: below the stone or above it? What if the person gives a slow and steady pull? Explain your answers.

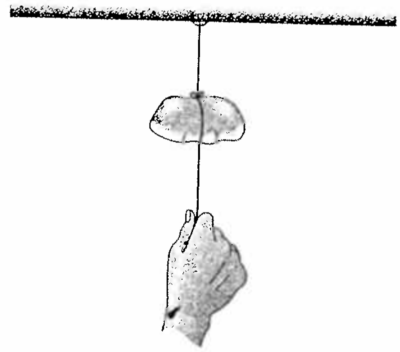

FIGURE 4–36 Question 9.

10. The force of gravity on a 2-kg rock is twice as great as that on a 1-kg rock. Why then doesn't the heavier rock fall faster?
11. Would a spring scale carried to the Moon give accurate results if the scale had been calibrated (*a*) in pounds, or (*b*) in kilograms?
12. You pull a box with a constant force across a frictionless table using an attached rope held horizontally. If you now pull the rope with the same force at an angle to the horizontal (with the box remaining flat on the table), does the acceleration of the box (*a*) remain the same, (*b*) increase, or (*c*) decrease? Explain.
13. When an object falls freely under the influence of gravity there is a net force mg exerted on it by the Earth. Yet by Newton's third law the object exerts an equal and opposite force on the Earth. Why doesn't the Earth move?
14. Compare the effort (or force) needed to lift a 10-kg object when you are on the Moon with the force needed to lift it on Earth. Compare the force needed to throw a 2-kg object horizontally with a given speed on the Moon and on Earth.

15. According to Newton's third law, each team in a tug of war (Fig. 4–37) pulls with equal force on the other team. What, then, determines which team will win?

FIGURE 4–37 Question 15. A tug of war. Describe the forces on each of the teams and on the rope.

16. A person exerts an upward force of 40 N to hold a bag of groceries. Describe the "reaction" force (Newton's third law) by stating (*a*) its magnitude, (*b*) its direction, (*c*) *on* what object it is exerted, and (*d*) *by* what object it is exerted.

17. When you stand still on the ground, how large a force does the ground exert on you? Why doesn't this force make you rise up into the air?

18. Whiplash sometimes results from an automobile accident when the victim's car is struck violently from the rear. Explain why the head of the victim seems to be thrown backward in this situation. Is it really?

19. A heavy crate rests on the bed of a flatbed truck. When the truck accelerates, the crate remains where it is on the truck, so it, too, accelerates. What force causes the crate to accelerate?

20. A block is given a push so that it slides up a ramp. After the block reaches its highest point, it slides back down but the magnitude of its acceleration is less on the descent than on the ascent. Why?

21. What would your bathroom scale read if you weighed yourself on an inclined plane? Assume the mechanism functions properly, even at an angle.

Problems

4–4 to 4–6 Newton's Laws, Gravitational Force, Normal Force

1. (I) What force is needed to accelerate a child on a sled (total mass = 60.0 kg) at $1.25\ \mathrm{m/s^2}$?
2. (I) A net force of 265 N accelerates a bike and rider at $2.30\ \mathrm{m/s^2}$. What is the mass of the bike and rider together?
3. (I) How much tension must a rope withstand if it is used to accelerate a 960-kg car horizontally along a frictionless surface at $1.20\ \mathrm{m/s^2}$?
4. (I) What is the weight of a 76-kg astronaut (*a*) on Earth, (*b*) on the Moon ($g = 1.7\ \mathrm{m/s^2}$), (*c*) on Mars ($g = 3.7\ \mathrm{m/s^2}$), (*d*) in outer space traveling with constant velocity?
5. (II) A 20.0-kg box rests on a table. (*a*) What is the weight of the box and the normal force acting on it? (*b*) A 10.0-kg box is placed on top of the 20.0-kg box, as shown in Fig. 4–38. Determine the normal force that the table exerts on the 20.0-kg box and the normal force that the 20.0-kg box exerts on the 10.0-kg box.

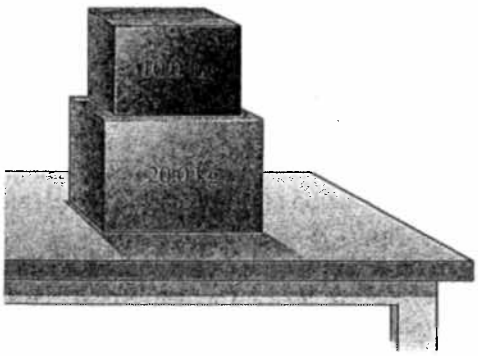

FIGURE 4–38 Problem 5.

6. (II) What average force is required to stop an 1100-kg car in 8.0 s if the car is traveling at 95 km/h?
7. (II) What average force is needed to accelerate a 7.00-gram pellet from rest to 125 m/s over a distance of 0.800 m along the barrel of a rifle?
8. (II) A fisherman yanks a fish vertically out of the water with an acceleration of $2.5\ \mathrm{m/s^2}$ using very light fishing line that has a breaking strength of 22 N. The fisherman unfortunately loses the fish as the line snaps. What can you say about the mass of the fish?
9. (II) A 0.140-kg baseball traveling 35.0 m/s strikes the catcher's mitt, which, in bringing the ball to rest, recoils backward 11.0 cm. What was the average force applied by the ball on the glove?
10. (II) How much tension must a rope withstand if it is used to accelerate a 1200-kg car vertically upward at $0.80\ \mathrm{m/s^2}$?
11. (II) A particular race car can cover a quarter-mile track (402 m) in 6.40 s starting from a standstill. Assuming the acceleration is constant, how many "*g*'s" does the driver experience? If the combined mass of the driver and race car is 485 kg, what horizontal force must the road exert on the tires?
12. (II) A 12.0-kg bucket is lowered vertically by a rope in which there is 163 N of tension at a given instant. What is the acceleration of the bucket? Is it up or down?
13. (II) An elevator (mass 4850 kg) is to be designed so that the maximum acceleration is 0.0680*g*. What are the maximum and minimum forces the motor should exert on the supporting cable?
14. (II) A 75-kg petty thief wants to escape from a third-story jail window. Unfortunately, a makeshift rope made of sheets tied together can support a mass of only 58 kg. How might the thief use this "rope" to escape? Give a quantitative answer.
15. (II) A person stands on a bathroom scale in a motionless elevator. When the elevator begins to move, the scale briefly reads only 0.75 of the person's regular weight. Calculate the acceleration of the elevator, and find the direction of acceleration.

16. (II) The cable supporting a 2125-kg elevator has a maximum strength of 21,750 N. What maximum upward acceleration can it give the elevator without breaking?

17. (II) (*a*) What is the acceleration of two falling sky divers (mass 132 kg including parachute) when the upward force of air resistance is equal to one-fourth of their weight? (*b*) After popping open the parachute, the divers descend leisurely to the ground at constant speed. What now is the force of air resistance on the sky divers and their parachute? See Fig. 4–39.

FIGURE 4–39 Problem 17.

18. (III) A person jumps from the roof of a house 3.9-m high. When he strikes the ground below, he bends his knees so that his torso decelerates over an approximate distance of 0.70 m. If the mass of his torso (excluding legs) is 42 kg, find (*a*) his velocity just before his feet strike the ground, and (*b*) the average force exerted on his torso by his legs during deceleration.

4–7 Newton's Laws and Vectors

19. (I) A box weighing 77.0 N rests on a table. A rope tied to the box runs vertically upward over a pulley and a weight is hung from the other end (Fig. 4–40). Determine the force that the table exerts on the box if the weight hanging on the other side of the pulley weighs (*a*) 30.0 N, (*b*) 60.0 N, and (*c*) 90.0 N.

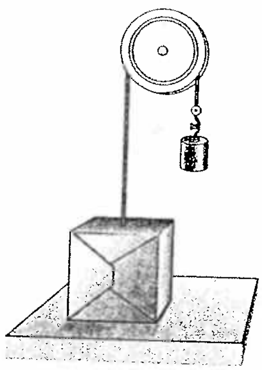

FIGURE 4–40 Problem 19.

20. (I) Draw the free-body diagram for a basketball player (*a*) just before leaving the ground on a jump, and (*b*) while in the air. See Fig. 4–41.

FIGURE 4–41 Problem 20.

21. (I) Sketch the free-body diagram of a baseball (*a*) at the moment it is hit by the bat, and again (*b*) after it has left the bat and is flying toward the outfield.

22. (I) A 650-N force acts in a northwesterly direction. A second 650-N force must be exerted in what direction so that the resultant of the two forces points westward? Illustrate your answer with a vector diagram.

23. (II) Arlene is to walk across a "high wire" strung horizontally between two buildings 10.0 m apart. The sag in the rope when she is at the midpoint is 10.0°, as shown in Fig. 4–42. If her mass is 50.0 kg, what is the tension in the rope at this point?

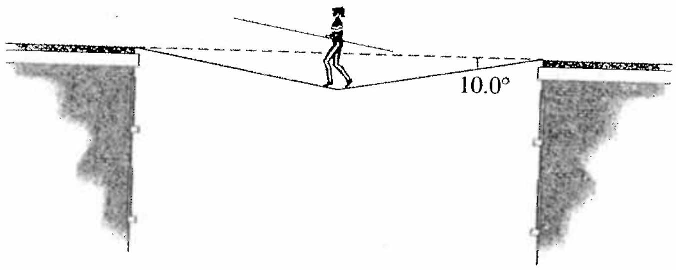

FIGURE 4–42 Problem 23.

24. (II) The two forces $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$ shown in Fig. 4–43a and b (looking down) act on a 27.0-kg object on a frictionless tabletop. If $F_1 = 10.2$ N and $F_2 = 16.0$ N, find the net force on the object and its acceleration for (*a*) and (*b*).

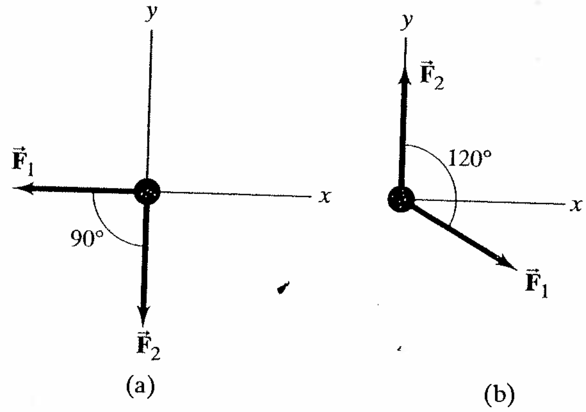

FIGURE 4–43 Problem 24.

25. (II) One 3.2-kg paint bucket is hanging by a massless cord from another 3.2-kg paint bucket, also hanging by a massless cord, as shown in Fig. 4–44. (*a*) If the buckets are at rest, what is the tension in each cord? (*b*) If the two buckets are pulled upward with an acceleration of 1.60 m/s^2 by the upper cord, calculate the tension in each cord.

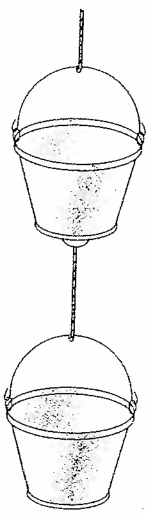

FIGURE 4–44 Problem 25.

26. (II) A person pushes a 14.0-kg lawn mower at constant speed with a force of $F = 88.0\,\text{N}$ directed along the handle, which is at an angle of 45.0° to the horizontal (Fig. 4–45). (*a*) Draw the free-body diagram showing all forces acting on the mower. Calculate (*b*) the horizontal friction force on the mower, then (*c*) the normal force exerted vertically upward on the mower by the ground. (*d*) What force must the person exert on the lawn mower to accelerate it from rest to 1.5 m/s in 2.5 seconds, assuming the same friction force?

FIGURE 4–45 Problem 26.

27. (II) Two snowcats tow a housing unit to a new location at McMurdo Base, Antarctica, as shown in Fig. 4–46. The sum of the forces $\vec{\mathbf{F}}_A$ and $\vec{\mathbf{F}}_B$ exerted on the unit by the horizontal cables is parallel to the line L, and $F_A = 4500\,\text{N}$. Determine F_B and the magnitude of $\vec{\mathbf{F}}_A + \vec{\mathbf{F}}_B$.

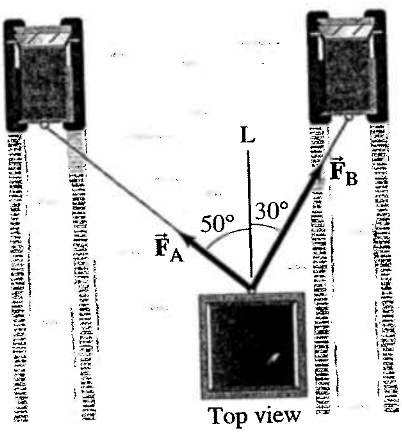

FIGURE 4–46 Problem 27.

28. (II) A train locomotive is pulling two cars of the same mass behind it, Fig. 4–47. Determine the ratio of the tension in the coupling between the locomotive and the first car (F_{T1}), to that between the first car and the second car (F_{T2}), for any nonzero acceleration of the train.

FIGURE 4–47 Problem 28.

29. (II) A window washer pulls herself upward using the bucket–pulley apparatus shown in Fig. 4–48. (*a*) How hard must she pull downward to raise herself slowly at constant speed? (*b*) If she increases this force by 15%, what will her acceleration be? The mass of the person plus the bucket is 65 kg.

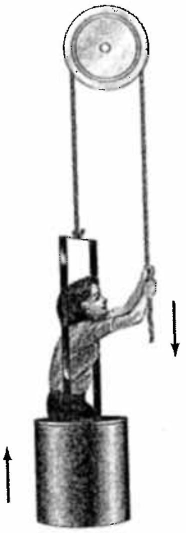

FIGURE 4–48 Problem 29.

30. (II) At the instant a race began, a 65-kg sprinter exerted a force of 720 N on the starting block at a 22° angle with respect to the ground. (*a*) What was the horizontal acceleration of the sprinter? (*b*) If the force was exerted for 0.32 s, with what speed did the sprinter leave the starting block?

31. (II) Figure 4–49 shows a block (mass m_A) on a smooth horizontal surface, connected by a thin cord that passes over a pulley to a second block (m_B), which hangs vertically. (*a*) Draw a free-body diagram for each block, showing the force of gravity on each, the force (tension) exerted by the cord, and any normal force. (*b*) Apply Newton's second law to find formulas for the acceleration of the system and for the tension in the cord. Ignore friction and the masses of the pulley and cord.

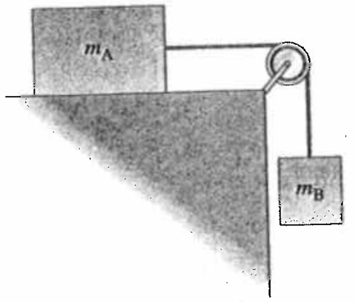

FIGURE 4–49 Problem 31. Mass m_A rests on a smooth horizontal surface, m_B hangs vertically.

32. (II) A pair of fuzzy dice is hanging by a string from your rearview mirror. While you are accelerating from a stoplight to 28 m/s in 6.0 s, what angle θ does the string make with the vertical? See Fig. 4–50.

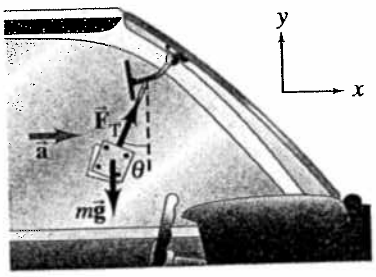

FIGURE 4–50 Problem 32.

33. (III) Three blocks on a frictionless horizontal surface are in contact with each other, as shown in Fig. 4–51. A force $\vec{F}$ is applied to block A (mass m_A). (*a*) Draw a free-body diagram for each block. Determine (*b*) the acceleration of the system (in terms of m_A, m_B, and m_C), (*c*) the net force on each block, and (*d*) the force of contact that each block exerts on its neighbor. (*e*) If $m_A = m_B = m_C = 12.0$ kg and $F = 96.0$ N, give numerical answers to (*b*), (*c*), and (*d*). Do your answers make sense intuitively?

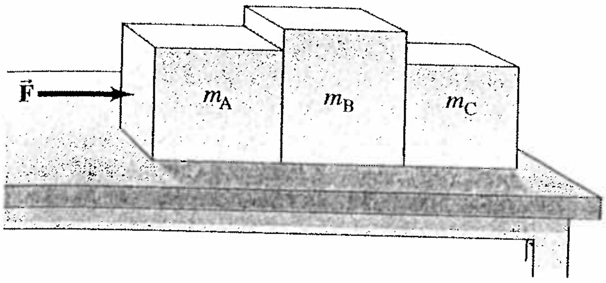

FIGURE 4–51 Problem 33.

34. (III) The two masses shown in Fig. 4–52 are each initially 1.80 m above the ground, and the massless frictionless pulley is 4.8 m above the ground. What maximum height does the lighter object reach after the system is released? [*Hint*: First determine the acceleration of the lighter mass and then its velocity at the moment the heavier one hits the ground. This is its "launch" speed. Assume it doesn't hit the pulley.]

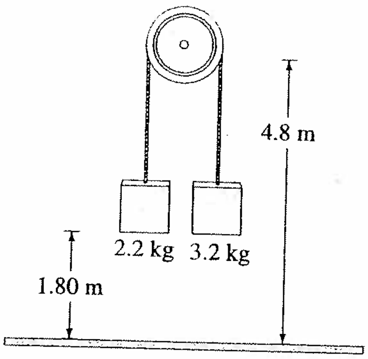

FIGURE 4–52 Problem 34.

35. (III) Suppose two boxes on a frictionless table are connected by a heavy cord of mass 1.0 kg. Calculate the acceleration of each box and the tension at each end of the cord, using the free-body diagrams shown in Fig. 4–53. Assume $F_P = 40.0$ N, and ignore sagging of the cord. Compare your results to Example 4–12 and Fig. 4–22.

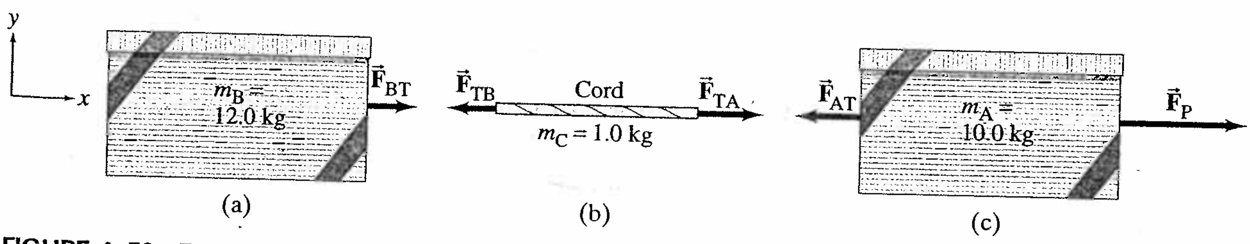

FIGURE 4–53 Problem 35. Free-body diagrams for two boxes on a table connected by a heavy cord, and being pulled to the right as in Fig. 4–22a. Vertical forces, $\vec{F}_N$ and $\vec{F}_G$, are not shown.

4–8 Newton's Laws with Friction; Inclines

36. (I) If the coefficient of kinetic friction between a 35-kg crate and the floor is 0.30, what horizontal force is required to move the crate at a steady speed across the floor? What horizontal force is required if μ_k is zero?

37. (I) A force of 48.0 N is required to start a 5.0-kg box moving across a horizontal concrete floor. (*a*) What is the coefficient of static friction between the box and the floor? (*b*) If the 48.0-N force continues, the box accelerates at $0.70\ m/s^2$. What is the coefficient of kinetic friction?

38. (I) Suppose that you are standing on a train accelerating at 0.20*g*. What minimum coefficient of static friction must exist between your feet and the floor if you are not to slide?

39. (I) What is the maximum acceleration a car can undergo if the coefficient of static friction between the tires and the ground is 0.80?

40. (II) The coefficient of static friction between hard rubber and normal street pavement is about 0.8. On how steep a hill (maximum angle) can you leave a car parked?

41. (II) A 15.0-kg box is released on a 32° incline and accelerates down the incline at $0.30\ m/s^2$. Find the friction force impeding its motion. What is the coefficient of kinetic friction?

42. (II) A car can decelerate at $-4.80\ m/s^2$ without skidding when coming to rest on a level road. What would its deceleration be if the road were inclined at 13° uphill? Assume the same static friction coefficient.

43. (II) (*a*) A box sits at rest on a rough 30° inclined plane. Draw the free-body diagram, showing all the forces acting on the box. (*b*) How would the diagram change if the box were sliding down the plane? (*c*) How would it change if the box were sliding up the plane after an initial shove?

44. (II) Drag-race tires in contact with an asphalt surface have a very high coefficient of static friction. Assuming a constant acceleration and no slipping of tires, estimate the coefficient of static friction needed for a drag racer to cover 1.0 km in 12 s, starting from rest.

45. (II) The coefficient of kinetic friction for a 22-kg bobsled on a track is 0.10. What force is required to push it down a 6.0° incline and achieve a speed of 60 km/h at the end of 75 m?

46. (II) For the system of Fig. 4–32 (Example 4–20) how large a mass would box A have to have to prevent any motion from occurring? Assume $\mu_s = 0.30$.

47. (II) A box is given a push so that it slides across the floor. How far will it go, given that the coefficient of kinetic friction is 0.20 and the push imparts an initial speed of 4.0 m/s?

48. (II) Two crates, of mass 75 kg and 110 kg, are in contact and at rest on a horizontal surface (Fig. 4–54). A 620-N force is exerted on the 75-kg crate. If the coefficient of kinetic friction is 0.15, calculate (*a*) the acceleration of the system, and (*b*) the force that each crate exerts on the other. (*c*) Repeat with the crates reversed.

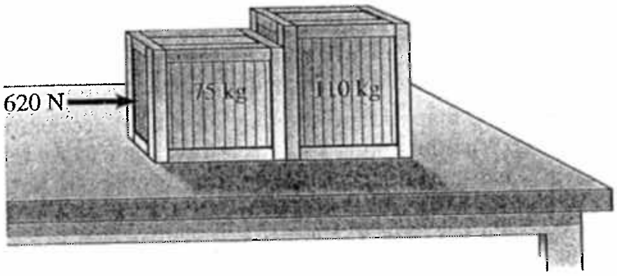

FIGURE 4–54 Problem 48.

49. (II) A flatbed truck is carrying a heavy crate. The coefficient of static friction between the crate and the bed of the truck is 0.75. What is the maximum rate at which the driver can decelerate and still avoid having the crate slide against the cab of the truck?

50. (II) On an icy day, you worry about parking your car in your driveway, which has an incline of 12°. Your neighbor's driveway has an incline of 9.0°, and the driveway across the street is at 6.0°. The coefficient of static friction between tire rubber and ice is 0.15. Which driveway(s) will be safe to park in?

51. (II) A child slides down a slide with a 28° incline, and at the bottom her speed is precisely half what it would have been if the slide had been frictionless. Calculate the coefficient of kinetic friction between the slide and the child.

52. (II) The carton shown in Fig. 4–55 lies on a plane tilted at an angle $\theta = 22.0°$ to the horizontal, with $\mu_k = 0.12$. (*a*) Determine the acceleration of the carton as it slides down the plane. (*b*) If the carton starts from rest 9.30 m up the plane from its base, what will be the carton's speed when it reaches the bottom of the incline?

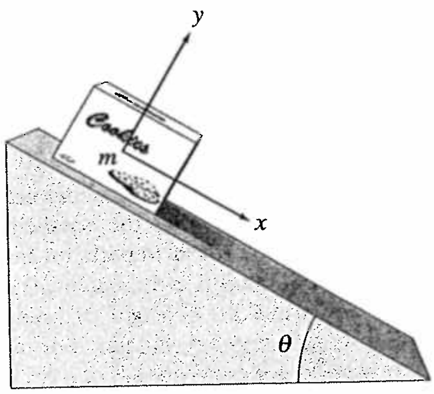

FIGURE 4–55 Carton on inclined plane. Problems 52 and 53.

53. (II) A carton is given an initial speed of 3.0 m/s up the 22.0° plane shown in Fig. 4–55. (*a*) How far up the plane will it go? (*b*) How much time elapses before it returns to its starting point? Ignore friction.

54. (II) A roller coaster reaches the top of the steepest hill with a speed of 6.0 km/h. It then descends the hill, which is at an average angle of 45° and is 45.0 m long. Estimate its speed when it reaches the bottom. Assume $\mu_k = 0.18$.

55. (II) An 18.0-kg box is released on a 37.0° incline and accelerates down the incline at 0.270 m/s^2. Find the friction force impeding its motion. How large is the coefficient of kinetic friction?

56. (II) A small box is held in place against a rough wall by someone pushing on it with a force directed upward at 28° above the horizontal. The coefficients of static and kinetic friction between the box and wall are 0.40 and 0.30, respectively. The box slides down unless the applied force has magnitude 13 N. What is the mass of the box?

57. (II) Piles of snow on slippery roofs can become dangerous projectiles as they melt. Consider a chunk of snow at the ridge of a roof with a pitch of 30°. (*a*) What is the minimum value of the coefficient of static friction that will keep the snow from sliding down? (*b*) As the snow begins to melt, the coefficient of static friction decreases and the snow eventually slips. Assuming that the distance from the chunk to the edge of the roof is 5.0 m and the coefficient of kinetic friction is 0.20, calculate the speed of the snow chunk when it slides off the roof. (*c*) If the edge of the roof is 10.0 m above ground, what is the speed of the snow when it hits the ground?

58. (III) (*a*) Show that the minimum stopping distance for an automobile traveling at speed v is equal to $v^2/2\mu_s g$, where μ_s is the coefficient of static friction between the tires and the road, and g is the acceleration of gravity. (*b*) What is this distance for a 1200-kg car traveling 95 km/h if $\mu_s = 0.75$?

59. (III) A coffee cup on the dashboard of a car slides forward on the dash when the driver decelerates from 45 km/h to rest in 3.5 s or less, but not if he decelerates in a longer time. What is the coefficient of static friction between the cup and the dash?

60. (III) A small block of mass m is given an initial speed v_0 up a ramp inclined at angle θ to the horizontal. It travels a distance d up the ramp and comes to rest. Determine a formula for the coefficient of kinetic friction between block and ramp.

61. (III) The 75-kg climber in Fig. 4–56 is supported in the "chimney" by the friction forces exerted on his shoes and back. The static coefficients of friction between his shoes and the wall, and between his back and the wall, are 0.80 and 0.60, respectively. What is the minimum normal force he must exert? Assume the walls are vertical and that friction forces are both at a maximum. Ignore his grip on the rope.

FIGURE 4–56 Problem 61.

62. (III) Boxes are moved on a conveyor belt from where they are filled to the packing station 11.0 m away. The belt is initially stationary and must finish with zero speed. The most rapid transit is accomplished if the belt accelerates for half the distance, then decelerates for the final half of the trip. If the coefficient of static friction between a box and the belt is 0.60, what is the minimum transit time for each box?

63. (III) A block (mass m_1) lying on a frictionless inclined plane is connected to a mass m_2 by a massless cord passing over a pulley, as shown in Fig. 4–57. (*a*) Determine a formula for the acceleration of the system of the two blocks in terms of m_1, m_2, θ and g. (*b*) What conditions apply to masses m_1 and m_2 for the acceleration to be in one direction (say, m_1 down the plane), or in the opposite direction?

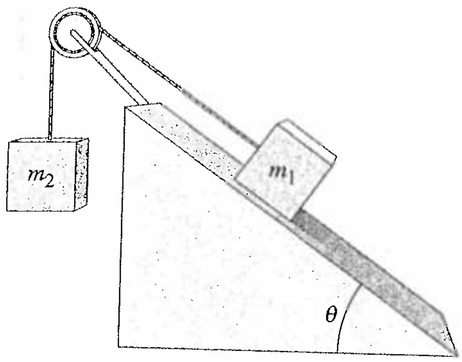

FIGURE 4–57 Problems 63 and 64.

64. (III) (*a*) Suppose the coefficient of kinetic friction between m_1 and the plane in Fig. 4–57 is $\mu_k = 0.15$, and that $m_1 = m_2 = 2.7$ kg. As m_2 moves down, determine the magnitude of the acceleration of m_1 and m_2, given $\theta = 25°$. (*b*) What smallest value of μ_k will keep this system from accelerating?

65. (III) A bicyclist of mass 65 kg (including the bicycle) can coast down a 6.0° hill at a steady speed of 6.0 km/h because of air resistance. How much force must be applied to climb the hill at the same speed and same air resistance?

General Problems

66. According to a simplified model of a mammalian heart, at each pulse approximately 20 g of blood is accelerated from 0.25 m/s to 0.35 m/s during a period of 0.10 s. What is the magnitude of the force exerted by the heart muscle?

67. A person has a reasonable chance of surviving an automobile crash if the deceleration is no more than 30 "g's." Calculate the force on a 70-kg person undergoing this acceleration. What distance is traveled if the person is brought to rest at this rate from 100 km/h?

68. (*a*) If the horizontal acceleration produced by an earthquake is a, and if an object is going to "hold its place" on the ground, show that the coefficient of static friction with the ground must be at least $\mu_s = a/g$. (*b*) The famous Loma Prieta earthquake that stopped the 1989 World Series produced ground accelerations of up to 4.0 m/s^2 in the San Francisco Bay Area. Would a chair have started to slide on a linoleum floor with coefficient of static friction 0.25?

69. An 1150-kg car pulls a 450-kg trailer. The car exerts a horizontal force of 3.8×10^3 N against the ground in order to accelerate. What force does the car exert on the trailer? Assume an effective friction coefficient of 0.15 for the trailer.

70. Police investigators, examining the scene of an accident involving two cars, measure 72-m-long skid marks of one of the cars, which nearly came to a stop before colliding. The coefficient of kinetic friction between rubber and the pavement is about 0.80. Estimate the initial speed of that car assuming a level road.

71. A car starts rolling down a 1-in-4 hill (1-in-4 means that for each 4 m traveled along the road, the elevation change is 1 m). How fast is it going when it reaches the bottom after traveling 55 m? (*a*) Ignore friction. (*b*) Assume an effective coefficient of friction equal to 0.10.

72. A 2.0-kg purse is dropped from the top of the Leaning Tower of Pisa and falls 55 m before reaching the ground with a speed of 29 m/s. What was the average force of air resistance?

73. A cyclist is coasting at a steady speed of 12 m/s but enters a muddy stretch where the effective coefficient of friction is 0.60. Will the cyclist emerge from the muddy stretch without having to pedal if the mud lasts for 11 m? If so, what will be the speed upon emerging?

74. A city planner is working on the redesign of a hilly portion of a city. An important consideration is how steep the roads can be so that even low-powered cars can get up the hills without slowing down. A particular small car, with a mass of 1100 kg, can accelerate on a level road from rest to 21 m/s (75 km/h) in 14.0 s. Using these data, calculate the maximum steepness of a hill.

75. Francesca, who likes physics experiments, dangles her watch from a thin piece of string while the jetliner she is in takes off from JFK Airport (Fig. 4–58). She notices that the string makes an angle of 25° with respect to the vertical as the aircraft accelerates for takeoff, which takes about 18 s. Estimate the takeoff speed of the aircraft.

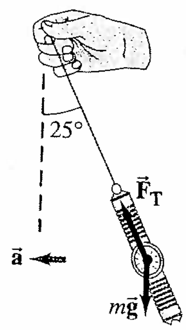

FIGURE 4–58 Problem 75.

76. A 28.0-kg block is connected to an empty 1.35-kg bucket by a cord running over a frictionless pulley (Fig. 4–59). The coefficient of static friction between the table and the block is 0.450 and the coefficient of kinetic friction between the table and the block is 0.320. Sand is gradually added to the bucket until the system just begins to move. (*a*) Calculate the mass of sand added to the bucket. (*b*) Calculate the acceleration of the system.

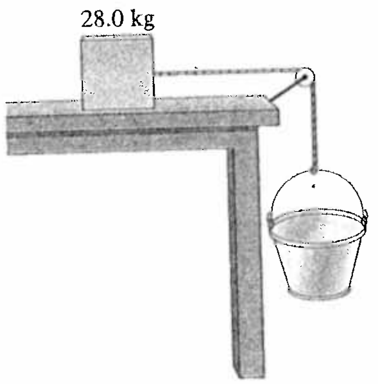

FIGURE 4–59 Problem 76.

77. In the design of a supermarket, there are to be several ramps connecting different parts of the store. Customers will have to push grocery carts up the ramps and it is obviously desirable that this not be too difficult. The engineer has done a survey and found that almost no one complains if the force directed up the ramp is no more than 20 N. Ignoring friction, at what maximum angle θ should the ramps be built, assuming a full 30-kg grocery cart?

78. (*a*) What minimum force F is needed to lift the piano (mass M) using the pulley apparatus shown in Fig. 4–60? (*b*) Determine the tension in each section of rope: F_{T1}, F_{T2}, F_{T3}, and F_{T4}.

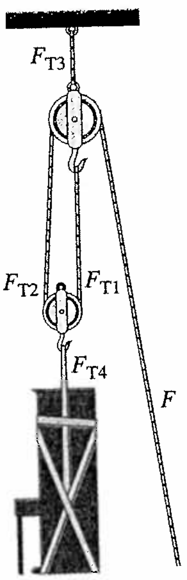

FIGURE 4–60 Problem 78.

79. A jet aircraft is accelerating at 3.5 m/s^2 at an angle of 45° above the horizontal. What is the total force that the cockpit seat exerts on the 75-kg pilot?

80. In the design process for a child-restraint chair, an engineer considers the following set of conditions: A 12-kg child is riding in the chair, which is securely fastened to the seat of an automobile (Fig. 4–61). Assume the automobile is involved in a head-on collision with another vehicle. The initial speed v_0 of the car is 45 km/h, and this speed is reduced to zero during the collision time of 0.20 s. Assume a constant car deceleration during the collision and estimate the net horizontal force F that the straps of the restraint chair must exert on the child in order to keep her fixed to the chair. Treat the child as a particle and state any additional assumptions made during your analysis.

FIGURE 4–61 Problem 80.

81. A 7650-kg helicopter accelerates upward at 0.80 m/s^2 while lifting a 1250-kg frame at a construction site, Fig. 4–62. (*a*) What is the lift force exerted by the air on the helicopter rotors? (*b*) What is the tension in the cable (ignore its mass) that connects the frame to the helicopter? (*c*) What force does the cable exert on the helicopter?

FIGURE 4–62 Problem 81.

82. A super high-speed 12-car Italian train has a mass of 660 metric tons (660,000 kg). It can exert a maximum force of 400 kN horizontally against the tracks, whereas at maximum velocity (300 km/h), it exerts a force of about 150 kN. Calculate (*a*) its maximum acceleration, and (*b*) estimate the force of air resistance at top speed.

83. A 65-kg ice skater coasts with no effort for 75 m until she stops. If the coefficient of kinetic friction between her skates and the ice is $\mu_k = 0.10$, how fast was she moving at the start of her coast?

84. Two rock climbers, Bill and Karen, use safety ropes of similar length. Karen's rope is more elastic, called a *dynamic rope* by climbers. Bill has a *static rope*, not recommended for safety purposes in pro climbing. Karen falls freely about 2.0 m and then the rope stops her over a distance of 1.0 m (Fig. 4–63). (*a*) Estimate, assuming that the force is constant, how large a force she will feel from the rope. (Express the result in multiples of her weight.) (*b*) In a similar fall, Bill's rope stretches by 30 cm only. How many times his weight will the rope pull on him? Which climber is more likely to be hurt?

FIGURE 4–63 Problem 84.

85. A fisherman in a boat is using a "10-lb test" fishing line. This means that the line can exert a force of 45 N without breaking (1 lb = 4.45 N). (*a*) How heavy a fish can the fisherman land if he pulls the fish up vertically at constant speed? (*b*) If he accelerates the fish upward at 2.0 m/s^2, what maximum weight fish can he land? (*c*) Is it possible to land a 15-lb trout on 10-lb test line? Why or why not?

86. An elevator in a tall building is allowed to reach a maximum speed of 3.5 m/s going down. What must the tension be in the cable to stop this elevator over a distance of 2.6 m if the elevator has a mass of 1300 kg including occupants?

87. Two boxes, $m_1 = 1.0$ kg with a coefficient of kinetic friction of 0.10, and $m_2 = 2.0$ kg with a coefficient of 0.20, are placed on a plane inclined at $\theta = 30°$. (*a*) What acceleration does each box experience? (*b*) If a taut string is connected to the boxes (Fig. 4–64), with m_2 initially farther down the slope, what is the acceleration of each box? (*c*) If the initial configuration is reversed with m_1 starting lower with a taut string, what is the acceleration of each box?

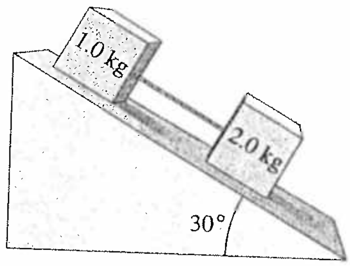

FIGURE 4–64 Problem 87.

88. A 75.0-kg person stands on a scale in an elevator. What does the scale read (in N and in kg) when the elevator is (*a*) at rest, (*b*) ascending at a constant speed of 3.0 m/s, (*c*) falling at 3.0 m/s, (*d*) accelerating upward at 3.0 m/s^2, (*e*) accelerating downward at 3.0 m/s^2?

89. Three mountain climbers who are roped together are ascending an icefield inclined at 21.0° to the horizontal. The last climber slips, pulling the second climber off his feet. The first climber is able to hold them both. If each climber has a mass of 75 kg, calculate the tension in each of the two sections of rope between the three climbers. Ignore friction between the ice and the fallen climbers.

Answers to Exercises

A: (*a*) The same; (*b*) the sports car; (*c*) third law for part (a), second law for part (b).

B: The force applied by the person is insufficient to keep the box moving.

C: No; yes.

D: Yes; no.