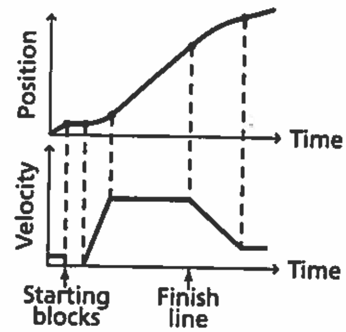
40. Graphs A sprinter walks up to the starting blocks at a constant speed and positions herself for the start of the race. She waits until she hears the starting pistol go off, and then accelerates rapidly until she attains a constant velocity. She maintains this velocity until she crosses the finish line, and then she slows down to a walk, taking more time to slow down than she did to speed up at the beginning of the race. Sketch a velocity-time and a position-time graph to represent her motion. Draw them one above the other on the same time scale. Indicate on your *p-t* graph where the starting blocks and finish line are.



41. Critical Thinking Describe how you could calculate the acceleration of an automobile. Specify the measuring instruments and the procedures that you would use.

One person reads a stopwatch and calls out time intervals. Another person reads the speedometer at each time and records it. Plot speed versus time and find the slope.

Practice Problems

3.3 Free Fall pages 72–75

page 74

42. A construction worker accidentally drops a brick from a high scaffold.

a. What is the velocity of the brick after 4.0 s?

Say upward is the positive direction.

$v_f = v_i + at,\ a = -g = -9.80\ m/s^2$

$v_f = 0.0\ m/s + (-9.80\ m/s^2)(4.0\ s)$

$= -39$ **m/s when the upward direction is positive**

b. How far does the brick fall during this time?

$d = v_i t + \frac{1}{2}at^2$

$= 0 + \left(\frac{1}{2}\right)(-9.80\ m/s^2)(4.0\ s)^2$

$= -78\ m$

The brick falls 78 m.

43. Suppose for the previous problem you choose your coordinate system so that the opposite direction is positive.

a. What is the brick's velocity after 4.0 s?

Now the positive direction is downward.

$v_f = v_i + at,\ a = g = 9.80\ \text{m/s}^2$

$v_f = 0.0\ \text{m/s} + (9.80\ \text{m/s}^2)(4.0\ \text{s})$

$= +39\ \text{m/s}$ **when the downward direction is positive**

b. How far does the brick fall during this time?

$d = v_i t + \frac{1}{2}at^2,\ a = g = 9.80\ \text{m/s}^2$

$= (0.0\ \text{m/s})(4.0\ \text{s}) +$

$\left(\frac{1}{2}\right)(9.80\ \text{m/s}^2)(4.0\ \text{s})^2$

$= +78\ \text{m}$

The brick still falls 78 m.

44. A student drops a ball from a window 3.5 m above the sidewalk. How fast is it moving when it hits the sidewalk?

$v_f^2 = v_i^2 + 2ad,\ a = g$ **and** $v_i = 0$

so $v_f = \sqrt{2gd}$

$= \sqrt{(2)(9.80\ \text{m/s}^2)(3.5\ \text{m})}$

$= 8.3\ \text{m/s}$

45. A tennis ball is thrown straight up with an initial speed of 22.5 m/s. It is caught at the same distance above the ground.

a. How high does the ball rise?

$a = -g$, **and at the maximum height,** $v_f = 0$

$v_f^2 = v_i^2 + 2ad$ **becomes**

$v_i^2 = 2gd$

$d = \frac{v_i^2}{2g} = \frac{(22.5\ \text{m/s})^2}{(2)(9.80\ \text{m/s}^2)} = 25.8\ \text{m}$

b. How long does the ball remain in the air? *Hint: The time it takes the ball to rise equals the time it takes to fall.*

Calculate time to rise using $v_f = v_i + at$, **with** $a = -g$ **and** $v_f = 0$

$t = \frac{v_i}{g} = \frac{22.5\ \text{m/s}}{9.80\ \text{m/s}^2} = 2.30\ \text{s}$

The time to fall equals the time to rise, so the time to remain in the air is

$t_{air} = 2t_{rise} = (2)(2.30\ \text{s}) = 4.60\ \text{s}$

46. You decide to flip a coin to determine whether to do your physics or English homework first. The coin is flipped straight up.

a. If the coin reaches a high point of 0.25 m above where you released it, what was its initial speed?

$v_f^2 = v_i^2 + 2a\Delta d$

$v_i = \sqrt{v_f^2 + 2g\Delta d}$ **where** $a = -g$

and $v_f = 0$ **at the height of the toss, so**

$v_i = \sqrt{(0.0\text{ m/s})^2 + (2)(9.80\text{ m/s}^2)(0.25\text{ m})}$

$= 2.2\text{ m/s}$

b. If you catch it at the same height as you released it, how much time did it spend in the air?

$v_f = v_i + at$ **where** $a = -g$

$v_i = 2.2\text{ m/s}$ **and**

$v_f = -2.2\text{ m/s}$

$t = \frac{v_f - v_i}{-g}$

$= \frac{-2.2\text{ m/s} - 2.2\text{ m/s}}{-9.80\text{ m/s}^2}$

$= 0.45\text{ s}$

Section Review

3.3 Free Fall pages 72–75

page 75

47. Maximum Height and Flight Time Acceleration due to gravity on Mars is about one-third that on Earth. Suppose you throw a ball upward with the same velocity on Mars as on Earth.

a. How would the ball's maximum height compare to that on Earth?

Acceleration of an object results from the influence of the planet's gravity. Because the gravity on Mars is one-third that on Earth, the maximum height would be three times higher.

b. How would its flight time compare?

Because the gravity on Mars is one-third that on Earth, the flight time would be three times as long.

48. Velocity and Acceleration Suppose you throw a ball straight up into the air. Describe the changes in the velocity of the ball. Describe the changes in the acceleration of the ball.

Velocity is reduced at a constant rate as the ball travels upward. At its highest point, velocity is zero. As the ball begins to drop, the velocity begins to increase in the negative direction until it reaches the height from which it was initially released. At that point, the ball has the same speed it had upon release. The acceleration is constant throughout the ball's flight.

49. Final Velocity Your sister drops your house keys down to you from the second floor window. If you catch them 4.3 m from where your sister dropped them, what is the velocity of the keys when you catch them?

Upward is positive

$v_f^2 = v_i^2 + 2a\Delta d$ **where** $a = -g$

$v_f = \sqrt{v_i^2 - 2g\Delta d}$

$= \sqrt{(0.0\ \text{m/s})^2 - (2)(9.80\ \text{m/s}^2)(-4.3\ \text{m})}$

$= 9.2\ \text{m/s}$

50. Initial Velocity A student trying out for the football team kicks the football straight up in the air. The ball hits him on the way back down. If it took 3.0 s from the time when the student punted the ball until he gets hit by the ball, what was the football's initial velocity?

Choose a coordinate system with up as the positive direction and the origin at the punter. Choose the initial time at the punt and the final time at the top of the football's flight.

$v_f = v_i + at_f$ **where** $a = -g$

$v_i = v_f + gt_f$

$= 0.0\ \text{m/s} + (9.80\ \text{m/s}^2)(1.5\ \text{s})$

$= 15\ \text{m/s}$

51. Maximum Height When the student in the previous problem kicked the football, approximately how high did the football travel?

$v_f^2 = v_i^2 + 2a(\Delta d)$ **where** $a = -g$

$$\Delta d = \frac{v_f^2 - v_i^2}{-2g}$$

$$= \frac{(0.0\ \text{m/s})^2 - (15\ \text{m/s})^2}{(-2)(9.80\ \text{m/s}^2)}$$

$= 11\ \text{m}$

52. Critical Thinking When a ball is thrown vertically upward, it continues upward until it reaches a certain position, and then it falls downward. At that highest point, its velocity is instantaneously zero. Is the ball accelerating at the highest point? Devise an experiment to prove or disprove your answer.

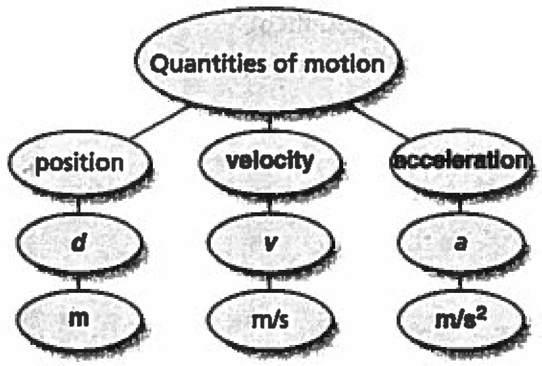
The ball is accelerating; its velocity is changing. Take a strobe photo to measure its position. From photos, calculate the ball's velocity.

Chapter Assessment

Concept Mapping

page 80

53. Complete the following concept map using the following symbols or terms: *d, velocity, m/s*^{2}*, v, m, acceleration.*



Mastering Concepts

page 80

54. How are velocity and acceleration related? (3.1)

Acceleration is the change in velocity divided by the time interval in which it occurs: it is the rate of change of velocity.

55. Give an example of each of the following. (3.1)

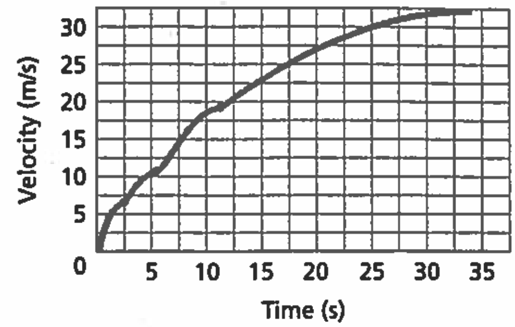
a. an object that is slowing down, but has a positive acceleration

If forward is the positive direction, a car moving backward at decreasing speed

b. an object that is speeding up, but has a negative acceleration

In the same coordinate system, a car moving backward at increasing speed

56. **Figure 3-16** shows the velocity-time graph for an automobile on a test track. Describe how the velocity changes with time. (3.1)



■ **Figure 3-16**

The car starts from rest and increases its speed.

57. What does the slope of the tangent to the curve on a velocity-time graph measure? (3.1)

Instantaneous acceleration

58. Can a car traveling on an interstate highway have a negative velocity and a positive acceleration at the same time? Explain. Can the car's velocity change signs while it is traveling with constant acceleration? Explain. (3.1)

Yes, a car's velocity is positive or negative with respect to its direction of motion from some point of reference. One direction of motion is defined as positive, and velocities in that direction are considered positive. The opposite direction of motion is considered negative; all velocities in that direction are negative. An object undergoing positive acceleration is either increasing its velocity in the positive direction or reducing its velocity in the negative direction. A car's velocity can change signs when experiencing constant acceleration. For example, it can be traveling right, while the acceleration is to the left. The car slows down, stops, and then starts accelerating to the left.

59. Can the velocity of an object change when its acceleration is constant? If so, give an example. If not, explain. (3.1)

Yes, the velocity of an object can change when its acceleration is constant. Example: dropping a book. The

longer it drops, the faster it goes, but the acceleration is constant at g.

60. If an object's velocity-time graph is a straight line parallel to the t-axis, what can you conclude about the object's acceleration? (3.1)

When the velocity-time graph is a line parallel to the t-axis, the acceleration is zero.

61. What quantity is represented by the area under a velocity-time graph? (3.2)

the change in displacement

62. Write a summary of the equations for position, velocity, and time for an object experiencing motion with uniform acceleration. (3.2)

$$t_f = \frac{(v_f - v_i)}{a}$$

$$v_f = v_i + at_f$$

$$\bar{v} = \frac{\Delta v}{2} = \frac{v_f - v_i}{2}$$

$$\Delta d = \bar{v}\Delta t$$

$$= \frac{v_f - v_i}{2}\Delta t$$

assuming $t_i = 0$, then

$$\Delta t = t_f$$

$$\Delta d = \left(\frac{v_f - v_i}{2}\right)t_f$$

63. Explain why an aluminum ball and a steel ball of similar size and shape, dropped from the same height, reach the ground at the same time. (3.3)

All objects accelerate toward the ground at the same rate.

64. Give some examples of falling objects for which air resistance cannot be ignored. (3.3)

Student answers will vary. Some examples are sheets of paper, parachutes, leaves, and feathers.

65. Give some examples of falling objects for which air resistance can be ignored. (3.3)

Student answers will vary. Some examples are a steel ball, a rock, and a person falling through small distances.

Applying Concepts

pages 80–81

66. Does a car that is slowing down always have a negative acceleration? Explain.

No, if the positive axis points in the direction opposite the velocity, the acceleration will be positive.

67. **Croquet** A croquet ball, after being hit by a mallet, slows down and stops. Do the velocity and acceleration of the ball have the same signs?

No, they have opposite signs.

68. If an object has zero acceleration, does it mean its velocity is zero? Give an example.

No, $a = 0$ when velocity is constant.

69. If an object has zero velocity at some instant, is its acceleration zero? Give an example.

No, a ball rolling uphill has zero velocity at the instant it changes direction, but its acceleration is nonzero.

70. If you were given a table of velocities of an object at various times, how would you find out whether the acceleration was constant?

Draw a velocity-time graph and see whether the curve is a straight line or calculate accelerations using $\bar{a} = \frac{\Delta v}{\Delta t}$ and compare the answers to see if they are the same.

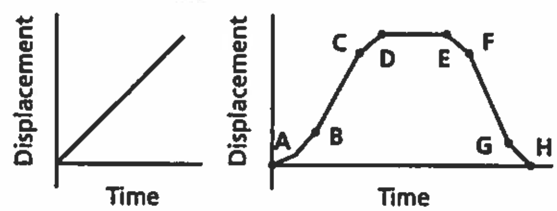
71. The three notches in the graph in Figure 3-16 occur where the driver changed gears. Describe the changes in velocity and acceleration of the car while in first gear. Is the acceleration just before a gear change larger or smaller than the acceleration just after the change? Explain your answer.

Velocity increases rapidly at first, then more slowly. Acceleration is greatest at the beginning but is reduced as velocity increases. Eventually, it is necessary for the driver to shift into second gear. The acceleration is smaller just before the gear change because the slope is less at that point on the graph. Once the driver shifts and the gears engage, acceleration and the slope of the curve increase.

72. Use the graph in Figure 3-16 and determine the time interval during which the acceleration is largest and the time interval during which the acceleration is smallest.

The acceleration is largest during an interval starting at $t = 0$ and lasting about 2.5 s. It is smallest beyond 33 s, where $a = 0$.

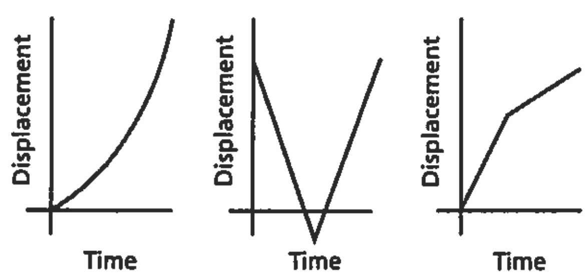
73. Explain how you would walk to produce each of the position-time graphs in **Figure 3-17.**



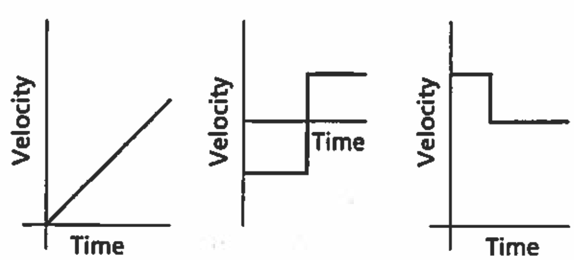
■ **Figure 3-17**

(1) Walk in the positive direction at a constant speed. (2) Walk in the positive direction at an increasing speed for a short time; keep walking at a moderate speed for twice that amount of time; slow down over a short time and stop; remain stopped; and turn around and repeat the procedure until the original position is reached.

74. Draw a velocity-time graph for each of the graphs in **Figure 3-18.**



■ **Figure 3-18**



75. An object shot straight up rises for 7.0 s before it reaches its maximum height. A second object falling from rest takes 7.0 s to reach the ground. Compare the displacements of the two objects during this time interval.

Both objects traveled the same distance. The object that is shot straight upward rises to the same height from which the other object fell.

76. **The Moon** The value of g on the Moon is one-sixth of its value on Earth.

a. Would a ball that is dropped by an astronaut hit the surface of the Moon with a greater, equal, or lesser speed than that of a ball dropped from the same height to Earth?

The ball will hit the Moon with a lesser speed because the acceleration due to gravity is less on the Moon.

b. Would it take the ball more, less, or equal time to fall?

The ball will take more time to fall.

77. **Jupiter** The planet Jupiter has about three times the gravitational acceleration of Earth. Suppose a ball is thrown vertically upward with the same initial velocity on Earth and on Jupiter. Neglect the effects of Jupiter's atmospheric resistance and assume that gravity is the only force on the ball.

a. How does the maximum height reached by the ball on Jupiter compare to the maximum height reached on Earth?

The relationship between d and g is an inverse one: $d_f = \frac{(v_f^2 - v_i^2)}{2g}$.

If g increases by three times, or $d_f = \frac{(v_f^2 - v_i^2)}{2(3g)}$, d_f changes by $\frac{1}{3}$. Therefore, a ball on Jupiter would rise to a height of $\frac{1}{3}$ that on Earth.

b. If the ball on Jupiter were thrown with an initial velocity that is three times greater, how would this affect your answer to part **a?**

With $v_f = 0$, the value d_f is directly proportional to the square of initial velocity, v_i. That is, $d_f = v_f^2 - \frac{(3v_i)^2}{2g}$. On Earth, an initial velocity three times greater results in a ball rising nine times higher. On Jupiter, however, the height of nine times higher would be reduced to only three times higher because of d_f's inverse relationship to a g that is three times greater.

78. Rock A is dropped from a cliff and rock B is thrown upward from the same position.

a. When they reach the ground at the bottom of the cliff, which rock has a greater velocity?

Rock B hits the ground with a greater velocity.

b. Which has a greater acceleration?

They have the same acceleration, the acceleration due to gravity.

c. Which arrives first?

rock A

Mastering Problems

3.1 Acceleration

pages 81–82

Level 1

79. A car is driven for 2.0 h at 40.0 km/h, then for another 2.0 h at 60.0 km/h in the same direction.

a. What is the car's average velocity?

Total distance:
80.0 km + 120.0 km = 200.0 km
total time is 4.0 hours, so,
$$\bar{v} = \frac{\Delta d}{\Delta t} = \frac{200.0\text{ km}}{4.0\text{ h}} = 5.0\times10^{1}\text{ km/h}$$

b. What is the car's average velocity if it is driven 1.0×10^2 km at each of the two speeds?