## *End-of-Chapter Exercises*

**Exercises 1 – 12 are conceptual questions that are designed to see if you have understood the main concepts of the chapter.**

1. Refer to the position-versus-time graph in Figure 2.22 for your motion along a straight sidewalk. Consider the following four time intervals:
   Interval 1: between $t$ = 0 and $t$ = 10 s
   Interval 2: between $t$ = 5 s and $t$ = 10 s
   Interval 3: between $t$ = 10 s and $t$ = 15 s
   Interval 4: between $t$ = 15 s and $t$ = 35 s.
   Rank these intervals, from largest to smallest, based on the (a) distance traveled during the interval; (b) magnitude of the displacement during the interval. Express your rankings in a form like 2>1=3>4.

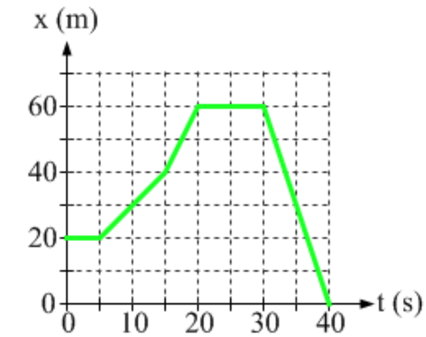



**Figure 2.22**: A position-versus-time graph, for Exercises 1 – 3.

2. Refer again to the position-versus-time graph in Figure 2.22 for your motion along a straight sidewalk. Consider the following four time intervals:
   Interval 1: between $t$ = 0 and $t$ = 10 s
   Interval 2: between $t$ = 5 s and $t$ = 10 s
   Interval 3: between $t$ = 10 s and $t$ = 15 s
   Interval 4: between $t$ = 15 s and $t$ = 35 s.
   Rank these intervals, from largest to smallest, based on the: (a) average speed over the interval; (b) magnitude of the average velocity over the interval. Express your rankings in a form like 2>1=3>4.

3. Compare the graph in Figure 2.22, showing your position-versus-time as you move along a straight sidewalk, to the graph in Figure 2.23, showing your velocity-versus-time for a different motion along the same straight sidewalk. (a) In a few sentences, make up a story to accompany the motion depicted in the position-versus-time graph. (b) In a few sentences, make up a story to accompany the motion depicted in the velocity-versus-time graph.

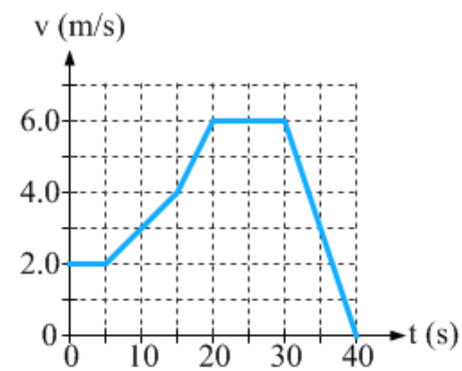



**Figure 2.23**: A velocity-versus-time graph, for Exercises 3 – 4.

4. Three of your friends look at the velocity-versus-time graph in Figure 2.23, depicting your motion along a straight sidewalk. They make the following comments:
   Andy: "The graph shows that you were at rest between 0 and 5 seconds, and at rest again between 20 and 30 seconds."
   Jennifer: "The graph shows that you were moving in one direction the entire time, until the end when you come to rest."
   Sue: "The graph shows that you were traveling one way for a while, and then later you were traveling in the opposite direction."

   What do you agree or disagree with about each of these comments?

5. Consider the motion diagram in Figure 2.24, showing the position of an object at regular time intervals as it moves in one dimension. Is this a complete motion diagram, or is there anything missing that would help us to better determine what the object's motion is like?

**Figure 2.24**: Motion diagram, for Exercise 5.

6. Consider the motion diagram in Figure 2.25, showing the position of an object at 1-second time intervals as it moves in one dimension. (a) Over the time interval from $t = 0$ to $t = 10$ s, describe the object's motion. (b) When does the object experience a non-zero acceleration? (c) Describe a real-life situation that could match this motion diagram.

**Figure 2.25**: Motion diagram, for Exercise 6.


7. Consider the positions in Figure 2.26. What is the total distance traveled in moving from (a) $\vec{x}_0$ directly to $\vec{x}_1$? (b) $\vec{x}_1$ directly to $\vec{x}_0$? (c) $\vec{x}_0$ to $\vec{x}_2$ and then to $\vec{x}_1$? What is the displacement in moving from
(d) $\vec{x}_0$ to $\vec{x}_1$? (e) $\vec{x}_1$ to $\vec{x}_0$?
(f) $\vec{x}_0$ to $\vec{x}_2$ and then to $\vec{x}_1$?

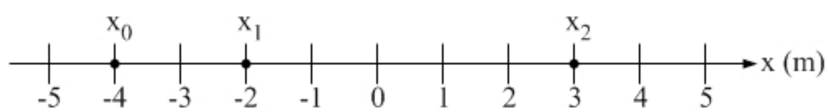



**Figure 2.26**: Three different positions ( $\vec{x}_0$ , $\vec{x}_1$, and $\vec{x}_2$ ) along an *x*-axis, for Exercise 7.

8. Describe a situation that matches each of the following, or state that it is impossible. (a) A person is traveling vertically down but with an upward acceleration. (b) A car has a velocity directed east and an acceleration directed east. (c) A baseball is at rest but has a non-zero acceleration.

9. Describe a situation that matches each of the following, or state that it is impossible. (a) An object has no acceleration and yet it is moving. (b) An object has a non-zero acceleration but it remains at rest.

10. Come up with an example that matches the following description of a motion, or state that it is impossible, assuming that the motion is in 1 dimension. (a) An object's average velocity is zero, but it did cover some distance over the time interval in question. (b) An object's velocity is positive for more than half the time, but its net displacement is negative. (c) An object's instantaneous velocity is, for some fraction of a particular time interval, equal to four times its average velocity over that time interval.

11. Consider the motion diagrams in Figure 2.27, showing the positions of two objects at 1-second intervals starting at $t = 0$ as both objects move to the right. Assume that whenever either object accelerates, its acceleration is constant and it accelerates for exactly 1 second. During the time interval depicted, which object has (a) the largest instantaneous speed? (b) the smallest instantaneous speed? (c) the average velocity with the largest magnitude over the interval $t = 0$ to $t = 9$ s?

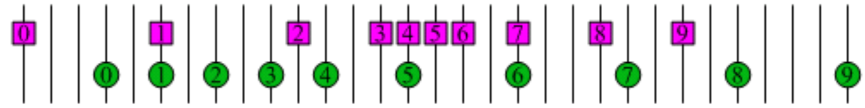



**Figure 2.27**: A pair of motion diagrams for Exercises 11 – 12. The numbers shown correspond to the time in seconds (e.g., the circle with the 4 in it shows the location of the bottom object at $t$ = 4 s).

12. Consider the motion diagrams in Figure 2.27, showing the positions of two different objects at 1-second intervals starting at $t$ = 0 as both objects move to the right. You can assume that whenever either object accelerates its acceleration is constant and it accelerates for exactly 1 second. Note that your answers to this exercise should be of the form "At $t$ = 4 s", or "At some time during the 1-s interval between $t$ = 3 s and $t$ = 4 s." During the time interval depicted are there any times when the objects have
(a) the same horizontal position? If so, state when this occurs.
(b) the same velocity? If so, state when this occurs.
(c) the same acceleration? If so, state when this occurs.

**Exercises 13 – 18 deal with calculating averages.**

13. In 1973, the horse Secretariat set the record for the 1.25-mile Kentucky Derby with a time of 1:59 2/5 (one minute, 59.4 seconds). What was Secretariat's average speed in m/s?

14. The gold medalists in four events at the 2004 Athens Olympics were as follows: In the women's cycling road race, consisting of 9 laps around a 13.2 km/lap course, Sara Carrigan of Australia won in a time of 3:24:24 (3 h, 24 min, 24 s); in the 50-meter freestyle swim, Gary Hall of the USA swam one length of the pool in 21.93 s; in men's single sculls rowing, Olaf Tufte of Norway rowed the 2000 m course in 6:49.30 (6 min, 49.30 s); and in the women's 100-meter race on the track Yuliya Nesterenko of Belarus won in a time of 10.93 s. (a) Rank these athletes based on their average speed over their respective races, from largest to smallest. (b) Rank them instead based on the magnitude of their average velocity.

15. In the women's 200-meter backstroke event in swimming at the 2004 Athens Olympics, Kirsty Coventry of Zimbabwe swam the four lengths of the pool in a time of 2:09.19 (2 min., 9.19 s). At the instant Coventry touched the wall to win the race, the eighth-place swimmer in the race, Aya Terakawa of Japan, still had a few meters left to swim. (a) Which of these two swimmers had the largest average speed over the 2:09.19 time interval from the start of the race to when Kirsty Coventry touched the wall? (b) Over the same time interval, which swimmer had an average velocity with a larger magnitude? Briefly justify your answers.

16. The following times are given for the Porsche 911 Turbo Cabriolet to achieve a particular speed when accelerating from rest: 0 to 60 mph (miles per hour) in 3.8 s; 0 to 100 mph in 9.2 s; and 0 to 130 mph in 16.0 s. (a) In each of the three cases, what is the magnitude of the car's average acceleration? (b) Does the Porsche exhibit constant acceleration, or not? Briefly comment.

17. You are competing in a duathlon, an event that involves running and cycling. This duathlon involves running once around a particular loop, cycling twice around the same loop, and then finishing the race by again running once around the loop. If your average speed when running is 4.0 m/s and your average speed when cycling is 6.0 m/s, what was your average speed for the race? Assume that the time spent during the run-bike and bike-run transitions is negligible.

18. You take a trip, covering a total distance of 20 km. For the first 10 km you travel on horseback at an average speed of 20 km/h. You then switch to a different mode of transportation. What speed should you average over the second 10 km of the trip if you want your average speed for the entire trip to be (a) 10 km/h? (b) 30 km/h? (c) 40 km/h?

**Exercises 19 - 26 deal with interpreting graphs.**

19. The graph in Figure 2.28 shows your motion as you move along a straight sidewalk. Over the 40-second interval what is (a) your net displacement? (b) the total distance traveled?

20. The graph in Figure 2.28 shows your motion as you move along a straight sidewalk. Over the 40-second interval what is (a) your average velocity? (b) your average speed?

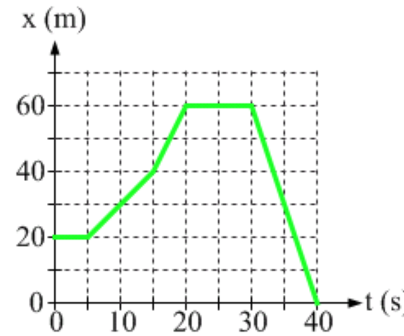



**Figure 2.28**: A position-versus-time graph, for Exercises 19 – 21.

21. Refer again to the position-versus-time graph in Figure 2.28 for your motion along a straight sidewalk. (a) Sketch the corresponding velocity-versus-time graph for the motion. (b) What is your instantaneous velocity at $t$ = 25 s? (c) What is your average velocity over the interval between $t$ = 0 and $t$ = 25 s? (d) What is your instantaneous velocity at $t$ = 35 s? (e) What is your average velocity over the interval between $t$ = 0 and $t$ = 35 s?

22. If all you were given was the graph of velocity-versus-time in Figure 2.29, and you knew the motion depicted was for your motion along a straight sidewalk, could you answer the following questions? Simply write "Yes" if you can answer a particular question, and if you cannot explain why not. (a) What is your velocity at $t$ = 25 s? (b) What is your acceleration at $t$ = 25 s? (c) What is your position at $t$ = 25 s? (d) What is your displacement between $t$ = 0 and $t$ = 25 s? (e) Are you walking east or west? (f) Are you walking forward or backward?

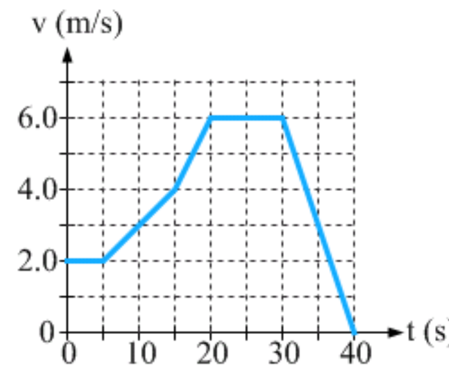



**Figure 2.29**: A velocity-versus-time graph, for Exercises 22 – 26.

23. Refer again to the velocity-versus-time graph in Figure 2.29 for your motion along a straight sidewalk. If your position at $t$ =0 is +20 m from some convenient origin, determine your position, velocity, and acceleration at the following times: (a) $t$ = 10 s, (b) $t$ = 25 s, (c) $t$ = 35 s.

24. Refer again to the velocity-versus-time graph in Figure 2.29 for your motion along a straight sidewalk. If your position at $t$ = 0 is +20 m from some convenient origin, sketch corresponding graphs of your position as a function of time as well as your acceleration as a function of time.

25. Refer again to the velocity-versus-time graph in Figure 2.29 for your motion along a straight sidewalk. Over the 40-second interval, what is your (a) total distance traveled? (b) net displacement? (c) average speed? (d) average velocity?

26. Refer again to the velocity-versus-time graph in Figure 2.29 for your motion along a straight sidewalk. Sketch the corresponding motion diagram showing your position, which you can represent by circles or X's, at 5-second intervals starting from $t$ = 0.

**Exercises 27 – 34 deal with understanding and interpreting motion diagrams.**

**Figure 2.30**: Motion diagram for Exercises 27 – 29.

27. Consider the motion diagram in Figure 2.30, showing the position of an object at regular time intervals as it moves in one dimension. Assume that the object's acceleration is constant throughout the time interval covered by the motion diagram and that the object does not reverse direction during the motion. (a) In what direction is the object moving? (b) In what direction is the acceleration? (c) In one or two sentences, describe a real-life situation that could match this motion diagram.

28. Consider the motion diagram in Figure 2.30, showing the position of an object at regular time intervals as it moves in one dimension. The object starts from rest from the left-most point and then has a constant acceleration directed right for the entire time interval covered by the motion diagram (and continues to have this acceleration afterwards). If the vertical lines in the picture are 0.20 m apart and the time it takes the object to go from the initial position to the final position is 6.0 s, determine (a) the object's speed as it passes through the last position shown in the diagram, and (b) its acceleration.

29. Consider the motion diagram in Figure 2.30, showing the position of an object at regular time intervals as it moves in one dimension. Let's say that the object is moving from right to left, and experiencing a constant acceleration that brings it instantaneously to rest at the left-most point. The successive positions of the object are shown at 0.20 s intervals, starting from the right-most point at $t = 0$. The vertical lines in the picture are 0.20 m apart. (a) Make a copy of the diagram, labeling the positions shown on the diagram with the times. (b) Assuming the object still experiences the same constant acceleration after $t = 1.0$ s, add to the diagram the positions of the object at 0.20 s intervals between $t = 1.0$ s and $t = 2.0$ s. (c) What is the object's acceleration? (d) What is the object's velocity at $t = 0$? (e) What is the object's average velocity over the interval from $t = 0$ to $t = 1.0$ s?

30. Sketch a motion diagram for an object on the $x$-axis that (a) has a constant position; (b) has a constant acceleration of 1.0 m/s$^2$ in the negative $x$ direction.

31. (a) Sketch a motion diagram for an object on the $x$-axis that is moving with a constant non-zero velocity in the positive $x$ direction. (b) Add a motion diagram for a second object moving on a path that is parallel to the first object, but with a velocity 1.5 times larger than that of the first object.

32. Consider the motion diagram in Figure 2.31, showing the position of an object at 1-second time intervals as it moves in one dimension. Assume that the time is known precisely. If the object's velocity at $t = 4$ s is 4.0 m/s to the right, determine the object's average velocity over the time intervals (a) $t = 0$ to $t = 4$ s; (b) $t = 4$ s to $t = 7$ s; (c) $t = 7$ s to $t = 10$ s; (d) $t = 0$ to $t = 10$ s.

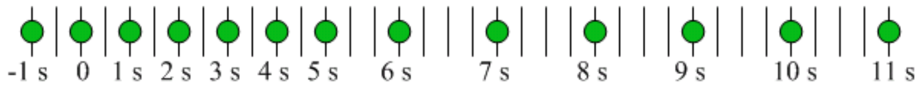



**Figure 2.31**: Motion diagram for Exercises 32 – 35.

33. Repeat Exercise 32, but now determine the object's average acceleration over the given time intervals instead of the average velocity.

34. Consider the motion diagram in Figure 2.31, showing the position of an object at 1-second time intervals as it moves in one dimension. Assume the time is known precisely. If the object's velocity at $t = 0$ is 2.0 m/s to the right, determine the object's (a) displacement, (b) average velocity, and (c) average acceleration over the time interval $t = 0$ to $t = 8$ s. (d) Would your answers to parts (a) – (c) change if you considered the time interval $t = 0$ to $t = 7$ s instead? State whether the magnitude of each of these vector quantities would increase, decrease, or stay the same.

**Exercises 35 – 38 deal with transforming between various representations of motion.**

35. Consider the motion diagram in Figure 2.31, showing the position of an object at 1-second time intervals as it moves along the x-axis. If, at $t = 0$, the object's velocity is 2.0 m/s to the right, and its position is $x = 0$ m, plot a graph of the object's (a) position, (b) velocity, and (c) acceleration over the interval $t = 0$ to $t = 10$ s. Assume the object has a constant non-zero acceleration lasting 1 second during this interval.

36. A plot of an object's position as a function of time is shown in Figure 2.32. (a) Briefly describe a real-life situation that would match the motion described by the graph. (b) Plot the corresponding velocity graph. (c) Draw the corresponding motion diagram.

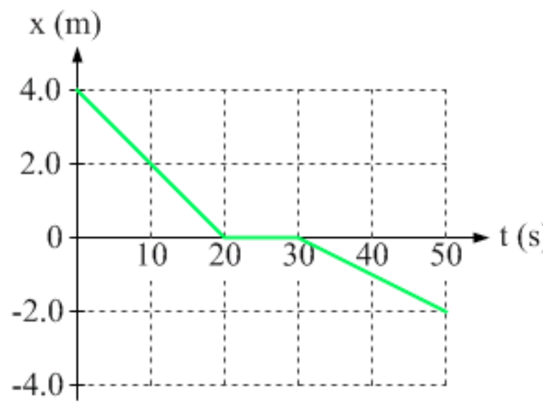



**Figure 2.32**: A graph of position-versus-time, for Exercise 36.

37. You are running along a straight path at constant velocity. After a few seconds, you see your friend, so you stop to chat. After a few seconds, she asks you to walk with her, so you start walking in the same direction you were originally running. (a) Sketch a graph showing your velocity as a function of time. (b) Sketch a graph showing your position as a function of time. (c) Draw a motion diagram for this motion.

38. A plot of an object's acceleration as a function of time is shown in Figure 2.33. (a) Sketch a velocity graph that would match this acceleration graph. (b) Comment on whether there is only one correct answer to part (a). (c) Briefly describe a real-life situation that would match this motion.

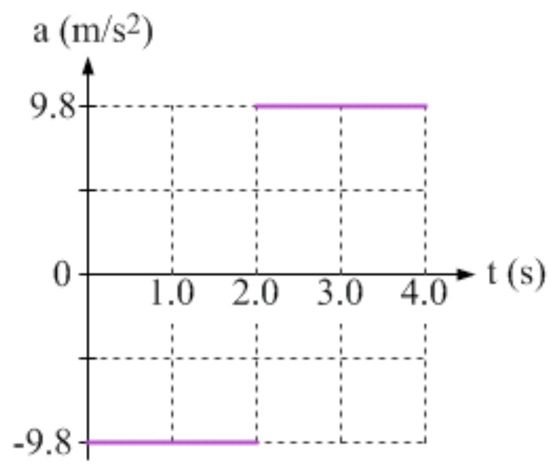



**Figure 2.33**: A graph of acceleration as a function of time, for Exercise 38.

**Exercises 39 – 48 are designed to give you practice in solving a typical one-dimensional motion problem**. Try to solve all exercises using a systematic approach. For each of these exercises start by doing the following parts. (a) **Picture the scene** - draw a diagram of the situation. Choose an origin to measure displacements from and mark that on the diagram. Choose a positive direction and indicate that with an arrow on the diagram. (b) **Organize the data** - create a table summarizing everything you know, as well as the unknowns you want to solve for.

39. You release a ball from rest, and it drops exactly 1.8 m to the floor below. Your goals in this exercise are to determine the ball's velocity just before impact and the time it takes the ball to reach the ground. Use $g = 10 \text{ m/s}^2$. Carry out parts (a) – (b) as described above. (c) Which equation(s) will you use to determine the ball's velocity just before impact? (d) Solve for that velocity. (e) Which equation(s) will you use to determine the time it takes the ball to reach the ground? (f) Solve for that time.

40. When a traffic light turns green, you accelerate from rest along the road with a constant acceleration of $3.0 \text{ m/s}^2$. The goal here is to determine how long it takes you to reach the speed limit of 80 km/h. Carry out parts (a) and (b) as described above. (c) Which equation(s) will you use to find the time it takes to reach 80 km/h? (d) Find that time.

41. You throw a baseball straight up into the air, giving it an initial speed of 12 m/s. The baseball hits the ground 2.6 seconds later. To make the calculations easy, use $g = 10 \text{ m/s}^2$. Your goals in this exercise are to solve for the initial height above the ground from which you launched the ball, and to find the maximum height above the ground reached by the ball in its motion. Carry out parts (a) and (b) as described above. (c) Which equation(s) will you use to find the initial height above the ground from which the ball was launched? (d) Solve for that initial height. (e) Which equation(s) will you use to find the maximum height above the ground reached by the ball? (f) Solve for that maximum height.

42. In this exercise you will analyze the method you used in the previous exercise, so all these questions pertain to what you did to solve the previous exercise. (a) Is there only one correct choice for the origin? Why did you make the choice you made? (b) Is there only one correct choice for the positive direction? Would your answers to (d) and (f) above change if you chose the opposite direction to be positive? (c) Find an alternative method to determine the initial height above the ground from which the ball was launched, and show that it gives the same answer as the method you used in the previous exercise. (d) Find an alternative method to determine the maximum height above the ground reached by the ball in its motion, and show that it gives the same answer as the method you used in the previous exercise.

43. A toy car is rolling down a ramp. When it passes a particular point you determine that it is traveling at a speed of 20 cm/s, and in the next 1.0 seconds it travels 40 cm. The goal of this exercise is to determine the car's acceleration, which we will assume to be constant. Carry out parts (a) and (b) as described above. (c) Which equation(s) will you use to determine the acceleration? (d) What is that acceleration?

44. Repeat parts (c) and (d) of Exercise 43, but calculate the answers another way, without using the equation(s) you used in Exercise 43.

45. You give a toy car an initial velocity of 1.00 m/s directed up a ramp. The car takes a total of 4.00 s to roll up the ramp and then roll back down again into your hand. Assuming you catch the car at the same point from which you released it, and that the acceleration is constant through the entire motion, the goal of the exercise is to determine the maximum distance the car was from your hand during the motion. Carry out parts (a) and (b) as

described above. (c) Which equation(s) will you use to determine the maximum distance the car was from your hand during the motion? (d) What is that maximum distance?

46. One of the events in the X Games is the Street Luge, in which competitors race on wheeled carts down an incline. Let's say that in one of the races a competitor starts from rest and then covers 100 m in 5.0 seconds. The goal of this exercise is to determine what the acceleration is, assuming it to be constant. Carry out parts (a) and (b) as described above. (c) What is the acceleration?

47. A professional baseball pitcher can throw a baseball with a speed of 150 km/h. Assuming the pitcher accelerates the ball from rest through a distance of 2.0 m, the goal of this exercise is to determine the ball's acceleration and the time over which this acceleration occurs. Carry out parts (a) and (b) as described above. (c) What is the ball's acceleration? (d) What is the time over which the acceleration occurs?

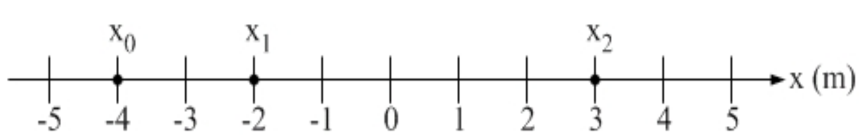
48. You're driving along a straight road at a speed of 48.0 km/h when you see a deer in the road 35.0 m ahead of you. After applying the brakes it takes you 2.00 s to bring your car to rest, but there is a reaction time period (the time between when you first see the deer and when you first apply the brakes) during which the car continues to travel at 48.0 km/h. The goal of this exercise is to answer the question: Assuming the acceleration is constant during the braking phase of the motion, what is the longest your reaction time can be if you are to stop the car before reaching the deer? Carry out parts (a) and (b) as described above. Note that there are two phases to the motion, a constant velocity phase and a constant-acceleration phase, so you should clearly separate the information for the two phases in your table. (c) Briefly describe the method you will use to solve the exercise. (d) Solve for your maximum possible reaction time.

**General problems and conceptual questions**

49. In Figure 2.13, we sketched graphs of the position and velocity of three cars as a function of time as they moved with constant velocity. Sketch a graph of the acceleration of each car as a function of time.

50. Consider the three positions shown in Figure 2.34. Starting at $\vec{x}_0$, it takes you 9.0 s to walk to $\vec{x}_2$ and then an additional 3.0 s to walk to $\vec{x}_1$. For this motion, find your (a) average speed and (b) average velocity.

**Figure 2.34**: Three different positions ($\vec{x}_0$, $\vec{x}_1$, and $\vec{x}_2$) along an *x*-axis, for Exercise 50.




51. In the men's 100-meter track race at the 2004 Athens Olympics, Justin Gatlin of the USA won the gold medal with a time of 9.85 s. Shawn Crawford (USA) ended up fourth in a time of 9.89 s. Estimate the distance separating these two runners at the finish line.

52. On August 16, 1960, Joe Kittinger of the United States Air Force jumped from a helium balloon from a height of 102,800 feet. After being in free fall for 4 minutes and 36 seconds, and falling for 85,300 feet, he opened his parachute and eventually landed safely on the ground. Assume that the acceleration was constant to answer parts (a) and (b). (a) What was the acceleration during the free fall? (b) What was Kittinger's speed just before he opened his parachute? (c) Comment on whether you think Kittinger's acceleration was constant during the fall. Depending on what source you read, Kittinger either broke, or came close to breaking, the sound barrier during this event.

53. Who was Colonel John Paul Stapp and why is he relevant to the material in this chapter? In particular, what was the magnitude of the maximum acceleration he experienced?

54. You throw a ball straight up into the air and catch it again at the same height from which you let it go. Considering the motion from the instant you release the ball until the instant you catch it again, the motion takes a time $T$ and the ball reaches a maximum height $H$ above the point where you release it. You now repeat the process, but this time the ball has twice the initial velocity of the previous motion. (a) How high above the release point does the ball go this time? (b) How long does this motion take?

55. You throw a ball straight up into the air, releasing it with a speed of 20 m/s. Assuming $g = 10 \text{ m/s}^2$, you catch the ball 4.0 seconds later at the same point from which you let it go. Consider the motion from just after you release the ball until just before it returns to your hand. For the round trip, determine the ball's: (a) average velocity; (b) average speed; (c) average acceleration.

56. While a commuter train is stopped to pick up passengers, a freight train goes by at a constant speed of 36 km/h. Exactly 1 minute after the front of the freight train passes the front of the commuter train, the commuter train starts to move. After another 1 minute of constant acceleration, the commuter train reaches a speed of 72 km/h, and then moves at constant speed. Both trains are going the same way on parallel tracks. How much more time passes until the front of the commuter train passes the front of the freight train?

57. Two balls are launched at the same time. Ball A is released from rest from the top of a tall building of height $H$. Ball B is fired straight up from the ground with an initial velocity such that it just reaches the top of the same building. Neglect air resistance. (a) Which ball has the largest magnitude acceleration at the point they pass one another? (b) If ball A takes a time $T$ to reach the ground, and ball B takes the same time $T$ to reach the top of the building, which ball has the highest speed at time $T/2$? (c) How far from the ground are the two balls when they pass one another? Express your answer in terms of $H$. (d) Sketch a graph showing the velocity of ball A, and the velocity of ball B, as a function of time. Start from when the balls are launched, and end when ball A reaches the ground.

58. A cat and a dog are having a 100 m race. When the starting gun goes off, the dog lies down for a nap. The cat moves forward with a constant acceleration, reaching a speed of 2.0 m/s when she is 20 m from the starting line. After reaching that point, the cat travels at a constant velocity of 2.0 m/s until crossing the finish line. After 45 seconds, the dog wakes up from his nap and covers the 100 m with a constant acceleration of $2.0 \text{ m/s}^2$. (a) Who wins the race? Clearly justify your answer. (b) What is the distance between the animals when the winner crosses the finish line? (c) What is the distance between the animals at the only time (other than at the start of the race) they have the same velocity?

59. Consider the motion diagrams in Figure 2.35, showing the positions of two different objects at 1-second intervals starting at $t$ = 0. Assume the top object, which has its position at regular intervals denoted by squares, is at $x$ = 0 at $t$ = 0, and that the vertical lines in the diagram are 1.0 m apart. Plot a graph of this object's (a) position, (b) velocity, and (c) acceleration over the interval between $t$ = 0 and $t$ = 9 s. You can assume that whenever the object accelerates its acceleration is constant and it accelerates for exactly 1 second.

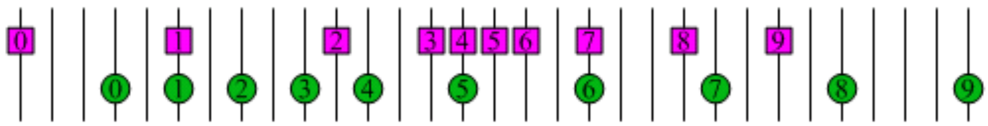



**Figure 2.35**: A pair of motion diagrams for Exercises 59 – 60. The numbers shown correspond to the time in seconds (e.g., the circle with the 4 in it shows the location of the bottom object at $t$ = 4 s).

60. Consider the motion diagrams in Figure 2.35, showing the positions of two different objects at 1-second intervals starting at $t$ = 0 as both objects move to the right. Which of the objects has the average velocity with the largest magnitude over the time interval (a) $t$ = 0 to $t$ = 4 s, (b) $t$ = 0 to $t$ = 6 s, (c) $t$ = 2 s to $t$ = 7 s?

61. You overhear two of your classmates discussing the issue of the acceleration of a ball that is tossed straight up into the air. Comment on each of their statements.

*Jim: As the ball goes up, it slows down, so the acceleration is negative, while as the ball comes down again it speeds up, so the acceleration is positive. In other words, the acceleration changes sign when the ball changes direction.*

***Karen: What about the magnitude of the acceleration? I think it decreases to zero as the ball travels up, and then increases again as the ball comes down.***

*Jim: That sounds like the velocity. Remember that the acceleration is just the acceleration due to gravity, so that has a constant magnitude the whole time.*

62. Referring back to the previous question, the conversation continues with two more classmates joining the discussion. Again, comment on each statement as they discuss the ball's acceleration at the instant it reaches the highest point.

*Maria: Karen, isn't the ball's acceleration constant the whole time, even at the highest point? Are you saying that the acceleration is zero at that point?*

***Jose: I think Karen's right about that. Acceleration is velocity over time, so when the velocity goes to zero the acceleration must be zero, too.***

*Maria: Actually, isn't acceleration the change in velocity over some time interval? So, don't we have to consider how the velocity changes rather than worrying about what the value of the velocity is?*