End-of-Chapter Exercises

Several of these exercises can be answered without a calculator, if you use $g = 10$ m/s^2.

Exercises 1 – 12 are conceptual questions designed to see whether you understand the main concepts of the chapter.

1. Why is it more tiring to walk for an hour up a hill than it is to walk for an hour on level ground?

2. (a) Is it possible for the gravitational potential energy of a system to be negative? (b) Is it possible for the kinetic energy of a system to be negative? (c) Can the total mechanical energy of a system be negative?

3. Given the right (or wrong, depending on your perspective) conditions, a mudslide or avalanche can occur, in which a section of earth or snow that has been at rest slides down a steep slope, reaching impressive speeds. Where does all the kinetic energy that the mud or snow has at the bottom of the slope come from?

4. Three identical blocks (see Figure 7.15) are released simultaneously from rest from the same height *h* above the floor. Block A falls straight down, while blocks B and C slide down frictionless ramps. B's ramp is steeper than C's. (a) Rank the blocks according to their speed, from largest to smallest, when they reach the floor. (b) Rank the blocks according to the time it takes them to reach the floor, from greatest to least. (c) If the two ramps are not frictionless, and the coefficient of friction between the block and ramp is identical for the ramps, do any of your rankings above change? If so, how?

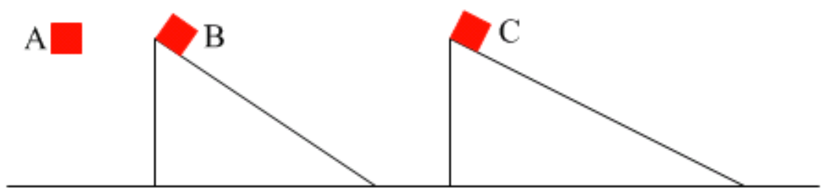

Figure 7.15: Three identical blocks are simultaneously released from rest from the same height above the floor, for Exercise 4.

5. You are on a diving platform 3.0 m above the surface of a swimming pool. Compare the speed you have when you hit the water if you: A, drop almost straight down from rest; B, run horizontally at 4.0 m/s off the platform; C, leap almost straight up, with an initial speed of 4.0 m/s, from the end of the platform.

6. Consider the following situations. For each, state whether or not you would apply energy methods, force/projectile motion methods, or either to solve the exercise. You don't have to solve the exercise, but you can if you wish. (a) Find the maximum height reached by a ball fired straight up from level ground with a speed of 8.0 m/s. (b) Find the maximum height reached by a ball launched from level ground at a 45˚ angle above the horizontal if its launch speed is 8.0 m/s. (c) Find the time taken by the ball in part (b) to reach maximum height. (d) Determine which of the balls, the one in (a) or the one in (b), returns to ground level with the higher speed. (e) Determine the horizontal distance traveled by the ball in (b) before it returns to ground level.

7. You drop a large rock on an empty soda can, crushing the can. (a) Is mechanical energy conserved in this process? Explain. (b) Is energy conserved in this process? Explain.

8. A block of mass m is released from rest at a height h above the base of a frictionless loop-the-loop track, as shown in Figure 7.16. The loop has a radius R. In this situation, $h = 3R$, and, defining the block's gravitational potential energy to be zero at point a, the block's gravitational potential energy at point b is twice the size of the block's kinetic energy at point b. Sketch energy bar graphs showing the block's gravitational potential energy, kinetic energy, and total mechanical energy at (a) the starting point; (b) point a; (c) point b.

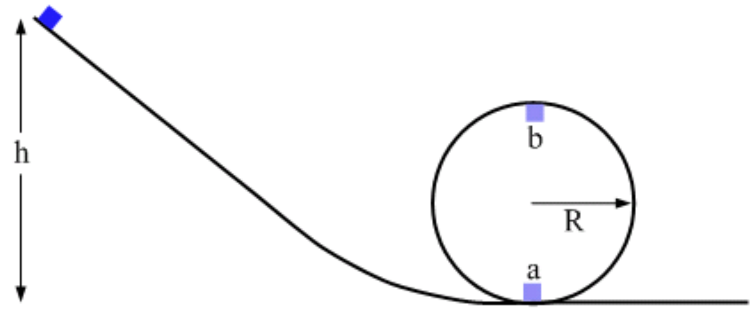

Figure 7.16: A block released from rest from a height h above the bottom of a loop-the-loop track, for Exercise 8.

9. Two boxes, A and B, are released simultaneously from rest from the top of ramps that have the same shape. Box A slides without friction down its ramp, while a kinetic friction force acts on box B as it slides down its ramp. The two boxes have the same mass. For the two boxes, plot the following as a function of time: (a) the kinetic energy; (b) the gravitational potential energy, taking the bottom of the ramp to be zero; (c) the total mechanical energy. There are no numbers here, so just show the general trend on each graph.

10. Repeat Exercise 9, but now plot the graphs as a function of distance traveled along the ramp instead of as a function of time.

11. A block is sliding along a frictionless horizontal surface with a speed v when it encounters a spring. The spring compresses, bringing the spring momentarily to rest, and then the spring returns to its original length, reversing the direction of the block's motion. If the block moves away from the spring at speed v, how can we explain what the spring has done in terms of conservation of energy? Note: this is a preview of how we will handle energy conservation for springs in Chapter 12. Hint: is there a parallel between what the spring does to the block and what the force of gravity does to the block if we toss the block straight up in the air?

12. Comment on the applicability of conservation of energy, conservation of mechanical energy, and momentum conservation in each of the following situations. (a) A car accelerates from rest. (b) In six months, the Earth goes halfway around the Sun. (c) Two football players collide and come to rest on the ground. (d) A diver leaps from a cliff and plunges toward the ocean below.

Exercises 13 – 16 deal with various aspects of the same situation.

13. A ball with a mass of 200 g is tied to a light string with a length of 2.4 m. The end of the string is tied to a hook, and the ball hangs motionless below the hook. Keeping the string taut, you move the ball back and up until it is a vertical distance of 1.25 m above its equilibrium point. You then release the ball from rest. (a) What is the highest speed the ball achieves in its subsequent motion? (b) Where does the ball achieve this maximum speed? (c) What is the maximum height reached by the ball in its subsequent motion? (d) Of the three numerical values stated in this exercise, which one(s) do you actually require to solve the problem?

14. Take a ball with a mass of 200 g and drop it from rest. (a) When the ball has fallen a distance of 1.25 m, how fast is it going? (b) How does this speed compare to the maximum speed of the identical ball in Exercise 13? Briefly explain this result. (c) Which ball takes longer to drop through a distance of 1.25 m? Justify your answer.

15. Consider the ball in Exercise 13. (a) Is it reasonable to assume that the work done by non-conservative forces is negligible over the time during which the ball swings down through the equilibrium position and up to its maximum height point on the other side? Why or why not? (b) If we watch this ball for a long time, it will eventually stop and hang motionless below the hook. Explain, in terms of energy conservation, why the ball eventually comes to rest. (c) In part (b), how much work is done by resistive forces in bringing the ball to rest?

16. Consider the ball in Exercise 13. Assuming that mechanical energy is conserved (that friction and air resistance are negligible), graph the ball's potential energy, kinetic energy, and total energy as a function of height above the equilibrium position. Take the zero of potential energy to be the equilibrium position.

Exercises 17 – 20 are designed to give you some practice in applying the general method of solving a problem involving energy conservation. For each exercise, begin with the following: (a) Sketch a diagram of the situation, showing the system in at least two states that you will relate by using energy conservation. (b) Write out equation 7.1, and define a zero level for gravitational potential energy. It is usually most convenient to define a zero level so that the initial and/or final gravitational potential energy terms are zero. (c) Identify which, if any of the terms in the equation equal zero, and explain why they are zero.

17. You drop your keys, releasing them from rest from a height of 1.2 m above the floor. The goal of this exercise is to use energy conservation to determine the speed of the keys just before they reach the floor. Assume $g = 9.8 \text{ m/s}^2$. Parts (a) – (c) as above. (d) Use the remaining terms in the equation to find the speed of the keys before impact.

18. During a tennis match, you mis-hit the ball, making the ball go straight up in the air. The ball, which has a mass of 57 g, reaches a maximum height of 7.0 m above the point at which you hit it, and the ball's velocity just before you hit it was 12 m/s directed horizontally. The goal of the exercise is to determine how much work your racket did on the ball. Parts (a) – (c) as described above. (d) Determine the work the racket did on the ball. (e) Would your answer to part (d) change if the initial velocity was not horizontal but had the same magnitude?

19. You and your bike have a combined mass of 65 kg. Starting from rest, you pedal to the top of a hill, arriving there with a speed of 6.0 m/s. The net work done on you and the bike by non-conservative forces during the ride is 1.5×10^4 J. The goal of the exercise is to determine the height difference between your starting point and the top of the hill. Parts (a) – (c) as described above. (d) Determine the height difference between your start and end points.

20. A block slides back and forth, inside a frictionless hemispherical bowl. The block's speed is 20 cm/s when it is halfway (vertically) between the lowest point in the bowl and the point where it reaches its maximum height. The goal of the exercise is to determine the maximum height of the block, relative to the bottom of the bowl. Parts (a) – (c) as described above. (d) Determine the block's maximum height.

Exercises 21 – 25 involve energy bar graphs.

21. You throw a ball to your friend, launching it at an angle of 45° from the horizontal. Neglect air resistance, define the zero of gravitational potential energy to be the height from which you release the ball, and assume your friend catches the ball at the same height from which you released it. Draw a set of energy bar graphs, showing the ball's gravitational potential energy and the kinetic energy, for each of the following points: (a) the launch point; (b) the point at which the ball is halfway, vertically, between the launch point and the maximum height; (c) the point where it reaches maximum height.

22. You are on your bicycle at the top of an incline that has a constant slope. You release your brakes and coast down the incline with constant acceleration, taking a time T to reach the bottom. Neglecting all resistive forces, and taking the zero of gravitational potential energy to be at the bottom of the incline, sketch a set of energy bar graphs, showing your gravitational potential energy and kinetic energy for the following points: (a) your starting point (b) at a time of $T/2$ after you start to coast (c) halfway down the incline (d) at the bottom of the incline.

23. Repeat Exercise 22, but this time make it more realistic by accounting for a resistive force. The bar graphs should show your gravitational potential energy, kinetic energy, and total mechanical energy, with a separate bar graph for the work done by the resistive force. Assume the resistive force is constant, and that it causes your kinetic energy at the bottom of the incline to be half of what it would be if the resistive force were not present. If the total time it takes you to come down the incline is now T', in part (b) the energy bar graphs should represent the energies at a time of $T'/2$ after you start to coast.

24. You show three of your friends a set of energy bar graphs. The bar graphs represent the energy, at the release point, of a ball hanging down from a string that you have pulled up and back and released from rest, so it swings with a pendulum motion. These bar graphs are the "Initial" set in Figure 7.17. You ask your three friends to draw the bar graphs representing the ball's energy as it passes through the lowest point in its swing. Margot draws the set of bar graphs shown at the upper right, Jean the set on the lower left, and Wei the set on the lower right. (a) Are the sets of bar graphs, drawn by your friends, consistent with the idea of energy conservation? Justify your answer. (b) Which (if any) of your friends has the right answer? (b) If Jean has the right answer, from what height above the lowest point was the ball released? Assume each of the small rectangles making up the bar graphs represents 1 J, that $g = 10$ m/s^2, and that the ball's mass is 1.0 kg.

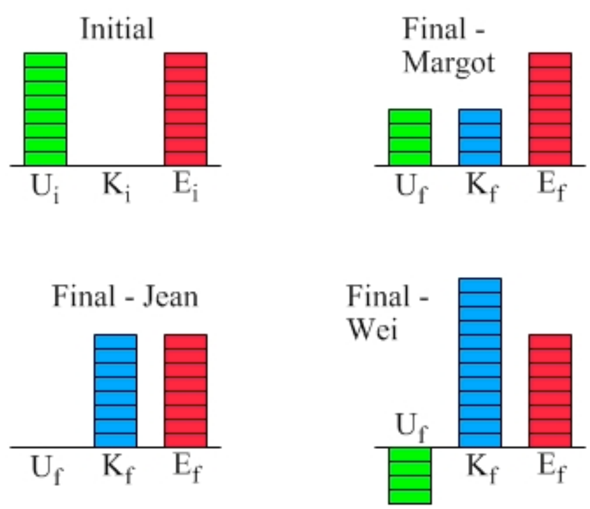

Figure 7.17: Energy bar graphs, for Exercise 24.

Exercises 25 – 29 are designed to give you some practice in applying the general method for solving a problem that involves a collision. For each exercise, start with the following parts: (a) Draw a diagram showing the objects immediately before and immediately after the collision. (b) Apply equation 7.2, the momentum-conservation equation. Choose a positive direction, and account for the fact that momentum is a vector with appropriate + and – signs.

25. A car with a mass of 2000 kg is traveling at a speed of 50 km/h on an icy road when it collides with a stationary truck. The two vehicles stick together after the collision, and their speed after the collision is 10 km/h. The goal of this exercise is to find the mass of the truck. Parts (a) – (b) as described above. (c) Solve for the mass of the truck.

26. Repeat Exercise 25, except that, in this case, the truck is moving at 20 km/h in the opposite direction of the car before the collision, and, after the collision, the two vehicles move together at 10 km/h in the same direction the truck was traveling initially.

27. Two identical air-hockey pucks experience a one-dimensional elastic collision on a frictionless air-hockey table. Before the collision, puck A is moving at a velocity of v to the right, while puck B has a velocity of $2v$ to the left. The goal of the exercise is to determine the velocity of each puck after the collision. Parts (a) – (b) as described above. (c) Use the elasticity relationship to get a second connection between the two final velocities. (d) Find the two final velocities.

28. Repeat Exercise 27, except that in this case puck B has a mass twice as large as the mass of puck A.

29. While shooting pool, you propel the cue ball at a speed of 1.0 m/s. It collides with the 8-ball (initially stationary), propelling the 8-ball into a corner pocket. The cue ball is deflected by 42˚ from its original path by the collision, and it moves away from the collision with a speed of 0.70 m/s. The goal of this exercise is to determine the magnitude and direction of the 8-ball's velocity after the collision. The cue ball has a little more mass than the 8-ball, but assume for this exercise that the masses are equal. Parts (a) – (b) as described above. For part (b), set up a table to keep track of the x and y components of the momenta of the two balls before and after the collision. (c) Use the information in the table to determine the velocity of the 8-ball after the collision.

Exercises 30 – 32 involve combining energy conservation and momentum conservation.

30. As shown in Figure 7.18, a wooden ball with a mass of 250 g swings back and forth on a string, pendulum style, reaching a maximum speed of 4.00 m/s when it passes through its equilibrium position. Use $g = 10.0$ m/s^2. (a) What is the maximum height above the equilibrium position reached by the ball in its motion? (b) At one instant, when the ball is at its equilibrium position and moving left at 4.00 m/s, it is struck by a bullet with a mass of 10.0 g. Before the collision, the bullet has a velocity of 300 m/s to the right. The bullet passes through the ball and emerges with a velocity of 100 m/s to the right. What is the magnitude and direction of the ball's velocity immediately after the collision? Neglect any change in mass for the ball.

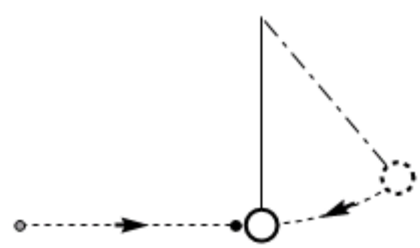

Figure 7.18: A bullet colliding with a ball on a string, for Exercise 30.

31. A pendulum, consisting of a ball of mass m on a light string of length 1.0 m, is swung back to a 45˚ angle and released from rest. The ball swings down and, at its lowest point, collides with a block of mass $2m$ that is on a frictionless horizontal surface. After the collision, the block slides 1.0 m across the frictionless surface and an additional 0.50 m across a horizontal surface where the coefficient of friction between the block and the surface is 0.10. (a) What is the block's speed after the collision? (b) What is the velocity of the ball after the collision? (c) Is the ball-block collision elastic, inelastic, or completely inelastic? Justify your answer. Use $g = 10$ m/s^2 to simplify the calculations.

32. Two balls hang from strings of the same length. Ball A, with a mass m, is swung back to a height h above its equilibrium position. Ball A is released from rest and swings down and hits ball B, which has a mass of $3m$. Assuming that all collisions between the balls are elastic, describe the subsequent motion of the two balls.

General Problems and Conceptual Questions

33. A Boeing 747 has a mass of about 3 x 10^5 kg, a cruising speed of 965 km/h, and cruises at an altitude of about 10 km. (a) Assuming the plane starts from rest at an airport at sea level, how much energy is required to reach its cruising height and altitude? Neglect air resistance in this calculation. (b) Comment on the validity of neglecting air resistance.

34. One way to estimate your power is to time yourself as you run up a flight of stairs. (a) In terms of simplifying the analysis, should you start from rest at the bottom of the stairs or should you give yourself a running start and try to keep your speed as constant as possible? (b) Which of the following distance(s) is/are most important for the power calculation, the magnitude of the straight-line displacement along the staircase or the vertical or horizontal components of this displacement? (c) Find a staircase and a stopwatch and estimate your average power.

35. A toy car rolls along a track. Starting from rest, the car drops gradually to a level 2.0 m below its starting point and then gradually rises to a level 1.0 m below its starting point, where it is traveling at a speed v_f. The goal of the exercise is to find v_f. Assume that mechanical energy is conserved, and use $g = 9.8$ m/s^2. (a) Should you first use energy conservation to relate the initial point to the lowest point, and then apply energy conservation to relate the lowest point to the final point, or can you relate the initial point directly to the final point using energy conservation? Justify your answer. (b) Find v_f.

36. Ball A is released from rest at a height h above the floor and has a speed v when it reaches the floor. (a) If ball B, which has half the mass of ball A, is released from rest at a height of $4h$ above the floor, what is its speed when it reaches the floor? Neglect air resistance. (b) What if ball B had double the mass of A instead?

37. A box with a mass of 2.0 kg slides at a constant speed of 3.0 m/s down a ramp. The ramp is in the shape of a 3-4-5 triangle, as shown in Figure 7.19. (a) Does friction act on the box? Briefly justify your answer. (b) If you decide that friction does act on the box, calculate the coefficient of kinetic friction between the box and the ramp. (c) The mass and speed of the box are given, but could you solve this exercise without them? Briefly explain.

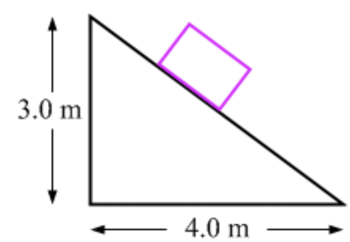

Figure 7.19: A box sliding on an incline, for Exercise 37.

38. A ball is launched with an initial velocity of 28.3 m/s, at a 45° angle, from the top of a cliff that is 10.0 m above the water below. Use $g = 10.0 \text{ m/s}^2$ to simplify the calculations. (a) What is the ball's speed when it hits the water? (b) What is the ball's speed when it reaches its maximum height? (c) What is the maximum height (measured from the water) reached by the ball in its flight? Note: you could answer these questions using projectile motion methods, but try using an energy conservation approach instead.

39. You drop a 50-gram Styrofoam ball from rest. After falling 80 cm, the ball hits the ground with a speed of 3.0 m/s. Use $g = 10 \text{ m/s}^2$. (a) With what speed would the ball have hit the ground if there had been no air resistance? (b) How much work did air resistance do on the ball during its fall? (c) Is your answer to (b) positive, negative, or zero? Explain.

40. As shown in Figure 7.20, two frictionless ramps are joined by a rough horizontal section that is 4.0 m long. A block is placed at a height of 124 cm up the ramp on the left and released from rest, reaching a maximum height of 108 cm on the ramp on the right before sliding back down again. (a) How far up the ramp on the left does the block get in its subsequent motion? (b) What is the coefficient of kinetic friction between the block and the rough surface? (c) At what location does the block eventually come to a permanent stop?

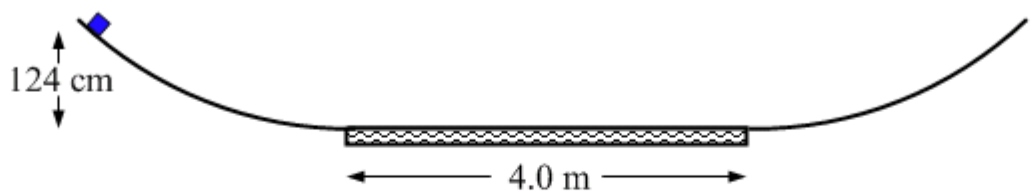

Figure 7.20: A block released from rest 124 cm above the bottom of a track. The curved parts of the track are frictionless, while there is some friction between the track and the block on the 4.0-meter long horizontal section of the track. For Exercises 40 – 42.

41. Consider again the situation described in Exercise 40. If you took this apparatus to the Moon, where the acceleration due to gravity is one-sixth of what it is on Earth, and released the block from rest from the same point, what (if anything) would change about the motion?

42. Consider again the situation described in Exercise 40. Now, a different block is released from the point shown, 124 cm above the flat part of the track. This block does not reach the other side at all, but instead it stops somewhere in the rough section of the track. (a) What could be different about this block compared to the block in exercise 35? (b) What, if anything, can you say about the coefficient of kinetic friction between this block and the rough surface based on the information given here?

43. Two ramps have the same length, height, and angle of incline. One of the ramps is frictionless, while for the second ramp the coefficient of kinetic friction between the ramp and a particular block is $\mu_K = 0.25$. You release the block from rest at the top of the frictionless ramp, and when it reaches the bottom of the incline its kinetic energy is a particular value K_1. When you repeat the process with the second ramp, you find that the block's kinetic energy at the bottom of the ramp is 80% of K_1. At what angle with respect to the horizontal are the ramps inclined?

44. Two blocks are connected by a string that passes over a massless, frictionless pulley, as shown in Figure 7.21. Block A, with a mass m_A = 2.0 kg, rests on a ramp measuring 3.0 m vertically and 4.0 m horizontally. Block B hangs vertically below the pulley. Note that you can solve this exercise entirely using forces and the constant-acceleration equations, but see if you can apply energy ideas instead. Use g = 10 m/s^2. When the system is released from rest, block A accelerates up the slope and block B accelerates straight down. When block B has fallen through a height h = 2.0 m, its speed is v = 6.0 m/s. (a) At any instant in time, how does the speed of block A compare to that of block B? (b) Assuming that no friction is acting on block A, what is the mass of block B?

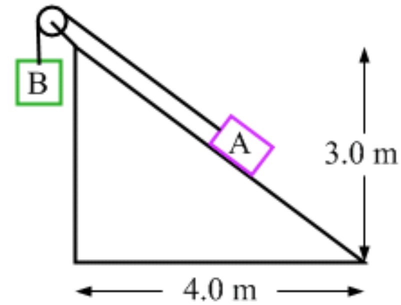

Figure 7.21: Two blocks connected by a string passing over a pulley, for Exercises 44 and 45.

45. Repeat Exercise 44, this time accounting for friction. If the coefficient of kinetic friction for the block A – ramp interaction is 0.625, what is the mass of block B?

46. Tarzan, with a mass of 80 kg, wants to swing across a ravine on a vine, but the cliff on the far side of the ravine is 1.0 m higher than the cliff where Tarzan is now and 2.0 m higher than Tarzan's lowest point in his swing. Use g = 10 m/s^2 to simplify the calculations. (a) If Tarzan wants to reach the cliff on the far side, how much kinetic energy must he have when he jumps off the cliff where he starts? (b) How fast is Tarzan going at the bottom of his swing? (c) If Tarzan swings along a circular arc of radius 10 m, what is the tension in the vine when Tarzan reaches the lowest point in his swing?

47. A block of mass m is released from rest at a height h above the base of a frictionless loop-the-loop track, as shown in Figure 7.22. The loop has a radius R. When the block is at point b, at the top of the loop, the normal force exerted on the block by the track is equal to mg. (a) What is h, in terms of R? (b) What is the normal force acting on the block at point a, at the bottom of the loop?

48. Consider again the situation described in Exercise 47, and shown in Figure 7.22. What is the block's speed at (a) point a (b) point b? Your answers should be given in terms of m, g, and/or R only.

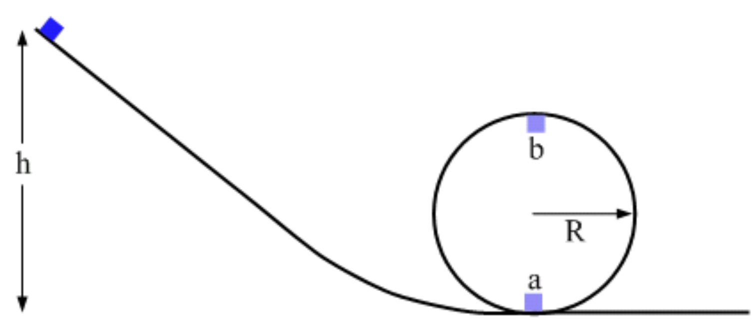

Figure 7.22: A block released from rest from a height h above the bottom of a loop-the-loop track, for Exercises 47 – 49.

49. A block of mass m is released from rest, at a height h above the base of a frictionless loop-the-loop track, as shown in Figure 7.22. The loop has a radius R. What is the minimum value of h necessary for the block to make it all the way around the loop without losing contact with the track? Express your answer in terms of R.

50. On an incline, set up a race between a low-friction block that slides easily down the incline and a ball that rolls down the incline. A good approximation of a low-friction block is a toy car, or a wheeled cart, with low-friction bearings in its wheels. (a) Predict the winner of the race if you release both objects from rest. Run the race to check your prediction. (b) If we assume that mechanical energy is conserved for both objects over the course of the race, how can you explain the result? Note: this is a preview of how we will handle energy conservation for rolling objects in chapter 11.

51. Two air-hockey pucks collide on a frictionless air-hockey table, as shown in Figure 7.23. Before the collision puck A, with a mass of m, is traveling at 20 m/s to the right, while puck B, with a mass of $4m$, is stationary. After the collision puck A is traveling to the left at 4.0 m/s. (a) What is the velocity of puck B after the collision? (b) Is this collision super-elastic, elastic, or inelastic? Justify your answer.

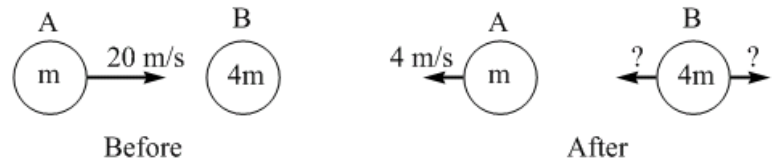

Figure 7.23: Two air-hockey pucks just before and just after they collide, for Exercise 51.

52. Two identical carts experience a collision on a horizontal track. Immediately before the collision, cart 1 is moving at speed v to the right, directly toward cart 2, which is moving at speed v to the left. If the collision is completely inelastic then: (a) What is the velocity of cart 1 immediately after the collision? (b) Is kinetic energy, or momentum, conserved in this collision? (c) What is the velocity of the system's center of mass before the collision? (d) What is the velocity of the system's center of mass after the collision?

53. Two carts experience a collision on a horizontal track. Immediately before the collision, cart 1 is moving at speed v to the right, directly toward cart 2, which is moving at speed v to the left. If cart 2's mass is three times larger than cart 1's mass, and the collision is completely inelastic, what is the velocity of cart 1 immediately after the collision?

54. A one-dimensional collision takes place between object 1, which has a mass m_1 and a velocity $\vec{v}_{1i}$ that is directed toward object 2, which has mass m_2 and is initially stationary.

    (a) If the collision is completely inelastic, what is the velocity of the two objects immediately after the collision? (b) If the collision is completely elastic, what are the velocities of the two objects after the collision? Hint: for part (b) make use of the elasticity, k, defined in equation 7.4. Making use of the result of part (b), (c) under what condition is object 1 stationary after the collision? (d) Under what condition does object 1 reverse its direction because of the collision?

55. A one-dimensional elastic collision between an object of mass m and velocity $+\vec{v}$, and a second object of mass $3m$ and velocity $-\vec{v}$, is a special case. (a) Find the velocities of the two objects after the collision to see why. Note that you can arrange such a collision by placing a baseball or tennis ball on top of a basketball and letting the balls fall straight down from rest. (b) Assuming the masses of the basketball and baseball are in the special 3:1 ratio, that all collisions are elastic, and that the balls are dropped from a height h above the floor, how high up should the baseball go after the collision?

56. Two cars of the same mass collide at an intersection. Just before the collision, one car is traveling east at 30 km/h and the other car is traveling south at 40 km/h. If the collision is completely inelastic, so that the two cars move as one object after the collision, what is the speed of the cars immediately after the collision?

57. Because you are an accident reconstruction expert, working with the local police department, you are called to the scene of an accident at a local parking lot. The speed limit posted in the parking lot is 20 miles per hour. Although nobody was hurt in the accident, the police officer in charge would like to determine whether or not anyone was at fault, for insurance purposes. When you reconstruct the accident, you find that the cars, an Acura MDX and a Volkswagen Jetta, were approaching one another at a 90˚ angle. After the collision, the cars locked together and slid for 3.3 m, traveling along a path at 45˚ to their original paths, before coming to rest. You also determine that the Acura has a mass of 2000 kg, the Jetta's mass is 1500 kg, and the coefficient of kinetic friction for the car tires sliding on the dry pavement is somewhere between 0.75 and 0.85. (a) Which car was traveling faster before the collision? (b) Should either one of the drivers be given a speeding ticket and be determined to be at fault for the accident? Justify your answer.

58. A wooden block with a mass of 200 g rests on two supports. A piece of sticky chewing gum with a mass of 50 g is fired straight up at the block, colliding with the block when the gum's speed is 10 m/s. The gum sticks to the block, and we want to find the maximum height reached by the block and gum in its subsequent motion. (a) To solve for this maximum height, should we set the gum's kinetic energy before the collision equal to the gravitational potential energy of the gum-block system after the collision? Why or why not? (b) What is the maximum height reached by the gum-block system?

59. Re-do Exploration 7.6, but solve it another way, using a whole-vector approach by adding vectors graphically. First, add the momentum of the first object before the collision to that of the second object before the collision. That resultant vector is the total momentum before the collision, and because momentum is conserved, it is also the total momentum after the collision. Using this fact and the known momentum of the second object after the collision, you should be able to use the cosine law to find the momentum of the first object after the collision. Does the result match what we found using the component method in Exploration 7.6?

60. You release a rubber ball, from rest, at a point 1.00 m above the floor, and you observe that the ball bounces back to a height of 87.0 cm. (a) What is the net impulse experienced by the ball, which has a mass of 50.0 g, while it is in contact with the floor? (b) What is the elasticity, k, characterizing the collision between the ball and the floor? (c) Assuming the elasticity is the same for each collision, how many times will the ball bounce off the floor before losing half its mechanical energy?

61. Two different collisions take place in a large level parking lot, which is otherwise empty of vehicles. In collision A, a car with mass M traveling at a speed of v_i , runs into a stationary truck of mass $4M$. In collision B, a truck of mass $4M$, traveling at the same speed v_i , runs into a stationary car of mass M. In both collisions, the two vehicles stick together and the combined object skids to a halt because of friction. Assume that the force of friction is constant and the same for both collisions. (a) What is the speed of the combined object immediately after (i) collision A? (ii) collision B? (b) If, in collision A, the combined object slides for a time T and a distance D after the collision, for how long and through what distance does the combined object slide in collision B?

62. Comment on the statements made by two students who are working together to solve the following problem, and state the answer to the problem. A cart with a mass of 2.0 kg has a velocity of 4.0 m/s in the positive *x*-direction. The first cart collides with a second cart, which is identical to the first and has a velocity of 2.0 m/s in the negative *x*-direction. After the collision, the first cart has a velocity of 1.0 m/s in the positive *x*-direction. What is the velocity of the second cart after the collision?

Martha: This is pretty easy. We can use momentum conservation, and we don't even have to worry about the masses, because the masses are the same. So, we have a total of 4 plus 2 equals 6 meters per second before the collision, so we must have a total of 6 meters per second afterwards, too. The first cart has 1 meter per second afterwards, so the second cart must have 5 meters per second afterwards.

George: But, what direction is it going afterwards? We need to give the velocity, so is it in the plus x-direction or the minus x-direction?

Martha: It can't be minus x, because that would mean the two carts would pass through each other. It must bounce back, and go in the plus x-direction.