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Problem difficulty is labeled as I (straightforward) to III (challenging).

Problems labeled [worksheet icon] can be done on a Dynamics Worksheet.
Problems labeled [shaded] integrate significant material from earlier chapters.

CONCEPTUAL QUESTIONS

1. Tarzan swings through the jungle on a vine. At the lowest point of his swing, is the tension in the vine greater than, less than, or equal to the gravitational force on Tarzan? Explain.
2. A car runs out of gas while driving down a hill. It rolls through the valley and starts up the other side. At the very bottom of the valley, which of the free-body diagrams in FIGURE Q8.2 is correct? The car is moving to the right, and drag and rolling friction are negligible.

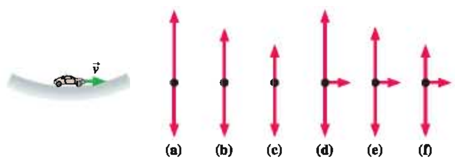


FIGURE Q8.2

3. FIGURE Q8.3 is a bird's-eye view of particles moving in horizontal circles on a tabletop. All are moving at the same speed. Rank in order, from largest to smallest, the tensions T_a to T_d. Give your answer in the form a > b = c > d and explain your ranking.

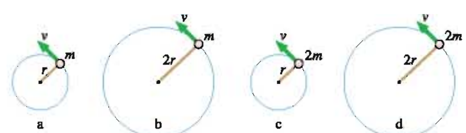


FIGURE Q8.3

4. A ball on a string moves in a vertical circle. When the ball is at its lowest point, is the tension in the string greater than, less than, or equal to the gravitational force on the ball? Explain.
5. FIGURE Q8.5 shows two balls of equal mass moving in vertical circles. Is the tension in string A greater than, less than, or equal to the tension in string B if the balls travel over the top of the circle (a) with equal speed and (b) with equal angular velocity?

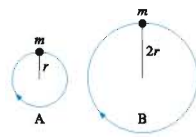


FIGURE Q8.5

6. Ramon and Sally are observing a toy car speed up as it goes around a circular track. Ramon says, "The car's speeding up, so there must be a net force parallel to the track." "I don't think so," replies Sally. "It's moving in a circle, and that requires centripetal acceleration. The net force has to point to the center of the circle." Do you agree with Ramon, Sally, or neither? Explain.
7. A jet plane is flying on a level course at constant speed. The engines are at full throttle.
   a. What is the net force on the plane? Explain.
   b. Draw a free-body diagram of the plane as seen from the side with the plane flying to the right. Name (don't just label) any and all forces shown on your diagram.
   c. Airplanes bank when they turn. Draw a free-body diagram of the plane as seen from behind as it makes a right turn.
   d. *Why* do planes bank as they turn? Explain.
8. A small projectile is launched parallel to the ground at height $h = 1$ m with sufficient speed to orbit a completely smooth, airless planet. A bug rides inside a small hole inside the projectile. Is the bug weightless? Explain.
9. You can swing a ball on a string in a vertical circle if you swing it fast enough. But if you swing too slowly, the string goes slack as the ball nears the top. Explain *why* there's a minimum speed to keep the ball moving in a circle.
10. A golfer starts with the club over her head and swings it to reach maximum speed as it contacts the ball. Halfway through her swing, when the golf club is parallel to the ground, does the acceleration vector of the club head point (a) straight down, (b) parallel to the ground, approximately toward the golfer's shoulders, (c) approximately toward the golfer's feet, or (d) toward a point above the golfer's head? Explain.

EXERCISES AND PROBLEMS

Exercises

Section 8.1 Dynamics in Two Dimensions

1. II As a science fair project, you want to launch an 800 g model rocket straight up and hit a horizontally moving target as it passes 30 m above the launch point. The rocket engine provides a constant thrust of 15.0 N. The target is approaching at a speed of 15 m/s. At what horizontal distance between the target and the rocket should you launch?
2. II A 500 g model rocket is on a cart that is rolling to the right at a speed of 3.0 m/s. The rocket engine, when it is fired, exerts an 8.0 N thrust on the rocket. Your goal is to have the rocket pass through a small horizontal hoop that is 20 m above the launch point. At what horizontal distance left of the hoop should you launch?

3. ‖ A 4.0×10^{10} kg asteroid is heading directly toward the center of the earth at a steady 20 km/s. To save the planet, astronauts strap a giant rocket to the asteroid perpendicular to its direction of travel. The rocket generates 5.0×10^9 N of thrust. The rocket is fired when the asteroid is 4.0×10^6 km away from earth. You can ignore the earth's gravitational force on the asteroid and their rotation about the sun.
   a. If the mission fails, how many hours is it until the asteroid impacts the earth?
   b. The radius of the earth is 6400 km. By what minimum angle must the asteroid be deflected to just miss the earth?
   c. The rocket fires at full thrust for 300 s before running out of fuel. Is the earth saved?

Section 8.2 Velocity and Acceleration in Uniform Circular Motion

Section 8.3 Dynamics of Uniform Circular Motion

4. | A 1500 kg car drives around a flat 200-m-diameter circular track at 25 m/s. What are the magnitude and direction of the net force on the car? What causes this force?
5. | A 1500 kg car takes a 50-m-radius unbanked curve at 15 m/s. What is the size of the friction force on the car?
6. ‖ A 200 g block on a 50-cm-long string swings in a circle on a horizontal, frictionless table at 75 rpm.
   a. What is the speed of the block?
   b. What is the tension in the string?
7. ‖ In the Bohr model of the hydrogen atom, an electron (mass $m = 9.1 \times 10^{-31}$ kg) orbits a proton at a distance of 5.3×10^{-11} m. The proton pulls on the electron with an electric force of 8.2×10^{-8} N. How many revolutions per second does the electron make?
8. ‖ A highway curve of radius 500 m is designed for traffic moving at a speed of 90 km/hr. What is the correct banking angle of the road?
9. ‖ Suppose the moon were held in its orbit not by gravity but by a massless cable attached to the center of the earth. What would be the tension in the cable? Use the table of astronomical data inside the back cover of the book.
10. ‖ A 30 g ball rolls around a 40-cm-diameter L-shaped track, shown in FIGURE EX8.10, at 60 rpm. What is the magnitude of the net force that the track exerts on the ball? Rolling friction can be neglected.

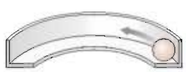


FIGURE EX8.10

Section 8.4 Circular Orbits

11. ‖ A satellite orbiting the moon very near the surface has a period of 110 min. What is the moon's acceleration due to gravity? Astronomical data are inside the back cover of the book.
12. ‖ What is the acceleration due to gravity of the sun at the distance of the earth's orbit? Astronomical data are inside the back cover of the book.

Section 8.5 Fictitious Forces

Section 8.6 Why Does the Water Stay in the Bucket?

13. | A car drives over the top of a hill that has a radius of 50 m. What maximum speed can the car have without flying off the road at the top of the hill?
14. ‖ The weight of passengers on a roller coaster increases by 50% as the car goes through a dip with a 30 m radius of curvature. What is the car's speed at the bottom of the dip?
15. ‖ A roller coaster car crosses the top of a circular loop-the-loop at twice the critical speed. What is the ratio of the normal force to the gravitational force?
16. ‖ The normal force equals the magnitude of the gravitational force as a roller coaster car crosses the top of a 40-m-diameter loop-the-loop. What is the car's speed at the top?
17. ‖ A student has 65-cm-long arms. What is the minimum angular velocity (in rpm) for swinging a bucket of water in a vertical circle without spilling any? The distance from the handle to the bottom of the bucket is 35 cm.

Section 8.7 Nonuniform Circular Motion

18. | A new car is tested on a 200-m-diameter track. If the car speeds up at a steady 1.5 m/s^2, how long after starting is the magnitude of its centripetal acceleration equal to the tangential acceleration?
19. ‖ A toy train rolls around a horizontal 1.0-m-diameter track. The coefficient of rolling friction is 0.10.
   a. What is the magnitude of the train's angular acceleration after it is released?
   b. How long does it take the train to stop if it's released with an angular speed of 30 rpm?

Problems

20. ‖ A popular pastime is to see who can push an object closest to the edge of a table without its going off. You push the 100 g object and release it 2.0 m from the table edge. Unfortunately, you push a little too hard. The object slides across, sails off the edge, falls 1.0 m to the floor, and lands 30 cm from the edge of the table. If the coefficient of kinetic friction is 0.50, what was the object's speed as you released it?
21. ‖ Alice tapes a small, 200 g model rocket to a 400 g ice hockey puck. The rocket generates 8.0 N of thrust. Alice orients the puck so that the rocket's nose points in the positive y-direction, then pushes the puck across frictionless ice in the positive x-direction with a speed of 2.0 m/s. The rocket fires at the exact instant the puck crosses the origin. Find an equation $y(x)$ for the puck's trajectory, then graph it.
22. ‖ Sam (75 kg) takes off up a 50-m-high, 10° frictionless slope on his jet-powered skis. The skis have a thrust of 200 N. He keeps his skis tilted at 10° after becoming airborne, as shown in FIGURE P8.22. How far does Sam land from the base of the cliff?

FIGURE P8.22

23. ‖ A motorcycle daredevil plans to ride up a 2.0-m-high, 20° ramp, sail across a 10-m-wide pool filled with hungry crocodiles, and land at ground level on the other side. He has done this stunt many times and approaches it with confidence. Unfortunately, the motorcycle engine dies just as he starts up the ramp. He is going 11 m/s at that instant, and the rolling friction of his rubber tires is not negligible. Does he survive, or does he become crocodile food?

24. ‖ A 5000 kg interceptor rocket is launched at an angle of 44.7°. The thrust of the rocket motor is 140,700 N.
 a. Find an equation $y(x)$ that describes the rocket's trajectory.
 b. What is the shape of the trajectory?
 c. At what elevation does the rocket reach the speed of sound, 330 m/s?

25. ‖ A rocket-powered hockey puck has a thrust of 2.0 N and a total mass of 1.0 kg. It is released from rest on a frictionless table, 4.0 m from the edge of a 2.0 m drop. The front of the rocket is pointed directly toward the edge. How far does the puck land from the base of the table?

26. ‖ A 500 g model rocket is resting horizontally at the top edge of a 40-m-high wall when it is accidentally bumped. The bump pushes it off the edge with a horizontal speed of 0.5 m/s and at the same time causes the engine to ignite. When the engine fires, it exerts a constant 20 N horizontal thrust away from the wall.
 a. How far from the base of the wall does the rocket land?
 b. Describe the trajectory of the rocket while it travels to the ground.

27. ‖ Communications satellites are placed in circular orbits where they stay directly over a fixed point on the equator as the earth rotates. These are called *geosynchronous orbits.* The altitude of a geosynchronous orbit is 3.58×10^7 m (≈22,000 miles).
 a. What is the period of a satellite in a geosynchronous orbit?
 b. Find the value of g at this altitude.
 c. What is the weight of a 2000 kg satellite in a geosynchronous orbit?

28. ‖ A 75 kg man weighs himself at the north pole and at the equator. Which scale reading is higher? By how much?

29. ‖ The father of Example 8.3 stands at the summit of a conical hill as he spins his 20 kg child around on a 5.0 kg cart with a 2.0-m-long rope. The sides of the hill are inclined at 20°. He again keeps the rope parallel to the ground, and friction is negligible. What rope tension will allow the cart to spin with the same 14 rpm it had in the example?

30. ‖ A 500 g ball swings in a vertical circle at the end of a 1.5-m-long string. When the ball is at the bottom of the circle, the tension in the string is 15 N. What is the speed of the ball at that point?

31. ‖‖ A concrete highway curve of radius 70 m is banked at a 15° angle. What is the maximum speed with which a 1500 kg rubber-tired car can take this curve without sliding?

32. ‖ A student ties a 500 g rock to a 1.0-m-long string and swings it around her head in a horizontal circle. At what angular speed, in rpm, does the string tilt down at a 10° angle?

33. ‖ A 5.0 g coin is placed 15 cm from the center of a turntable. The coin has static and kinetic coefficients of friction with the turntable surface of $\mu_s = 0.80$ and $\mu_k = 0.50$. The turntable very slowly speeds up to 60 rpm. Does the coin slide off?

34. ‖ You've taken your neighbor's young child to the carnival to ride the rides. She wants to ride The Rocket. Eight rocket-shaped cars hang by chains from the outside edge of a large steel disk. A vertical axle through the center of the ride turns the disk, causing the cars to revolve in a circle. You've just finished taking physics, so you decide to figure out the speed of the cars while you wait. You estimate that the disk is 5 m in diameter and the chains are 6 m long. The ride takes 10 s to reach full speed, then the cars swing out until the chains are 20° from vertical. What is the car's speed?

35. ‖ A *conical pendulum* is formed by attaching a 500 g ball to a 1.0-m-long string, then allowing the mass to move in a horizontal circle of radius 20 cm. FIGURE P8.35 shows that the string traces out the surface of a cone, hence the name.
 a. What is the tension in the string?
 b. What is the ball's angular speed, in rpm?

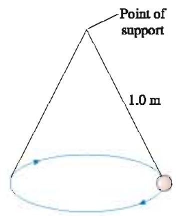


FIGURE P8.35

36. ‖ In an old-fashioned amusement park ride, passengers stand inside a 5.0-m-diameter hollow steel cylinder with their backs against the wall. The cylinder begins to rotate about a vertical axis. Then the floor on which the passengers are standing suddenly drops away! If all goes well, the passengers will "stick" to the wall and not slide. Clothing has a static coefficient of friction against steel in the range 0.60 to 1.0 and a kinetic coefficient in the range 0.40 to 0.70. A sign next to the entrance says "No children under 30 kg allowed." What is the minimum angular speed, in rpm, for which the ride is safe?

37. ‖ A 10 g steel marble is spun so that it rolls at 150 rpm around the *inside* of a vertically oriented steel tube. The tube, shown in FIGURE P8.37, is 12 cm in diameter. Assume that the rolling resistance is small enough for the marble to maintain 150 rpm for several seconds. During this time, will the marble spin in a horizontal circle, at constant height, or will it spiral down the inside of the tube?

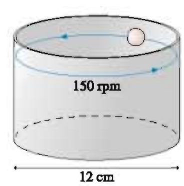


FIGURE P8.37

38. ‖ Three cars are driving at 25 m/s along the road shown in FIGURE P8.38. Car B is at the bottom of a hill and car C is at the top. Both hills have a 200 m radius of curvature. Suppose each car suddenly brakes hard and starts to skid. What is the tangential acceleration (i.e., the acceleration parallel to the road) of each car? Assume $\mu_k = 1.0$.

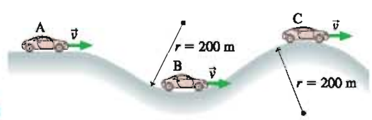


FIGURE P8.38

39. ‖ A 500 g ball moves in a vertical circle on a 102-cm-long string. If the speed at the top is 4.0 m/s, then the speed at the bottom will be 7.5 m/s. (You'll learn how to show this in Chapter 10.)
 a. What is the gravitational force acting on the ball?
 b. What is the tension in the string when the ball is at the top?
 c. What is the tension in the string when the ball is at the bottom?

40. ‖ While at the county fair, you decide to ride the Ferris wheel. Having eaten too many candy apples and elephant ears, you find the motion somewhat unpleasant. To take your mind off your stomach, you wonder about the motion of the ride. You estimate the radius of the big wheel to be 15 m, and you use your watch to find that each loop around takes 25 s.
 a. What are your speed and magnitude of your acceleration?

b. What is the ratio of your weight at the top of the ride to your weight while standing on the ground?
c. What is the ratio of your weight at the bottom of the ride to your weight while standing on the ground?

41. || In an amusement park ride called The Roundup, passengers stand inside a 16-m-diameter rotating ring. After the ring has acquired sufficient speed, it tilts into a vertical plane, as shown in FIGURE P8.41.

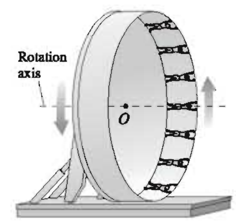


FIGURE P8.41

a. Suppose the ring rotates once every 4.5 s. If a rider's mass is 55 kg, with how much force does the ring push on her at the top of the ride? At the bottom?
b. What is the longest rotation period of the wheel that will prevent the riders from falling off at the top?

42. || You have a new job designing rides for an amusement park. In one ride, the rider's chair is attached by a 9.0-m-long chain to the top of a tall rotating tower. The tower spins the chair and rider around at the rate of 1.0 rev every 4.0 s. In your design, you've assumed that the maximum possible combined weight of the chair and rider is 150 kg. You've found a great price for chain at the local discount store, but your supervisor wonders if the chain is strong enough. You contact the manufacturer and learn that the chain is rated to withstand a tension of 3000 N. Will this chain be strong enough for the ride?

43. || Suppose you swing a ball in a vertical circle on a 1.0-m-long string. As you probably know from experience, there is a *minimum* angular velocity ω_{min} you must maintain if you want the ball to complete the full circle. If you swing the ball at $\omega < \omega_{min}$, then the string goes slack before the ball reaches the top of the circle. What is ω_{min}? Give your answer in rpm.

44. || A heavy ball with a weight of 100 N ($m = 10.2$ kg) is hung from the ceiling of a lecture hall on a 4.5-m-long rope. The ball is pulled to one side and released to swing as a pendulum, reaching a speed of 5.5 m/s as it passes through the lowest point. What is the tension in the rope at that point?

45. || It is proposed that future space stations create an artificial gravity by rotating. Suppose a space station is constructed as a 1000-m-diameter cylinder that rotates about its axis. The inside surface is the deck of the space station. What rotation period will provide "normal" gravity?

46. || Mass m_1 on the frictionless table of FIGURE P8.46 is connected by a string through a hole in the table to a hanging mass m_2. With what speed must m_1 rotate in a circle of radius r if m_2 is to remain hanging at rest?

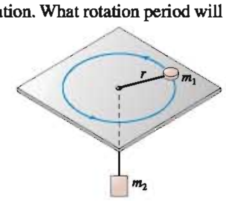


FIGURE P8.46

47. || A 100 g ball on a 60-cm-long string is swung in a vertical circle about a point 200 cm above the floor. The tension in the string when the ball is at the very bottom of the circle is 5.0 N. A very sharp knife is suddenly inserted, as shown in FIGURE P8.47, to cut the string directly below the point of support. How far to the right of where the string was cut does the ball hit the floor?

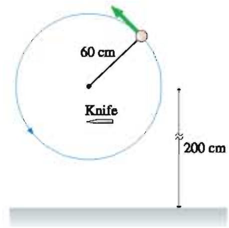


FIGURE P8.47

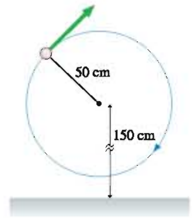


FIGURE P8.48

48. || A 60 g ball is tied to the end of a 50-cm-long string and swung in a vertical circle. The center of the circle, as shown in FIGURE P8.48, is 150 cm above the floor. The ball is swung at the minimum speed necessary to make it over the top without the string going slack. If the string is released at the instant the ball is at the top of the loop, how far to the right does the ball hit the ground?

49. || A 100 g ball on a 60-cm-long string is swung in a vertical circle about a point 200 cm above the floor. The string suddenly breaks when it is parallel to the ground and the ball is moving upward. The ball reaches a height 600 cm above the floor. What was the tension in the string an instant before it broke?

50. || A 1500 kg car starts from rest and drives around a flat 50-m-diameter circular track. The forward force provided by the car's drive wheels is a constant 1000 N.
a. What are the magnitude and direction of the car's acceleration at $t = 10$ s? Give the direction as an angle from the r-axis.
b. If the car has rubber tires and the track is concrete, at what time does the car begin to slide out of the circle?

51. || A 500 g steel block rotates on a steel table while attached to a 2.0-m-long massless rod. Compressed air fed through the rod is ejected from a nozzle on the back of the block, exerting a thrust force of 3.5 N. The nozzle is 70° from the radial line, as shown in FIGURE P8.51. The block starts from rest.

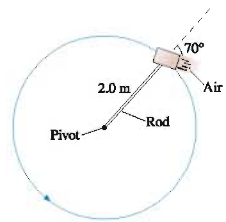


FIGURE P8.51

a. What is the block's angular velocity after 10 rev?
b. What is the tension in the rod after 10 rev?

52. || A 2.0 kg ball swings in a vertical circle on the end of an 80-cm-long string. The tension in the string is 20 N when its angle from the highest point on the circle is $\theta = 30°$.
a. What is the ball's speed when $\theta = 30°$?
b. What are the magnitude and direction of the ball's acceleration when $\theta = 30°$?

In Problems 53 and 54 you are given the equation (or equations) used to solve a problem. For each of these, you are to
a. Write a realistic problem for which this is the correct equation. Be sure that the answer your problem requests is consistent with the equation given.
b. Finish the solution of the problem.

53. $60\text{ N} = (0.30\text{ kg})\omega^2(0.50\text{ m})$

54. $(1500\text{ kg})(9.8\text{ m/s}^2) - 11{,}760\text{ N} = (1500\text{ kg})\,v^2/(200\text{ m})$

Challenge Problems

55. In the absence of air resistance, a projectile that lands at the elevation from which it was launched achieves maximum range when launched at a 45° angle. Suppose a projectile of mass m is launched with speed v_0 into a headwind that exerts a constant, horizontal retarding force $\vec{F}_{wind} = -F_{wind}\hat{\imath}$.
    a. Find an expression for the angle at which the range is maximum.
    b. By what percentage is the maximum range of a 0.50 kg ball reduced if $F_{wind} = 0.60$ N?
56. Derive Equations 8.4 for the acceleration of a projectile subject to drag.
57. Driving a spaceship isn't as easy as it looks in the movies. Imagine you're a physics student in the 31st century. You live in a remote space colony where the gravitational force from any stars or planets is negligible. You're on your way home from school, coasting along in your 20,000 kg personal spacecraft at 2.0 km/s, when the computer alerts you to the fact that the entrance to your pod is 500 km away along a line 30° from your present heading, as shown in FIGURE CP8.57. You need to make a left turn so that you can enter the pod going straight ahead at 1.0 km/s. You could do this with a series of small rocket burns, but you want to impress the girls in the spacecraft behind you by getting through the entrance with a single rocket burn. You can use small thrusters to quickly rotate your spacecraft to a different orientation before and after the main rocket burn.
    a. You need to determine three things: How to orient your spacecraft for the main rocket burn, the magnitude F_{thrust} of the rocket burn, and the length of the burn. Use a coordinate system in which you start at the origin and are initially moving along the x-axis. Measure the orientation of your spacecraft by the angle it makes with the positive x-axis. Your initial orientation is 0°. You can end the burn before you reach the entrance, but you're not allowed to have the engine on as you pass through the entrance. Mass loss during the burn is negligible.
    b. Calculate your position coordinates every 50 s until you reach the entrance, then plot a graph of your trajectory. Be sure to label the position of the entrance.

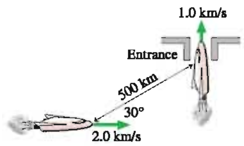


FIGURE CP8.57

58. A small ball rolls around a horizontal circle at height y inside the cone shown in FIGURE CP8.58. Find an expression of the ball's speed in terms of a, h, y, and g.

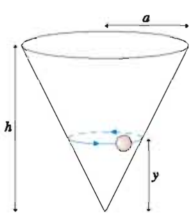


FIGURE CP8.58

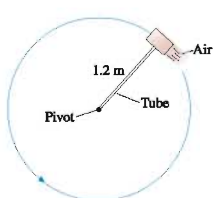


FIGURE CP8.59

59. A 500 g steel block rotates on a steel table while attached to a 1.2-m-long hollow tube as shown in FIGURE CP8.59. Compressed air fed through the tube and ejected from a nozzle on the back of the block exerts a thrust force of 4.0 N perpendicular to the tube. The maximum tension the tube can withstand without breaking is 50 N. If the block starts from rest, how many revolutions does it make before the tube breaks?
60. Two wires are tied to the 2.0 kg sphere shown in FIGURE CP8.60. The sphere revolves in a horizontal circle at constant speed.
    a. For what speed is the tension the same in both wires?
    b. What is the tension?

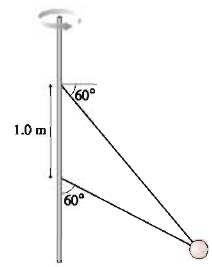


FIGURE CP8.60

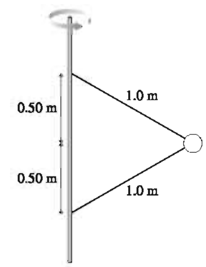


FIGURE CP8.61

61. Two wires are tied to the 300 g sphere shown in FIGURE CP8.61. The sphere revolves in a horizontal circle at a constant speed of 7.5 m/s. What is the tension in each of the wires?
62. A small ball rolls around a horizontal circle at height y inside a frictionless hemispherical bowl of radius R, as shown in FIGURE CP8.62.
    a. Find an expression for the ball's angular velocity in terms of R, y, and g.
    b. What is the minimum value of ω for which the ball can move in a circle?
    c. What is ω in rpm if $R = 20$ cm and the ball is halfway up?

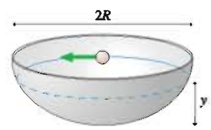


FIGURE CP8.62

63. You are flying to New York. You've been reading the in-flight magazine, which has an article about the physics of flying. You learned that the airflow over the wings creates a *lift force* that is always perpendicular to the wings. In level flight, the upward lift force exactly balances the downward gravitational force. The pilot comes on to say that, because of heavy traffic, the plane is going to circle the airport for a while. She says that you'll maintain a speed of 400 mph at an altitude of 20,000 ft. You start to wonder what the diameter of the plane's circle around the airport is. You notice that the pilot has banked the plane so that the wings are 10° from horizontal. The safety card in the seatback pocket informs you that the plane's wing span is 250 ft. What can you learn about the diameter?

Challenge Problems

55. In the absence of air resistance, a projectile that lands at the elevation from which it was launched achieves maximum range when launched at a 45° angle. Suppose a projectile of mass m is launched with speed v_0 into a headwind that exerts a constant, horizontal retarding force $\vec{F}_{wind} = -F_{wind}\hat{\imath}$.
    a. Find an expression for the angle at which the range is maximum.
    b. By what percentage is the maximum range of a 0.50 kg ball reduced if $F_{wind} = 0.60$ N?
56. Derive Equations 8.4 for the acceleration of a projectile subject to drag.
57. Driving a spaceship isn't as easy as it looks in the movies. Imagine you're a physics student in the 31st century. You live in a remote space colony where the gravitational force from any stars or planets is negligible. You're on your way home from school, coasting along in your 20,000 kg personal spacecraft at 2.0 km/s, when the computer alerts you to the fact that the entrance to your pod is 500 km away along a line 30° from your present heading, as shown in FIGURE CP8.57. You need to make a left turn so that you can enter the pod going straight ahead at 1.0 km/s. You could do this with a series of small rocket burns, but you want to impress the girls in the spacecraft behind you by getting through the entrance with a single rocket burn. You can use small thrusters to quickly rotate your spacecraft to a different orientation before and after the main rocket burn.

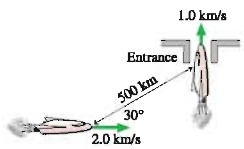


FIGURE CP8.57

    a. You need to determine three things: How to orient your spacecraft for the main rocket burn, the magnitude F_{thrust} of the rocket burn, and the length of the burn. Use a coordinate system in which you start at the origin and are initially moving along the x-axis. Measure the orientation of your spacecraft by the angle it makes with the positive x-axis. Your initial orientation is 0°. You can end the burn before you reach the entrance, but you're not allowed to have the engine on as you pass through the entrance. Mass loss during the burn is negligible.
    b. Calculate your position coordinates every 50 s until you reach the entrance, then plot a graph of your trajectory. Be sure to label the position of the entrance.
58. A small ball rolls around a horizontal circle at height y inside the cone shown in FIGURE CP8.58. Find an expression of the ball's speed in terms of a, h, y, and g.

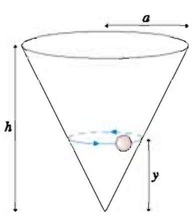


FIGURE CP8.58

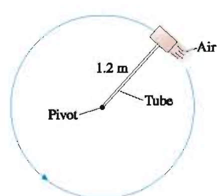


FIGURE CP8.59

59. A 500 g steel block rotates on a steel table while attached to a 1.2-m-long hollow tube as shown in FIGURE CP8.59. Compressed air fed through the tube and ejected from a nozzle on the back of the block exerts a thrust force of 4.0 N perpendicular to the tube. The maximum tension the tube can withstand without breaking is 50 N. If the block starts from rest, how many revolutions does it make before the tube breaks?
60. Two wires are tied to the 2.0 kg sphere shown in FIGURE CP8.60. The sphere revolves in a horizontal circle at constant speed.
    a. For what speed is the tension the same in both wires?
    b. What is the tension?

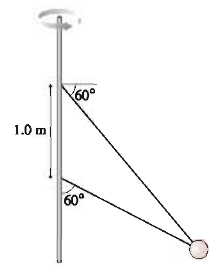
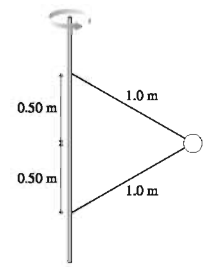


FIGURE CP8.60



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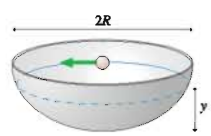

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