4.E: Practice

4.E.1 Conceptual Questions

4.E.1.1 Displacement and Velocity Vectors

1. What form does the trajectory of a particle have if the distance from any point A to point B is equal to the magnitude of the displacement from A to B?
2. Give an example of a trajectory in two or three dimensions caused by independent perpendicular motions.
3. If the instantaneous velocity is zero, what can be said about the slope of the position function?

4.E.1.2 Acceleration Vector

4. If the position function of a particle is a linear function of time, what can be said about its acceleration?
5. If an object has a constant x-component of the velocity and suddenly experiences an acceleration in the y direction, does the x-component of its velocity change?
6. If an object has a constant x-component of velocity and suddenly experiences an acceleration at an angle of 70° in the x direction, does the x-component of velocity change?

4.E.1.3 Projectile Motion

7. Answer the following questions for projectile motion on level ground assuming negligible air resistance, with the initial angle being neither 0° nor 90° : (a) Is the velocity ever zero? (b) When is the velocity a minimum? A maximum? (c) Can the velocity ever be the same as the initial velocity at a time other than at t = 0? (d) Can the speed ever be the same as the initial speed at a time other than at t = 0?
8. Answer the following questions for projectile motion on level ground assuming negligible air resistance, with the initial angle being neither 0° nor 90° : (a) Is the acceleration ever zero? (b) Is the vector $\vec{v}$ ever parallel or antiparallel to the vector $\vec{a}$? (c) Is the vector $\vec{v}$ ever perpendicular to the vector $\vec{a}$? If so, where is this located?
9. A dime is placed at the edge of a table so it hangs over slightly. A quarter is slid horizontally on the table surface perpendicular to the edge and hits the dime head on. Which coin hits the ground first?

4.E.1.4 Uniform Circular Motion

10. Can centripetal acceleration change the speed of a particle undergoing circular motion?
11. Can tangential acceleration change the speed of a particle undergoing circular motion?

4.E.1.5 Relative Motion in One and Two Dimensions

12. What frame or frames of reference do you use instinctively when driving a car? When flying in a commercial jet?
13. A basketball player dribbling down the court usually keeps his eyes fixed on the players around him. He is moving fast. Why doesn’t he need to keep his eyes on the ball?
14. If someone is riding in the back of a pickup truck and throws a softball straight backward, is it possible for the ball to fall straight down as viewed by a person standing at the side of the road? Under what condition would this occur? How would the motion of the ball appear to the person who threw it?
15. The hat of a jogger running at constant velocity falls off the back of his head. Draw a sketch showing the path of the hat in the jogger’s frame of reference. Draw its path as viewed by a stationary observer. Neglect air resistance.
16. A clod of dirt falls from the bed of a moving truck. It strikes the ground directly below the end of the truck. (a) What is the direction of its velocity relative to the truck just before it hits? (b) Is this the same as the direction of its velocity relative to ground just before it hits? Explain your answers.

4.E.1.6 Rotational Variables

1. A clock is mounted on the wall. As you look at it, what is the direction of the angular velocity vector of the second hand?
2. What is the value of the angular acceleration of the second hand of the clock on the wall?
3. A baseball bat is swung. Do all points on the bat have the same angular velocity? The same tangential speed?
4. The blades of a blender on a counter are rotating clockwise as you look into it from the top. If the blender is put to a greater speed what direction is the angular acceleration of the blades?

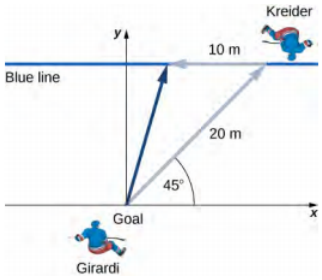
4.E.1.7 Rotation with Constant Angular Acceleration

5. If a rigid body has a constant angular acceleration, what is the functional form of the angular velocity in terms of the time variable?
6. If a rigid body has a constant angular acceleration, what is the functional form of the angular position?
7. If the angular acceleration of a rigid body is zero, what is the functional form of the angular velocity?
8. A massless tether with a masses tied to both ends rotates about a fixed axis through the center. Can the total acceleration of the tether/mass combination be zero if the angular velocity is constant?

4.E.2 Problems

4.E.2.1 Displacement and Velocity Vectors

17. The coordinates of a particle in a rectangular coordinate system are (1.0, –4.0, 6.0). What is the position vector of the particle?
18. The position of a particle changes from $\vec{r}_1 = (2.0\ \hat{i} + 3.0\ \hat{j})$cm to $\vec{r}_2 = (-4.0\ \hat{i} + 3.0\ \hat{j})$ cm. What is the particle's displacement?
19. The 18th hole at Pebble Beach Golf Course is a dogleg to the left of length 496.0 m. The fairway off the tee is taken to be the x direction. A golfer hits his tee shot a distance of 300.0 m, corresponding to a displacement $\Delta\vec{r}_1 = 300.0\text{ m}\ \hat{i}$, and hits his second shot 189.0 m with a displacement $\Delta\vec{r}_2 = 172.0\text{ m}\ \hat{i} + 80.3\text{ m}\ \hat{j}$. What is the final displacement of the golf ball from the tee?
20. A bird flies straight northeast a distance of 95.0 km for 3.0 h. With the x-axis due east and the y-axis due north, what is the displacement in unit vector notation for the bird? What is the average velocity for the trip?
21. A cyclist rides 5.0 km due east, then 10.0 km 20° west of north. From this point she rides 8.0 km due west. What is the final displacement from where the cyclist started?
22. New York Rangers defenseman Daniel Girardi stands at the goal and passes a hockey puck 20 m and 45° from straight down the ice to left wing Chris Kreider waiting at the blue line. Kreider waits for Girardi to reach the blue line and passes the puck directly across the ice to him 10 m away. What is the final displacement of the puck? See the following figure.



23. The position of a particle is $\vec{r}(t) = 4.0t^2\ \hat{i} - 3.0\ \hat{j} + 2.0t^3\ \hat{k}$ m. (a) What is the velocity of the particle at 0 s and at 1.0 s? (b) What is the average velocity between 0 s and 1.0 s?
24. Clay Matthews, a linebacker for the Green Bay Packers, can reach a speed of 10.0 m/s. At the start of a play, Matthews runs downfield at 45° with respect to the 50-yard line and covers 8.0 m in 1 s. He then runs straight down the field at 90° with respect to the 50-yard line for 12 m, with an elapsed time of 1.2 s. (a) What is Matthews' final displacement from the start of the play? (b) What is his average velocity?
25. The F-35B Lighting II is a short-takeoff and vertical landing fighter jet. If it does a vertical takeoff to 20.00-m height above the ground and then follows a flight path angled at 30° with respect to the ground for 20.00 km, what is the final displacement?

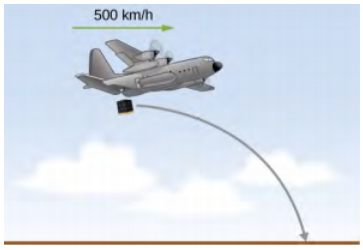
4.E.2.2 Acceleration Vector

26. The position of a particle is $\vec{r}\ (t) = (3.0^{\,2}\ \hat{i} + 5.0\ \hat{j} - 6.0t\ \hat{k})$ m. (a) Determine its velocity and acceleration as functions of time. (b) What are its velocity and acceleration at time t = 0?
27. A particle's acceleration is $(4.0\ \hat{i} + 3.0\ \hat{j})\text{m/s}^2$. At t = 0, its position and velocity are zero. (a) What are the particle's position and velocity as functions of time? (b) Find the equation of the path of the particle. Draw the x- and y-axes and sketch the trajectory of the particle.

28. A boat leaves the dock at t = 0 and heads out into a lake with an acceleration of 2.0 m/s^2 $\hat{i}$. A strong wind is pushing the boat, giving it an additional velocity of 2.0 m/s $\hat{i}$ + 1.0 m/s $\hat{j}$. (a) What is the velocity of the boat at t = 10 s? (b) What is the position of the boat at t = 10s? Draw a sketch of the boat's trajectory and position at t = 10 s, showing the x- and y-axes.
29. The position of a particle for t > 0 is given by $\vec{r}$(t) = (3.0t^2 $\hat{i}$ − 7.0t^3 $\hat{j}$ − 5.0t^{-2} $\hat{k}$) m. (a) What is the velocity as a function of time? (b) What is the acceleration as a function of time? (c) What is the particle's velocity at t = 2.0 s? (d) What is its speed at t = 1.0 s and t = 3.0 s? (e) What is the average velocity between t = 1.0 s and t = 2.0 s?
30. The acceleration of a particle is a constant. At t = 0 the velocity of the particle is (10 $\hat{i}$ + 20 $\hat{j}$)m/s. At t = 4 s the velocity is 10 $\hat{j}$ m/s. (a) What is the particle's acceleration? (b) How do the position and velocity vary with time? Assume the particle is initially at the origin.
31. A particle has a position function $\vec{r}$(t) = cos(1.0t) $\hat{i}$ + sin(1.0t) $\hat{j}$ + t $\hat{k}$, where the arguments of the cosine and sine functions are in radians. (a) What is the velocity vector? (b) What is the acceleration vector?
32. A Lockheed Martin F-35 II Lighting jet takes off from an aircraft carrier with a runway length of 90 m and a takeoff speed 70 m/s at the end of the runway. Jets are catapulted into airspace from the deck of an aircraft carrier with two sources of propulsion: the jet propulsion and the catapult. At the point of leaving the deck of the aircraft carrier, the F-35's acceleration decreases to a constant acceleration of 5.0 m/s^2 at 30° with respect to the horizontal. (a) What is the initial acceleration of the F-35 on the deck of the aircraft carrier to make it airborne? (b) Write the position and velocity of the F-35 in unit vector notation from the point it leaves the deck of the aircraft carrier. (c) At what altitude is the fighter 5.0 s after it leaves the deck of the aircraft carrier? (d) What is its velocity and speed at this time? (e) How far has it traveled horizontally?

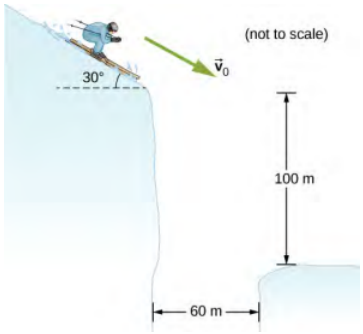
4.E.2.3 Projectile Motion

33. A bullet is shot horizontally from shoulder height (1.5 m) with and initial speed 200 m/s. (a) How much time elapses before the bullet hits the ground? (b) How far does the bullet travel horizontally?
34. A marble rolls off a tabletop 1.0 m high and hits the floor at a point 3.0 m away from the table's edge in the horizontal direction. (a) How long is the marble in the air? (b) What is the speed of the marble when it leaves the table's edge? (c) What is its speed when it hits the floor?
35. A dart is thrown horizontally at a speed of 10 m/ s at the bull's-eye of a dartboard 2.4 m away, as in the following figure. (a) How far below the intended target does the dart hit? (b) What does your answer tell you about how proficient dart players throw their darts?
36. An airplane flying horizontally with a speed of 500 km/h at a height of 800 m drops a crate of supplies (see the following figure). If the parachute fails to open, how far in front of the release point does the crate hit the ground?

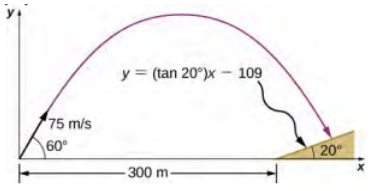


37. Suppose the airplane in the preceding problem fires a projectile horizontally in its direction of motion at a speed of 300 m/s relative to the plane. (a) How far in front of the release point does the projectile hit the ground? (b) What is its speed when it hits the ground?
38. A fastball pitcher can throw a baseball at a speed of 40 m/s (90 mi/h). (a) Assuming the pitcher can release the ball 16.7 m from home plate so the ball is moving horizontally, how long does it take the ball to reach home plate? (b) How far does the ball drop between the pitcher's hand and home plate?
39. A projectile is launched at an angle of 30° and lands 20 s later at the same height as it was launched. (a) What is the initial speed of the projectile? (b) What is the maximum altitude? (c) What is the range? (d) Calculate the displacement from the point of launch to the position on its trajectory at 15 s.
40. A basketball player shoots toward a basket 6.1 m away and 3.0 m above the floor. If the ball is released 1.8 m above the floor at an angle of 60° above the horizontal, what must the initial speed be if it were to go through the basket?

41. At a particular instant, a hot air balloon is 100 m in the air and descending at a constant speed of 2.0 m/s. At this exact instant, a girl throws a ball horizontally, relative to herself, with an initial speed of 20 m/s. When she lands, where will she find the ball? Ignore air resistance.
42. A man on a motorcycle traveling at a uniform speed of 10 m/s throws an empty can straight upward relative to himself with an initial speed of 3.0 m/s. Find the equation of the trajectory as seen by a police officer on the side of the road. Assume the initial position of the can is the point where it is thrown. Ignore air resistance.
43. An athlete can jump a distance of 8.0 m in the broad jump. What is the maximum distance the athlete can jump on the Moon, where the gravitational acceleration is onesixth that of Earth?
44. The maximum horizontal distance a boy can throw a ball is 50 m. Assume he can throw with the same initial speed at all angles. How high does he throw the ball when he throws it straight upward?
45. A rock is thrown off a cliff at an angle of 53° with respect to the horizontal. The cliff is 100 m high. The initial speed of the rock is 30 m/s. (a) How high above the edge of the cliff does the rock rise? (b) How far has it moved horizontally when it is at maximum altitude? (c) How long after the release does it hit the ground? (d) What is the range of the rock? (e) What are the horizontal and vertical positions of the rock relative to the edge of the cliff at t = 2.0 s, t = 4.0 s, and t = 6.0 s?
46. Trying to escape his pursuers, a secret agent skis off a slope inclined at 30° below the horizontal at 60 km/h. To survive and land on the snow 100 m below, he must clear a gorge 60 m wide. Does he make it? Ignore air resistance.



47. A golfer on a fairway is 70 m away from the green, which sits below the level of the fairway by 20 m. If the golfer hits the ball at an angle of 40° with an initial speed of 20 m/s, how close to the green does she come?
48. A projectile is shot at a hill, the base of which is 300 m away. The projectile is shot at 60° above the horizontal with an initial speed of 75 m/s. The hill can be approximated by a plane sloped at 20° to the horizontal. Relative to the coordinate system shown in the following figure, the equation of this straight line is y = (tan 20°)x − 109. Where on the hill does the projectile land?



49. An astronaut on Mars kicks a soccer ball at an angle of 45° with an initial velocity of 15 m/s. If the acceleration of gravity on Mars is 3.7 m/s, (a) what is the range of the soccer kick on a flat surface? (b) What would be the range of the same kick on the Moon, where gravity is one-sixth that of Earth?
50. Mike Powell holds the record for the long jump of 8.95 m, established in 1991. If he left the ground at an angle of 15°, what was his initial speed?
51. MIT's robot cheetah can jump over obstacles 46 cm high and has speed of 12.0 km/h. (a) If the robot launches itself at an angle of 60° at this speed, what is its maximum height? (b) What would the launch angle have to be to reach a height of 46 cm?
52. Mt. Asama, Japan, is an active volcano. In 2009, an eruption threw solid volcanic rocks that landed 1 km horizontally from the crater. If the volcanic rocks were launched at an angle of 40° with respect to the horizontal and landed 900 m below the crater, (a) what would be their initial velocity and (b) what is their time of flight?

53. Drew Brees of the New Orleans Saints can throw a football 23.0 m/s (50 mph). If he angles the throw at 10° from the horizontal, what distance does it go if it is to be caught at the same elevation as it was thrown?
54. The Lunar Roving Vehicle used in NASA's late Apollo missions reached an unofficial lunar land speed of 5.0 m/s by astronaut Eugene Cernan. If the rover was moving at this speed on a flat lunar surface and hit a small bump that projected it off the surface at an angle of 20°, how long would it be "airborne" on the Moon?
55. A soccer goal is 2.44 m high. A player kicks the ball at a distance 10 m from the goal at an angle of 25°. What is the initial speed of the soccer ball?
56. Olympus Mons on Mars is the largest volcano in the solar system, at a height of 25 km and with a radius of 312 km. If you are standing on the summit, with what initial velocity would you have to fire a projectile from a cannon horizontally to clear the volcano and land on the surface of Mars? Note that Mars has an acceleration of gravity of 3.7 m/s^2.
57. In 1999, Robbie Knievel was the first to jump the Grand Canyon on a motorcycle. At a narrow part of the canyon (69.0 m wide) and traveling 35.8 m/s off the takeoff ramp, he reached the other side. What was his launch angle?
58. You throw a baseball at an initial speed of 15.0 m/s at an angle of 30° with respect to the horizontal. What would the ball's initial speed have to be at 30° on a planet that has twice the acceleration of gravity as Earth to achieve the same range? Consider launch and impact on a horizontal surface.
59. Aaron Rogers throws a football at 20.0 m/s to his wide receiver, who is running straight down the field at 9.4 m/s. If Aaron throws the football when the wide receiver is 10.0 m in front of him, what angle does Aaron have to launch the ball at so the receiver catches it 20.0 m in front of Aaron?

4.E.2.4 Uniform Circular Motion

60. A flywheel is rotating at 30 rev/s. What is the total angle, in radians, through which a point on the flywheel rotates in 40 s?
61. A particle travels in a circle of radius 10 m at a constant speed of 20 m/s. What is the magnitude of the acceleration?
62. Cam Newton of the Carolina Panthers throws a perfect football spiral at 8.0 rev/s. The radius of a pro football is 8.5 cm at the middle of the short side. What is the centripetal acceleration of the laces on the football?
63. A fairground ride spins its occupants inside a flying saucer-shaped container. If the horizontal circular path the riders follow has an 8.00-m radius, at how many revolutions per minute are the riders subjected to a centripetal acceleration equal to that of gravity?
64. A runner taking part in the 200-m dash must run around the end of a track that has a circular arc with a radius of curvature of 30.0 m. The runner starts the race at a constant speed. If she completes the 200-m dash in 23.2 s and runs at constant speed throughout the race, what is her centripetal acceleration as she runs the curved portion of the track?
65. What is the acceleration of Venus toward the Sun, assuming a circular orbit?
66. An experimental jet rocket travels around Earth along its equator just above its surface. At what speed must the jet travel if the magnitude of its acceleration is g?
67. A fan is rotating at a constant 360.0 rev/min. What is the magnitude of the acceleration of a point on one of its blades 10.0 cm from the axis of rotation?
68. A point located on the second hand of a large clock has a radial acceleration of 0.1 cm/s^2. How far is the point from the axis of rotation of the second hand?

4.E.2.5 Relative Motion in One and Two Dimensions

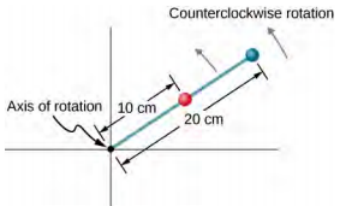
69. The coordinate axes of the reference frame S′ remain parallel to those of S, as S′ moves away from S at a constant velocity $\vec{v}_{S'} = (4.0\ \hat{i} + 3.0\ \hat{j} + 5.0\ \hat{k})$ m/s. (a) If at time t = 0 the origins coincide, what is the position of the origin O′ in the S frame as a function of time? (b) How is particle position for $\vec{r}$(t) and $\vec{r}\,'$(t), as measured in S and S′, respectively, related? (c) What is the relationship between particle velocities $\vec{v}$(t) and $\vec{v}\,'$(t)? (d) How are accelerations $\vec{a}$(t) and $\vec{a}\,'$(t) related?
70. The coordinate axes of the reference frame S′ remain parallel to those of S, as S′ moves away from S at a constant velocity $\vec{v}_{S'S} = (1.0\ \hat{i} + 2.0\ \hat{j} + 3.0\ \hat{k})$t m/s. (a) If at time t = 0 the origins coincide, what is the position of origin O′ in the S frame as a function of time? (b) How is particle position for $\vec{r}$(t) and $\vec{r}'$(t) , as measured in S and S′, respectively, related? (c) What is the relationship between particle velocities $\vec{v}$(t) and $\vec{v}'$(t)? (d) How are accelerations $\vec{a}$(t) and $\vec{a}'$(t) related?
71. The velocity of a particle in reference frame A is $(2.0\ \hat{i} + 3.0\ \hat{j})$ m/s. The velocity of reference frame A with respect to reference frame B is 4.0 $\hat{k}$ m/s, and the velocity of reference frame B with respect to C is 2.0 $\hat{j}$ m/s. What is the velocity

of the particle in reference frame C?

72. Raindrops fall vertically at 4.5 m/s relative to the earth. What does an observer in a car moving at 22.0 m/s in a straight line measure as the velocity of the raindrops?
73. A seagull can fly at a velocity of 9.00 m/s in still air. (a) If it takes the bird 20.0 min to travel 6.00 km straight into an oncoming wind, what is the velocity of the wind? (b) If the bird turns around and flies with the wind, how long will it take the bird to return 6.00 km?
74. A ship sets sail from Rotterdam, heading due north at 7.00 m/s relative to the water. The local ocean current is 1.50 m/s in a direction 40.0° north of east. What is the velocity of the ship relative to Earth?
75. A boat can be rowed at 8.0 km/h in still water. (a) How much time is required to row 1.5 km downstream in a river moving 3.0 km/h relative to the shore? (b) How much time is required for the return trip? (c) In what direction must the boat be aimed to row straight across the river? (d) Suppose the river is 0.8 km wide. What is the velocity of the boat with respect to Earth and how much time is required to get to the opposite shore? (e) Suppose, instead, the boat is aimed straight across the river. How much time is required to get across and how far downstream is the boat when it reaches the opposite shore?
76. A small plane flies at 200 km/h in still air. If the wind blows directly out of the west at 50 km/h, (a) in what direction must the pilot head her plane to move directly north across land and (b) how long does it take her to reach a point 300 km directly north of her starting point?
77. A cyclist traveling southeast along a road at 15 km/h feels a wind blowing from the southwest at 25 km/h. To a stationary observer, what are the speed and direction of the wind?
78. A river is moving east at 4 m/s. A boat starts from the dock heading 30° north of west at 7 m/s. If the river is 1800 m wide, (a) what is the velocity of the boat with respect to Earth and (b) how long does it take the boat to cross the river?

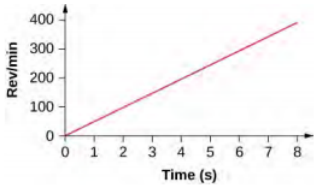
4.E.2.6 Rotational Variables

28. Calculate the angular velocity of Earth.
29. A track star runs a 400-m race on a 400-m circular track in 45 s. What is his angular velocity assuming a constant speed?
30. A wheel rotates at a constant rate of 2.0×10^3 rev/min. (a) What is its angular velocity in radians per second? (b) Through what angle does it turn in 10 s? Express the solution in radians and degrees.
31. A particle moves 3.0 m along a circle of radius 1.5 m. (a) Through what angle does it rotate? (b) If the particle makes this trip in 1.0 s at a constant speed, what is its angular velocity? (c) What is its acceleration?
32. A compact disc rotates at 500 rev/min. If the diameter of the disc is 120 mm, (a) what is the tangential speed of a point at the edge of the disc? (b) At a point halfway to the center of the disc?
33. **Unreasonable results**. The propeller of an aircraft is spinning at 10 rev/s when the pilot shuts off the engine. The propeller reduces its angular velocity at a constant 2.0 rad/s^2 for a time period of 40 s. What is the rotation rate of the propeller in 40 s? Is this a reasonable situation?
34. A gyroscope slows from an initial rate of 32.0 rad/s at a rate of 0.700 rad/s^2. How long does it take to come to rest?
35. On takeoff, the propellers on a UAV (unmanned aerial vehicle) increase their angular velocity for 3.0 s from rest at a rate of $\omega = (25.0t)$ rad/s where t is measured in seconds. (a) What is the instantaneous angular velocity of the propellers at t = 2.0 s? (b) What is the angular acceleration?
36. The angular position of a rod varies as $20.0t^2$ radians from time t = 0. The rod has two beads on it as shown in the following figure, one at 10 cm from the rotation axis and the other at 20 cm from the rotation axis. (a) What is the instantaneous angular velocity of the rod at t = 5 s? (b) What is the angular acceleration of the rod? (c) What are the tangential speeds of the beads at t = 5 s? (d) What are the tangential accelerations of the beads at t = 5 s? (e) What are the centripetal accelerations of the beads at t = 5 s?



4.E.2.7 Rotation with Constant Angular Acceleration

37. A wheel has a constant angular acceleration of 5.0 rad/s^2. Starting from rest, it turns through 300 rad. (a) What is its final angular velocity? (b) How much time elapses while it turns through the 300 radians?
38. During a 6.0-s time interval, a flywheel with a constant angular acceleration turns through 500 radians that acquire an angular velocity of 100 rad/s. (a) What is the angular velocity at the beginning of the 6.0 s? (b) What is the angular acceleration of the flywheel?
39. The angular velocity of a rotating rigid body increases from 500 to 1500 rev/min in 120 s. (a) What is the angular acceleration of the body? (b) Through what angle does it turn in this 120 s?
40. A flywheel slows from 600 to 400 rev/min while rotating through 40 revolutions. (a) What is the angular acceleration of the flywheel? (b) How much time elapses during the 40 revolutions?
41. A wheel 1.0 m in radius rotates with an angular acceleration of 4.0 rad/s^2. (a) If the wheel's initial angular velocity is 2.0 rad/s, what is its angular velocity after 10 s? (b) Through what angle does it rotate in the 10-s interval? (c) What are the tangential speed and acceleration of a point on the rim of the wheel at the end of the 10-s interval?
42. A vertical wheel with a diameter of 50 cm starts from rest and rotates with a constant angular acceleration of 5.0 rad/s^2 around a fixed axis through its center counterclockwise. (a) Where is the point that is initially at the bottom of the wheel at t = 10 s? (b) What is the point's linear acceleration at this instant?
43. A circular disk of radius 10 cm has a constant angular acceleration of 1.0 rad/s^2; at t = 0 its angular velocity is 2.0 rad/s. (a) Determine the disk's angular velocity at t = 5.0 s . (b) What is the angle it has rotated through during this time? (c) What is the tangential acceleration of a point on the disk at t = 5.0 s?
44. The angular velocity vs. time for a fan on a hovercraft is shown below. (a) What is the angle through which the fan blades rotate in the first 8 seconds? (b) Verify your result using the kinematic equations.



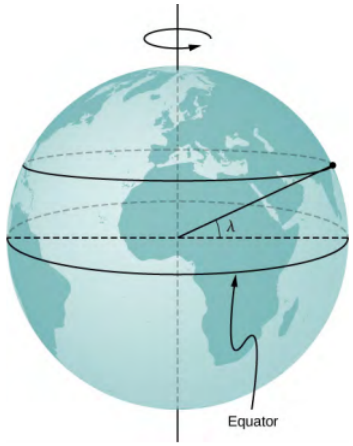
45. A rod of length 20 cm has two beads attached to its ends. The rod with beads starts rotating from rest. If the beads are to have a tangential speed of 20 m/s in 7 s, what is the angular acceleration of the rod to achieve this?

4.E.2.8 Relating Angular and Translational Quantities

46. At its peak, a tornado is 60.0 m in diameter and carries 500 km/h winds. What is its angular velocity in revolutions per second?
47. A man stands on a merry-go-round that is rotating at 2.5 rad/s. If the coefficient of static friction between the man's shoes and the merry-go-round is μS = 0.5, how far from the axis of rotation can he stand without sliding?
48. An ultracentrifuge accelerates from rest to 100,000 rpm in 2.00 min. (a) What is the average angular acceleration in rad/s^2? (b) What is the tangential acceleration of a point 9.50 cm from the axis of rotation? (c) What is the centripetal acceleration in m/s^2 and multiples of g of this point at full rpm? (d) What is the total distance traveled by a point 9.5 cm from the axis of rotation of the ultracentrifuge?
49. A wind turbine is rotating counterclockwise at 0.5 rev/s and slows to a stop in 10 s. Its blades are 20 m in length. (a) What is the angular acceleration of the turbine? (b) What is the centripetal acceleration of the tip of the blades at t = 0 s? (c) What is the magnitude and direction of the total linear acceleration of the tip of the blades at t = 0 s?
50. What is (a) the angular speed and (b) the linear speed of a point on Earth's surface at latitude 30° N. Take the radius of the Earth to be 6309 km. (c) At what latitude would your linear speed be 10 m/s?
51. A child with mass 30 kg sits on the edge of a merrygo-round at a distance of 3.0 m from its axis of rotation. The merry-go-round accelerates from rest up to 0.4 rev/s in 10 s. If the coefficient of static friction between the child and the surface of the merry-go-round is 0.6, does the child fall off before 5 s?
52. A bicycle wheel with radius 0.3m rotates from rest to 3 rev/s in 5 s. What is the magnitude and direction of the total acceleration vector at the edge of the wheel at 1.0 s?
53. The angular velocity of a flywheel with radius 1.0 m varies according to $\omega(t) = 2.0t$. Plot $a_c(t)$ and $a_t(t)$ from t = 0 to 3.0 s for r = 1.0 m. Analyze these results to explain when $a_c >> a_t$ and when $a_c << a_t$ for a point on the flywheel at a radius of 1.0 m.

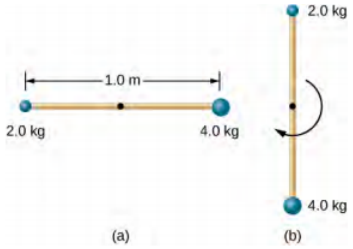
4.E.3 Additional Problems

79. A Formula One race car is traveling at 89.0 m/s along a straight track enters a turn on the race track with radius of curvature of 200.0 m. What centripetal acceleration must the car have to stay on the track?
80. A particle travels in a circular orbit of radius 10 m. Its speed is changing at a rate of 15.0 m/s^2 at an instant when its speed is 40.0 m/s. What is the magnitude of the acceleration of the particle?
81. The driver of a car moving at 90.0 km/h presses down on the brake as the car enters a circular curve of radius 150.0 m. If the speed of the car is decreasing at a rate of 9.0 km/h each second, what is the magnitude of the acceleration of the car at the instant its speed is 60.0 km/h?
82. A race car entering the curved part of the track at the Daytona 500 drops its speed from 85.0 m/s to 80.0 m/s in 2.0 s. If the radius of the curved part of the track is 316.0 m, calculate the total acceleration of the race car at the beginning and ending of reduction of speed.
83. An elephant is located on Earth's surface at a latitude λ. Calculate the centripetal acceleration of the elephant resulting from the rotation of Earth around its polar axis. Express your answer in terms of λ, the radius RE of Earth, and time T for one rotation of Earth. Compare your answer with g for $\lambda = 40°$.

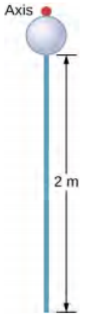


84. A proton in a synchrotron is moving in a circle of radius 1 km and increasing its speed by $v(t) = c_1 + c_2t^2$, where $c_1 = 2.0 \times 10^5$ m/s, $c_2 = 10^5$ m/s^3. (a) What is the proton's total acceleration at t = 5.0 s? (b) At what time does the expression for the velocity become unphysical?
85. A propeller blade at rest starts to rotate from t = 0 s to t = 5.0 s with a tangential acceleration of the tip of the blade at 3.00 m/s^2. The tip of the blade is 1.5 m from the axis of rotation. At t = 5.0 s, what is the total acceleration of the tip of the blade?
86. A particle is executing circular motion with a constant angular frequency of $\omega = 4.00$ rad/s. If time t = 0 corresponds to the position of the particle being located at y = 0 m and x = 5 m, (a) what is the position of the particle at t = 10 s? (b) What is its velocity at this time? (c) What is its acceleration?
87. A particle's centripetal acceleration is $a_C = 4.0$ m/s^2 at t = 0 s where it is on the x-axis and moving counterclockwise in the xy plane. It is executing uniform circular motion about an axis at a distance of 5.0 m. What is its velocity at t = 10 s?
88. A rod 3.0 m in length is rotating at 2.0 rev/s about an axis at one end. Compare the centripetal accelerations at radii of (a) 1.0 m, (b) 2.0 m, and (c) 3.0 m.
89. A particle located initially at $(1.5\ \hat{j} + 4.0\ \hat{k})$m undergoes a displacement of $(2.5\ \hat{i} + 3.2\ \hat{j} - 1.2\ \hat{k})$ m. What is the final position of the particle?
90. The position of a particle is given by $\vec{r}(t) = (50\text{ m/s})t\ \hat{i} - (4.9\text{ m/s}^2)t^2\ \hat{j}$. (a) What are the particle's velocity and acceleration as functions of time? (b) What are the initial conditions to produce the motion?
91. A spaceship is traveling at a constant velocity of $\vec{v}(t) = 250.0\ \hat{i}$ m/s when its rockets fire, giving it an acceleration of $\vec{a}(t) = (3.0\ \vec{i} + 4.0\ \hat{k})m/s^2$. What is its velocity 5 s after the rockets fire?
92. A crossbow is aimed horizontally at a target 40 m away. The arrow hits 30 cm below the spot at which it was aimed. What is the initial velocity of the arrow?
93. A long jumper can jump a distance of 8.0 m when he takes off at an angle of 45° with respect to the horizontal. Assuming he can jump with the same initial speed at all angles, how much distance does he lose by taking off at 30°?

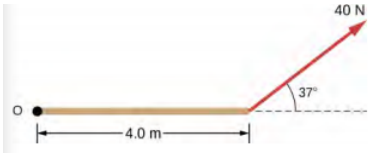
94. On planet Arcon, the maximum horizontal range of a projectile launched at 10 m/s is 20 m. What is the acceleration of gravity on this planet?
95. A mountain biker encounters a jump on a race course that sends him into the air at 60° to the horizontal. If he lands at a horizontal distance of 45.0 m and 20 m below his launch point, what is his initial speed?
96. Which has the greater centripetal acceleration, a car with a speed of 15.0 m/s along a circular track of radius 100.0 m or a car with a speed of 12.0 m/s along a circular track of radius 75.0 m?
97. A geosynchronous satellite orbits Earth at a distance of 42,250.0 km and has a period of 1 day. What is the centripetal acceleration of the satellite?
98. Two speedboats are traveling at the same speed relative to the water in opposite directions in a moving river. An observer on the riverbank sees the boats moving at 4.0 m/s and 5.0 m/s. (a) What is the speed of the boats relative to the river? (b) How fast is the river moving relative to the shore?
99. A cyclist is riding such that the wheels of the bicycle have a rotation rate of 3.0 rev/s. If the cyclist brakes such that the rotation rate of the wheels decrease at a rate of 0.3 rev/s^2, how long does it take for the cyclist to come to a complete stop?
100. Calculate the angular velocity of the orbital motion of Earth around the Sun.
101. A phonograph turntable rotating at $33\frac{1}{3}$ rev/min slows down and stops in 1.0 min. (a) What is the turntable's angular acceleration assuming it is constant? (b) How many revolutions does the turntable make while stopping?
102. With the aid of a string, a gyroscope is accelerated from rest to 32 rad/s in 0.40 s under a constant angular acceleration. (a) What is its angular acceleration in rad/s^2? (b) How many revolutions does it go through in the process?
103. Suppose a piece of dust has fallen on a CD. If the spin rate of the CD is 500 rpm, and the piece of dust is 4.3 cm from the center, what is the total distance traveled by the dust in 3 minutes? (Ignore accelerations due to getting the CD rotating.)
104. A system of point particles is rotating about a fixed axis at 4 rev/s. The particles are fixed with respect to each other. The masses and distances to the axis of the point particles are $m_1 = 0.1$ kg, $r_1 = 0.2$ m, $m_2 = 0.05$ kg, $r_2 = 0.4$ m, $m_3 = 0.5$ kg, $r_3 = 0.01$ m. (a) What is the moment of inertia of the system? (b) What is the rotational kinetic energy of the system?
105. Calculate the moment of inertia of a skater given the following information. (a) The 60.0-kg skater is approximated as a cylinder that has a 0.110-m radius. (b) The skater with arms extended is approximated by a cylinder that is 52.5 kg, has a 0.110-m radius, and has two 0.900-m-long arms which are 3.75 kg each and extend straight out from the cylinder like rods rotated about their ends.
106. A stick of length 1.0 m and mass 6.0 kg is free to rotate about a horizontal axis through the center. Small bodies of masses 4.0 and 2.0 kg are attached to its two ends (see the following figure). The stick is released from the horizontal position. What is the angular velocity of the stick when it swings through the vertical?



115. A pendulum consists of a rod of length 2 m and mass 3 kg with a solid sphere of mass 1 kg and radius 0.3 m attached at one end. The axis of rotation is as shown below. What is the angular velocity of the pendulum at its lowest point if it is released from rest at an angle of 30°?



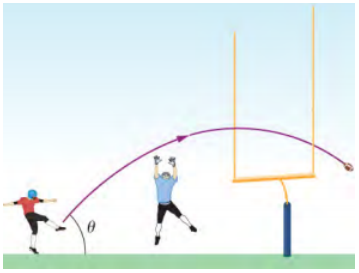
116. Calculate the torque of the 40-N force around the axis through O and perpendicular to the plane of the page as shown below.



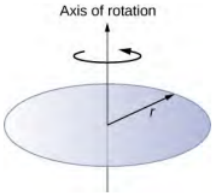
117. Two children push on opposite sides of a door during play. Both push horizontally and perpendicular to the door. One child pushes with a force of 17.5 N at a distance of 0.600 m from the hinges, and the second child pushes at a distance of 0.450 m. What force must the second child exert to keep the door from moving? Assume friction is negligible.
118. The force of 20 $\hat{j}$ N is applied at $\vec{r}$ = (4.0 $\hat{i}$ − 2.0 $\hat{j}$) m. What is the torque of this force about the origin? 119. An automobile engine can produce 200 N • m of torque. Calculate the angular acceleration produced if 95.0% of this torque is applied to the drive shaft, axle, and rear wheels of a car, given the following information. The car is suspended so that the wheels can turn freely. Each wheel acts like a 15.0-kg disk that has a 0.180-m radius. The walls of each tire act like a 2.00-kg annular ring that has inside radius of 0.180 m and outside radius of 0.320 m. The tread of each tire acts like a 10.0-kg hoop of radius 0.330 m. The 14.0-kg axle acts like a rod that has a 2.00-cm radius. The 30.0-kg drive shaft acts like a rod that has a 3.20-cm radius.
119. A grindstone with a mass of 50 kg and radius 0.8 m maintains a constant rotation rate of 4.0 rev/s by a motor while a knife is pressed against the edge with a force of 5.0 N. The coefficient of kinetic friction between the grindstone and the blade is 0.8. What is the power provided by the motor to keep the grindstone at the constant rotation rate?

4.E.4 Challenge Problems

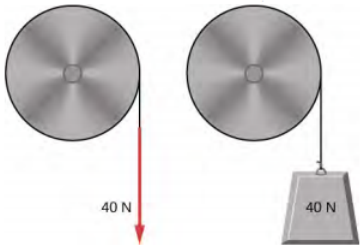
99. World's Longest Par 3. The tee of the world's longest par 3 sits atop South Africa's Hanglip Mountain at 400.0 m above the green and can only be reached by helicopter. The horizontal distance to the green is 359.0 m. Neglect air resistance and answer the following questions. (a) If a golfer launches a shot that is 40° with respect to the horizontal, what initial velocity must she give the ball? (b) What is the time to reach the green?
100. When a field goal kicker kicks a football as hard as he can at 45° to the horizontal, the ball just clears the 3-m-high crossbar of the goalposts 45.7 m away. (a) What is the maximum speed the kicker can impart to the football? (b) In addition to clearing the crossbar, the football must be high enough in the air early during its flight to clear the reach of the onrushing defensive lineman. If the lineman is 4.6 m away and has a vertical reach of 2.5 m, can he block the 45.7-m field goal attempt? (c) What if the lineman is 1.0 m away?



101. A truck is traveling east at 80 km/h. At an intersection 32 km ahead, a car is traveling north at 50 km/h. (a) How long after this moment will the vehicles be closest to each other? (b) How far apart will they be at that point?
102. The angular acceleration of a rotating rigid body is given by α = (2.0 − 3.0t) rad/s^2. If the body starts rotating from rest at t = 0, (a) what is the angular velocity? (b) Angular position? (c) What angle does it rotate through in 10 s? (d) Where does the vector perpendicular to the axis of rotation indicating 0° at t = 0 lie at t = 10 s?
103. Earth's day has increased by 0.002 s in the last century. If this increase in Earth's period is constant, how long will it take for Earth to come to rest?
104. A disk of mass m, radius R, and area A has a surface mass density $\sigma = \frac{mr}{AR}$ (see the following figure). What is the moment of inertia of the disk about an axis through the center?



124. Zorch, an archenemy of Rotation Man, decides to slow Earth's rotation to once per 28.0 h by exerting an opposing force at and parallel to the equator. Rotation Man is not immediately concerned, because he knows Zorch can only exert a force of 4.00 x 10^7 N (a little greater than a Saturn V rocket's thrust). How long must Zorch push with this force to accomplish his goal? (This period gives Rotation Man time to devote to other villains.)
125. A cord is wrapped around the rim of a solid cylinder of radius 0.25 m, and a constant force of 40 N is exerted on the cord shown, as shown in the following figure. The cylinder is mounted on frictionless bearings, and its moment of inertia is 6.0 kg • m^2. (a) Use the work energy theorem to calculate the angular velocity of the cylinder after 5.0 m of cord have been removed. (b) If the 40-N force is replaced by a 40-N weight, what is the angular velocity of the cylinder after 5.0 m of cord have unwound?



4.E.5 Contributors and Attributions

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