

8.1 Rigid Bodies, Translations, and Rotations

- MC** In pure rotational motion of a rigid body, (a) all the particles of the body have the same angular velocity, (b) all the particles of the body have the same tangential velocity, (c) acceleration is always zero, (d) there are always two simultaneous axes of rotation. (a)
- MC** For an object with only rotational motion, all particles of the object have the same (a) instantaneous velocity, (b) average velocity, (c) distance from the axis of rotation, (d) instantaneous angular velocity. (d)
- MC** The condition for rolling without slipping is (a) $a_c = r\omega^2$, (b) $v_{\text{CM}} = r\omega$, (c) $F = ma$, (d) $a_c = v^2/r$. (b)
- MC** A rolling object (a) has an axis of rotation through the axis of symmetry, (b) has a zero velocity at the point or line of contact, (c) will slip if $s = r\theta$, (d) all of the preceding. (b)
- MC** For the tires on your skidding car, (a) $v_{\text{CM}} = r\omega$, (b) $v_{\text{CM}} > r\omega$, (c) $v_{\text{CM}} < r\omega$, (d) none of the preceding. (b)
- CQ** Suppose someone in your physics class says that it is possible for a rigid body to have translational motion and rotational motion at the same time. Would you agree? If so, give an example. [yes; rolling motion](#)
- CQ** For a rolling cylinder, what would happen if the tangential speed v were less than $r\omega$? Is it possible for v to be greater than $r\omega$? Explain. [slipping; yes, sliding](#)
- CQ** If the top of your automobile tire is moving with a speed of v , what is the reading of your speedometer? [v/2](#)
- A wheel rolls five revolutions on a horizontal surface without slipping. If the center of the wheel moves 3.2 m, what is the radius of the wheel? [0.10 m](#)
- A bowling ball with a radius of 15.0 cm travels down the alley so that its center of mass is moving at 3.60 m/s. The bowler estimates that it makes about 7.50 complete revolutions in 2.00 seconds. Is it rolling without slipping? Prove your answer, assuming that the bowler's quick observation limits answers to two significant figures. [ω ≈ 24 rad/s, no slipping](#)
- A ball with a radius of 15 cm rolls on a level surface, and the translational speed of the center of mass is 0.25 m/s. What is the angular speed about the center of mass if the ball rolls without slipping? [1.7 rad/s](#)
- A bocce ball with a diameter of 6.00 cm rolls without slipping on a level lawn. It has an initial angular speed of 2.35 rad/s and comes to rest after 2.50 m. Assuming constant deceleration, (a) determine the magnitude of its angular deceleration and (b) the magnitude of the maximum tangential acceleration of the ball's surface (tell where that part is located). (a) [0.0331 rad/s²](#) (b) [1.99 × 10⁻³ m/s²](#)
- A cylinder with a diameter of 20 cm rolls with an angular speed of 0.50 rad/s on a level surface. If the cylinder experiences a uniform tangential acceleration of 0.018 m/s² without slipping until its angular speed is 1.25 rad/s, through how many complete revolutions does the cylinder rotate during the time it accelerates? [0.58 rotations](#)

8.2 Torque, Equilibrium, and Stability

- MC** It is possible to have a net torque when (a) all forces act through the axis of rotation, (b) $\sum \vec{F}_i = 0$, (c) an object is in rotational equilibrium, (d) an object remains in unstable equilibrium. (b)
- MC** If an object in unstable equilibrium is displaced slightly, (a) its potential energy will decrease, (b) the center of gravity is directly above the axis of rotation, (c) no gravitational work is done, (d) stable equilibrium follows. (a)
- MC** Torque has the same units as (a) work, (b) force, (c) angular velocity, (d) angular acceleration. (a)
- CQ** When lifting an object with the use of the back rather than the legs, we often experience back pain. Why? [back muscles have to exert greater torque](#)
- CQ** A gymnast on the balance beam will squat when she feels she is losing her balance. Why? [to lower center of gravity](#)
- CQ** Explain the balancing acts in ▶ Fig. 8.33. Where are the centers of gravity? [the centers of gravity must be directly below the base of support](#)
- CQ** "Popping a wheelie" is a motorcycle stunt in which the front end of the cycle raises up off the ground on a fast start, and can remain there for some distance. Explain the physics involved in this stunt. [frictional torque causes cycle to rotate upward, balanced by weight torque](#)
- CQ** In the cases of both stable and unstable equilibrium, a small displacement of the center of gravity causes

gravitational work to be done. (See the balls and bowls in Fig. 8.11.) However, there is another type of equilibrium in which the displacement of the center of mass involves no gravitational work. This is called *neutral equilibrium*, and the displaced center of gravity essentially moves in a straight line. Give an example of an object in neutral equilibrium. [a cylinder or sphere on a level surface](#)

25. ● In Fig. 8.4a, if the arm makes a 37° angle with the horizontal and a torque of $18 \text{ m}\cdot\text{N}$ is to be produced, what force must the biceps muscle supply? $5.6 \times 10^2 \text{ N}$
32. IE ●● Telephone and electrical lines are allowed to sag between poles so that the tension will not be too great when something hits or sits on the line. (a) Is it possible to have the lines perfectly horizontal? Why or why not? (b) Suppose that a line were stretched almost perfectly horizontally between two poles that are 30 m apart. If a 0.25-kg bird perches on the wire midway between the poles and the wire sags 1.0 cm, what would be the tension in the wire? (a) no (b) $1.8 \times 10^3 \text{ N}$ (>400 lb!)
35. ●● A bowling ball (mass 7.00 kg and radius 17.0 cm) is released so fast that it skids without rotating down the alley (at least for a while). Assume the ball skids to your right and the coefficient of sliding friction between the ball and the lane surface is 0.400. (a) What is the direction of the torque exerted by the friction on the ball about the center of mass of the ball? (b) Determine the magnitude of this torque (again about the ball's center of mass). (a) clockwise (b) $4.66 \text{ m}\cdot\text{N}$
46. ●●● Suppose that the board in Fig. 8.40 were suspended from vertical ropes attached to each end instead of resting on scaffolding. If the painter stood 1.5 m from one end of the board, what would the tensions in the ropes be? (See Exercise 43 for additional data.) $2.6 \times 10^2 \text{ N}$; $5.7 \times 10^2 \text{ N}$

8.3 Rotational Dynamics

49. MC The moment of inertia of a rigid body (a) depends on the axis of rotation, (b) cannot be zero, (c) depends on mass distribution, (d) all of the preceding. (d)
50. MC Which of the following best describes the physical quantity called torque: (a) rotational analogue of force, (b) energy due to rotation, (c) rate of change of linear momentum, or (d) force that is tangent to a circle? (a)
51. MC In general, the moment of inertia is greater when (a) more mass is farther from the axis of rotation, (b) more mass is closer to the axis of rotation, (c) it makes no difference. (a)
52. MC The moment of inertia about an axis parallel to the axis through the center of mass depends on (a) the mass of the rigid body, (b) the distance between the axes, (c) the moment of inertia about the axis through the center of mass, or (d) all of the preceding. (d)
54. CQ Why does the moment of inertia of a rigid body have different values for different axes of rotation? What does this mean physically? [depends on how mass is distributed about an axis](#)
55. CQ When a hard-boiled egg lying on a table is given a quick torque (spin), it will rise up and spin on one end like a top. A raw egg will not. Why the difference? [hard-boiled egg is a rigid body](#)
61. ● A light meterstick is loaded with masses of 2.0 kg and 4.0 kg at the 30-cm and 75-cm positions, respectively. (a) What is the moment of inertia about an axis through the 0-cm end of the meterstick? (b) What is the moment of inertia about an axis through the center of mass of the system? (c) Use the parallel-axis theorem to find the moment of inertia about the axis through the 0-cm end of the stick, and compare the result with the result of part (a). (a) $2.4 \text{ kg}\cdot\text{m}^2$ (b) $0.27 \text{ kg}\cdot\text{m}^2$ (c) $2.4 \text{ kg}\cdot\text{m}^2$ (same)
66. ●● A submarine door is designed so it has a rectangular plate that rotates on two rectangular shafts as shown in ▼ Fig. 8.44. Each shaft has a mass of 50.0 kg and a length of 25.0 cm. The door has a mass of 200 kg and measures 50.0 cm by 1.00 m. Determine the moment of inertia of this door/hatch system about the hinge line (shown as the dashed vertical line in the figure). $56.3 \text{ kg}\cdot\text{m}^2$
68. ●● For the system shown in ▼ Fig. 8.45, $m_1 = 8.0 \text{ kg}$, $m_2 = 3.0 \text{ kg}$, $\theta = 30^\circ$, and the radius and mass of the pulley are 0.10 m and 0.10 kg, respectively. (a) What is the acceleration of the masses? (Neglect friction and the string's mass.) (b) If the pulley has a constant frictional torque of $0.050 \text{ m}\cdot\text{N}$ when the system is in motion, what is the acceleration of the masses? [Hint: Isolate the forces. The tensions in the strings are different. Why?] (a) 0.89 m/s^2 (b) 0.84 m/s^2

8.4 Rotational Work and Kinetic Energy

74. MC From $W = \tau\theta$, the unit of rotational work is the (a) watt, (b) $\text{N}\cdot\text{m}$, (c) $\text{kg}\cdot\text{rad/s}^2$, (d) $\text{N}\cdot\text{rad}$. (b)
75. MC A bowling ball rolls without slipping on a flat surface. The ball has (a) rotational kinetic energy, (b) translational kinetic energy, (c) both translational and rotational kinetic energy, (d) neither translational nor rotational kinetic energy. (c)

76. **MC** A rolling cylinder on a level surface has (a) rotational kinetic energy, (b) translational kinetic energy, (c) both translational and rotational kinetic energies. (c)
78. **CQ** In order to produce fuel-efficient vehicles, automobile manufacturers want to minimize rotational kinetic energy and maximize translational kinetic energy when a car is traveling. If you were the designer of wheels of a certain diameter, how would you design them? **small total mass with more mass near the center**
79. **CQ** What is required to produce a change in rotational kinetic energy? **rotational work**
85. ●● A sphere with a radius of 15 cm rolls on a level surface with a constant angular speed of 10 rad/s. To what height on a 30° inclined plane will the sphere roll before coming to rest? (Neglect frictional losses.) **0.16 m**
90. ●● A hoop starts from rest at a height 1.2 m above the base of an inclined plane and rolls down under the influence of gravity. What is the linear speed of the hoop's center of mass just as the hoop leaves the incline and rolls onto a horizontal surface? (Neglect friction.) **3.4 m/s**
94. ●●● In a tumbling clothes dryer, the cylindrical drum (radius 50.0 cm and mass 35.0 kg) rotates once every second. (a) Determine its rotational kinetic energy about its central axis. (b) If it started from rest and reached that speed in 2.50 s, determine the average net torque on the dryer drum. (a) **173 J** (b) **22.0 m·N**

8.5 Angular Momentum

96. **MC** The units of angular momentum are (a) N·m, (b) kg·m/s², (c) kg·m²/s, (d) J·m. (c)
97. **MC** The Earth's orbital speed is greatest about (a) March 21, (b) June 21, (c) Sept. 21, (d) Dec. 21. (d)
98. **MC** The angular momentum may be increased by (a) decreasing the moment of inertia, (b) decreasing the angular velocity, (c) increasing the product of the angular momentum and moment of inertia, (d) none of these. (c)
105. ● A 10-kg rotating disk of radius 0.25 m has an angular momentum of 0.45 kg·m²/s. What is the angular speed of the disk? **1.4 rad/s**
109. ●● A father gently places his small son on a rotating merry-go-round. The merry-go-round is essentially a disk with a mass of 250 kg and a radius of 2.50 m initially rotating at one revolution every 5.00 seconds. Assume the boy has a mass of 15.0 kg and is placed (without slipping) near the edge of the merry-go-round. Determine the final angular speed of the merry-go-round/boy combination. **1.18 rad/s**
114. ●●● While repairing his bicycle, a student has it upside down and has the front wheel spinning at 2.00 rev/s. Assume the wheel has a mass of 3.25 kg and all of the mass is located on the rim, which has a radius of 41.0 cm. To slow the wheel, he places his hand on the tire, thereby exerting a tangential force of friction on the wheel. It takes 3.50 s to come to rest. Use the change in angular momentum to determine the force he exerts on the wheel. Assume the frictional force of the axle is negligible. **4.78 N**