ANGULAR MOMENTUM

Angular Momentum

1. Which of the following objects have angular momentum? (Select all that apply)
   - A A ball rolling down an incline
   - B A pulley rotating at a constant speed
   - C A ball falling through the air
   - D A wheel rolling without slipping

2. What is the SI unit for angular momentum?
   - A kg·m/s
   - B N·s
   - C kg·m^2
   - D kg·m^2/s

3. A solid cylinder is rolling along the ground. Its angular momentum depends on which of the following? (Select all that apply)
   - A Its mass
   - B Its radius
   - C Its angular velocity
   - D None of the above

4. Two wheels with the same size, shape and mass are rolling in opposite directions with the same linear speed. Which of the following is true? (Select all that apply)
   - A The magnitudes of their angular momentums are the same
   - B The relationship between the magnitudes of their angular momentums cannot be determined without more information about their angular speeds
   - C The signs (positive/negative) of their angular momentums are the same
   - D The signs (positive/negative) of their angular momentums are different

5. If a net torque is applied to an object for a period of time, which of the following things would change? (Select all that apply)
   - A The object's momentum
   - B The object's angular momentum
   - C The object's rotational inertia
   - D The object's angular speed

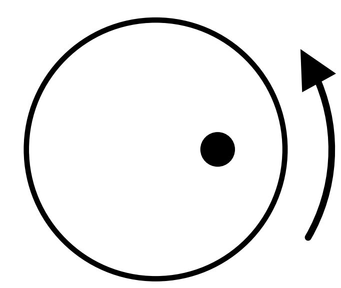
6. A pulley is rotating with an angular speed of ω. A torque is then applied to the pulley which brings the pulley to rest after a period of time Δt. If the torque had three times its magnitude instead, how long would it have taken to stop the pulley in terms of Δt?
   - A Δt
   - B $\Delta t/3$
   - C $3\Delta t$
   - D $9\Delta t$

7. If an object is spinning counterclockwise, which of the following would increase its angular momentum?
   - A A counterclockwise torque
   - B A clockwise torque
   - C Either a clockwise or a counterclockwise torque
   - D None of the above

8. A system consists of three rotating objects. If there is no net external torque exerted on the system, which of the following is true? (Select all that apply)
   - A The total angular momentum of the system is zero
   - B The total rotational kinetic energy of the system is conserved
   - C The angular momentum of each object is conserved
   - D The total angular momentum of the system is conserved

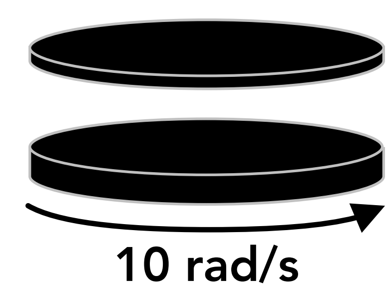
9. A figure skater is spinning in place with their arms straight out away from their body. What will happen if they pull their arms in close to their body?
   - A They will spin faster
   - B They will spin slower
   - C Their angular speed will stay the same
   - D A change to their angular speed cannot be determined

10. A top-down view of a person standing on a spinning merry-go-round is shown on the right. The platform is spinning freely on a center axle with no external force turning it. If the person wants slow down the platform, which direction should they walk?



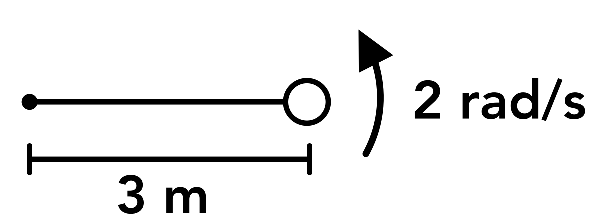
   - A Towards the center of the platform
   - B Towards the outer edge of the platform
   - C Neither of the above will change the speed of the platform

11. A solid disk with a mass of 5 kg and a radius of 40 cm is spinning at 10 rad/s. Another disk with a mass of 2 kg and the same radius, which is not spinning, is dropped onto the spinning disk from above and the two disks stick together. What is the new angular speed of the two disks?



12. A solid cylinder with a radius of 20 cm is spinning at 150 rpm. If the cylinder has an angular momentum of 8 kg·m²/s, what is the mass of the cylinder?

13. A 10 kg sphere is attached to the end of a rod with negligible mass which is rotating about its left end as shown on the right. What is the angular momentum of the rod-sphere system?



Answers

1. A, B, D
2. D
3. A, B, C
4. A, D
5. B, D
6. B
7. A
8. D
9. A
10. B
11. 7.14 rad/s
12. 25.5 kg
13. 180 kg·m²/s

Answers - Angular Momentum

1. **Answer: A, B, D**
   An object has angular momentum when it is rotating.

2. **Answer: D**
   The SI unit for angular momentum is kg·m²/s.

3. **Answer: A, B, C**
   The equation for angular momentum is given below. Angular momentum depends on the angular velocity and the rotational inertia, which depends on the mass and radius of the cylinder.
   $L = I\omega \qquad I = \frac{1}{2}mR^2$

4. **Answer: A, D**
   The wheels have the same rotational inertia because they have the same size, shape and mass. The wheels have the same radius and linear speed so we know they have the same angular speed, which is given by $v = r\omega$. Angular momentum is a vector which depends on the direction of the angular velocity, and the wheels are rotating in opposite directions so their angular momentums have opposite signs (positive and negative).

5. **Answer: B, D**
   A net torque applied to an object for a period of time will change the object's angular momentum, which we might call a "rotational impulse". Unless given a reason to assume otherwise, we assume an object's rotational inertia (it's mass and shape) does not change so the object's angular speed must change.
   $\tau\Delta t = \Delta L = I\Delta\omega$

6. **Answer: B**
   The equation for rotational impulse is given below. The change in angular momentum is the same in each case, so if the torque is multiplied by 3 then the period of time must be divided by 3.
   $\Delta L = \tau\Delta t$

7. **Answer: A**
   The object starts with a counterclockwise angular velocity so it has a counterclockwise angular momentum. A counterclockwise torque would increase its angular velocity and angular momentum. A clockwise torque would decrease its angular velocity and angular momentum.

8. **Answer: D**
   If there is no net external torque acting on a system then the total angular momentum of the system is conserved.

9. **Answer: A**
   The angular momentum of the skater is conserved. By bringing their arms in closer to their body they are decreasing their rotational inertia (their mass is closer to the axis of rotation), so their angular speed must increase to maintain the same angular momentum.
   $L = I\omega$

10. **Answer: B**
The total angular momentum of the person and platform system is conserved. By walking towards the outer edge of the platform, away from the center, they are increasing the rotational inertia of the system so the angular speed of the system must decrease.
$\boldsymbol{L = I\omega}$

11. **Answer: 7.14 rad/s**
This is a perfectly inelastic collision and the total angular momentum of the two disks is conserved.
Top disk: $I = \frac{1}{2}mR^2 = \frac{1}{2}(2\text{ kg})(0.4\text{ m})^2 = 0.16\text{ kg·m}^2$
Bottom disk: $I = \frac{1}{2}mR^2 = \frac{1}{2}(5\text{ kg})(0.4\text{ m})^2 = 0.4\text{ kg·m}^2$
$\sum L_i = \sum L_f \quad I_1\omega_{1i} + I_2\omega_{2i} = (I_1 + I_2)\omega_f \quad (0.16\text{ kg·m}^2)(0\text{ rad/s}) + (0.4\text{ kg·m}^2)(10\text{ rad/s}) = (0.56\text{ kg·m}^2)\omega_f$
$\omega_f = 7.14\text{ rad/s}$

12. **Answer: 25.5 kg**
$\omega = \frac{150\text{ rev}}{\text{min}} \times \frac{2\pi\text{ rad}}{1\text{ rev}} \times \frac{1\text{ min}}{60\text{ s}} = 15.71\text{ rad/s}$
$L = I\omega \quad L = \frac{1}{2}mR^2\omega \quad (8\text{ kg·m}^2\text{/s}) = \frac{1}{2}m(0.2\text{ m})^2(15.71\text{ rad/s}) \quad m = 25.5\text{ kg}$

13. **Answer: 180 kg·m²/s**
The rotational inertia can be found by treating the sphere as a point mass of 10 kg at a distance of 3 m from the axis of rotation.
$L = I\omega = mr^2\omega = (10\text{ kg})(3\text{ m})^2(2\text{ rad/s}) = 180\text{ kg·m}^2\text{/s}$