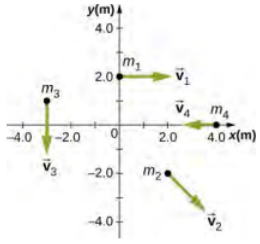
7.E: Angular Momentum (Exercises)

Conceptual Questions

1. Can you assign an angular momentum to a particle without first defining a reference point?
2. For a particle traveling in a straight line, are there any points about which the angular momentum is zero? Assume the line intersects the origin.
3. Under what conditions does a rigid body have angular momentum but not linear momentum?
4. If a particle is moving with respect to a chosen origin it has linear momentum. What conditions must exist for this particle's angular momentum to be zero about the chosen origin?
5. If you know the velocity of a particle, can you say anything about the particle's angular momentum?

Problems

6. A 0.2-kg particle is travelling along the line y = 2.0 m with a velocity 5.0 m/s. What is the angular momentum of the particle about the origin?
7. A bird flies overhead from where you stand at an altitude of 300.0 m and at a speed horizontal to the ground of 20.0 m/s. The bird has a mass of 2.0 kg. The radius vector to the bird makes an angle θ with respect to the ground. The radius vector to the bird and its momentum vector lie in the xy-plane. What is the bird's angular momentum about the point where you are standing?
8. A Formula One race car with mass 750.0 kg is speeding through a course in Monaco and enters a circular turn at 220.0 km/h in the counterclockwise direction about the origin of the circle. At another part of the course, the car enters a second circular turn at 180 km/h also in the counterclockwise direction. If the radius of curvature of the first turn is 130.0 m and that of the second is 100.0 m, compare the angular momenta of the race car in each turn taken about the origin of the circular turn.
9. A particle of mass 5.0 kg has position vector $\vec{r} = \begin{bmatrix} 2.0\ \text{m} \\ -3.0\ \text{m} \\ 0.0\ \text{m} \end{bmatrix}$ at a particular instant of time when its velocity is $\vec{v} = \begin{bmatrix} 3.0\ \text{m/s} \\ 0.0\ \text{m/s} \\ 0.0\ \text{m/s} \end{bmatrix}$ with respect to the origin. (a) What is the angular momentum of the particle? (b) If a force $\vec{F} = \begin{bmatrix} 0.0\ \text{N} \\ 5.0\ \text{N} \\ 0.0\ \text{N} \end{bmatrix}$ acts on the particle at this instant, what is the torque about the origin?
10. Use the right-hand rule to determine the directions of the angular momenta about the origin of the particles as shown below. The z-axis is out of the page.

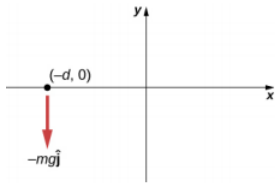


11. Suppose the particles in the preceding problem have masses m_1 = 0.10 kg, m_2 = 0.20 kg, m_3 = 0.30 kg, m_4 = 0.40 kg. The velocities of the particles are $\vec{v}_1 = \begin{bmatrix} 2.0\ \text{m/s} \\ 0.0\ \text{m/s} \\ 0.0\ \text{m/s} \end{bmatrix}$, $\vec{v}_2 = \begin{bmatrix} 3.0\ \text{m/s} \\ -3.0\ \text{m/s} \\ 0.0\ \text{m/s} \end{bmatrix}$, $\vec{v}_3 = \begin{bmatrix} 0.0\ \text{m/s} \\ -1.5\ \text{m/s} \\ 0.0\ \text{m/s} \end{bmatrix}$, $\vec{v}_4 = \begin{bmatrix} -4.0\ \text{m/s} \\ 0.0\ \text{m/s} \\ 0.0\ \text{m/s} \end{bmatrix}$. (a) Calculate the angular momentum of each particle about the origin. (b) What is the total angular momentum of the four-particle system about the origin?
12. Two particles of equal mass travel with the same speed in opposite directions along parallel lines separated by a distance d. Show that the angular momentum of this two-particle system is the same no matter what point is used as the reference for calculating the angular momentum.

13. An airplane of mass 4.0 x 10^4 kg flies horizontally at an altitude of 10 km with a constant speed of 250 m/s relative to Earth. (a) What is the magnitude of the airplane's angular momentum relative to a ground observer directly below the plane? (b) Does the angular momentum change as the airplane flies along its path?

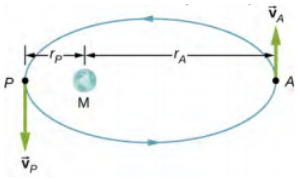
14. At a particular instant, a 1.0-kg particle's position is $\vec{r} = \begin{bmatrix} 2.0\ \text{m} \\ -4.0\ \text{m} \\ 6.0\ \text{m} \end{bmatrix}$, its velocity is $\vec{v}_2 = \begin{bmatrix} -1.0\ \text{m/s} \\ 4.0\ \text{m/s} \\ 1.0\ \text{m/s} \end{bmatrix}$, and the force on it is $\vec{F} = \begin{bmatrix} 10.0\ \text{N} \\ 15.0\ \text{N} \\ 0.0\ \text{N} \end{bmatrix}$. (a) What is the angular momentum of the particle about the origin? (b) What is the torque on the particle about the origin? (c) What is the time rate of change of the particle's angular momentum at this instant?

15. A particle of mass m is dropped at the point (−d, 0) and falls vertically in Earth's gravitational field −g in the y-direction. (a) What is the expression for the angular momentum of the particle around the z-axis, which points directly out of the page as shown below? (b) Calculate the torque on the particle around the z-axis. (c) Is the torque equal to the time rate of change of the angular momentum?

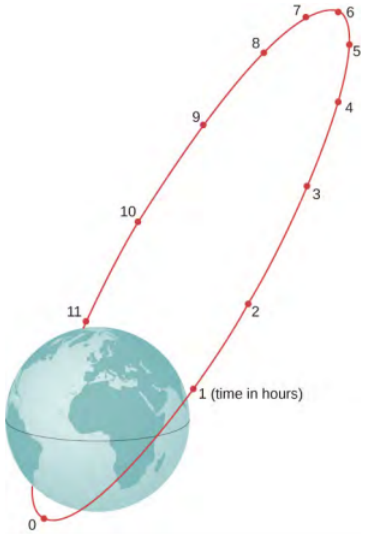


16. (a) Calculate the angular momentum of Earth in its orbit around the Sun. (b) Compare this angular momentum with the angular momentum of Earth about its axis.

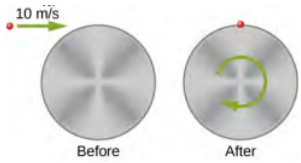
17. An Earth satellite has its apogee at 2500 km above the surface of Earth and perigee at 500 km above the surface of Earth. At apogee its speed is 730 m/s. What is its speed at perigee? Earth's radius is 6370 km (see below).



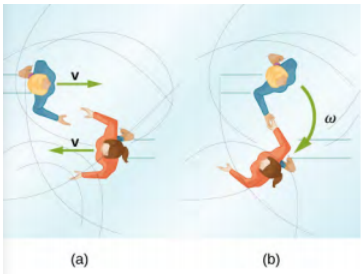
18. A Molniya orbit is a highly eccentric orbit of a communication satellite so as to provide continuous communications coverage for Scandinavian countries and adjacent Russia. The orbit is positioned so that these countries have the satellite in view for extended periods in time (see below). If a satellite in such an orbit has an apogee at 40,000.0 km as measured from the center of Earth and a velocity of 3.0 km/s, what would be its velocity at perigee measured at 200.0 km altitude?



19. Shown below is a small particle of mass 20 g that is moving at a speed of 10.0 m/s when it collides and sticks to the edge of a uniform solid cylinder. The cylinder is free to rotate about its axis through its center and is perpendicular to the page. The cylinder has a mass of 0.5 kg and a radius of 10 cm, and is initially at rest. (a) What is the angular velocity of the system after the collision?



20. A merry-go-round has a radius of 2.0 m and a moment of inertia 300 kg • m^2. A boy of mass 50 kg runs tangent to the rim at a speed of 4.0 m/s and jumps on. If the merry-go-round is initially at rest, what is the angular velocity after the boy jumps on?
21. Twin skaters approach one another as shown below and lock hands. (a) Calculate their final angular velocity, given each had an initial speed of 2.50 m/s relative to the ice. Each has a mass of 70.0 kg, and each has a center of mass located 0.800 m from their locked hands. You may approximate their moments of inertia to be that of point masses at this radius.



22. A baseball catcher extends his arm straight up to catch a fast ball with a speed of 40 m/s. The baseball is 0.145 kg and the catcher's arm length is 0.5 m and mass 4.0 kg. (a) What is the angular velocity of the arm immediately after catching the ball as measured from the arm socket? (b) What is the torque applied if the catcher stops the rotation of his arm 0.3 s after catching the ball?
23. A particle has mass 0.5 kg and is traveling along the line x = 5.0 m at 2.0 m/s in the positive y-direction. What is the particle's angular momentum about the origin?
24. A proton is accelerated in a cyclotron to 5.0 x 10^6 m/s in 0.01 s. The proton follows a circular path. If the radius of the cyclotron is 0.5 km, (a) What is the angular momentum of the proton about the center at its maximum speed? (b) What is the torque on the proton about the center as it accelerates to maximum speed?
25. A potter's disk spins from rest up to 10 rev/s in 15 s. The disk has a mass 3.0 kg and radius 30.0 cm. What is the angular momentum of the disk at t = 5 s, t = 10 s?
26. Suppose you start an antique car by exerting a force of 300 N on its crank for 0.250 s. What is the angular momentum given to the engine if the handle of the crank is 0.300 m from the pivot and the force is exerted to create maximum torque the entire time?

Contributors and Attributions

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