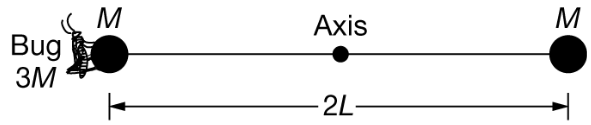
Physics C Assignment 6.3

Angular Momentum and Impulse

1. Two identical spheres of mass M are fastened to opposite ends of a rod of length $2L$. The radii of the spheres are negligible when compared to the length $2L$, and the rod has negligible mass. This system is initially at rest with the rod horizontal and is free to rotate about a frictionless axis through the center of the rod. The axis is horizontal and perpendicular to the plane of the page. A bug of mass $3M$ lands gently on the sphere on the left, as shown in the figure above. Assume that the size of the bug is small compared with the length of the rod.



After the bug lands, the rod begins to rotate. Which of the following correctly describes the change in the magnitude of the angular momentum of the bug-rod-spheres system and the change in gravitational potential energy of the bug-rod-spheres-Earth system as the rod rotates but before the rod becomes vertical?
A) Angular momentum remains constant, gravitational potential energy remains constant
B) Angular momentum remains constant, gravitational potential energy increases
C) Angular momentum remains constant, gravitational potential energy decreases
D) Angular momentum increases, gravitational potential energy increases
E) Angular momentum increases, gravitational potential energy decreases

2. A machine is applying a torque to rotationally accelerate a metal disk during a manufacturing process. An engineer is using a graph of torque as a function of time to determine how much the disk's angular speed increases during the process.
The graph of torque as a function of time starts at an initial torque value and is a straight line with positive slope. What aspect of the graph and possibly other quantities must be used to calculate how much the disk's angular speed increases during the process?
A) The slope of the graph multiplied by the disk's radius will equal the change in angular speed.
B) The area under the graph multiplied by the disk's radius will equal the change in angular speed.
C) The slope of the graph divided by the disk's rotational inertia will equal the change in angular speed.
D) The area under the graph divided by the disk's rotational inertia will equal the change in angular speed.
E) The area under the graph multiplied by the disk's rotational inertia will equal the change in angular speed.

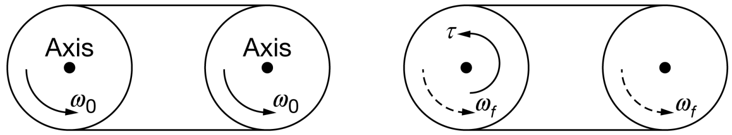


Figure 1 Figure 2

3. Two identical uniform disks are connected by a belt of negligible mass. The rotational inertia of each disk is I. Each disk is initially rotating in a counterclockwise direction at angular speed ω_0 around an axis passing through the center of the disk, as shown in Figure 1 above. A constant external counterclockwise torque τ acts on the left disk. It increases the angular speed of each disk to ω_f, as shown in Figure 2 above. Which of the following equations is correct for the change in angular momentum of the two disks?

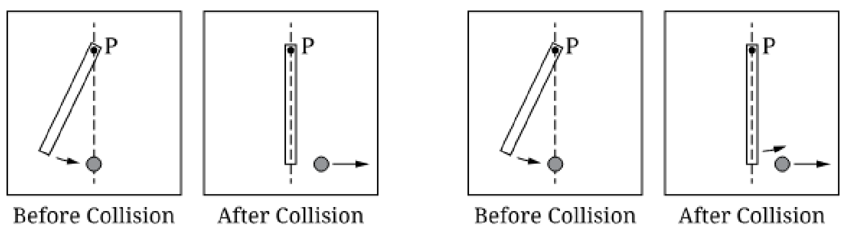
A) $\Delta L = 2I(\omega_f - \omega_0)$

B) $\Delta L = I(\omega_f - \omega_0)$

C) $\Delta L = (\omega_f - \omega_0)^2$

D) $\Delta L = \frac{1}{2}I(\omega_f - \omega_0)$

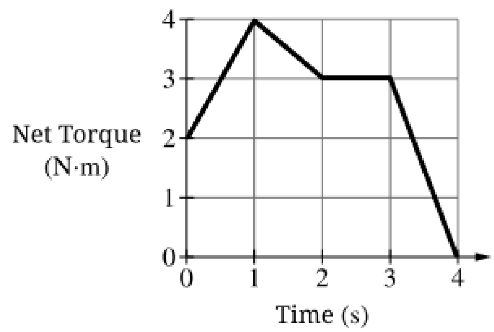
E) $\Delta L = \frac{1}{2}I(\omega_f - \omega_0)^2$



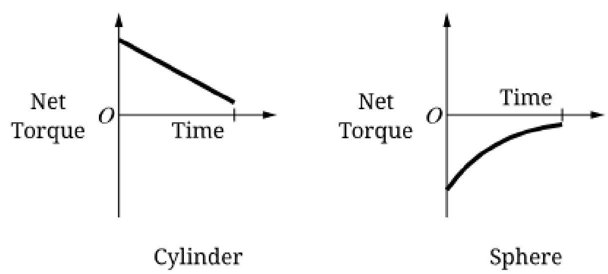
Collision 1 Collision 2

Top Views

4. In the two collisions depicted in the figures, a bar is rotating about a pivot end, labeled Point P, on top of a horizontal surface before striking a disk that is initially at rest. The two collisions use the same bar but different disks, where the two disks are the same mass and size but are made of different materials. After each collision, the disk moves to the right at a constant velocity. After Collision 1, The bar stops rotating. After Collision 2, the bar is still rotating in the same direction, and the disk is moving more slowly than after Collision 1. There is negligible friction between the bar and the pivot, between the bar and the surface, and between each disk and the surface. After which collision does the disk have a greater velocity? Justify your answer.

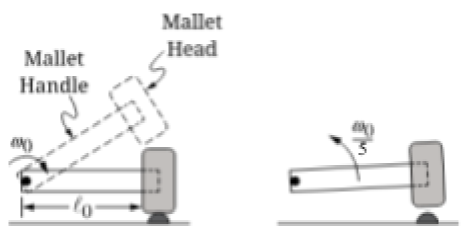


5. A disk can rotate about an axis through its center and perpendicular to the plane of the disk. The graph shows the net torque exerted on the disk as a function of time. Find the angular impulse delivered to the disk on the interval $0 < t < 4$.

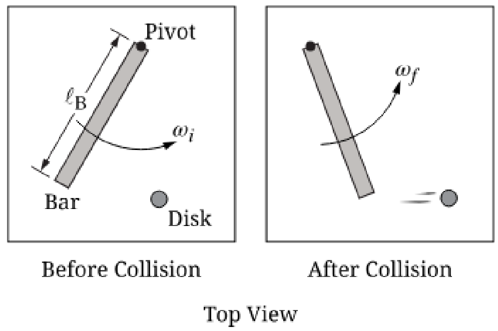


6. The two graphs show the net torque exerted on two rotating objects, a cylinder, and a sphere, as a function of time. If both objects are initially rotating in the positive direction, taken to be counterclockwise, for which object does the angular momentum <u>increase</u> in magnitude during the time interval shown? Justify your answer.

7. A disk is spinning clockwise, when a counterclockwise torque is applied for a short time. In which direction is the angular impulse delivered to the disk? Justify your answer.

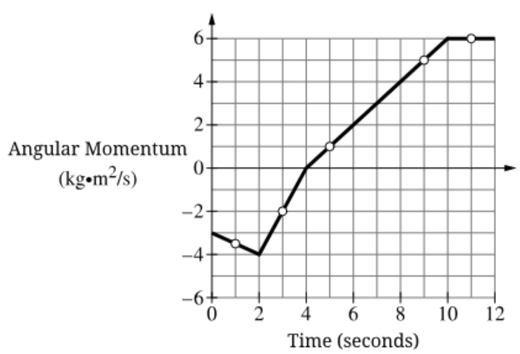


8. A mallet rotates about a pivot near one end of its handle and is moving clockwise with an angular speed ω_0 as it strikes a small, stationary rubber bumper, as shown in the figure. Immediately after the impact, the mallet is rotating counterclockwise about the pivot with an angular speed $\frac{\omega_0}{5}$. The handle of the mallet has length ℓ_0, mass m_0, and rotational inertia $I_0 = \frac{1}{3}m_0\ell_0^2$ about the pivot. The head of the mallet is small compared to the length of the handle, has the same mass m_0 as the handle, and is located ℓ_0 from the pivot. If the mallet is in contact with the bumper for an amount of time Δt, what is the magnitude of the average force that the mallet exerts on the rubber bumper during the contact time, in terms of m_0, ℓ_0, ω_0, and Δt ?



9. A bar of length ℓ_B is on a horizontal tabletop and is free to rotate about a fixed vertical pivot point at one end, as shown in the figures. The rotational inertia of the bar about the pivot is I_B. The bar rotates in the counterclockwise direction with angular velocity ω_i before its free end collides with a small, stationary disk of mass m_D. After the collision, the bar continues to rotate in the counterclockwise direction with angular velocity ω_f, and the disk moves forward with translational velocity v_D. All frictional forces are negligible, and the disk is much smaller in size than ℓ_B. With respect to the pivot, what is the magnitude of the angular impulse exerted on the bar during the collision?

A) $m_D \ell_B v_D$
B) $I_B|\omega_f - \omega_i|$
C) $I_B\omega_f + \ell_B m_D v_D$
D) Both A and B are correct



10. A momentum wheel is a rotating wheel aboard a satellite used to control the angular orientation of the satellite. Engineers who are testing a momentum wheel on Earth apply a time-varying torque to the wheel and determine the wheel's resulting angular momentum. The graph shows the wheel's angular momentum as a function of time during one of the tests. For which of the following time intervals did the torque on the wheel change by the least amount?

A) Between 1 and 3 seconds
B) Between 3 and 5 seconds
C) Between 5 and 9 seconds
D) Between 9 and 11 seconds

Figure 1

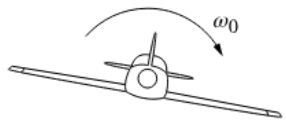
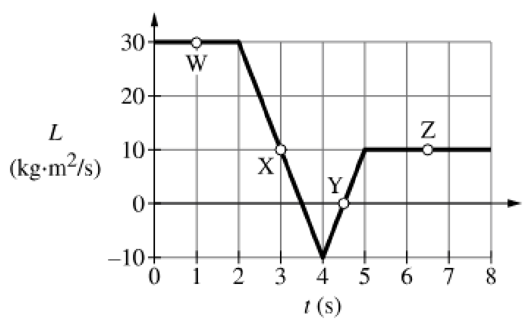


Figure 2

Front Views of Airplane

11. An airplane is performing rolls, which are rotations about the airplane's central axis, as shown in the figures. In Figure 1, at $t = 0$, the airplane is rotating in the counterclockwise direction with an angular speed of ω_0. Figure 2 shows the airplane $t = 5$ seconds later, when it is rotating in the clockwise direction with an angular speed of ω_0. If the airplane's rotational inertia about its central axis is I_A, what is the magnitude of the airplane's average torque between $t = 0$ and $t = 5$?



12. A cylinder is rotating about its central axis. The graph shows the cylinder's angular momentum L as a function of time t, where the positive direction is taken to be counterclockwise. Rank the torques τ_W, τ_X, τ_Y, and τ_Z in descending order (greatest to least).