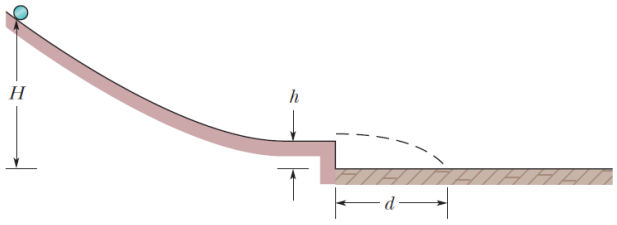
Tutorial 3 Rotational Dynamics & Angular Momentum

Rotational Dynamics

1 A yo-yo has a rotational inertia of 950 g cm^2 and a mass of 120 g. Its axle radius is 3.2 mm, and its string is 120 cm long. The yo-yo rolls from rest down to the end of the string.

(a) What is the magnitude of its linear acceleration?
(b) How long does it take to reach the end of the string? As it reaches the end of the string, what are its
(c) linear speed,
(d) translational kinetic energy,
(e) rotational kinetic energy, and
(f) angular speed?

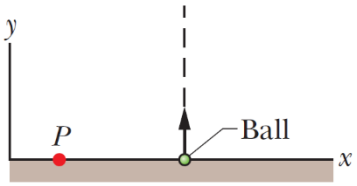
2 *Nonuniform cylindrical object.* In The figure, a cylindrical object of mass *M* and radius *R* rolls smoothly from rest down a ramp and onto a horizontal section. From there it rolls off the ramp and onto the floor, landing a horizontal distance *d* = 0.506 m from the end of the ramp. The initial height of the object is *H* = 0.90 m; the end of the ramp is at height *h* = 0.10 m. The object consists of an outer cylindrical shell (of a certain uniform density) that is glued to a central cylinder (of a different uniform density).The rotational inertia of the object can be expressed in the general form $I = \beta MR^2$, but β is not 0.5 as it is for a cylinder of uniform density.



Determine β.

Angular Momentum

3 In the figure, a 0.400 kg ball is shot directly upward at initial speed 40.0 m s^{-1}.



What is its angular momentum about *P*, 2.00 m horizontally from the launch point, when the ball is

(a) at maximum height and
(b) halfway back to the ground?

What is the torque on the ball about *P* due to the gravitational force when the ball is

(c) at maximum height and
(d) halfway back to the ground?

4 The angular momentum of a flywheel having a rotational inertia of 0.140 kg m^2 about its central axis decreases from 3.00 to 0.800 kg m^2 s^{-1} in 1.50 s.

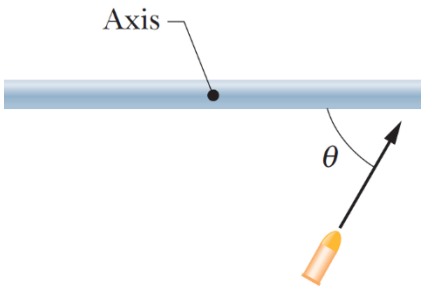
(a) What is the magnitude of the average torque acting on the flywheel about its central axis during this period?
(b) Assuming a constant angular acceleration, through what angle does the flywheel turn?
(c) How much work is done on the wheel?
(d) What is the average power of the flywheel?

5 A disk with a rotational inertia of 7.00 kg m^2 rotates like a merry-go-round while undergoing a time-independent torque given by $\tau = (5.00 + 2.00t)$ N m. At time $t = 1\ s$, its angular momentum is 5.00 kg m^2 s^{-1}.

What is its angular momentum at $t = 3.00$ s?

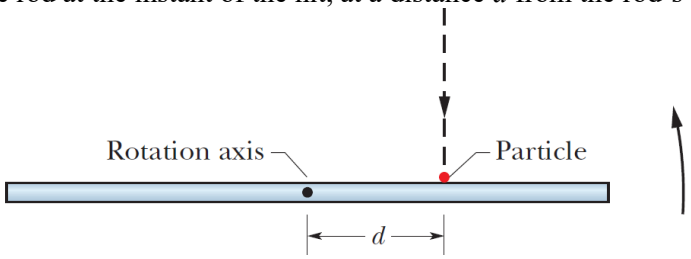
Conservation of Angular Momentum

6 In Fig. 11-50 (an overhead view), a uniform thin rod of length 0.500 m and mass 4.00 kg can rotate in a horizontal plane about a vertical axis through its center. The rod is at rest when a 3.00 g bullet traveling in the rotation plane is fired into one end of the rod. In the view from above, the bullet's path makes angle $\theta = 60.0°$ with the rod.



If the bullet lodges in the rod and the angular velocity of the rod is 10 rad s^{-1} immediately after the collision, what is the bullet's speed just before impact?

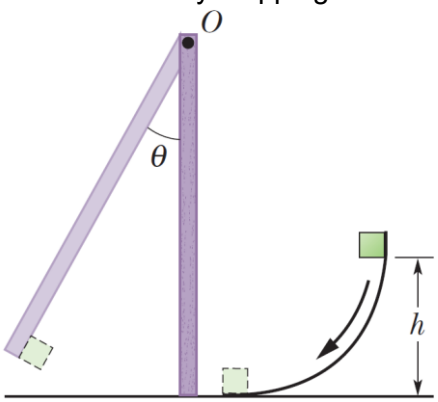
7 The figure is an overhead view of a thin uniform rod of length 0.600 m and mass M rotating horizontally at 80.0 rad s^{-1} counterclockwise about an axis through its center. A particle of mass $M/3.00$ and traveling horizontally at speed 40.0 m s^{-1} hits the rod and sticks. The particle's path is perpendicular to the rod at the instant of the hit, at a distance d from the rod's center.



(a) At what value of d are rod and particle stationary after the hit?

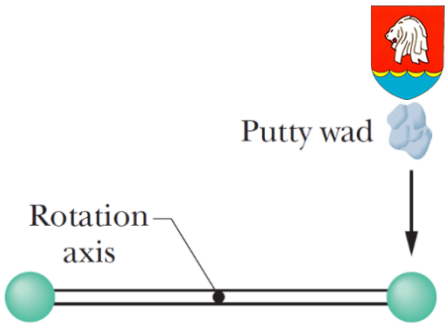
(b) In which direction do rod and particle rotate if d is greater than this value?

8 In the figure, a small 50 g block slides down a frictionless surface through height $h = 20$ cm and then sticks to a uniform rod of mass 100 g and length 40 cm. The rod pivots about point O through angle θ before momentarily stopping.



Determine θ.

9 Two 2.00 kg balls are attached to the ends of a thin rod of length 50.0 cm and negligible mass. The rod is free to rotate in a vertical plane without friction about a horizontal axis through its center. With the rod initially horizontal, a 50.0 g wad of wet putty drops onto one of the balls, hitting it with a speed of 3.00 m s^{-1} and then sticking to it.



(a) What is the angular speed of the system just after the putty wad hits?
(b) What is the ratio of the kinetic energy of the system after the collision to that of the putty wad just before?
(c) Through what angle will the system rotate before it momentarily stops?

Answers

1		
	(a)	13 cm s^{-2}
	(b)	4.4 s
	(c)	- 54.8 cm s^{-1}
	(d)	1.8×10^{-2} J
	(e)	1.4 J
	(f)	27 rev s^{-1}
2	β = 0.25	
3	**(a)**	Zero
	(b)	L = - 22.6 kg m^2 s^{-1}
	(c)	τ = - 7.84 N m
	(d)	τ = - 7.84 N m
4	**(a)**	- 1.47 N m
	(b)	20.4 rad
	(c)	- 29.9 J
	(d)	19.9 W
5	23.0 kg m^2 s^{-1}	
6	1300 m s^{-1}	
7	**(a)**	d = 0.180 m
8	32°	
9	**(a)**	0.148 rad s^{-1}
	(b)	0.0123
	(c)	181°