The parking brake on a 1800 kg Cadillac has failed, and it is rolling slowly, at 1.1 mph, toward a group of small children. Seeing the situation, you realize you have just enough time to drive your 1200 kg Volkswagen head-on into the Cadillac and save the children. With what speed should you impact the Cadillac to bring it to a halt?

\[ 1.65 \text{ mph} \]

Two particles collide and bounce apart. The figure below shows the initial momenta of both and the final momentum of particle 2.

(a) What is the final momentum of particle 1?
- x-component \( -2 \) kg\cdot m/s
- y-component \( 4 \) kg\cdot m/s

(b) Show the momentum vector on the diagram and write it in component form. (Do this on paper. Your instructor may ask you to turn in your work.)

A 16 g ball of clay traveling east at 3.0 m/s collides with a 30 g ball of clay traveling north at 2.0 m/s. What are the speed and the direction of the resulting 46 g ball of
Far in space, where gravity is negligible, a 410 kg rocket traveling at 75 m/s fires its engines. Figure P9.26 shows the thrust force as a function of time, with the horizontal axis in 8 s increments. The mass lost by the rocket during these 24 s is negligible.

**Figure P9.26**

(a) What impulse does the engine impart to the rocket?  
\[ 12000 \text{ N} \cdot \text{s} \]

(b) At what time does the rocket reach its maximum speed?  
\[ 24 \text{ s} \]  
What is the maximum speed?  
\[ 104 \text{ m/s} \]

A tennis player swings her 1000 g racket with a speed of 9 m/s. She hits a 60 g tennis ball that was approaching her at a speed of 24 m/s. The ball rebounds at 40 m/s.

(a) How fast is her racket moving immediately after the impact? You can ignore the interaction of the racket with her hand for the brief duration of the collision.  
\[ 5.16 \text{ m/s} \]

(b) If the tennis ball and racket are in contact for 10 ms, what is the average force that the racket exerts on the ball?  
\[ 384 \text{ N} \]  
How does this compare to the ball's weight?  
\[ \frac{F_{\text{avg}}}{W_{\text{ball}}} = 653 \]
Three identical train cars, coupled together, are rolling east at 3.0 m/s. A fourth car traveling east at 4.0 m/s catches up with the three and couples to make a four-car train. A moment later, the train cars hit a fifth car that was at rest on the tracks, and it couples to make a five-car train. What is the speed of the five-car train? (Take all five train cars as identical.)

\[ 2.6 \text{ m/s} \]

7. Knight 13.011. [455130] 0/1 points Show Details

What is the net torque on the pulley about the axle if \( T_1 = 16 \text{ N} \) and \( T_2 = 34 \text{ N} \)?

\[ 0.36 \text{ N}\cdot\text{m clockwise} \]

---Select---

8. Knight 13.014. [380274] 0/2 points Show Details

The 22 cm diameter disk in Figure Ex13.14 can rotate on an axle through its center. What is the net torque about the axle if \( F = 22 \text{ N} \)?

\[ 1.14 \text{ N}\cdot\text{m clockwise} \]

---Select---

9. Knight 13.017. [455084] 0/3 points Show Details
The four masses shown in Figure Ex13.17 are connected by massless, rigid rods.

![Figure Ex13.17](image)

(a) Find the coordinates of the center of mass if \( M_A = 100 \) g and \( M_B = M_C = M_D = 180 \) g.

\[ x = 0.0562 \text{ m} \]
\[ y = 0.0562 \text{ m} \]

(b) Find the moment of inertia about an axis that passes through mass A and is perpendicular to the page.

\[ 0.0072 \text{ kg m}^2 \]
(5.57 cm, 5.57 cm)

(b) Find the moment of inertia about a diagonal axis that passes through masses B and D.

13.8 kg·cm²

(a) Find the coordinates of the center of mass.

(0.06 m, 0.0395 m)

(b) Find the moment of inertia about an axis that passes through mass A and is perpendicular to the page.

0.002 kg·m²

(c) Find the moment of inertia about an axis that passes through masses B and C.

0.00125 kg·m²

An object whose moment of inertia is 2.0 kg·m² experiences the torque shown in Figure Ex13.21. What is the object's angular velocity at \( t = 1.4 \) s? Assume it starts from rest.

0.9 rad/s
13. How much torque must the pin exert to keep the rod from rotating if the rod has a length \( L = 65 \text{ cm} \) and a mass \( m = 4.0 \text{ kg} \)?

\[ 15.9 \text{ N-m} \] counterclockwise

14. The two objects in Figure Ex13.27 are balanced on the pivot, with \( m = 1.8 \text{ kg} \). What is the distance \( d \)?

\[ 1.34 \text{ m} \]

15. The three 160 g masses in Figure Ex13.29 are connected by massless, rigid rods to form a triangle. What is the triangle's rotational kinetic energy if it rotates at 6.0 rev/s about an axis through the center?

\[ 18.2 \text{ J} \]
16. A thin, 99 g disk with a diameter of 7.1 cm rotates about an axis through its center with 0.12 J of kinetic energy. What is the speed of a point on the rim?

2.2 m/s

17. A 310 g ball and a 590 g ball are connected by a 40 cm long massless, rigid rod. The structure rotates about its center of mass at 135 rpm. What is its rotational kinetic energy?

3.25 J

18. A 9.0 cm diameter, 408 g sphere is released from rest at the top of a 3.3 m long, 25° incline. It rolls, without slipping, to the bottom.

(a) What is the sphere's angular velocity at the bottom of the incline?

98.2 rad/s

(b) What fraction of its kinetic energy is translational?

0.714

19. What is the angular momentum of the 320 g rotating bar in Figure Ex13.46?

1.34 kg·m²/s

Figure Ex13.46

20. What is the angular momentum of the 1.0 kg, 6.0 cm diameter rotating disk in Figure Ex13.47?
A 3.0 m long rigid beam with a mass of 105 kg is supported at each end. An 75 kg student stands 2.0 m from support 1. How much upward force does each support exert on the beam?

- Right support: 1000 N
- Left support: 760 N

An 76 kg construction worker sits down 2.0 m from the end of a 1420 kg steel beam to eat his lunch. The cable supporting the beam is rated at 15,000 N.

Should the worker be worried? To answer this, determine the tension in the cable.
A 3.0 m long ladder leans against a frictionless wall. The coefficient of static friction between the ladder and the floor is 0.42. What is the minimum angle the ladder can make with the floor without slipping?

50°

A 0.7 kg mass at (x, y) = (20 cm, 20 cm) and a 2.4 kg mass at (20 cm, 100 cm) are connected by a massless, rigid rod. They rotate about the center of mass.

(a) What are the coordinates of the center of mass?
(20 cm, 81.9 cm)

(b) What is the moment of inertia about the center of mass?
0.347 kg·m²

(c) What constant torque will cause an angular velocity of 6.25 rad/s at the end of 3.0 s, starting from rest?
0.723 N·m

(d) At what angle, with respect to the axis of the rod, should 1.5 N forces be applied to each mass to give the torque you found in part c?
37°

Starting from rest, a 12 cm diameter compact disk takes 4.0 s to reach its operating angular velocity of 1905 rpm. Assume that the angular acceleration is constant. The disk's moment of inertia is 2.5 × 10⁻⁵ kg·m².

(a) How much torque is applied to the disk?
0.00125 N·m

(b) How many revolutions does it make before reaching full speed?
63.5 revolutions

The two blocks, \( m_1 = 2.7 \) kg and \( m_2 = 4.6 \), in the figure below are connected by a massless rope that passes over a pulley. The pulley is 12 cm in diameter and has a mass of 2.0 kg. As the pulley turns, friction at the axle exerts a torque of magnitude 0.56 Nm. If the blocks are released from rest, how long does it take the 4.6 kg block to reach the floor from a height of \( h = 1.0 \) m?
A 2.4 kg, 20 cm diameter turntable rotates at 100 rpm on frictionless bearings. Two 400 g blocks fall from above, hit the turntable simultaneously at opposite ends of a diagonal, and stick. What is the turntable’s angular velocity, in rpm, just after this event?

\[ 60 \text{ rpm} \]

The figure below shows a 106 g puck revolving in a 19.8 cm radius circle on a frictionless table. The string passes through a hole in the center of the table and is tied to two 205 g weights.

(a) What speed does the puck need to support the two weights?

\[ 2.74 \text{ m/s} \]

(b) Suppose a flame burns through the string and causes the lower weight to fall off while the puck is revolving. What will be the puck’s speed after the weight drops?
What will be the radius of its trajectory after the weight drops? 24.9 cm

29. A 1000 kg cart is rolling to the right at 3.5 m/s. A 90 kg man is standing on the right end of the cart. What is the speed of the cart if the man suddenly starts running to the left with a speed of 10 m/s relative to the cart? 4.33 m/s

30. In a ballistics test, a 25 g bullet traveling horizontally at 1200 m/s goes through a 25 cm thick 350 kg stationary target and emerges with a speed of 850 m/s. The target is free to slide on a smooth horizontal surface.

(a) How long is the bullet in the target? 0.000244 s
(b) What average force does it exert on the target? 35900 N (magnitude only)

(b) What is the target's speed just after the bullet emerges? 0.025 m/s

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