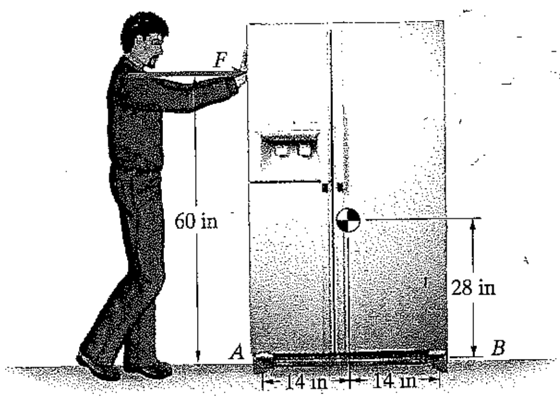
Problems

18.1 A horizontal force $F = 30$ lb is applied to the 230-lb refrigerator as shown. Friction is negligible.

(a) What is the magnitude of the refrigerator's acceleration?

(b) What normal forces are exerted on the refrigerator by the floor at A and B?

18.2 Solve Problem 18.1 if the coefficient of kinetic friction at A and B is $\mu_k = 0.1$.

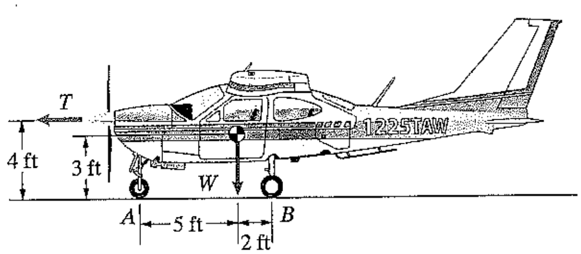


Problems 18.1/18.2

18.3 As the 2800-lb airplane begins its takeoff run at $t = 0$, its propeller exerts a horizontal force $T = 1000$ lb. Neglect horizontal forces exerted on the wheels by the runway.

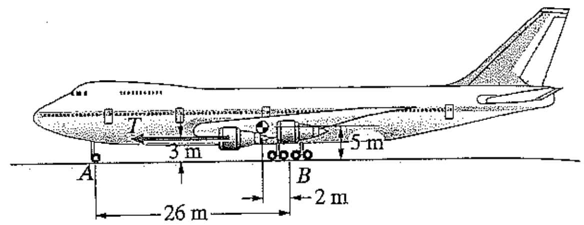
(a) What distance has the airplane moved at $t = 2$ s?

(b) What normal forces are exerted on the tires at A and B?



Problem 18.3

▶ 18.4 The Boeing 747 begins its takeoff run at time $t = 0$. The normal forces exerted on its tires at A and B are $N_A = 175$ kN and $N_B = 2800$ kN. If you assume that these forces are constant and neglect horizontal forces other than the thrust T, how fast is the airplane moving at $t = 4$ s? (See Active Example 18.1.)

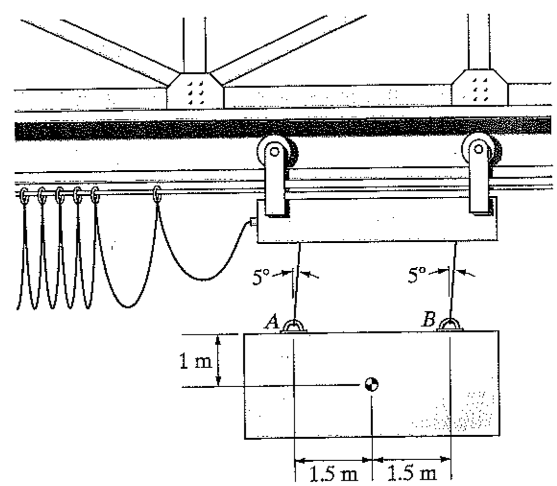


Problem 18.4

18.5 The crane moves to the right with constant acceleration, and the 800-kg load moves without swinging.

(a) What is the acceleration of the crane and load?

(b) What are the tensions in the cables attached at A and B?

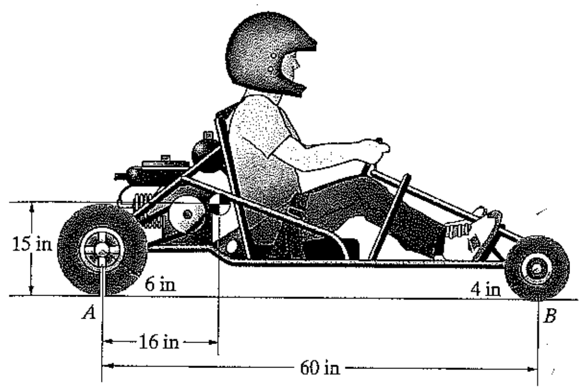


Problem 18.5

18.6 The total weight of the go-cart and driver is 240 lb. The location of their combined center of mass is shown. The rear drive wheels together exert a 24-lb horizontal force on the track. Neglect the horizontal forces exerted on the front wheels.

(a) What is the magnitude of the go-cart's acceleration?

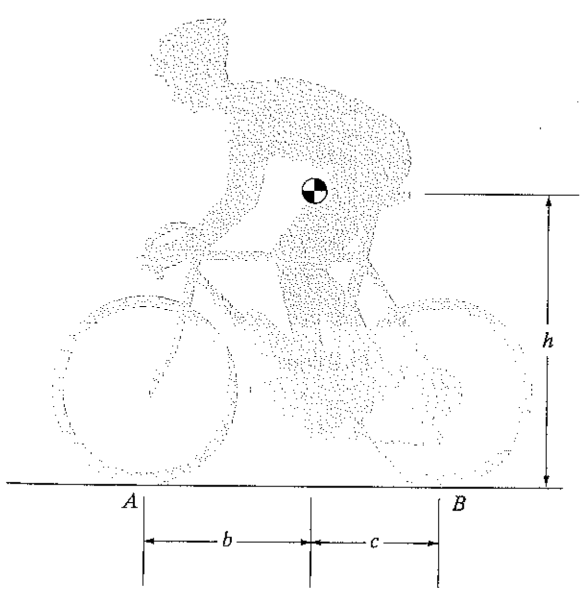
(b) What normal forces are exerted on the tires at A and B?



Problem 18.6

18.7 The total weight of the bicycle and rider is 160 lb. The location of their combined center of mass is shown. The dimensions shown are $b = 21$ in, $c = 16$ in, and $h = 38$ in. What is the largest acceleration the bicycle can have without the front wheel leaving the ground? Neglect the horizontal force exerted on the front wheel by the road.

Strategy: You want to determine the value of the acceleration that causes the normal force exerted on the front wheel by the road to equal zero.

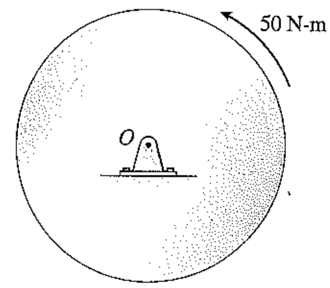


Problem 18.7

18.8 The moment of inertia of the disk about O is $I = 20$ kg-m^2. At $t = 0$, the stationary disk is subjected to a constant 50 N-m torque.

(a) What is the magnitude of the resulting angular acceleration of the disk?

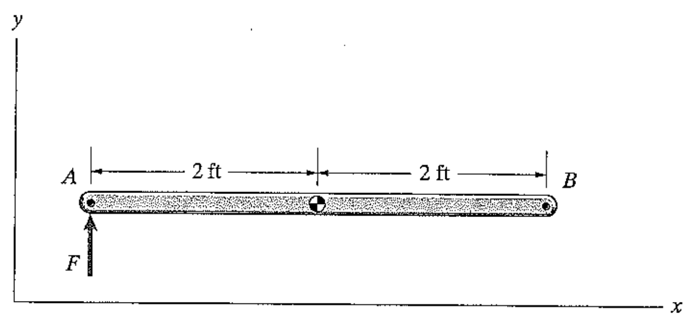
(b) How fast is the disk rotating (in rpm) at $t = 4$ s?



Problem 18.8

18.9 The 10-lb bar is on a smooth horizontal table. The figure shows the bar viewed from above. Its moment of inertia about the center of mass is $I = 0.8$ slug-ft^2. The bar is stationary when the force $F = 5$ lb is applied in the direction parallel to the y axis. At that instant, determine (a) the acceleration of the center of mass, and (b) the acceleration of point A.

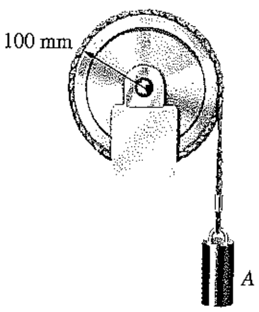
18.10 The 10-lb bar is on a smooth horizontal table. The figure shows the bar viewed from above. Its moment of inertia about the center of mass is $I = 0.8$ slug-ft^2. The bar is stationary when the force $F = 5$ lb is applied in the direction parallel to the y axis. At that instant, determine the acceleration of point B.



Problems 18.9/18.10

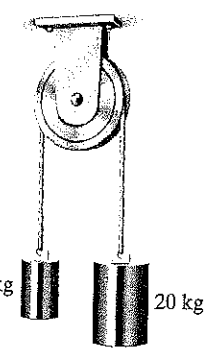
18.15 The moment of inertia of the pulley about its axis is $I = 0.005$ kg-m^2. If the 1-kg mass A is released from rest, how far does it fall in 0.5 s?

Strategy: Draw individual free-body diagrams of the pulley and the mass.



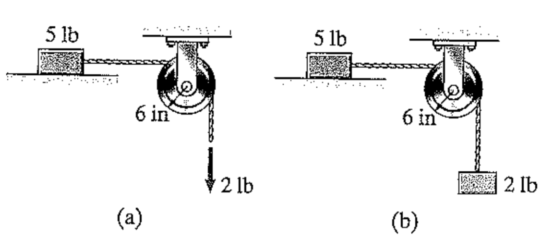
Problem 18.15

18.16 The radius of the pulley is 125 mm and the moment of inertia about its axis is $I = 0.05$ kg-m^2. If the system is released from rest, how far does the 20-kg mass fall in 0.5 s? What is the tension in the rope between the 20-kg mass and the pulley?



Problem 18.16

18.17 The moment of inertia of the pulley is 0.4 slug-ft^2. The coefficient of kinetic friction between the 5-lb weight and the horizontal surface is $\mu_k = 0.2$. Determine the magnitude of the acceleration of the 5-lb weight in each case.



Problem 18.17

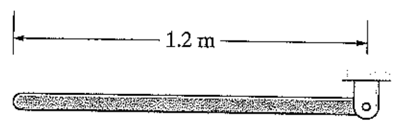
18.18 The 5-kg slender bar is released from rest in the horizontal position shown. Determine the bar's counterclockwise angular acceleration (a) at the instant it is released, and (b) at the instant when it has rotated 45°.

▶ 18.19 The 5-kg slender bar is released from rest in the horizontal position shown. At the instant when it has rotated 45°, its angular velocity is 4.16 rad/s. At that instant, determine the magnitude of the force exerted on the bar by the pin support. (See Example 18.4.)

18.20 The 5-kg slender bar is released from rest in the horizontal position shown. Determine the magnitude of its angular velocity when it has fallen to the vertical position.

Strategy: Draw the free-body diagram of the bar when it has fallen through an arbitrary angle θ and apply the equation of angular motion to determine the bar's angular acceleration as a function of θ. Then use the chain rule to write the angular acceleration as

$$\alpha = \frac{d\omega}{dt} = \frac{d\omega}{d\theta}\frac{d\theta}{dt} = \frac{d\omega}{d\theta}\omega.$$



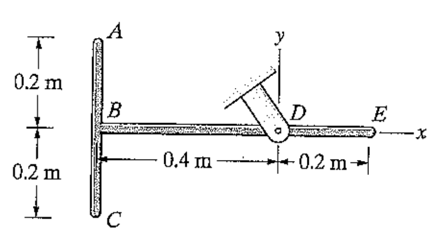
Problems 18.18–18.20

18.21 The object consists of the 2-kg slender bar ABC welded to the 3-kg slender bar BDE. The y axis is vertical.

(a) What is the object's moment of inertia about point D?

(b) Determine the object's counterclockwise angular acceleration at the instant shown.

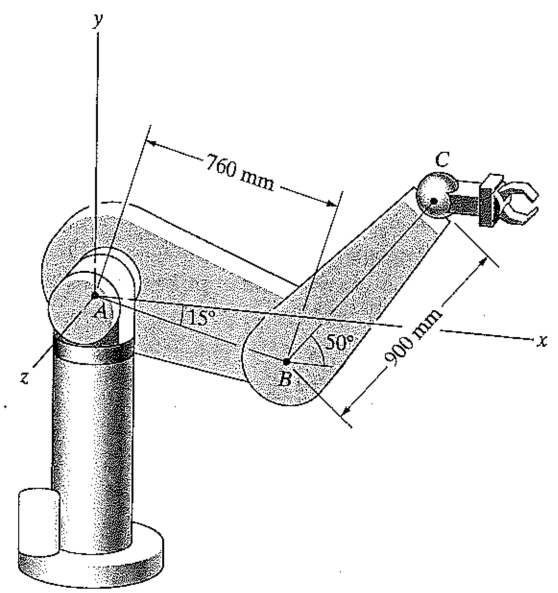
18.22 The object consists of the 2-kg slender bar ABC welded to the 3-kg slender bar BDE. The y axis is vertical. At the instant shown, the object has a counterclockwise angular velocity of 5 rad/s. Determine the components of the force exerted on it by the pin support.



Problems 18.21/18.22

18.30 Points B and C lie in the x–y plane. The y axis is vertical. The center of mass of the 18-kg arm BC is at the midpoint of the line from B to C, and the moment of inertia of the arm about the axis through the center of mass that is parallel to the z axis is 1.5 kg-m^2. At the instant shown, the angular velocity and angular acceleration vectors of arm AB are $\omega_{AB} = 0.6\mathbf{k}$ (rad/s) and $\alpha_{AB} = -0.3\mathbf{k}$ (rad/s^2). The angular velocity and angular acceleration vectors of arm BC are $\omega_{BC} = 0.4\mathbf{k}$ (rad/s) and $\alpha_{BC} = 2\mathbf{k}$ (rad/s^2). Determine the force and couple exerted on arm BC at B.

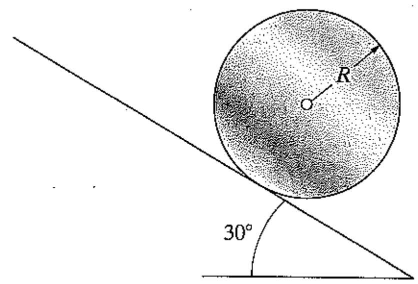
18.31 Points B and C lie in the x–y plane. The y axis is vertical. The center of mass of the 18-kg arm BC is at the midpoint of the line from B to C, and the moment of inertia of the arm about the axis through the center of mass that is parallel to the z axis is 1.5 kg-m^2. At the instant shown, the angular velocity and angular acceleration vectors of arm AB are $\omega_{AB} = 0.6\mathbf{k}$ (rad/s) and $\alpha_{AB} = -0.3\mathbf{k}$ (rad/s^2). The angular velocity vector of arm BC is $\omega_{BC} = 0.4\mathbf{k}$ (rad/s). If you want to program the robot so that the angular acceleration of arm BC is zero at this instant, what couple must be exerted on arm BC at B?



Problems 18.30/18.31

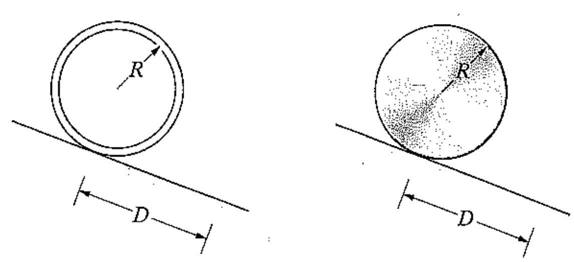
▶ 18.32 The radius of the 2-kg disk is $R = 80$ mm. Its moment of inertia is $I = 0.0064$ kg-m^2. It rolls on the inclined surface. If the disk is released from rest, what is the magnitude of the velocity of its center two seconds later? (See Active Example 18.2.)

▶ 18.33 The radius of the 2-kg disk is $R = 80$ mm. Its moment of inertia is $I = 0.0064$ kg-m^2. What minimum coefficient of static friction is necessary for the disk to roll, instead of slip, on the inclined surface? (See Active Example 18.2.)



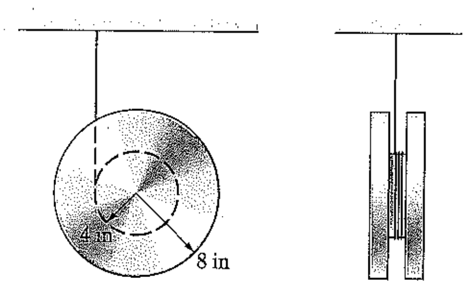
Problems 18.32/18.33

18.34 A thin ring and a homogeneous circular disk, each of mass m and radius R, are released from rest on an inclined surface. Determine the ratio $v_{\text{ring}}/v_{\text{disk}}$ of the velocities of their centers when they have rolled a distance D.



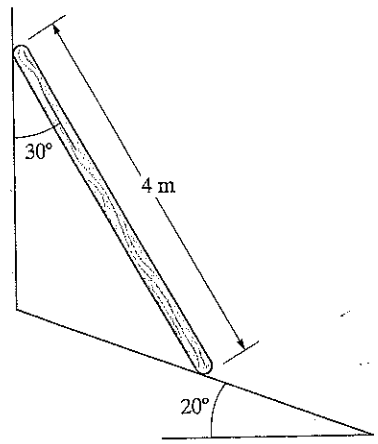
Problem 18.34

18.35 The stepped disk weighs 40 lb and its moment of inertia is $I = 0.2$ slug-ft^2. If the disk is released from rest, how long does it take its center to fall 3 ft? (Assume that the string remains vertical.)



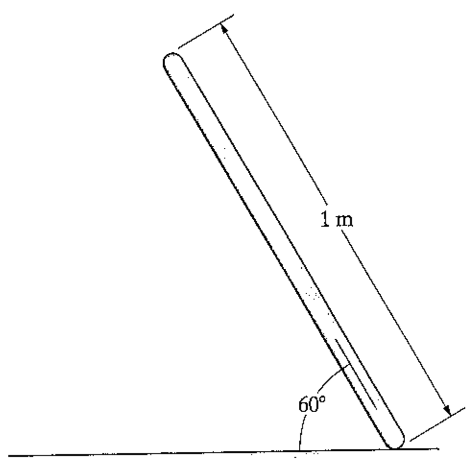
Problem 18.35

18.46 The 18-kg ladder is released from rest in the position shown. Model it as a slender bar and neglect friction. Determine its angular acceleration at the instant of release.



Problem 18.46

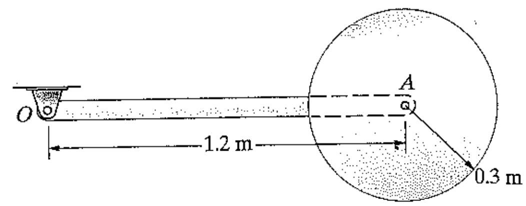
18.47 The 4-kg slender bar is released from rest in the position shown. Determine its angular acceleration at that instant if (a) the surface is rough and the bar does not slip, and (b) the surface is smooth.



Problem 18.47

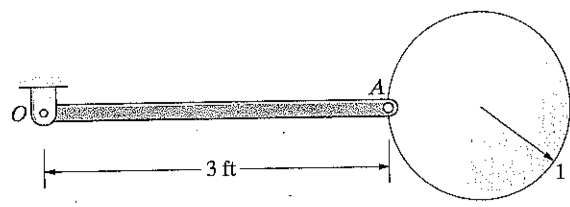
18.48 The masses of the bar and disk are 14 kg and 9 kg, respectively. The system is released from rest with the bar horizontal. Determine the bar's angular acceleration at that instant if (a) the bar and disk are welded together at A and (b) the bar and disk are connected by a smooth pin at A.

Strategy: In part (b), draw individual free-body diagrams of the bar and disk.



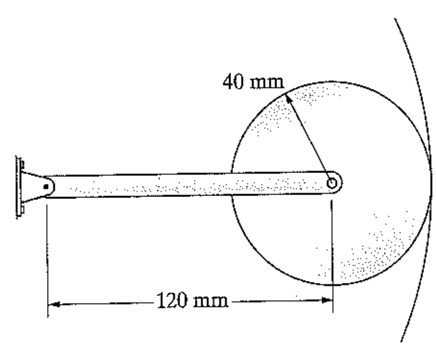
Problem 18.48

18.49 The 5-lb horizontal bar is connected to the 10-lb disk by a smooth pin at A. The system is released from rest in the position shown. What are the angular accelerations of the bar and disk at that instant?



Problem 18.49

18.50 The 0.1-kg slender bar and 0.2-kg cylindrical disk are released from rest with the bar horizontal. The disk rolls on the curved surface. What is the bar's angular acceleration at the instant it is released?



Problem 18.50