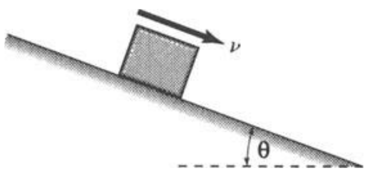


FIGURE P14.3.

clined plane as shown in Figure P14.3. If the coefficient of kinetic friction between the block and the plane is $\mu = 0.80$ and $\theta = 35°$, determine the distance s along the inclined plane through which the block moves before coming to rest.

14.4 A block of mass m is given an initial velocity v_0 down an inclined plane as shown in Figure P14.3. If the coefficient of kinetic friction between the block and the plane is μ, determine, in terms of v, g, μ, and θ, an expression for the time t required for the block to come to a complete stop. Discuss the limitations of this expression.

14.5 A pickup truck, traveling on a horizontal road with a speed of $v = 40$ mph, carries a load $W = 1500$ lb as shown in Figure P14.5. The brakes are applied suddenly and the truck comes to a full stop in a distance $s = 200$ ft. Determine the minimum coefficient of friction between the load and the truck bed if the load is not to move during the stopping operations.

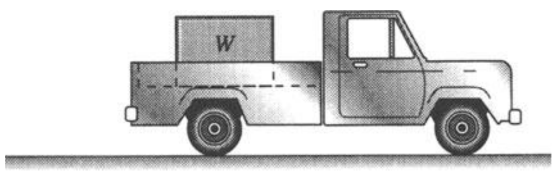


FIGURE P14.5.

14.6 A pickup truck, traveling on a horizontal road with a speed v, carries a load W as shown in Figure P14.5. The coefficient of friction between the load and the truck bed is μ. In terms of v, μ, and g, determine the smallest stopping distance s if the load is not to slide on the truck bed.

14.7 A collar of mass $m = 10$ kg is acted upon by a horizontal force $P = 100$ N as shown in Figure P14.7. If the collar starts from rest and the coefficient of kinetic friction between it and the rod is $\mu = 0.2$, determine (a) the acceleration of the collar, (b) the distance moved by the collar after 5 s, and (c) the velocity of the collar after it has moved a distance of 2 m along the rod.

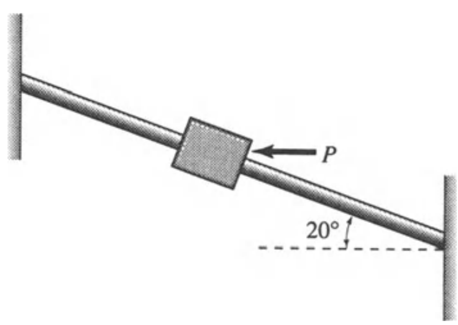


FIGURE P14.7.

14.8 Rework Problem 14.7 for the case when $P = 0$.

14.9 The system shown in Figure P14.9 is released from rest. The cable ABC is

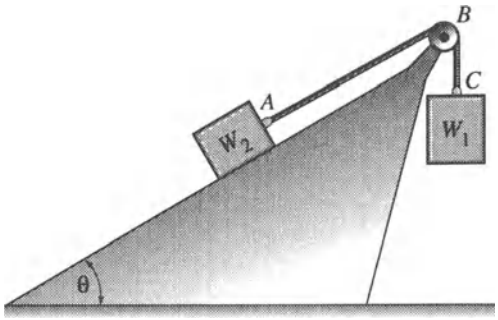


FIGURE P14.9.

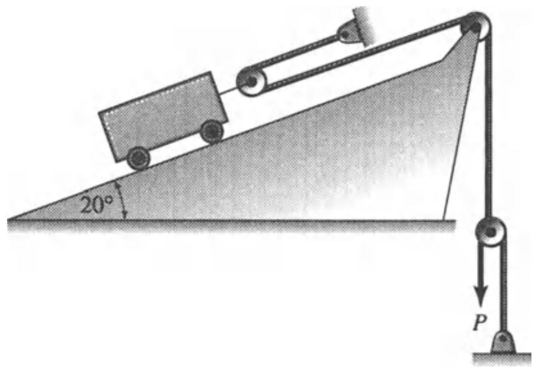


FIGURE P14.11.

flexible but inextensible, and the pulley at B may be assumed weightless and frictionless. If W_2 moves up the inclined plane, determine its magnitude if the system reaches a velocity $v = 15$ ft/s after 5 s has elapsed, given $W_1 = 100$ lb, $\theta = 30°$ and the coefficient of kinetic friction between W_2 and the inclined plane $\mu = 0.25$.

14.10 The system shown in Figure P14.9 is released from rest. The cable ABC is flexible but inextensible and the pulley at B may be assumed weightless and frictionless. If W_2 moves up the inclined plane and the coefficient of kinetic friction between it and the inclined plane is μ, determine, symbolically, in terms of W_1, W_2, μ, and θ, (a) the acceleration of the system and (b) the tension in the cable.

14.11 The pulley system shown in Figure P14.11 is used to pull the 500 kg cart up the 20° inclined plane. If the cart is to start from rest and travel for 5 s, determine the needed constant force P. What is the speed of the cart at the end of 5 s? Assume weightless and frictionless pulleys, and ignore friction and rolling resistance at the cart's wheels.

14.12 A weight $W = 20$ lb is suspended from a cable which passes over a frictionless pulley attached to the roof of an elevator as shown in Figure P14.12. The other end of the cable is attached to a spring (spring constant $k = 100$ lb/in.) which, in turn, is fastened to the floor of the elevator. Determine the total deformation of the spring (including the equilibrium deformation) when the elevator is accelerating (a) upward at a constant acceleration $a = 5$ ft/s^2 and (b) downward at a constant acceleration $a = 5$

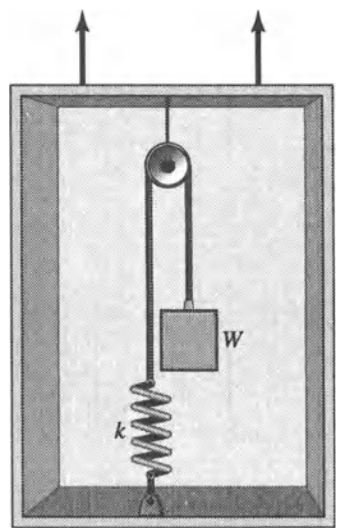


FIGURE P14.12.

ft/s^2. Assume the pulley and cable to be weightless.

14.13 A weight W is suspended from a cable which passes over a frictionless pulley attached to the roof of an elevator as shown in Figure P14.12. The other end of the cable is attached to a spring (spring constant k) which, in turn, is fastened to the floor of the elevator. Let the total deformation of the spring (including the equilibrium deformation) be δ. Develop expressions, in terms of W, k, δ, and g, for (a) the upward acceleration of the elevator and (b) the downward acceleration of the elevator.

14.14 A body of weight W is suspended from the roof of an elevator by two identical springs (spring constant $k = 10$ kN/m) as shown in Figure P14.14. When the elevator moves up with an acceleration $a = 1.5$ m/s^2, the total spring deformations (including the equilibrium deformation) are found to be $\delta = 0.02$ m each. Determine the magnitude of the weight W. Assume that the change in the 25° angles due to the spring deformations is negligible.

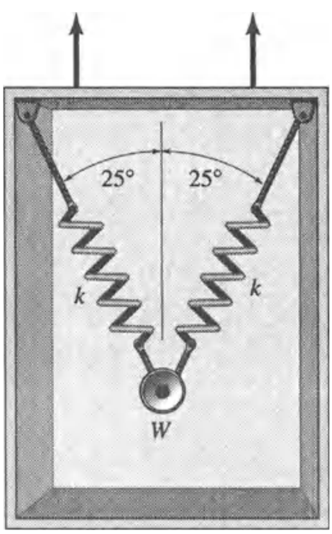
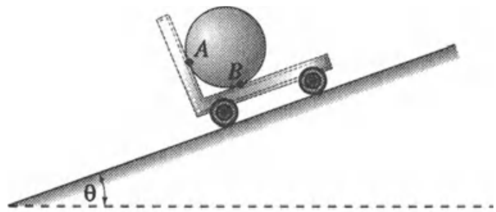


FIGURE P14.14.

14.15 A cylinder of weight $W = 75$ lb is placed against the back of a cart as shown in Figure P14.15. The cart is accelerated up the inclined plane with an acceleration $a = 7$ ft/s^2. If $\theta = 15°$ determine the forces F_A and F_B exerted on the cylinder at contact points A and B, respectively.



(a)

FIGURE P14.15.

14.16 A cylinder of weight W is placed against the back of a cart as shown in Figure P14.15. The cart is accelerated down the inclined plane with an acceleration a. Develop an expression for the acceleration a in terms of the angle θ for which the cylinder will separate from the cart at point A. What is the numerical value of a for $\theta = 20°$.

14.17 A workman hoists himself and his cage by means of the pulley-rope system shown in Figure P14.17. Assume that the pulley-rope system is weightless and frictionless. If the mass of the workman and his cage $m = 105$ kg., determine their acceleration if the workman pulls the rope with a constant force $P = 260$ N. If the workman starts from rest, how long must he maintain a constant pull of 260 N to reach a speed of 1 m/s?

14.18 A workman lowers himself and his cage by means of the pulley-rope system shown in Figure P14.17. Assume that

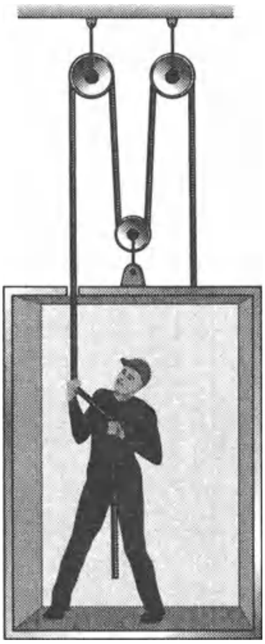


FIGURE P14.17.

the pulley-rope system is weightless and frictionless. If the mass of the workman and his cage is m and the workman maintains a constant pull P on the rope, develop a symbolic expression relating the acceleration a to the constant pull P and the mass m. Also, if the cage starts from rest, develop a symbolic expression for its speed after it has moved a distance h downward. What is the maximum value of P in terms of g and m if the cage is to accelerate downward?

14.19 The passenger train shown in Figure P14.19 is moving at a constant speed on level tracks when the brakes are applied suddenly to produce a constant deceleration $a = 3$ ft/s^2. Assume that each of the two cars and the engine develops a braking force equal to F. If $W_1 = 50{,}000$ lb and $W_2 = 60{,}000$ lb, determine (a) the magnitude of the braking force F and (b) the coupling force between the engine and the first car.

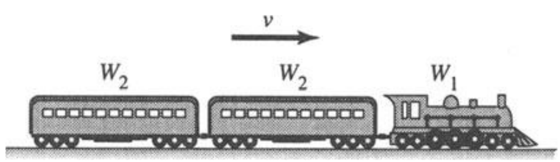


FIGURE P14.19.

14.20 The passenger train shown in Figure 14.19 is moving at a constant speed on level tracks when the brakes are applied suddenly to produce a deceleration a. Assume that each of the two cars and the engine develop a braking force F. Determine, symbolically, in terms of W_1, W_2, a, and g, (a) an expression for the braking force F and (b) an expression for the coupling force between the first and second cars. If $W_1 = 300$ kN, $W_2 = 400$ kN and $a = 1.5$ m/s^2, find a numerical value for this coupling force.

14.21 A crane is used to hoist a 4,000-lb beam at an acceleration of 4 ft/s^2. Determine the forces induced in truss members AB and AC. Assume the pulley at A to be weightless and frictionless.

14.22 The coefficient of kinetic friction μ between the pavement and the tires of a car of mass m was obtained experimentally by bringing up the speed of the car to a certain value v, applying the brakes, and allowing the car to come to a complete stop. If the length of the skid marks is denoted by s, develop an expression

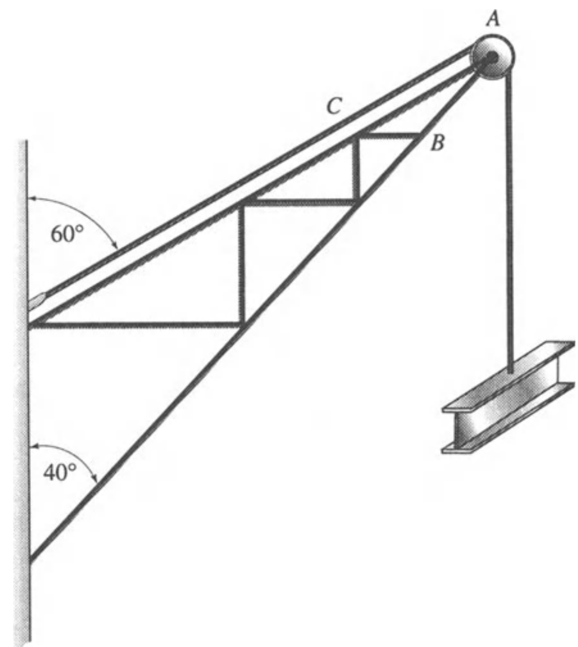


FIGURE P14.21.

for μ in terms of v, g, and s. What is the numerical value of the coefficient of kinetic friction if $m = 1{,}600$ kg, $v = 100$ km/h and $s = 80$ m?

14.23 A 100-lb package is released from rest at time $t = 0$ on a 30° inclined plane as shown in Figure P14.23. The coefficient of friction between the package and the plane is 0.3. When $t = 5$ s, a force $F = (5 + 2t^3)$ lb, where t is in seconds, is applied to the package as shown. Determine (a) the velocity of the package and the distance it has traveled when F is applied and (b) the additional time that elapses before the package is brought to a full stop. *Hint: Use the relationship $a = dv/dt$, and solve the resulting expression for time t by trial and error.*

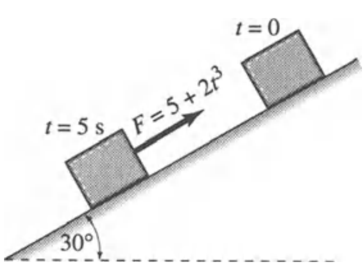


FIGURE P14.23.

14.24 A motorcyclist wants to jump across a river from point A to point B, which is at a horizontal distance X and a vertical distance Y from point A, as shown in Figure P14.24. To do so, he has to get a running start by accelerating up the inclined plane and leaving point A with a minimum speed v. Consider the motorcyclist to be a particle, neglect air resistance, and determine this minimum speed symbolically in terms of X, Y and θ.

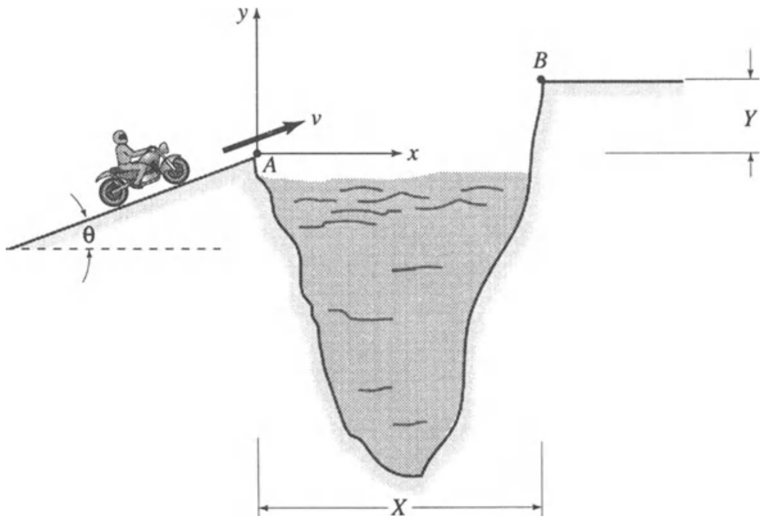


FIGURE P14.24.

14.25 An experimental 2,000-lb missile is fired vertically upward as shown in Figure P14.25. At a height of 4,000 ft above ground level, the propelling rockets fail when the missile has a velocity of 800 ft/s and the missile continues on a vertical free-flight motion. If the air resistance is approximated by the relation $R = 0.1v$ lb where v is the speed of the missile in ft/s, determine the additional height h to which the missile rises.

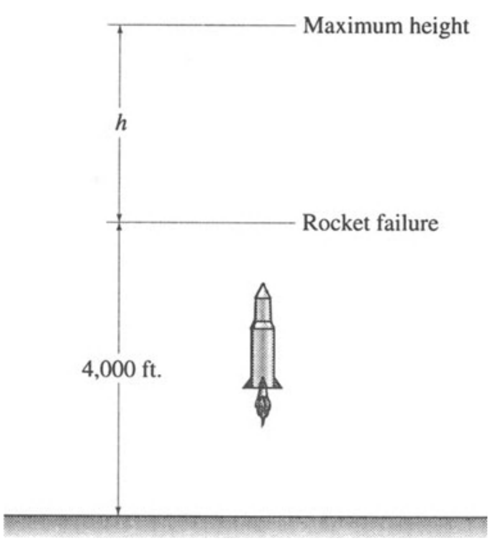


FIGURE P14.25.

14.26 Refer to Problem 14.25 and determine the speed with which the missile hits the ground. *Hint: Use the height $h = 9{,}680$ ft found in Problem 14.25, the relation $v\,dv = a\,ds$, and solve the resulting velocity equation by trial and error.*

14.27 A rock of weight W, dropped above the surface of the water in a tank, hits the water with a downward speed v_1 as shown in Figure P14.27. The resistance of the water to the motion of the rock is approximated by the relation $R = Cv$ where C is a constant and v is the speed of the rock. If the velocity with which the rock hits the bottom of the tank is v_2, determine the depth h of the tank in terms of v_1, v_2, C, g, and W.

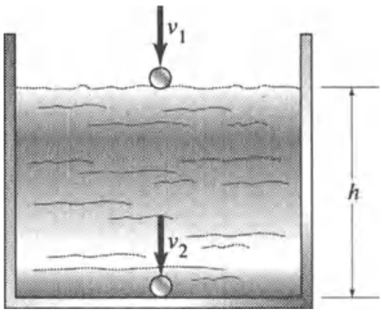


FIGURE P14.27.

14.28 A small experimental fighter plane of mass $m = 6{,}000$ kg uses a parachute to reduce the stopping distance s after landing as shown in Figure P14.28. If the plane touches ground at a speed of 250 km/h, and, if resistance to motion, including air drag, is approximated by the relation $R = (10000 + 0.5v^2)$ N where v is the speed of the plane in m/s, determine the stopping distance s.

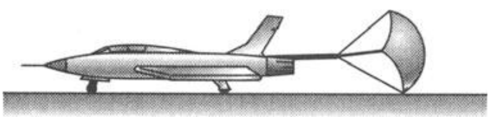


FIGURE P14.28.

14.29 A block of weight $W = 10$ lb slides in a straight line along a horizontal plane under the influence of a force $F = (2 + t^2)$ lb where t is the time in seconds. The coefficient of kinetic friction between the block and the plane is $\mu = 0.3$. If the block starts with an initial velocity $v_0 = 5$ ft/s, determine its final velocity after 4 s.

14.30 The slider shown in Figure P14.30 moves in the frictionless horizontal slot under the influence of the spring whose spring constant is $k = 15$ N/m. The mass of the slider $m = 6$ kg, and the unstretched length of the spring $L_u = 0.5$ m. Determine the velocity of the slider at point **B** if it is released from rest at point A.

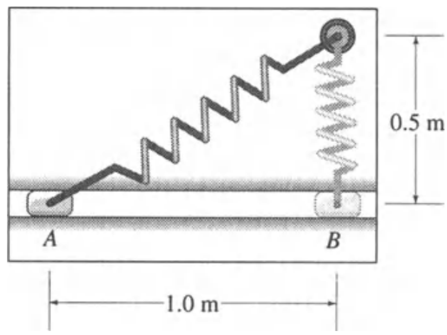


FIGURE P14.30.

14.31 Block A, which weighs 100 lb, is placed on block **B** which weighs 300 lb. The system is placed on a 20° inclined plane and attached to a pulley arrangement as shown in Figure P14.31. The coefficient of kinetic friction between blocks A and B is 0.25 and that between block B and

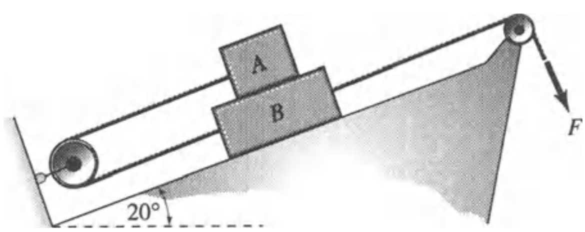


FIGURE P14.31.

the inclined plane is 0.15. Determine the magnitude of the force F needed to produce an acceleration of block B equal to 5 ft/s^2. What would be the acceleration of block A? Assume weightless and frictionless pulleys.

14.32 Consider the system shown in Figure P14.32 in which $m_A = 50$ kg, $m_B = 40$ kg, and $m_C = 40$ kg. The coefficient of kinetic friction between the inclined plane and block B is $\mu = 0.2$. Determine the acceleration of block A and the tension in cables AB and BC after the system is released from rest.

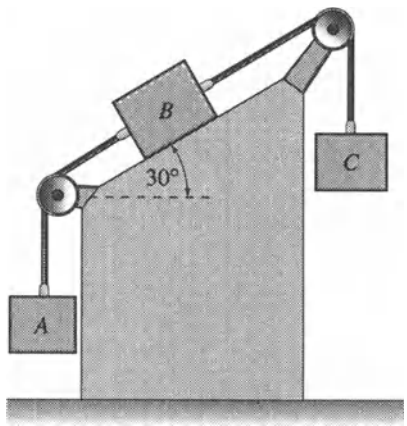


FIGURE P14.32.

14.4 Newton's Second Law in Normal and Tangential Components

In certain cases dealing with the motion of a particle of mass m along a curved path, it is convenient to express Newton's second law of motion in terms of normal and tangential components. Consider, for example, a particle of mass m moving along a curved path as shown in Figure 14.5. For any position of the particle along its path, a rectangular t-n-b coordinate system moving with the particle may be established. The coordinate t is referred to as the tangential coordinate and is obviously along the tangent to the path and pointed in the direction of motion. The coordinate n is known as the principal normal coordinate and is always directed toward the center of curvature of the path, point C. As

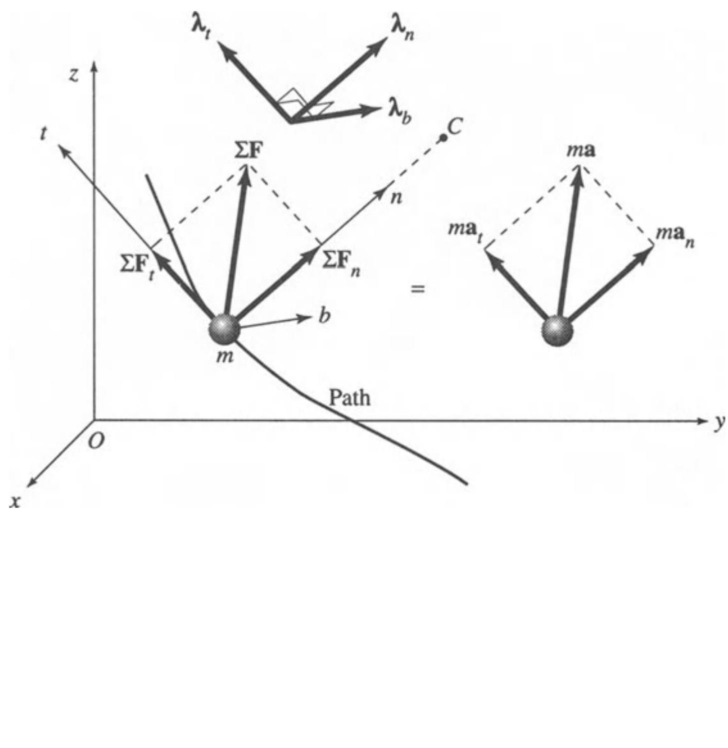
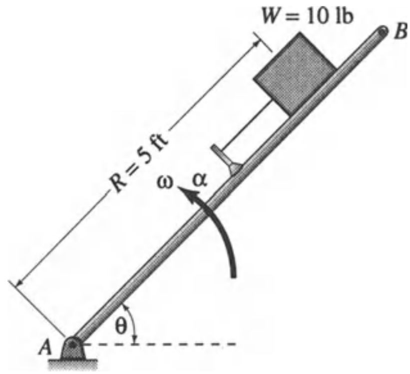
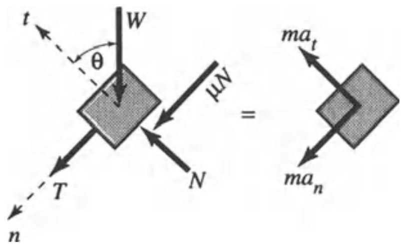


FIGURE 14.5.



(a)



(b)

FIGURE E14.11.

which, when solved for α, yields

$$\alpha = \frac{g[T + W(\mu\cos\theta + \sin\theta)]}{WR(2\theta - \mu)}. \qquad \text{(e)}$$

If the given numerical values are substituted in Eq. (e),

$$\alpha = 3.30 \text{ rad/s}^2. \qquad \text{ANS.}$$

■

Problems

14.33 A person loosely attaches one end of a string of length $L = 18$ in. to his index finger and the other end to a small stone of weight $W = 2$ oz. He imparts a constant angular speed $\omega = 6$ rad/s to the string-stone system to make it rotate in a vertical plane describing a circular path. Determine the force that the string exerts on his finger when the stone is (a) at its highest point and (b) at its lowest point.

14.34 Refer to Problem 14.33 and determine the constant angular speed ω that must be maintained if the finger is to experience no force from the string when the stone is at its highest point.

14.35 A bob B of mass m is attached to a cord BA of length L as shown in Figure P14.35 and made to rotate in a horizontal plane at constant speed v. (a) Determine an expression for this constant speed v in terms of g, L, and θ. (b) If $L = 1.5$ m and $\theta = 60°$, find the constant angular speed at which the cord-bob system must rotate about the vertical axis through the pivot at A.

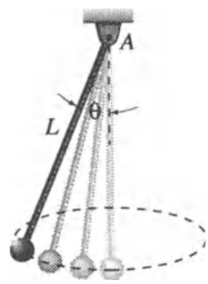


FIGURE P14.35.

14.36 A block of weight $W = 12$ lb is placed on board AB which can rotate freely about the hinge at B in a vertical plane as shown in Figure P14.36. The coefficient of friction between the block and the board is μ. The board starts from rest, when $\theta = 0$, rotating in a cw direction at a constant angular acceleration $\alpha = 4$ rad/s^2. If the block is on the verge of motion with respect to the board when θ reaches a value of 60°, determine the coefficient of friction.

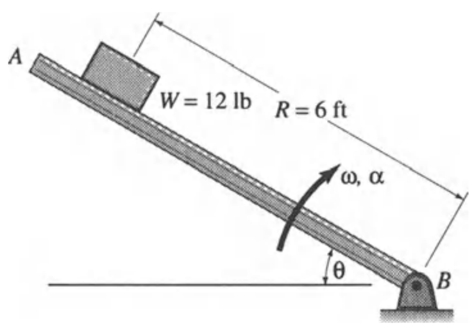


FIGURE P14.36.

14.37 A locomotive engine weighing 20,000 lb is traveling along the horizontal, curved tracks AB shown in Figure P14.37. At point A where the radius of curvature is 1,200 ft, it has a constant speed of 60 mph. The engineer applies the brakes and slows down the locomotive so that, when it reaches point B, where the radius of curvature is 300 ft, it has a constant speed of 40 mph. Determine the horizontal force exerted by the tracks on the wheels of the locomotive at (a) point A and (b) point B.

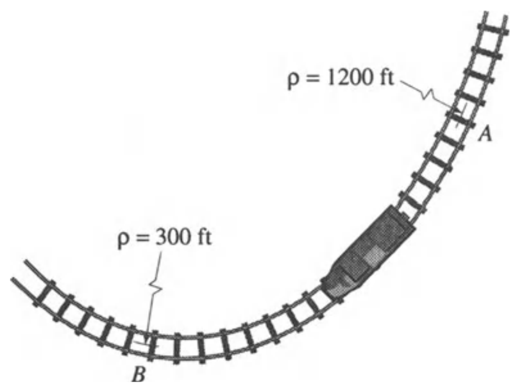


FIGURE P14.37.

14.38 The pendulum shown in Figure P14.38 consists of a bob of weight W and a rigid rod of length L. It is released from rest in the position when $\theta = 0$. (a) Develop symbolic expressions, in terms of W, L, g, and θ for the speed v of the bob and the tension T in the rod. (b) If $W = 20$ N, $L = 2$ m and $\theta = 45°$, find numerical values for v and T. (c) What are the

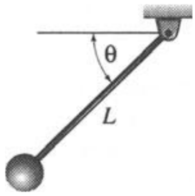


FIGURE P14.38.

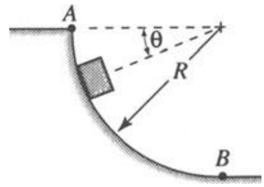


FIGURE P14.39.

values of θ ($0° \leq \theta \leq 90°$) for which v and T assume their maximum magnitudes. What are these maximum magnitudes?

14.39 A small package of weight W is released from rest at point A down the smooth circular surface AB whose radius is R as shown in Figure P14.39. (a) Develop symbolic expressions, in terms of W, R, g, and θ, for the speed v of the package and for the force N between it and the smooth surface. (b) If $W = 5$ lb, $R = 10$ ft and $\theta = 30°$, find v and N. (c) What are the values of θ ($0° \leq \theta \leq 90°$) for which v and N attain their maximum magnitudes. What are these maximum magnitudes?

14.40 A stunt driver is to drive his car on the inside surface of a vertical cylindrical structure of radius R as shown in Figure P14.40. (a) Develop a symbolic expression for the minimum radius R in terms of the coefficient of friction μ between the tires and the wall and the constant speed of the car v. (b) What is the value of R if $\mu = 0.5$ and $v = 70$ km/h.

14.41 A stunt car of total weight W passes point A at the bottom of a frictionless circular path with a speed v, as shown in Figure P14.41. If the engine is turned off

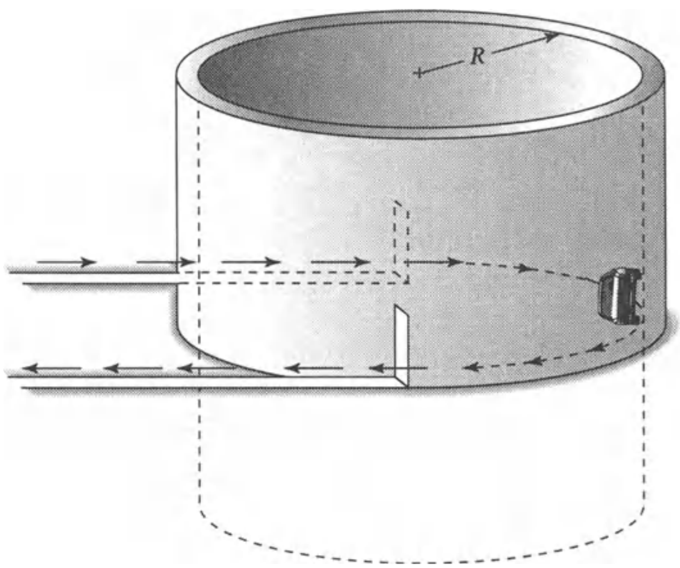


FIGURE P14.40.

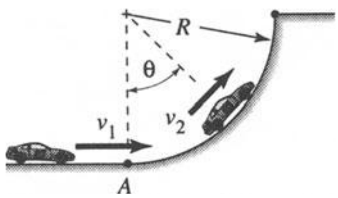


FIGURE P14.41.

at point A, derive symbolic relations for the angle θ and for the normal force N between the car and the path, for any speed v_2 along the circular path. Express your answers in terms of W, R, v_1, v_2, and g. What are the values of θ and N when $v_2 = 0$. Let $W = 3{,}000$ lb, $R = 200$ ft, and $v_1 = 75$ mph.

14.42 A person skis down the smooth slope AB which may be approximated by the equation $y = 0.05x^2$, as shown in Figure P14.42. If he starts from rest at point A, determine (a) his speed at point B and (b) the force between him and the snow at point B. The mass of the person and his equipment $m = 80$ kg. *Hint: Integrate the expression* $v\,dv = a\,ds$ *to find the speed at B.*

14.43 A stunt pilot of weight $W = 160$ lb flies his plane at a constant speed $v = 120$ mph in a vertical circular loop as shown in Figure P14.43. Determine (a) the ra-

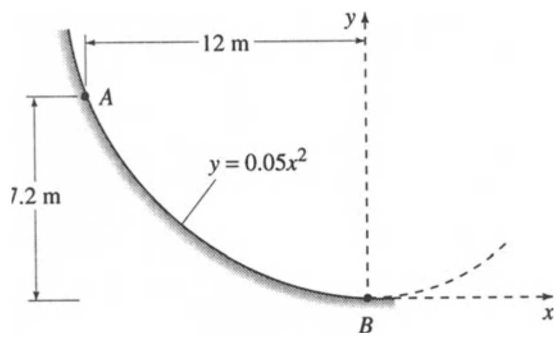


FIGURE P14.42.

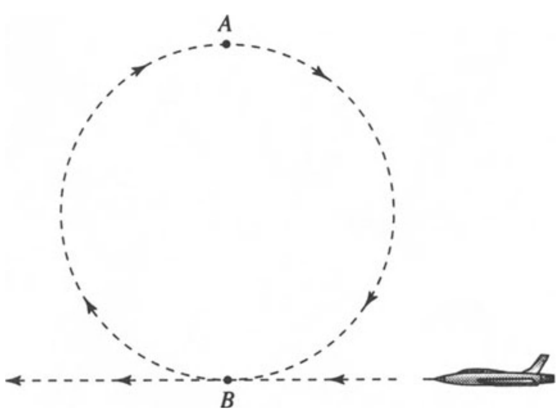


FIGURE P14.43.

dius of the circular loop if he experiences weightlessness (i.e., an apparent weight of zero) at the top of the loop (point A) and (b) his apparent weight at the bottom of the loop (point B).

14.44 A small body of weight $W = 10$ N is suspended by two wires AC and BC as shown in Figure P14.44. Determine the force in wire AC (a) immediately after wire BC is cut and (b) when it reaches the vertical position (i.e., when the body is directly under support A).

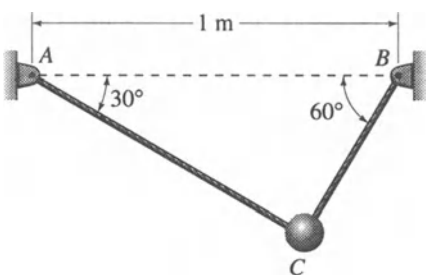


FIGURE P14.44.

14.45 A small body (particle) of weight $W =$ 10 N is attached to two wires AC and BC, as shown in Figure P14.44. This particle is given a circular motion forcing it to rotate about a horizontal axis AB. If, at the bottom of the swing (the position shown), the force in wire BC is known to be 15 N, determine, for this position, the force in wire AC and the linear speed of the body.

14.46 Figure P14.46 represents, schematically, the mechanism for an amusement ride in a carnival. The mechanism rotates about vertical axis AB at a constant angular speed ω. (a) Develop a symbolic expression for ω in terms of θ, L, and g where θ and L are defined in Figure P14.46. (b) If $L = 5$ ft, find a numerical value for the angular speed ω in order

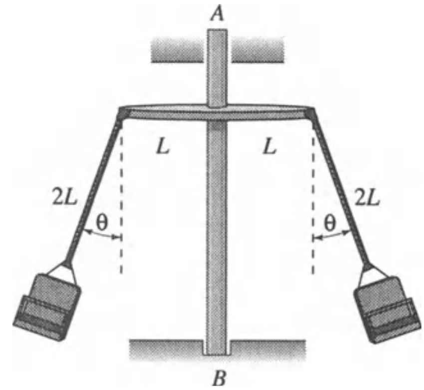


FIGURE P14.46.

for the angle θ to have values of 30° and 60°.

14.47 A racetrack is banked at an angle θ to the horizontal and has a radius of curvature R measured in a horizontal plane as shown in Figure P14.47. The coefficient of friction between the tires of the race car and the pavement is μ. (a) Develop a symbolic expression, in terms of R, θ, μ, and g, for the maximum speed of the car v so that it does not skid on the pavement away from the track's center of curvature. (b) Specialize this expression for the case when $\mu = 0$. Find, for this case, the needed bank angle θ if $v =$ 100 mph and $R = 1000$ ft.

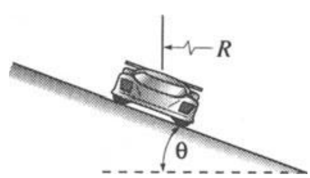


FIGURE P14.47.

14.48 Refer to Problem 14.47. Specialize the expression developed in part (a) for the case where $v = 150$ km/h, $R = 250$ m,