

Questions

1 In Fig. 6-12, if the box is stationary and the angle θ between the horizontal and force \vec{F} is increased somewhat, do the following quantities increase, decrease, or remain the same: (a) F_x ; (b) f_s ; (c) F_N ; (d) $f_{s,max}$? (e) If, instead, the box is sliding and θ is increased, does the magnitude of the frictional force on the box increase, decrease, or remain the same?

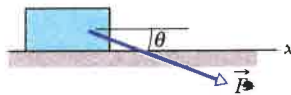


Figure 6-12 Question 1.

2 Repeat Question 1 for force \vec{F} angled upward instead of downward as drawn.

3 In Fig. 6-13, horizontal force \vec{F}_1 of magnitude 10 N is applied to a box on a floor, but the box does not slide. Then, as the magnitude of vertical force \vec{F}_2 is increased from zero, do the following quantities increase, decrease, or stay the same: (a) the magnitude of the frictional force \vec{f}_s on the box; (b) the magnitude of the normal force \vec{F}_N on the box from the floor; (c) the maximum value $f_{s,max}$ of the magnitude of the static frictional force on the box; (d) Does the box eventually slide?

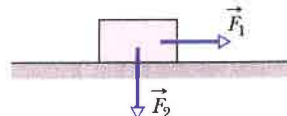


Figure 6-13 Question 3.

4 In three experiments, three different horizontal forces are applied to the same block lying on the same countertop. The force magnitudes are $F_1 = 12$ N, $F_2 = 8$ N, and $F_3 = 4$ N. In each experiment, the block remains stationary in spite of the applied force. Rank the forces according to (a) the magnitude f_s of the static frictional force on the block from the countertop and (b) the maximum value $f_{s,max}$ of that force, greatest first.

5 If you press an apple crate against a wall so hard that the crate cannot slide down the wall, what is the direction of (a) the static frictional force \vec{f}_s on the crate from the wall and (b) the normal force \vec{F}_N on the crate from the wall? If you increase your push, what happens to (c) f_s , (d) F_N , and (e) $f_{s,max}$?

6 In Fig. 6-14, a block of mass m is held stationary on a ramp by the frictional force on it from the ramp. A force \vec{F} , directed up the ramp, is then applied to the block and gradually increased in magnitude from zero. During the increase, what happens to the direction and magnitude of the frictional force on the block?

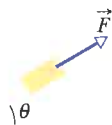


Figure 6-14 Question 6.

7 Reconsider Question 6 but with the force \vec{F} now directed down the ramp. As the magnitude of \vec{F} is increased from zero, what happens to the direction and magnitude of the frictional force on the block?

8 In Fig. 6-15, a horizontal force of 100 N is to be applied to a 10 kg slab that is initially stationary on a frictionless floor, to accelerate the slab. A 10 kg block lies on top of the slab; the coefficient of friction μ between the block and the slab is not known, and the

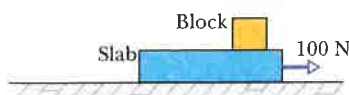


Figure 6-15 Question 8.

block might slip. In fact, the contact between the block and the slab might even be frictionless. (a) Considering that possibility, what is the possible range of values for the magnitude of the slab's acceleration a_{slab} ? (Hint: You don't need written calculations; just consider extreme values for μ .) (b) What is the possible range for the magnitude a_{block} of the block's acceleration?

9 Figure 6-16 shows the overhead view of the path of an amusement-park ride that travels at constant speed through five circular arcs of radii R_0 , $2R_0$, and $3R_0$. Rank the arcs according to the magnitude of the centripetal force on a rider traveling in the arcs, greatest first.

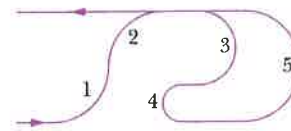


Figure 6-16 Question 9.

10 In 1987, as a Halloween stunt, two sky divers passed a pumpkin back and forth between them while they were in free fall just west of Chicago. The stunt was great fun until the last sky diver with the pumpkin opened his parachute. The pumpkin broke free from his grip, plummeted about 0.5 km, ripped through the roof of a house, slammed into the kitchen floor, and splattered all over the newly remodeled kitchen. From the sky diver's viewpoint and from the pumpkin's viewpoint, why did the sky diver lose control of the pumpkin?

11 A person riding a Ferris wheel moves through positions at (1) the top, (2) the bottom, and (3) midheight. If the wheel rotates at a constant rate, rank these three positions according to (a) the magnitude of the person's centripetal acceleration, (b) the magnitude of the net centripetal force on the person, and (c) the magnitude of the normal force on the person, greatest first.

12 During a routine flight in 1956, test pilot Tom Attridge put his jet fighter into a 20° dive for a test of the aircraft's 20 mm machine cannons. While traveling faster than sound at 4000 m altitude, he shot a burst of rounds. Then, after allowing the cannons to cool, he shot another burst at 2000 m; his speed was then 344 m/s, the speed of the rounds relative to him was 730 m/s, and he was still in a dive.

Almost immediately the canopy around him was shredded and his right air intake was damaged. With little flying capability left, the jet crashed into a wooded area, but Attridge managed to escape the resulting explosion. Explain what apparently happened just after the second burst of cannon rounds. (Attridge has been the only pilot who has managed to shoot himself down.)

13 A box is on a ramp that is at angle θ to the horizontal. As θ is increased from zero, and before the box slips, do the following increase, decrease, or remain the same: (a) the component of the gravitational force on the box, along the ramp, (b) the magnitude of the static frictional force on the box from the ramp, (c) the component of the gravitational force on the box, perpendicular to the ramp, (d) the magnitude of the normal force on the box from the ramp, and (e) the maximum value $f_{s,max}$ of the static frictional force?


Problems

 Tutoring problem available (at instructor's discretion) in WileyPLUS and WebAssign

 Worked-out solution available in Student Solutions Manual

 Number of dots indicates level of problem difficulty

 Additional information available in *The Flying Circus of Physics* and at flyingcircusofphysics.com

 Worked-out solution is at



 Interactive solution is at

<http://www.wiley.com/college/halliday>


Module 6-1 Friction

•1 The floor of a railroad flatcar is loaded with loose crates having a coefficient of static friction of 0.25 with the floor. If the train is initially moving at a speed of 48 km/h, in how short a distance can the train be stopped at constant acceleration without causing the crates to slide over the floor?

•2 In a pickup game of dorm shuffleboard, students crazed by final exams use a broom to propel a calculus book along the dorm hallway. If the 3.5 kg book is pushed from rest through a distance of 0.90 m by the horizontal 25 N force from the broom and then has a speed of 1.60 m/s, what is the coefficient of kinetic friction between the book and floor?

•3   A bedroom bureau with a mass of 45 kg, including drawers and clothing, rests on the floor. (a) If the coefficient of static friction between the bureau and the floor is 0.45, what is the magnitude of the minimum horizontal force that a person must apply to start the bureau moving? (b) If the drawers and clothing, with 17 kg mass, are removed before the bureau is pushed, what is the new minimum magnitude?

•4 A slide-loving pig slides down a certain 35° slide in twice the time it would take to slide down a frictionless 35° slide. What is the coefficient of kinetic friction between the pig and the slide?

•5  A 2.5 kg block is initially at rest on a horizontal surface. A horizontal force \vec{F} of magnitude 6.0 N and a vertical force \vec{P} are then applied to the block (Fig. 6-17). The coefficients of friction for the block and surface are $\mu_s = 0.40$ and $\mu_k = 0.25$. Determine the magnitude of the frictional force acting on the block if the magnitude of \vec{P} is (a) 8.0 N, (b) 10 N, and (c) 12 N.

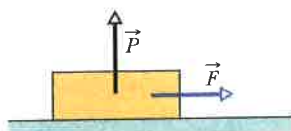





Figure 6-17 Problem 5.

•6 A baseball player with mass $m = 79$ kg, sliding into second base, is retarded by a frictional force of magnitude 470 N. What is the coefficient of kinetic friction μ_k between the player and the ground?

•7   A person pushes horizontally with a force of 220 N on a 55 kg crate to move it across a level floor. The coefficient of kinetic friction between the crate and the floor is 0.35. What is the magnitude of (a) the frictional force and (b) the acceleration of the crate?


•8  *The mysterious sliding stones.* Along the remote Racetrack Playa in Death Valley, California, stones sometimes gouge out prominent trails in the desert floor, as if the stones had been migrating (Fig. 6-18). For years curiosity mounted about why the stones moved. One explanation was that strong winds during occasional rainstorms would drag the rough stones

over ground softened by rain. When the desert dried out, the trails behind the stones were hard-baked in place. According to measurements, the coefficient of kinetic friction between the stones and the wet playa ground is about 0.80. What horizontal force must act on a 20 kg stone (a typical mass) to maintain the stone's motion once a gust has started it moving? (Story continues with Problem 37.)



Jerry Schad/Photo Researchers, Inc.

Figure 6-18 Problem 8. What moved the stone?

•9  A 3.5 kg block is pushed along a horizontal floor by a force \vec{F} of magnitude 15 N at an angle $\theta = 40^\circ$ with the horizontal (Fig. 6-19). The coefficient of kinetic friction between the block and the floor is 0.25. Calculate the magnitudes of (a) the frictional force on the block from the floor and (b) the block's acceleration.

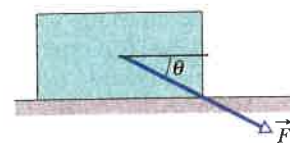


Figure 6-19 Problems 9 and 32.

•10 Figure 6-20 shows an initially stationary block of mass m on a floor. A force of magnitude $0.500mg$ is then applied at upward angle $\theta = 20^\circ$. What is the magnitude of the acceleration of the block across the floor if the friction coefficients are (a) $\mu_s = 0.600$ and $\mu_k = 0.500$ and (b) $\mu_s = 0.400$ and $\mu_k = 0.300$?

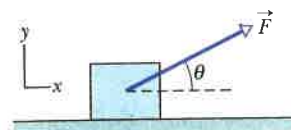



Figure 6-20 Problem 10.

•11  A 68 kg crate is dragged across a floor by pulling on a rope attached to the crate and inclined 15° above the horizontal. (a) If the coefficient of static friction is 0.50, what minimum force magnitude is required from the rope to start the crate moving? (b) If $\mu_k = 0.35$, what is the magnitude of the initial acceleration of the crate?

•12 In about 1915, Henry Sincosky of Philadelphia suspended himself from a rafter by gripping the rafter with the thumb of each

hand on one side and the fingers on the opposite side (Fig. 6-21). Sincosky's mass was 79 kg. If the coefficient of static friction between hand and rafter was 0.70, what was the least magnitude of the normal force on the rafter from each thumb or opposite fingers? (After suspending himself, Sincosky chinned himself on the rafter and then moved hand-over-hand along the rafter. If you do not think Sincosky's grip was remarkable, try to repeat his stunt.)



Figure 6-21 Problem 12.

- 13 A worker pushes horizontally on a 35 kg crate with a force of magnitude 110 N. The coefficient of static friction between the crate and the floor is 0.37. (a) What is the value of $f_{s,max}$ under the circumstances? (b) Does the crate move? (c) What is the frictional force on the crate from the floor? (d) Suppose, next, that a second worker pulls directly upward on the crate to help out. What is the least vertical pull that will allow the first worker's 110 N push to move the crate? (e) If, instead, the second worker pulls horizontally to help out, what is the least pull that will get the crate moving?

•14 Figure 6-22 shows the cross section of a road cut into the side of a mountain. The solid line AA' represents a weak bedding plane along which sliding is possible. Block B directly above the highway is separated from uphill rock by a large crack (called a *joint*), so that only friction between the block and the bedding plane prevents sliding. The mass of the block is 1.8×10^7 kg, the dip angle θ of the bedding plane is 24° , and the coefficient of static friction between block and plane is 0.63. (a) Show that the block will not slide under these circumstances. (b) Next, water seeps into the joint and expands upon freezing, exerting on the block a force \vec{F} parallel to AA' . What minimum value of force magnitude F will trigger a slide down the plane?

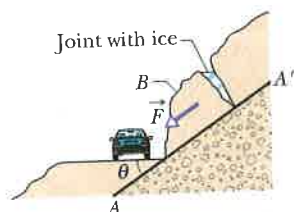


Figure 6-22 Problem 14.

- 15 The coefficient of static friction between Teflon and scrambled eggs is about 0.04. What is the smallest angle from the horizontal that will cause the eggs to slide across the bottom of a Teflon-coated skillet?

•16 A loaded penguin sled weighing 80 N rests on a plane inclined at angle $\theta = 20^\circ$ to the horizontal (Fig. 6-23). Between the sled and the plane, the coefficient of static friction is 0.25, and the coefficient of kinetic friction is 0.15. (a) What is the least magnitude of the force \vec{F} , parallel to the plane, that will prevent the sled from slipping down the plane? (b) What is the minimum magnitude F that will start the sled moving up the plane? (c) What value of F is required to move the sled up the plane at constant velocity?

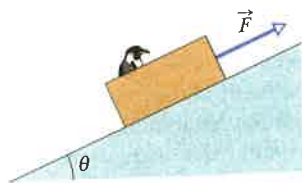


Figure 6-23 Problems 16 and 22.

- 17 In Fig. 6-24, a force \vec{P} acts on a block weighing 45 N. The block is

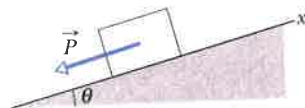


Figure 6-24 Problem 17.

initially at rest on a plane inclined at angle $\theta = 15^\circ$ to the horizontal. The positive direction of the x axis is up the plane. Between block and plane, the coefficient of static friction is $\mu_s = 0.50$ and the coefficient of kinetic friction is $\mu_k = 0.34$. In unit-vector notation, what is the frictional force on the block from the plane when \vec{P} is (a) $(-5.0 \text{ N})\hat{i}$, (b) $(-8.0 \text{ N})\hat{i}$, and (c) $(-15 \text{ N})\hat{i}$?

- 18 You testify as an *expert witness* in a case involving an accident in which car A slid into the rear of car B , which was stopped at a red light along a road headed down a hill (Fig. 6-25). You find that the slope of the hill is $\theta = 12.0^\circ$, that the cars were separated by distance $d = 24.0$ m when the driver of car A put the car into a slide (it lacked any automatic anti-brake-lock system), and that the speed of car A at the onset of braking was $v_0 = 18.0$ m/s. With what speed did car A hit car B if the coefficient of kinetic friction was (a) 0.60 (dry road surface) and (b) 0.10 (road surface covered with wet leaves)?

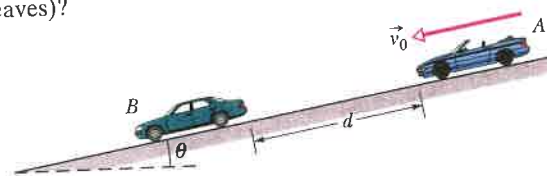


Figure 6-25 Problem 18.

- 19 A 12 N horizontal force \vec{F} pushes a block weighing 5.0 N against a vertical wall (Fig. 6-26). The coefficient of static friction between the wall and the block is 0.60, and the coefficient of kinetic friction is 0.40. Assume that the block is not moving initially. (a) Will the block move? (b) In unit-vector notation, what is the force on the block from the wall?

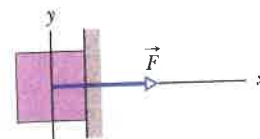


Figure 6-26 Problem 19.

- 20 In Fig. 6-27, a box of Cheerios (mass $m_C = 1.0$ kg) and a box of Wheaties (mass $m_W = 3.0$ kg) are accelerated across a horizontal surface by a horizontal force \vec{F} applied to the Cheerios box. The magnitude of the frictional force on the Cheerios box is 2.0 N, and the magnitude of the frictional force on the Wheaties box is 4.0 N. If the magnitude of \vec{F} is 12 N, what is the magnitude of the force on the Wheaties box from the Cheerios box?

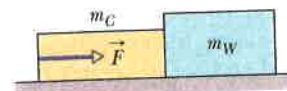


Figure 6-27 Problem 20.

- 21 An initially stationary box of sand is to be pulled across a floor by means of a cable in which the tension should not exceed 1100 N. The coefficient of static friction between the box and the floor is 0.35. (a) What should be the angle between the cable and the horizontal in order to pull the greatest possible amount of sand, and (b) what is the weight of the sand and box in that situation?

••22 In Fig. 6-23, a sled is held on an inclined plane by a cord pulling directly up the plane. The sled is to be on the verge of moving up the plane. In Fig. 6-28, the magnitude F required of the cord's force on the sled is plotted versus a range of values for the coefficient of static friction μ_s between sled and plane: $F_1 = 2.0$ N, $F_2 = 5.0$ N, and $\mu_2 = 0.50$. At what angle θ is the plane inclined?

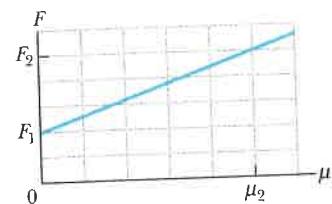


Figure 6-28 Problem 22.

••23 When the three blocks in Fig. 6-29 are released from rest, they accelerate with a magnitude of 0.500 m/s^2 . Block 1 has mass M , block 2 has $2M$, and block 3 has $2M$. What is the coefficient of kinetic friction between block 2 and the table?

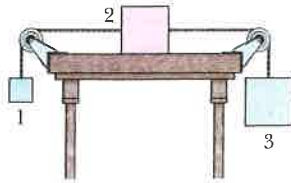


Figure 6-29 Problem 23.

••24 A 4.10 kg block is pushed along a floor by a constant applied force that is horizontal and has a magnitude of 40.0 N . Figure 6-30 gives the block's speed v versus time t as the block moves along an x axis on the floor. The scale of the figure's vertical axis is set by $v_s = 5.0 \text{ m/s}$. What is the coefficient of kinetic friction between the block and the floor?

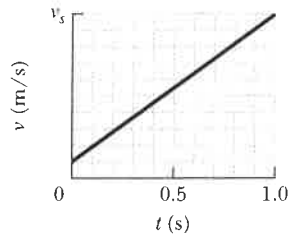


Figure 6-30 Problem 24.

••25 **SSM WWW** Block B in Fig. 6-31 weighs 711 N . The coefficient of static friction between block and table is 0.25 ; angle θ is 30° ; assume that the cord between B and the knot is horizontal. Find the maximum weight of block A for which the system will be stationary.

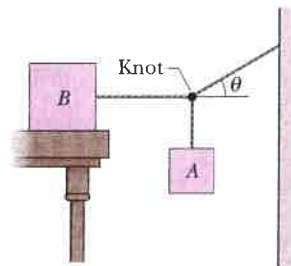


Figure 6-31 Problem 25.

••26 **GO** Figure 6-32 shows three crates being pushed over a concrete floor by a horizontal force \vec{F} of magnitude 440 N . The masses of the crates are $m_1 = 30.0 \text{ kg}$, $m_2 = 10.0 \text{ kg}$, and $m_3 = 20.0 \text{ kg}$. The coefficient of kinetic friction between the floor and each of the crates is 0.700 . (a) What is the magnitude F_{32} of the force on crate 3 from crate 2? (b) If the crates then slide onto a polished floor, where the coefficient of kinetic friction is less than 0.700 , is magnitude F_{32} more than, less than, or the same as it was when the coefficient was 0.700 ?

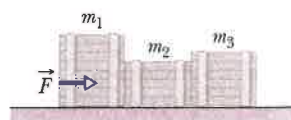


Figure 6-32 Problem 26.

••27 **GO** Body A in Fig. 6-33 weighs 102 N , and body B weighs 32 N . The coefficients of friction between A and the incline are $\mu_s = 0.56$ and $\mu_k = 0.25$. Angle θ is 40° . Let the positive direction of an x axis be up the incline. In unit-vector notation, what is the acceleration of A if A is initially (a) at rest, (b) moving up the incline, and (c) moving down the incline?

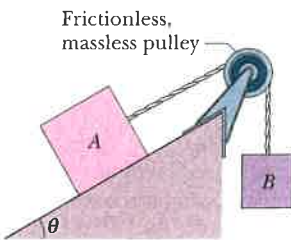


Figure 6-33 Problems 27 and 28.

••28 In Fig. 6-33, two blocks are connected over a pulley. The mass of block A is 10 kg , and the coefficient of kinetic friction between A and the incline is 0.20 . Angle θ of the incline is 30° . Block A slides down the incline at constant speed. What is the mass of block B ? Assume the connecting rope has negligible mass. (The pulley's function is only to redirect the rope.)

••29 **GO** In Fig. 6-34, blocks A and B have weights of 44 N and 22 N , respectively. (a) Determine the minimum weight of block C to keep A from sliding if μ_s between A and the table is 0.20 . (b) Block C suddenly is lifted off A . What is the acceleration of block A if μ_k between A and the table is 0.15 ?

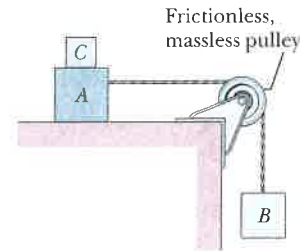


Figure 6-34 Problem 29.

••30 A toy chest and its contents have a combined weight of 180 N . The coefficient of static friction between toy chest and floor is 0.42 . The child in Fig. 6-35 attempts to move the chest across the floor by pulling on an attached rope. (a) If θ is 42° , what is the magnitude of the force \vec{F} that the child must exert on the rope to put the chest on the verge of moving? (b) Write an expression for the magnitude F required to put the chest on the verge of moving as a function of the angle θ . Determine (c) the value of θ for which F is a minimum and (d) that minimum magnitude.

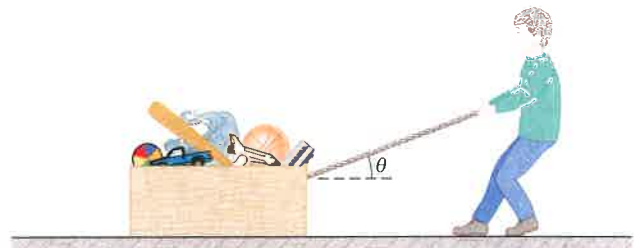


Figure 6-35 Problem 30.

••31 **SSM** Two blocks, of weights 3.6 N and 7.2 N , are connected by a massless string and slide down a 30° inclined plane. The coefficient of kinetic friction between the lighter block and the plane is 0.10 , and the coefficient between the heavier block and the plane is 0.20 . Assuming that the lighter block leads, find (a) the magnitude of the acceleration of the blocks and (b) the tension in the taut string.

••32 **GO** A block is pushed across a floor by a constant force that is applied at downward angle θ (Fig. 6-19). Figure 6-36 gives the acceleration magnitude a versus a range of values for the coefficient of kinetic friction μ_k between block and floor: $a_1 = 3.0 \text{ m/s}^2$, $\mu_{k2} = 0.20$, and $\mu_{k3} = 0.40$. What is the value of θ ?

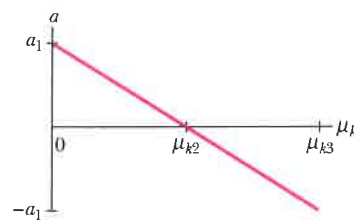


Figure 6-36 Problem 32.

••33 SSM A 1000 kg boat is traveling at 90 km/h when its engine is shut off. The magnitude of the frictional force \vec{f}_k between boat and water is proportional to the speed v of the boat: $f_k = 70v$, where v is in meters per second and f_k is in newtons. Find the time required for the boat to slow to 45 km/h.

••34 GO In Fig. 6-37, a slab of mass $m_1 = 40$ kg rests on a frictionless floor, and a block of mass $m_2 = 10$ kg rests on top of the slab. Between block and slab, the coefficient of static friction is 0.60, and the coefficient of kinetic friction is 0.40. A horizontal force \vec{F} of magnitude 100 N begins to pull directly on the block, as shown. In unit-vector notation, what are the resulting accelerations of (a) the block and (b) the slab?

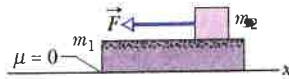


Figure 6-37 Problem 34.

••35 ILW The two blocks ($m = 16$ kg and $M = 88$ kg) in Fig. 6-38 are not attached to each other. The coefficient of static friction between the blocks is $\mu_s = 0.38$, but the surface beneath the larger block is frictionless. What is the minimum magnitude of the horizontal force \vec{F} required to keep the smaller block from slipping down the larger block?

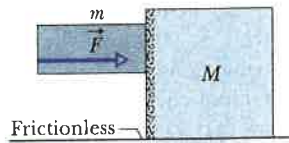


Figure 6-38 Problem 35.

Module 6-2 The Drag Force and Terminal Speed

•36 The terminal speed of a sky diver is 160 km/h in the spread-eagle position and 310 km/h in the nosedive position. Assuming that the diver's drag coefficient C does not change from one position to the other, find the ratio of the effective cross-sectional area A in the slower position to that in the faster position.

••37 Continuation of Problem 8. Now assume that Eq. 6-14 gives the magnitude of the air drag force on the typical 20 kg stone, which presents to the wind a vertical cross-sectional area of 0.040 m^2 and has a drag coefficient C of 0.80. Take the air density to be 1.21 kg/m^3 , and the coefficient of kinetic friction to be 0.80. (a) In kilometers per hour, what wind speed V along the ground is needed to maintain the stone's motion once it has started moving? Because winds along the ground are retarded by the ground, the wind speeds reported for storms are often measured at a height of 10 m. Assume wind speeds are 2.00 times those along the ground. (b) For your answer to (a), what wind speed would be reported for the storm? (c) Is that value reasonable for a high-speed wind in a storm? (Story continues with Problem 65.)

••38 Assume Eq. 6-14 gives the drag force on a pilot plus ejection seat just after they are ejected from a plane traveling horizontally at 1300 km/h. Assume also that the mass of the seat is equal to the mass of the pilot and that the drag coefficient is that of a sky diver. Making a reasonable guess of the pilot's mass and using the appropriate v_t value from Table 6-1, estimate the magnitudes of (a) the drag force on the pilot + seat and (b) their horizontal deceleration (in terms of g), both just after ejection. (The result of (a) should indicate an engineering requirement: The seat must include a protective barrier to deflect the initial wind blast away from the pilot's head.)

••39 Calculate the ratio of the drag force on a jet flying at 1000 km/h at an altitude of 10 km to the drag force on a prop-driven transport flying at half that speed and altitude. The density

of air is 0.38 kg/m^3 at 10 km and 0.67 kg/m^3 at 5.0 km. Assume that the airplanes have the same effective cross-sectional area and drag coefficient C .

••40 In downhill speed skiing a skier is retarded by both the air drag force on the body and the kinetic frictional force on the skis. (a) Suppose the slope angle is $\theta = 40.0^\circ$, the snow is dry snow with a coefficient of kinetic friction $\mu_k = 0.0400$, the mass of the skier and equipment is $m = 85.0$ kg, the cross-sectional area of the (tucked) skier is $A = 1.30 \text{ m}^2$, the drag coefficient is $C = 0.150$, and the air density is 1.20 kg/m^3 . (a) What is the terminal speed? (b) If a skier can vary C by a slight amount dC by adjusting, say, the hand positions, what is the corresponding variation in the terminal speed?

Module 6-3 Uniform Circular Motion

•41 A cat dozes on a stationary merry-go-round in an amusement park, at a radius of 5.4 m from the center of the ride. Then the operator turns on the ride and brings it up to its proper turning rate of one complete rotation every 6.0 s. What is the least coefficient of static friction between the cat and the merry-go-round that will allow the cat to stay in place, without sliding (or the cat clinging with its claws)?

•42 Suppose the coefficient of static friction between the road and the tires on a car is 0.60 and the car has no negative lift. What speed will put the car on the verge of sliding as it rounds a level curve of 30.5 m radius?

•43 ILW What is the smallest radius of an unbanked (flat) track around which a bicyclist can travel if her speed is 29 km/h and the μ_s between tires and track is 0.32?

•44 During an Olympic bobsled run, the Jamaican team makes a turn of radius 7.6 m at a speed of 96.6 km/h. What is their acceleration in terms of g ?

••45 SSM ILW A student of weight 667 N rides a steadily rotating Ferris wheel (the student sits upright). At the highest point, the magnitude of the normal force \vec{F}_N on the student from the seat is 556 N. (a) Does the student feel "light" or "heavy" there? (b) What is the magnitude of \vec{F}_N at the lowest point? If the wheel's speed is doubled, what is the magnitude F_N at the (c) highest and (d) lowest point?

••46 A police officer in hot pursuit drives her car through a circular turn of radius 300 m with a constant speed of 80.0 km/h. Her mass is 55.0 kg. What are (a) the magnitude and (b) the angle (relative to vertical) of the net force of the officer on the car seat? (Hint: Consider both horizontal and vertical forces.)

••47 A circular-motion addict of mass 80 kg rides a Ferris wheel around in a vertical circle of radius 10 m at a constant speed of 6.1 m/s. (a) What is the period of the motion? What is the magnitude of the normal force on the addict from the seat when both go through (b) the highest point of the circular path and (c) the lowest point?

••48 A roller-coaster car at an amusement park has a mass of 1200 kg when fully loaded with passengers. As the car passes over the top of a circular hill of radius 18 m, assume that its speed is not changing. At the top of the hill, what are the (a) magnitude F_N and (b) direction (up or down) of the normal force on the car from the track if the car's speed is $v = 11 \text{ m/s}$? What are (c) F_N and (d) the direction if $v = 14 \text{ m/s}$?

••49 **GO** In Fig. 6-39, a car is driven at constant speed over a circular hill and then into a circular valley with the same radius. At the top of the hill, the normal force on the driver from the car seat is 0. The driver's mass is 70.0 kg. What is the magnitude of the normal force on the driver from the seat when the car passes through the bottom of the valley?

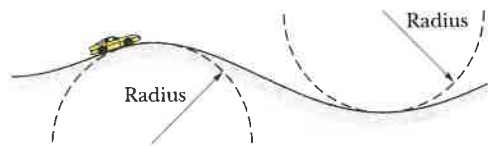


Figure 6-39 Problem 49.

••50 An 85.0 kg passenger is made to move along a circular path of radius $r = 3.50$ m in uniform circular motion. (a) Figure 6-40a is a plot of the required magnitude F of the net centripetal force for a range of possible values of the passenger's speed v . What is the plot's slope at $v = 8.30$ m/s? (b) Figure 6-40b is a plot of F for a range of possible values of T , the period of the motion. What is the plot's slope at $T = 2.50$ s?

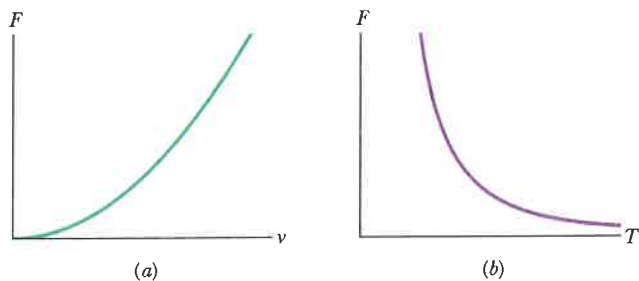


Figure 6-40 Problem 50.

••51 **SSM WWW** An airplane is flying in a horizontal circle at a speed of 480 km/h (Fig. 6-41). If its wings are tilted at angle $\theta = 40^\circ$ to the horizontal, what is the radius of the circle in which the plane is flying? Assume that the required force is provided entirely by an "aerodynamic lift" that is perpendicular to the wing surface.

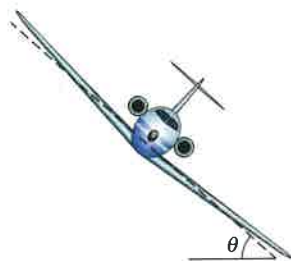


Figure 6-41 Problem 51.

••52 **GO** An amusement park ride consists of a car moving in a vertical circle on the end of a rigid boom of negligible mass. The combined weight of the car and riders is 5.0 kN, and the circle's radius is 10 m. At the top of the circle, what are the (a) magnitude F_B and (b) direction (up or down) of the force on the car from the boom if the car's speed is $v = 5.0$ m/s? What are (c) F_B and (d) the direction if $v = 12$ m/s?

••53 An old streetcar rounds a flat corner of radius 9.1 m, at 16 km/h. What angle with the vertical will be made by the loosely hanging hand straps?

••54 **GO** In designing circular rides for amusement parks, mechanical engineers must consider how small variations in certain parameters can alter the net force on a passenger. Consider a passenger of mass m riding around a horizontal circle of radius r at speed v . What is the variation dF in the net force magnitude for (a) a variation dr in the radius with v held constant, (b) a variation

dv in the speed with r held constant, and (c) a variation dT in the period with r held constant?

••55 A bolt is threaded onto one end of a thin horizontal rod, and the rod is then rotated horizontally about its other end. An engineer monitors the motion by flashing a strobe lamp onto the rod and bolt, adjusting the strobe rate until the bolt appears to be in the same eight places during each full rotation of the rod (Fig. 6-42). The strobe rate is 2000 flashes per second; the bolt has mass 30 g and is at radius 3.5 cm. What is the magnitude of the force on the bolt from the rod?

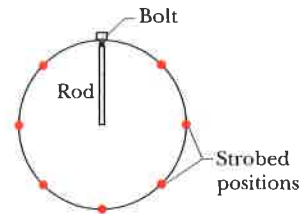


Figure 6-42 Problem 55.

••56 **GO** A banked circular highway curve is designed for traffic moving at 60 km/h. The radius of the curve is 200 m. Traffic is moving along the highway at 40 km/h on a rainy day. What is the minimum coefficient of friction between tires and road that will allow cars to take the turn without sliding off the road? (Assume the cars do not have negative lift.)

••57 **GO** A puck of mass $m = 1.50$ kg slides in a circle of radius $r = 20.0$ cm on a frictionless table while attached to a hanging cylinder of mass $M = 2.50$ kg by means of a cord that extends through a hole in the table (Fig. 6-43). What speed keeps the cylinder at rest?

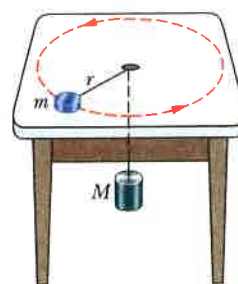


Figure 6-43 Problem 57.

••58 **GO** **Brake or turn?** Figure 6-44 depicts an overhead view of a car's path as the car travels toward a wall. Assume that the driver begins to brake the car when the distance to the wall is $d = 107$ m, and take the car's mass as $m = 1400$ kg, its initial speed as $v_0 = 35$ m/s, and the coefficient of static friction as $\mu_s = 0.50$. Assume that the car's weight is distributed evenly on the four wheels, even during braking. (a) What magnitude of static friction is needed (between tires and road) to stop the car just as it reaches the wall? (b) What is the maximum possible static friction $f_{s,max}$? (c) If the coefficient of kinetic friction between the (sliding) tires and the road is $\mu_k = 0.40$, at what speed will the car hit the wall? To avoid the crash, a driver could elect to turn the car so that it just barely misses the wall, as shown in the figure. (d) What magnitude of frictional force would be required to keep the car in a circular path of radius d and at the given speed v_0 , so that the car moves in a quarter circle and then parallel to the wall? (e) Is the required force less than $f_{s,max}$ so that a circular path is possible?

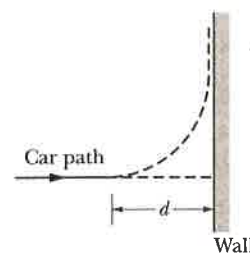


Figure 6-44 Problem 58.

••59 **SSM ILW** In Fig. 6-45, a 1.34 kg ball is connected by means of two massless strings, each of length $L = 1.70$ m, to a vertical, rotating rod. The strings are tied to the rod with separation $d = 1.70$ m and are taut. The tension in the upper string is 35 N. What are the (a) tension in the lower string, (b) magnitude of the net force \vec{F}_{net} on the ball, and (c) speed of the ball? (d) What is the direction of \vec{F}_{net} ?

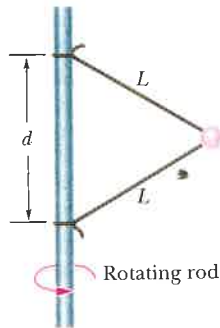


Figure 6-45
Problem 59.

Additional Problems

60 **GO** In Fig. 6-46, a box of ant aunts (total mass $m_1 = 1.65$ kg) and a box of ant uncles (total mass $m_2 = 3.30$ kg) slide down an inclined plane while attached by a massless rod parallel to the plane. The angle of incline is $\theta = 30.0^\circ$. The coefficient of kinetic friction between the aunt box and the incline is $\mu_1 = 0.226$; that between the uncle box and the incline is $\mu_2 = 0.113$. Compute (a) the tension in the rod and (b) the magnitude of the common acceleration of the two boxes. (c) How would the answers to (a) and (b) change if the uncles trailed the aunts?

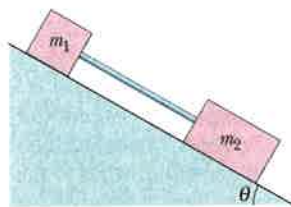


Figure 6-46 Problem 60.

61 **SSM** A block of mass $m_t = 4.0$ kg is put on top of a block of mass $m_b = 5.0$ kg. To cause the top block to slip on the bottom one while the bottom one is held fixed, a horizontal force of at least 12 N must be applied to the top block. The assembly of blocks is now placed on a horizontal, frictionless table (Fig. 6-47). Find the magnitudes of (a) the maximum horizontal force \vec{F} that can be applied to the lower block so that the blocks will move together and (b) the resulting acceleration of the blocks.

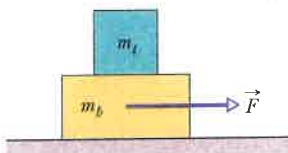


Figure 6-47 Problem 61.

62 A 5.00 kg stone is rubbed across the horizontal ceiling of a cave passageway (Fig. 6-48). If the coefficient of kinetic friction is 0.65 and the force applied to the stone is angled at $\theta = 70.0^\circ$, what must the magnitude of the force be for the stone to move at constant velocity?

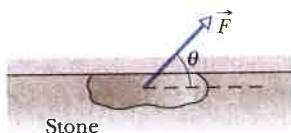


Figure 6-48 Problem 62.

63 **✎** In Fig. 6-49, a 49 kg rock climber is climbing a “chimney.” The coefficient of static friction between her shoes and the rock is 1.2; between her back and the rock is 0.80. She has reduced her push against the rock until her back and her shoes are on the verge of slipping. (a) Draw a free-body diagram of her. (b) What is the magnitude of her push against the rock? (c) What fraction of her weight is supported by the frictional force on her shoes?



Figure 6-49 Problem 63.

64 A high-speed railway car goes around a flat, horizontal circle of radius 470 m at a constant speed. The magnitudes of the horizontal and vertical components of the force of the car on a 51.0 kg passenger are 210 N and 500 N, respectively. (a) What is the magnitude of the net force (of all the forces) on the passenger? (b) What is the speed of the car?

65 **✎** Continuation of Problems 8 and 37. Another explanation is that the stones move only when the water dumped on the playa during a storm freezes into a large, thin sheet of ice. The stones are trapped in place in the ice. Then, as air flows across the ice during a wind, the air-drag forces on the ice and stones move them both, with the stones gouging out the trails. The magnitude of the air-drag force on this horizontal “ice sail” is given by $D_{\text{ice}} = 4C_{\text{ice}}\rho A_{\text{ice}}v^2$, where C_{ice} is the drag coefficient (2.0×10^{-3}), ρ is the air density (1.21 kg/m^3), A_{ice} is the horizontal area of the ice, and v is the wind speed along the ice.

Assume the following: The ice sheet measures 400 m by 500 m by 4.0 mm and has a coefficient of kinetic friction of 0.10 with the ground and a density of 917 kg/m^3 . Also assume that 100 stones identical to the one in Problem 8 are trapped in the ice. To maintain the motion of the sheet, what are the required wind speeds (a) near the sheet and (b) at a height of 10 m? (c) Are these reasonable values for high-speed winds in a storm?

66 **GO** In Fig. 6-50, block 1 of mass $m_1 = 2.0$ kg and block 2 of mass $m_2 = 3.0$ kg are connected by a string of negligible mass and are initially held in place. Block 2 is on a frictionless surface tilted at $\theta = 30^\circ$. The coefficient of kinetic friction between block 1 and the horizontal surface is 0.25. The pulley has negligible mass and friction. Once they are released, the blocks move. What then is the tension in the string?

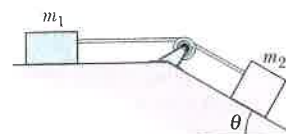


Figure 6-50 Problem 66.

67 In Fig. 6-51, a crate slides down an inclined right-angled trough. The coefficient of kinetic friction between the crate and the trough is μ_k . What is the acceleration of the crate in terms of μ_k , θ , and g ?

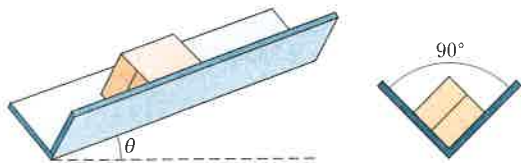


Figure 6-51 Problem 67.

68 **Engineering a highway curve.** If a car goes through a curve too fast, the car tends to slide out of the curve. For a banked curve with friction, a frictional force acts on a fast car to oppose the tendency to slide out of the curve; the force is directed down the bank (in the direction water would drain). Consider a circular curve of radius $R = 200$ m and bank angle θ , where the coefficient of static friction between tires and pavement is μ_s . A car (without negative lift) is driven around the curve as shown in Fig. 6-11. (a) Find an expression for the car speed v_{\max} that puts the car on the verge of sliding out. (b) On the same graph, plot v_{\max} versus angle θ for the range 0° to 50° , first for $\mu_s = 0.60$ (dry pavement) and then for $\mu_s = 0.050$ (wet or icy pavement). In kilometers per hour, evaluate v_{\max} for a bank angle of $\theta = 10^\circ$ and for (c) $\mu_s = 0.60$ and (d) $\mu_s = 0.050$. (Now you can see why accidents occur in highway curves when icy conditions are not obvious to drivers, who tend to drive at normal speeds.)

69 A student, crazed by final exams, uses a force \vec{P} of magnitude 80 N and angle $\theta = 70^\circ$ to push a 5.0 kg block across the ceiling of his room (Fig. 6-52). If the coefficient of kinetic friction between the block and the ceiling is 0.40, what is the magnitude of the block's acceleration?

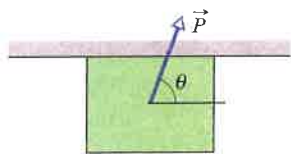


Figure 6-52 Problem 69.

70 **GO** Figure 6-53 shows a *conical pendulum*, in which the bob (the small object at the lower end of the cord) moves in a horizontal circle at constant speed. (The cord sweeps out a cone as the bob rotates.) The bob has a mass of 0.040 kg, the string has length $L = 0.90$ m and negligible mass, and the bob follows a circular path of circumference 0.94 m. What are (a) the tension in the string and (b) the period of the motion?

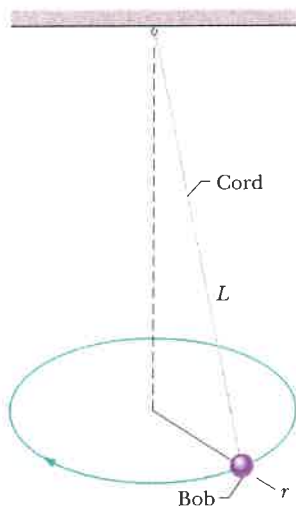


Figure 6-53 Problem 70.

71 An 8.00 kg block of steel is at rest on a horizontal table. The coefficient of static friction between the block and the table is 0.450. A force is to be applied to the block.

To three significant figures, what is the magnitude of that applied force if it puts the block on the verge of sliding when the force is directed (a) horizontally, (b) upward at 60.0° from the horizontal, and (c) downward at 60.0° from the horizontal?

72 A box of canned goods slides down a ramp from street level into the basement of a grocery store with acceleration 0.75 m/s^2 directed down the ramp. The ramp makes an angle of 40° with the horizontal. What is the coefficient of kinetic friction between the box and the ramp?

73 In Fig. 6-54, the coefficient of kinetic friction between the block and inclined plane is 0.20, and angle θ is 60° . What are the (a) magnitude a and (b) direction (up or down the plane) of the block's acceleration if the block is sliding down the plane? What are (c) a and (d) the direction if the block is sent sliding up the plane?



Figure 6-54 Problem 73.

74 A 110 g hockey puck sent sliding over ice is stopped in 15 m by the frictional force on it from the ice. (a) If its initial speed is 6.0 m/s, what is the magnitude of the frictional force? (b) What is the coefficient of friction between the puck and the ice?

75 A locomotive accelerates a 25-car train along a level track. Every car has a mass of 5.0×10^4 kg and is subject to a frictional force $f = 250v$, where the speed v is in meters per second and the force f is in newtons. At the instant when the speed of the train is 30 km/h, the magnitude of its acceleration is 0.20 m/s^2 . (a) What is the tension in the coupling between the first car and the locomotive? (b) If this tension is equal to the maximum force the locomotive can exert on the train, what is the steepest grade up which the locomotive can pull the train at 30 km/h?

76 A house is built on the top of a hill with a nearby slope at angle $\theta = 45^\circ$ (Fig. 6-55). An engineering study indicates that the slope angle should be reduced because the top layers of soil along the slope might slip past the lower layers. If the coefficient of static friction between two such layers is 0.5, what is the least angle ϕ through which the present slope should be reduced to prevent slippage?

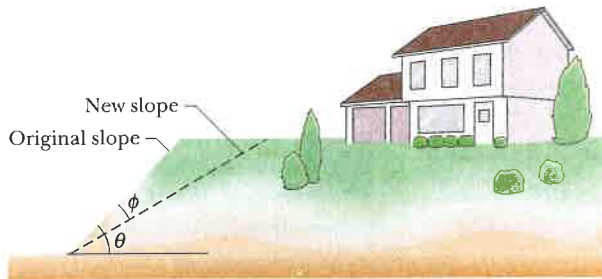


Figure 6-55 Problem 76.

77 What is the terminal speed of a 6.00 kg spherical ball that has a radius of 3.00 cm and a drag coefficient of 1.60? The density of the air through which the ball falls is 1.20 kg/m^3 .

78 A student wants to determine the coefficients of static friction and kinetic friction between a box and a plank. She places the box on the plank and gradually raises one end of the plank. When the angle of inclination with the horizontal reaches 30° , the box starts to slip, and it then slides 2.5 m down the plank in 4.0 s at constant acceleration. What are (a) the coefficient of static friction and (b) the coefficient of kinetic friction between the box and the plank?

79 SSM Block *A* in Fig. 6-56 has mass $m_A = 4.0$ kg, and block *B* has mass $m_B = 2.0$ kg. The coefficient of kinetic friction between block *B* and the horizontal plane is $\mu_k = 0.50$. The inclined plane is frictionless and at angle $\theta = 30^\circ$. The pulley serves only to change the direction of the cord connecting the blocks. The cord has negligible mass. Find (a) the tension in the cord and (b) the magnitude of the acceleration of the blocks.

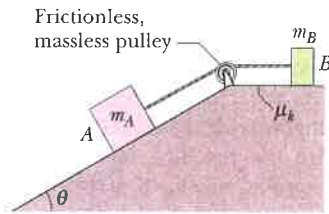


Figure 6-56 Problem 79.

80 Calculate the magnitude of the drag force on a missile 53 cm in diameter cruising at 250 m/s at low altitude, where the density of air is 1.2 kg/m^3 . Assume $C = 0.75$.

81 SSM A bicyclist travels in a circle of radius 25.0 m at a constant speed of 9.00 m/s. The bicycle-rider mass is 85.0 kg. Calculate the magnitudes of (a) the force of friction on the bicycle from the road and (b) the net force on the bicycle from the road.

82 In Fig. 6-57, a stuntman drives a car (without negative lift) over the top of a hill, the cross section of which can be approximated by a circle of radius $R = 250$ m. What is the greatest speed at which he can drive without the car leaving the road at the top of the hill?

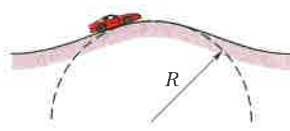


Figure 6-57 Problem 82.

83 You must push a crate across a floor to a docking bay. The crate weighs 165 N. The coefficient of static friction between crate and floor is 0.510, and the coefficient of kinetic friction is 0.32. Your force on the crate is directed horizontally. (a) What magnitude of your push puts the crate on the verge of sliding? (b) With what magnitude must you then push to keep the crate moving at a constant velocity? (c) If, instead, you then push with the same magnitude as the answer to (a), what is the magnitude of the crate's acceleration?

84 In Fig. 6-58, force \vec{F} is applied to a crate of mass m on a floor where the coefficient of static friction between crate and floor is μ_s . Angle θ is initially 0° but is gradually increased so that the force vector rotates clockwise in the figure. During the rotation, the magnitude F of the force is continuously adjusted so that the crate is always on the verge of sliding. For $\mu_s = 0.70$, (a) plot the ratio F/mg versus θ and (b) determine the angle θ_{inf} at which the ratio approaches an infinite value. (c) Does lubricating the floor increase or decrease θ_{inf} , or is the value unchanged? (d) What is θ_{inf} for $\mu_s = 0.60$?

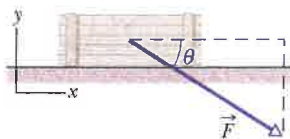


Figure 6-58 Problem 84.

85 In the early afternoon, a car is parked on a street that runs down a steep hill, at an angle of 35.0° relative to the horizontal. Just then the coefficient of static friction between the tires and the street surface is 0.725. Later, after nightfall, a sleet storm hits the area, and the coefficient decreases due to both the ice and a chemi-

cal change in the road surface because of the temperature decrease. By what percentage must the coefficient decrease if the car is to be in danger of sliding down the street?

86 A sling-thrower puts a stone (0.250 kg) in the sling's pouch (0.010 kg) and then begins to make the stone and pouch move in a vertical circle of radius 0.650 m. The cord between the pouch and the person's hand has negligible mass and will break when the tension in the cord is 33.0 N or more. Suppose the sling-thrower could gradually increase the speed of the stone. (a) Will the breaking occur at the lowest point of the circle or at the highest point? (b) At what speed of the stone will that breaking occur?

87 SSM A car weighing 10.7 kN and traveling at 13.4 m/s without negative lift attempts to round an unbanked curve with a radius of 61.0 m. (a) What magnitude of the frictional force on the tires is required to keep the car on its circular path? (b) If the coefficient of static friction between the tires and the road is 0.350, is the attempt at taking the curve successful?

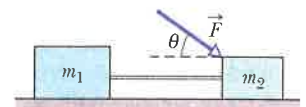


Figure 6-59 Problem 88.

88 In Fig. 6-59, block 1 of mass $m_1 = 2.0$ kg and block 2 of mass $m_2 = 1.0$ kg are connected by a string of negligible mass. Block 2 is pushed by force \vec{F} of magnitude 20 N and angle $\theta = 35^\circ$. The coefficient of kinetic friction between each block and the horizontal surface is 0.20. What is the tension in the string?

89 SSM A filing cabinet weighing 556 N rests on the floor. The coefficient of static friction between it and the floor is 0.68, and the coefficient of kinetic friction is 0.56. In four different attempts to move it, it is pushed with horizontal forces of magnitudes (a) 222 N, (b) 334 N, (c) 445 N, and (d) 556 N. For each attempt, calculate the magnitude of the frictional force on it from the floor. (The cabinet is initially at rest.) (e) In which of the attempts does the cabinet move?

90 In Fig. 6-60, a block weighing 22 N is held at rest against a vertical wall by a horizontal force \vec{F} of magnitude 60 N. The coefficient of static friction between the wall and the block is 0.55, and the coefficient of kinetic friction between them is 0.38. In six experiments, a second force \vec{P} is applied to the block and directed parallel to the wall with these magnitudes and directions: (a) 34 N, up, (b) 12 N, up, (c) 48 N, up, (d) 62 N, up, (e) 10 N, down, and (f) 18 N, down. In each experiment, what is the magnitude of the frictional force on the block? In which does the block move (g) up the wall and (h) down the wall? (i) In which is the frictional force directed down the wall?

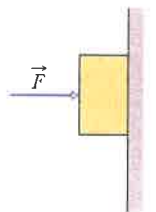


Figure 6-60 Problem 90.

91 SSM A block slides with constant velocity down an inclined plane that has slope angle θ . The block is then projected up the same plane with an initial speed v_0 . (a) How far up the plane will it move before coming to rest? (b) After the block comes to rest, will it slide down the plane again? Give an argument to back your answer.

92 A circular curve of highway is designed for traffic moving at 60 km/h. Assume the traffic consists of cars without negative lift. (a) If the radius of the curve is 150 m, what is the correct angle of banking of the road? (b) If the curve were not banked, what would be the minimum coefficient of friction between tires and road that would keep traffic from skidding out of the turn when traveling at 60 km/h?

93 A 1.5 kg box is initially at rest on a horizontal surface when at $t = 0$ a horizontal force $\vec{F} = (1.8t)\hat{i}$ N (with t in seconds) is applied to the box. The acceleration of the box as a function of time t is given by $\vec{a} = 0$ for $0 \leq t \leq 2.8$ s and $\vec{a} = (1.2t - 2.4)\hat{i}$ m/s² for $t > 2.8$ s. (a) What is the coefficient of static friction between the box and the surface? (b) What is the coefficient of kinetic friction between the box and the surface?

94 A child weighing 140 N sits at rest at the top of a playground slide that makes an angle of 25° with the horizontal. The child keeps from sliding by holding onto the sides of the slide. After letting go of the sides, the child has a constant acceleration of 0.86 m/s² (down the slide, of course). (a) What is the coefficient of kinetic friction between the child and the slide? (b) What maximum and minimum values for the coefficient of static friction between the child and the slide are consistent with the information given here?

95 In Fig. 6-61 a fastidious worker pushes directly along the handle of a mop with a force \vec{F} . The handle is at an angle θ with the vertical, and μ_s and μ_k are the coefficients of static and kinetic friction between the head of the mop and the floor. Ignore the mass of the handle and assume that all the mop's mass m is in its head. (a) If the mop head moves along the floor with a constant velocity, then what is F ? (b) Show that if θ is less than a certain value θ_0 , then \vec{F} (still directed along the handle) is unable to move the mop head. Find θ_0 .

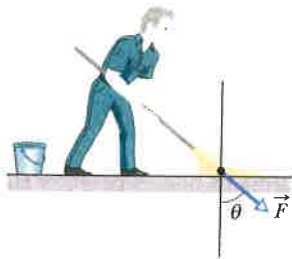


Figure 6-61 Problem 95.

96 A child places a picnic basket on the outer rim of a merry-go-round that has a radius of 4.6 m and revolves once every 30 s. (a) What is the speed of a point on that rim? (b) What is the lowest value of the coefficient of static friction between basket and merry-go-round that allows the basket to stay on the ride?

97 SSM A warehouse worker exerts a constant horizontal force of magnitude 85 N on a 40 kg box that is initially at rest on the horizontal floor of the warehouse. When the box has moved a distance of 1.4 m, its speed is 1.0 m/s. What is the coefficient of kinetic friction between the box and the floor?

98 In Fig. 6-62, a 5.0 kg block is sent sliding up a plane inclined at $\theta = 37^\circ$ while a horizontal force \vec{F} of magnitude 50 N acts on it. The coefficient of kinetic friction between block and plane is 0.30. What are the (a) magnitude and (b) direction (up or down the plane) of the block's acceleration? The block's initial speed is 4.0 m/s. (c) How far up the plane does the block go? (d) When it reaches its highest point, does it remain at rest or slide back down the plane?

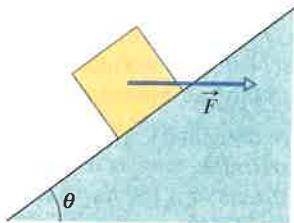


Figure 6-62 Problem 98.

99 An 11 kg block of steel is at rest on a horizontal table. The coefficient of static friction between block and table is 0.52. (a) What is the magnitude of the horizontal force that will put the block on the verge of moving? (b) What is the magnitude of a force acting upward 60° from the horizontal that will put the block on the verge of moving? (c) If the force acts downward at 60° from the horizontal, how large can its magnitude be without causing the block to move?

100 A ski that is placed on snow will stick to the snow. However, when the ski is moved along the snow, the rubbing warms and partially melts the snow, reducing the coefficient of kinetic friction and promoting sliding. Waxing the ski makes it water repellent and reduces friction with the resulting layer of water. A magazine reports that a new type of plastic ski is especially water repellent and that, on a gentle 200 m slope in the Alps, a skier reduced his top-to-bottom time from 61 s with standard skis to 42 s with the new skis. Determine the magnitude of his average acceleration with (a) the standard skis and (b) the new skis. Assuming a 3.0° slope, compute the coefficient of kinetic friction for (c) the standard skis and (d) the new skis.

101 Playing near a road construction site, a child falls over a barrier and down onto a dirt slope that is angled downward at 35° to the horizontal. As the child slides down the slope, he has an acceleration that has a magnitude of 0.50 m/s² and that is directed up the slope. What is the coefficient of kinetic friction between the child and the slope?

102 A 100 N force, directed at an angle θ above a horizontal floor, is applied to a 25.0 kg chair sitting on the floor. If $\theta = 0^\circ$, what are (a) the horizontal component F_h of the applied force and (b) the magnitude F_N of the normal force of the floor on the chair? If $\theta = 30.0^\circ$, what are (c) F_h and (d) F_N ? If $\theta = 60.0^\circ$, what are (e) F_h and (f) F_N ? Now assume that the coefficient of static friction between chair and floor is 0.420. Does the chair slide or remain at rest if θ is (g) 0° , (h) 30.0° , and (i) 60.0° ?

103 A certain string can withstand a maximum tension of 40 N without breaking. A child ties a 0.37 kg stone to one end and, holding the other end, whirls the stone in a vertical circle of radius 0.91 m, slowly increasing the speed until the string breaks. (a) Where is the stone on its path when the string breaks? (b) What is the speed of the stone as the string breaks?

104 A four-person bobsled (total mass = 630 kg) comes down a straightaway at the start of a bobsled run. The straightaway is 80.0 m long and is inclined at a constant angle of 10.2° with the horizontal. Assume that the combined effects of friction and air drag produce on the bobsled a constant force of 62.0 N that acts parallel to the incline and up the incline. Answer the following questions to three significant digits. (a) If the speed of the bobsled at the start of the run is 6.20 m/s, how long does the bobsled take to come down the straightaway? (b) Suppose the crew is able to reduce the effects of friction and air drag to 42.0 N. For the same initial velocity, how long does the bobsled now take to come down the straightaway?

105 As a 40 N block slides down a plane that is inclined at 25° to the horizontal, its acceleration is 0.80 m/s², directed up the plane. What is the coefficient of kinetic friction between the block and the plane?

- Q 1.** *a* and *c* tie, then *b* 3. decreases 5. *a*, *b*, *c* 7. (a) 0; (b) 350 km/h; (c) 350 km/h; (d) same (nothing changed about the vertical motion) 9. (a) all tie; (b) all tie; (c) 3, 2, 1; (d) 3, 2, 1 11. 2, then 1 and 4 tie, then 3 13. (a) yes; (b) no; (c) yes 15. (a) decreases; (b) increases 17. maximum height
P 1. (a) 6.2 m 3. $(-2.0\text{ m})\hat{i} + (6.0\text{ m})\hat{j} - (10\text{ m})\hat{k}$ 5. (a) 7.59 km/h; (b) 22.5° east of due north 7. $(-0.70\text{ m/s})\hat{i} + (1.4\text{ m/s})\hat{j} - (0.40\text{ m/s})\hat{k}$ 9. (a) 0.83 cm/s; (b) 0°; (c) 0.11 m/s; (d) -63° 11. (a) $(6.00\text{ m})\hat{i} - (106\text{ m})\hat{j}$; (b) $(19.0\text{ m/s})\hat{i} - (224\text{ m/s})\hat{j}$; (c) $(24.0\text{ m/s}^2)\hat{i} - (336\text{ m/s}^2)\hat{j}$; (d) -85.2° 13. (a) $(8\text{ m/s}^2)\hat{j} + (1\text{ m/s})\hat{k}$; (b) $(8\text{ m/s}^2)\hat{j}$ 15. (a) $(-1.50\text{ m/s})\hat{j}$; (b) $(4.50\text{ m})\hat{i} - (2.25\text{ m})\hat{j}$ 17. $(32\text{ m/s})\hat{i}$ 19. (a) $(72.0\text{ m})\hat{i} + (90.7\text{ m})\hat{j}$; (b) 49.5° 21. (a) 18 cm; (b) 1.9 m 23. (a) 3.03 s; (b) 758 m; (c) 29.7 m/s 25. 43.1 m/s (155 km/h) 27. (a) 10.0 s; (b) 897 m 29. 78.5° 31. 3.35 m 33. (a) 202 m/s; (b) 806 m; (c) 161 m/s; (d) -171 m/s 35. 4.84 cm 37. (a) 1.60 m; (b) 6.86 m; (c) 2.86 m 39. (a) 32.3 m; (b) 21.9 m/s; (c) 40.4°; (d) below 41. 55.5° 43. (a) 11 m; (b) 23 m; (c) 17 m/s; (d) 63° 45. (a) ramp; (b) 5.82 m; (c) 31.0° 47. (a) yes; (b) 2.56 m 49. (a) 31°; (b) 63° 51. (a) 2.3°; (b) 1.1 m; (c) 18° 53. (a) 75.0 m; (b) 31.9 m/s; (c) 66.9°; (d) 25.5 m 55. the third 57. (a) 7.32 m; (b) west; (c) north 59. (a) 12 s; (b) 4.1 m/s²; (c) down; (d) 4.1 m/s²; (e) up 61. (a) $1.3 \times 10^5\text{ m/s}$; (b) $7.9 \times 10^5\text{ m/s}^2$; (c) increase 63. 2.92 m 65. $(3.00\text{ m/s}^2)\hat{i} + (6.00\text{ m/s}^2)\hat{j}$ 67. 160 m/s² 69. (a) 13 m/s²; (b) eastward; (c) 13 m/s²; (d) eastward 71. 1.67 73. (a) $(80\text{ km/h})\hat{i} - (60\text{ km/h})\hat{j}$; (b) 0°; (c) answers do not change 75. 32 m/s 77. 60° 79. (a) 38 knots; (b) 1.5° east of due north; (c) 4.2 h; (d) 1.5° west of due south 81. (a) $(-32\text{ km/h})\hat{i} - (46\text{ km/h})\hat{j}$; (b) $[(2.5\text{ km}) - (32\text{ km/h})t]\hat{i} + [(4.0\text{ km}) - (46\text{ km/h})t]\hat{j}$; (c) 0.084 h; (d) $2 \times 10^2\text{ m}$ 83. (a) -30°; (b) 69 min; (c) 80 min; (d) 80 min; (e) 0°; (f) 60 min 85. (a) 2.7 km; (b) 76° clockwise 87. (a) 44 m; (b) 13 m; (c) 8.9 m 89. (a) 45 m; (b) 22 m/s 91. (a) $2.6 \times 10^2\text{ m/s}$; (b) 45 s; (c) increase 93. (a) 63 km; (b) 18° south of due east; (c) 0.70 km/h; (d) 18° south of due east; (e) 1.6 km/h; (f) 1.2 km/h; (g) 33° north of due east 95. (a) 1.5; (b) (36 m, 54 m) 97. (a) 62 ms; (b) $4.8 \times 10^2\text{ m/s}$ 99. 2.64 m 101. (a) 2.5 m; (b) 0.82 m; (c) 9.8 m/s²; (d) 9.8 m/s² 103. (a) 6.79 km/h; (b) 6.96° 105. (a) 16 m/s; (b) 23°; (c) above; (d) 27 m/s; (e) 57°; (f) below 107. (a) 4.2 m, 45°; (b) 5.5 m, 68°; (c) 6.0 m, 90°; (d) 4.2 m, 135°; (e) 0.85 m/s, 135°; (f) 0.94 m/s, 90°; (g) 0.94 m/s, 180°; (h) 0.30 m/s², 180°; (i) 0.30 m/s², 270° 109. (a) $5.4 \times 10^{-13}\text{ m}$; (b) decrease 111. (a) 0.034 m/s²; (b) 84 min 113. (a) 8.43 m; (b) -129° 115. (a) 2.00 ns; (b) 2.00 mm; (c) $1.00 \times 10^7\text{ m/s}$; (d) $2.00 \times 10^6\text{ m/s}$ 117. (a) 24 m/s; (b) 65° 119. 93° from the car's direction of motion 121. (a) $4.6 \times 10^{12}\text{ m}$; (b) $2.4 \times 10^5\text{ s}$ 123. (a) 6.29°; (b) 83.7° 125. (a) 3 × 10¹ m 127. (a) $(6.0\hat{i} + 4.2\hat{j})\text{ m/s}$; (b) $(18\hat{i} + 6.3\hat{j})\text{ m}$ 129. (a) 38 ft/s; (b) 32 ft/s; (c) 9.3 ft 131. (a) 11 m; (b) 45 m/s 133. (a) 5.8 m/s; (b) 17 m; (c) 67° 135. (a) 32.4 m; (b) -37.7 m 137. 88.6 km/h

Chapter 5

- CP 1.** *c*, *d*, and *e* (\vec{F}_1 and \vec{F}_2 must be head to tail, \vec{F}_{net} must be from tail of one of them to head of the other) 2. (a) and (b) 2 N, leftward (acceleration is zero in each situation) 3. (a) equal; (b) greater (acceleration is upward, thus net force on body must be upward) 4. (a) equal; (b) greater; (c) less 5. (a) increase; (b) yes; (c) same; (d) yes
Q 1. (a) 2, 3, 4; (b) 1, 3, 4; (c) 1, +y; 2, +x; 3, fourth quadrant; 4, third quadrant 3. increase 5. (a) 2 and 4; (b) 2 and 4 7. (a) M ; (b) M ; (c) M ; (d) $2M$; (e) $3M$ 9. (a) 20 kg; (b) 18 kg; (c) 10 kg; (d) all tie; (e) 3, 2, 1 11. (a) increases from initial value mg ; (b) decreases from mg to zero (after which the block moves up away from the floor)
P 1. 2.9 m/s^2 3. (a) 1.88 N; (b) 0.684 N; (c) $(1.88\text{ N})\hat{i} + (0.684\text{ N})\hat{j}$ 5. (a) $(0.86\text{ m/s}^2)\hat{i} - (0.16\text{ m/s}^2)\hat{j}$; (b) 0.88 m/s²; (c) -11° 7. (a)

- $(-32.0\text{ N})\hat{i} - (20.8\text{ N})\hat{j}$; (b) 38.2 N; (c) -147° 9. (a) 8.37 N; (b) -133°; (c) -125° 11. 9.0 m/s² 13. (a) 4.0 kg; (b) 1.0 kg; (c) 4.0 kg; (d) 1.0 kg 15. (a) 108 N; (b) 108 N; (c) 108 N 17. (a) 42 N; (b) 72 N; (c) 4.9 m/s² 19. $1.2 \times 10^5\text{ N}$ 21. (a) 11.7 N; (b) -59.0° 23. (a) $(285\text{ N})\hat{i} + (705\text{ N})\hat{j}$; (b) $(285\text{ N})\hat{i} - (115\text{ N})\hat{j}$; (c) 307 N; (d) -22.0°; (e) 3.67 m/s²; (f) -22.0° 25. (a) 0.022 m/s²; (b) $8.3 \times 10^4\text{ km}$; (c) $1.9 \times 10^3\text{ m/s}$ 27. 1.5 mm 29. (a) 494 N; (b) up; (c) 494 N; (d) down 31. (a) 1.18 m; (b) 0.674 s; (c) 3.50 m/s 33. $1.8 \times 10^4\text{ N}$ 35. (a) 46.7°; (b) 28.0° 37. (a) 0.62 m/s²; (b) 0.13 m/s²; (c) 2.6 m 39. (a) $2.2 \times 10^{-3}\text{ N}$; (b) $3.7 \times 10^{-3}\text{ N}$ 41. (a) 1.4 m/s²; (b) 4.1 m/s 43. (a) 1.23 N; (b) 2.46 N; (c) 3.69 N; (d) 4.92 N; (e) 6.15 N; (f) 0.250 N 45. (a) 31.3 kN; (b) 24.3 kN 47. $6.4 \times 10^3\text{ N}$ 49. (a) 2.18 m/s^2 ; (b) 116 N; (c) 21.0 m/s^2 51. (a) 3.6 m/s²; (b) 17 N 53. (a) 0.970 m/s²; (b) 11.6 N; (c) 34.9 N 55. (a) 1.1 N 57. (a) 0.735 m/s²; (b) down; (c) 20.8 N 59. (a) 4.9 m/s²; (b) 2.0 m/s²; (c) up; (d) 120 N 61. $2M/(a + g)$ 63. (a) 8.0 m/s; (b) +*x* 65. (a) 0.653 m/s³; (b) 0.896 m/s³; (c) 6.50 s 67. 81.7 N 69. 2.4 N 71. 16 N 73. (a) 2.6 N; (b) 17° 75. (a) 0; (b) 0.83 m/s²; (c) 0 77. (a) 0.74 m/s²; (b) 7.3 m/s² 79. (a) 11 N; (b) 2.2 kg; (c) 0; (d) 2.2 kg 81. 195 N 83. (a) 4.6 m/s²; (b) 2.6 m/s² 85. (a) rope breaks; (b) 1.6 m/s² 87. (a) 65 N; (b) 49 N 89. (a) $4.6 \times 10^3\text{ N}$; (b) $5.8 \times 10^3\text{ N}$ 91. (a) $1.8 \times 10^2\text{ N}$; (b) $6.4 \times 10^2\text{ N}$ 93. (a) 44 N; (b) 78 N; (c) 54 N; (d) 152 N 95. (a) 4 kg; (b) 6.5 m/s²; (c) 13 N 97. (a) $(1.0\hat{i} - 2.0\hat{j})\text{ N}$; (b) 2.2 N; (c) -63°; (d) 2.2 m/s²; (e) -63°

Chapter 6

- CP 1.** (a) zero (because there is no attempt at sliding); (b) 5 N; (c) no; (d) yes; (e) 8 N 2. (\vec{a} is directed toward center of circular path) (a) \vec{a} downward, \vec{F}_N upward; (b) \vec{a} and \vec{F}_N upward; (c) same; (d) greater at lowest point
Q 1. (a) decrease; (b) decrease; (c) increase; (d) increase; (e) increase 3. (a) same; (b) increases; (c) increases; (d) no 5. (a) upward; (b) horizontal, toward you; (c) no change; (d) increases; (e) increases 7. At first, \vec{f}_s is directed up the ramp and its magnitude increases from $mg \sin \theta$ until it reaches $f_{s,\text{max}}$. Thereafter the force is kinetic friction directed up the ramp, with magnitude f_k (a constant value smaller than $f_{s,\text{max}}$). 9. 4, 3, then 1, 2, and 5 tie 11. (a) all tie; (b) all tie; (c) 2, 3, 1 13. (a) increases; (b) increases; (c) decreases; (d) decreases; (e) decreases
P 1. 36 m 3. (a) $2.0 \times 10^2\text{ N}$; (b) $1.2 \times 10^2\text{ N}$ 5. (a) 6.0 N; (b) 3.6 N; (c) 3.1 N 7. (a) $1.9 \times 10^2\text{ N}$; (b) 0.56 m/s² 9. (a) 11 N; (b) 0.14 m/s² 11. (a) $3.0 \times 10^2\text{ N}$; (b) 1.3 m/s² 13. (a) $1.3 \times 10^2\text{ N}$; (b) no; (c) $1.1 \times 10^2\text{ N}$; (d) 46 N; (e) 17 N 15. 2° 17. (a) $(17\text{ N})\hat{i}$; (b) $(20\text{ N})\hat{i}$; (c) $(15\text{ N})\hat{i}$ 19. (a) no; (b) $(-12\text{ N})\hat{i} + (5.0\text{ N})\hat{j}$ 21. (a) 19°; (b) 3.3 kN 23. 0.37 25. $1.0 \times 10^2\text{ N}$ 27. (a) 0; (b) $(-3.9\text{ m/s}^2)\hat{i}$; (c) $(-1.0\text{ m/s}^2)\hat{i}$ 29. (a) 66 N; (b) 2.3 m/s² 31. (a) 3.5 m/s²; (b) 0.21 N 33. 9.9 s 35. $4.9 \times 10^2\text{ N}$ 37. (a) $3.2 \times 10^2\text{ km/h}$; (b) $6.5 \times 10^2\text{ km/h}$; (c) no 39. 2.3 41. 0.60 43. 21 m 45. (a) light; (b) 778 N; (c) 223 N; (d) 1.11 kN 47. (a) 10 s; (b) $4.9 \times 10^2\text{ N}$; (c) $1.1 \times 10^3\text{ N}$ 49. $1.37 \times 10^3\text{ N}$ 51. 2.2 km 53. 12° 55. $2.6 \times 10^3\text{ N}$ 57. 1.81 m/s 59. (a) 8.74 N; (b) 37.9 N; (c) 6.45 m/s; (d) radially inward 61. (a) 27 N; (b) 3.0 m/s² 63. (b) 240 N; (c) 0.60 65. (a) 69 km/h; (b) 139 km/h; (c) yes 67. $g(\sin \theta - 2^{0.5}\mu_k \cos \theta)$ 69. 3.4 m/s² 71. (a) 35.3 N; (b) 39.7 N; (c) 320 N 73. (a) 7.5 m/s²; (b) down; (c) 9.5 m/s²; (d) down 75. (a) $3.0 \times 10^5\text{ N}$; (b) 1.2° 77. 147 m/s 79. (a) 13 N; (b) 1.6 m/s² 81. (a) 275 N; (b) 877 N 83. (a) 84.2 N; (b) 52.8 N; (c) 1.87 m/s² 85. 3.4% 87. (a) $3.21 \times 10^3\text{ N}$; (b) yes 89. (a) 222 N; (b) 334 N; (c) 311 N; (d) 311 N; (e) c, d 91. (a) $v_0^2/(4g \sin \theta)$; (b) no 93. (a) 0.34; (b) 0.24 95. (a) $\mu_k mg/(\sin \theta - \mu_k \cos \theta)$; (b) $\theta_0 = \tan^{-1} \mu_s$ 97. 0.18 99. (a) 56 N; (b) 59 N; (c) $1.1 \times 10^3\text{ N}$ 101. 0.76 103. (a) bottom of circle; (b) 9.5 m/s 105. 0.56