

Review & Summary

Newtonian Mechanics The velocity of an object can change (the object can accelerate) when the object is acted on by one or more **forces** (pushes or pulls) from other objects. *Newtonian mechanics* relates accelerations and forces.

Force Forces are vector quantities. Their magnitudes are defined in terms of the acceleration they would give the standard kilogram. A force that accelerates that standard body by exactly 1 m/s^2 is defined to have a magnitude of 1 N. The direction of a force is the direction of the acceleration it causes. Forces are combined according to the rules of vector algebra. The **net force** on a body is the vector sum of all the forces acting on the body.

Newton's First Law If there is no net force on a body, the body remains at rest if it is initially at rest or moves in a straight line at constant speed if it is in motion.

Inertial Reference Frames Reference frames in which Newtonian mechanics holds are called *inertial reference frames* or *inertial frames*. Reference frames in which Newtonian mechanics does not hold are called *noninertial reference frames* or *noninertial frames*.

Mass The **mass** of a body is the characteristic of that body that relates the body's acceleration to the net force causing the acceleration. Masses are scalar quantities.

Newton's Second Law The net force \vec{F}_{net} on a body with mass m is related to the body's acceleration \vec{a} by

$$\vec{F}_{\text{net}} = m\vec{a}, \quad (5-1)$$

which may be written in the component versions

$$F_{\text{net},x} = ma_x \quad F_{\text{net},y} = ma_y \quad \text{and} \quad F_{\text{net},z} = ma_z. \quad (5-2)$$

The second law indicates that in SI units

$$1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2. \quad (5-3)$$

A **free-body diagram** is a stripped-down diagram in which only *one* body is considered. That body is represented by either a sketch or a dot. The external forces on the body are drawn, and a coordinate system is superimposed, oriented so as to simplify the solution.

Some Particular Forces A **gravitational force** \vec{F}_g on a body is a pull by another body. In most situations in this book, the other body is Earth or some other astronomical body. For Earth, the force is directed down toward the ground, which is assumed to be an inertial frame. With that assumption, the magnitude of \vec{F}_g is

$$F_g = mg, \quad (5-8)$$

where m is the body's mass and g is the magnitude of the free-fall acceleration.

The **weight** W of a body is the magnitude of the upward force needed to balance the gravitational force on the body. A body's weight is related to the body's mass by

$$W = mg. \quad (5-12)$$

A **normal force** \vec{F}_N is the force on a body from a surface against which the body presses. The normal force is always perpendicular to the surface.

A **frictional force** \vec{f} is the force on a body when the body slides or attempts to slide along a surface. The force is always parallel to the surface and directed so as to oppose the sliding. On a *frictionless surface*, the frictional force is negligible.

When a cord is under **tension**, each end of the cord pulls on a body. The pull is directed along the cord, away from the point of attachment to the body. For a *massless cord* (a cord with negligible mass), the pulls at both ends of the cord have the same magnitude T , even if the cord runs around a *massless, frictionless pulley* (a pulley with negligible mass and negligible friction on its axle to oppose its rotation).

Newton's Third Law If a force \vec{F}_{BC} acts on body B due to body C , then there is a force \vec{F}_{CB} on body C due to body B :

$$\vec{F}_{BC} = -\vec{F}_{CB}.$$

Questions

1 Figure 5-19 gives the free-body diagram for four situations in which an object is pulled by several forces across a frictionless floor, as seen from overhead. In which situations does the acceleration \vec{a} of the object have (a) an x component and (b) a y component?

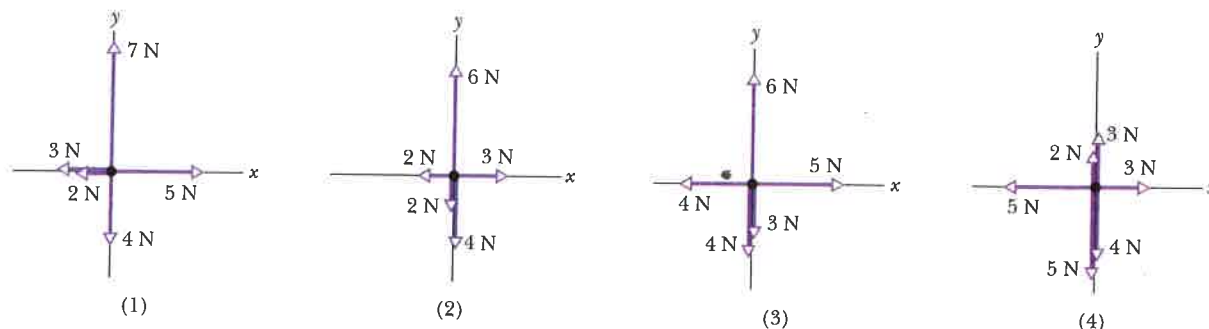


Figure 5-19 Question 1.

(c) In each situation, give the direction of \vec{a} by naming either a quadrant or a direction along an axis. (Don't reach for the calculator because this can be answered with a few mental calculations.)

- 2 Two horizontal forces,

$$\vec{F}_1 = (3\text{ N})\hat{i} - (4\text{ N})\hat{j} \quad \text{and} \quad \vec{F}_2 = -(1\text{ N})\hat{i} - (2\text{ N})\hat{j}$$

pull a banana split across a frictionless lunch counter. Without using a calculator, determine which of the vectors in the free-body diagram of Fig. 5-20 best represent (a) \vec{F}_1 and (b) \vec{F}_2 . What is the net-force component along (c) the x axis and (d) the y axis? Into which quadrants do (e) the net-force vector and (f) the split's acceleration vector point?

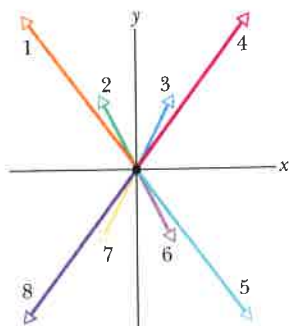


Figure 5-20 Question 2.

- 3 In Fig. 5-21, forces \vec{F}_1 and \vec{F}_2 are applied to a lunchbox as it slides at constant velocity over a frictionless floor. We are to decrease angle θ without changing the magnitude of \vec{F}_1 . For constant velocity, should we increase, decrease, or maintain the magnitude of \vec{F}_2 ?

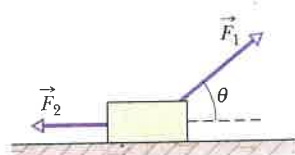


Figure 5-21 Question 3.

- 4 At time $t = 0$, constant \vec{F} begins to act on a rock moving through deep space in the $+x$ direction. (a) For time $t > 0$, which are possible functions $x(t)$ for the rock's position: (1) $x = 4t - 3$, (2) $x = -4t^2 + 6t - 3$, (3) $x = 4t^2 + 6t - 3$? (b) For which function is \vec{F} directed opposite the rock's initial direction of motion?

- 5 Figure 5-22 shows overhead views of four situations in which forces act on a block that lies on a frictionless floor. If the force magnitudes are chosen properly, in which situations is it possible that the block is (a) stationary and (b) moving with a constant velocity?

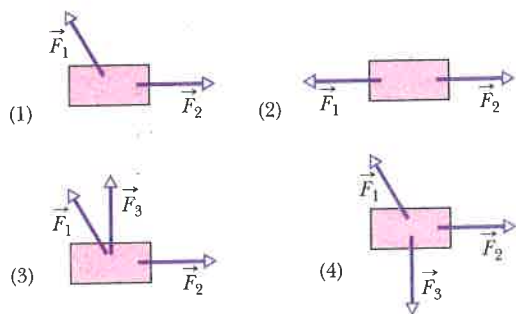


Figure 5-22 Question 5.

- 6 Figure 5-23 shows the same breadbox in four situations where horizontal forces are applied. Rank the situations according to the magnitude of the box's acceleration, greatest first.

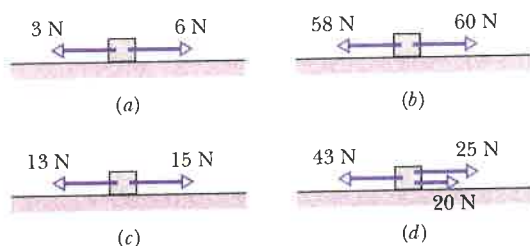


Figure 5-23 Question 6.

- 7 ~~July 17, 1981, Kansas City:~~ The newly opened Hyatt Regency is packed with people listening and dancing to a band playing favorites from the 1940s. Many of the people are crowded onto the walkways that hang like bridges across the wide atrium. Suddenly two of the walkways collapse, falling onto the merry-makers on the main floor.

The walkways were suspended one above another on vertical rods and held in place by nuts threaded onto the rods. In the original design, only two long rods were to be used, each extending through all three walkways (Fig. 5-24a). If each walkway and the merry-makers on it have a combined mass of M , what is the total mass supported by the threads and two nuts on (a) the lowest walkway and (b) the highest walkway?

Apparently someone responsible for the actual construction realized that threading nuts on a rod is impossible except at the ends, so the design was changed: Instead, six rods were used, each connecting two walkways (Fig. 5-24b). What now is the total mass supported by the threads and two nuts on (c) the lowest walkway, (d) the upper side of the highest walkway, and (e) the lower side of the highest walkway? It was this design that failed on that tragic night—a simple engineering error.

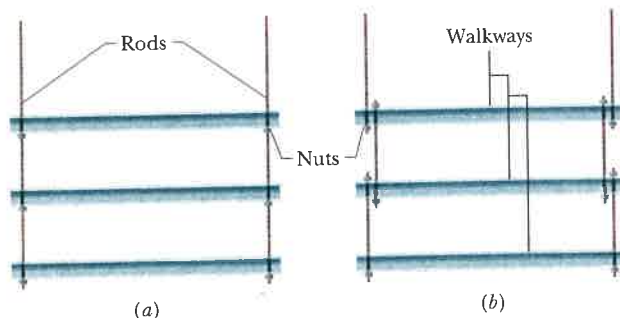


Figure 5-24 Question 7.

- 8 Figure 5-25 gives three graphs of velocity component $v_x(t)$ and three graphs of velocity component $v_y(t)$. The graphs are not to scale. Which $v_x(t)$ graph and which $v_y(t)$ graph best correspond to each of the four situations in Question 1 and Fig. 5-19?

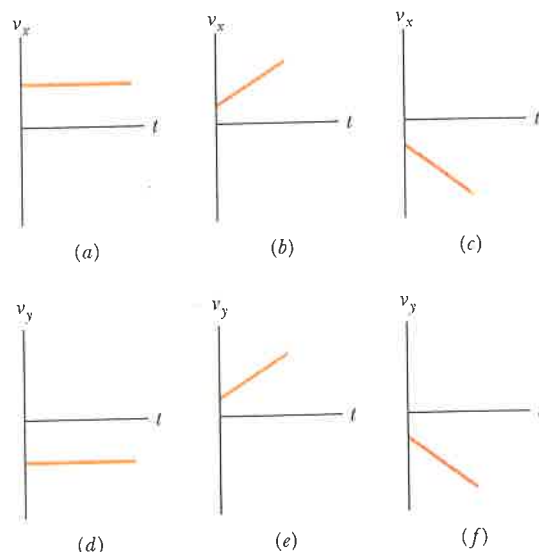


Figure 5-25 Question 8.

9 Figure 5-26 shows a train of four blocks being pulled across a frictionless floor by force \vec{F} . What total mass is accelerated to the right by (a) force \vec{F} , (b) cord 3, and (c) cord 1? (d) Rank the blocks according to their accelerations, greatest first. (e) Rank the cords according to their tension, greatest first.

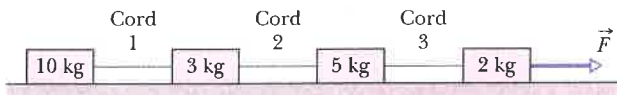


Figure 5-26 Question 9.

10 Figure 5-27 shows three blocks being pushed across a frictionless floor by horizontal force \vec{F} . What total mass is accelerated to the right by (a) force \vec{F} , (b) force \vec{F}_{21} on block 2 from block 1, and (c) force

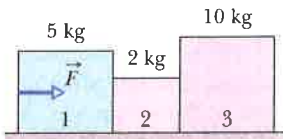


Figure 5-27 Question 10.

Problems

- Tutoring problem available (at instructor's discretion) in WileyPLUS and WebAssign
- Worked-out solution available in Student Solutions Manual
- Worked-out solution is at <http://www.wiley.com/college/halliday>
- Number of dots indicates level of problem difficulty
- Interactive solution is at <http://www.wiley.com/college/halliday>
- Additional information available in *The Flying Circus of Physics* and at flyingcircusofphysics.com

Module 5-1 Newton's First and Second Laws

- 1 Only two horizontal forces act on a 3.0 kg body that can move over a frictionless floor. One force is 9.0 N, acting due east, and the other is 8.0 N, acting 62° north of west. What is the magnitude of the body's acceleration?
- 2 Two horizontal forces act on a 2.0 kg chopping block that can slide over a frictionless kitchen counter, which lies in an xy plane. One force is $\vec{F}_1 = (3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$. Find the acceleration of the chopping block in unit-vector notation when the other force is (a) $\vec{F}_2 = (-3.0 \text{ N})\hat{i} + (-4.0 \text{ N})\hat{j}$, (b) $\vec{F}_2 = (-3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$, and (c) $\vec{F}_2 = (3.0 \text{ N})\hat{i} + (-4.0 \text{ N})\hat{j}$.
- 3 If the 1 kg standard body has an acceleration of 2.00 m/s² at 20.0° to the positive direction of an x axis, what are (a) the x component and (b) the y component of the net force acting on the body, and (c) what is the net force in unit-vector notation?
- 4 While two forces act on it, a particle is to move at the constant velocity $\vec{v} = (3 \text{ m/s})\hat{i} - (4 \text{ m/s})\hat{j}$. One of the forces is $\vec{F}_1 = (2 \text{ N})\hat{i} + (-6 \text{ N})\hat{j}$. What is the other force?
- 5 Three astronauts, propelled by jet backpacks, push and guide a 120 kg asteroid toward a processing dock, exerting the forces shown in Fig. 5-29, with $F_1 = 32 \text{ N}$, $F_2 = 55 \text{ N}$, $F_3 = 41 \text{ N}$, $\theta_1 = 30^\circ$, and $\theta_3 = 60^\circ$. What is the asteroid's acceleration (a) in unit-vector notation and as (b) a magnitude and (c) a direction relative to the positive direction of the x axis?

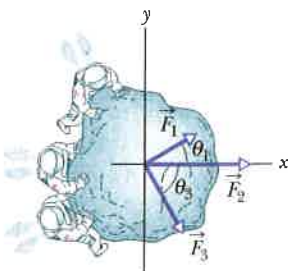


Figure 5-29 Problem 5.

\vec{F}_{32} on block 3 from block 2? (d) Rank the blocks according to their acceleration magnitudes, greatest first. (e) Rank forces \vec{F} , \vec{F}_{21} , and \vec{F}_{32} according to magnitude, greatest first.

11 A vertical force \vec{F} is applied to a block of mass m that lies on a floor. What happens to the magnitude of the normal force \vec{F}_N on the block from the floor as magnitude F is increased from zero if force \vec{F} is (a) downward and (b) upward?

12 Figure 5-28 shows four choices for the direction of a force of magnitude F to be applied to a block on an inclined plane. The directions are either horizontal or vertical. (For choice b , the force is not enough to lift the block off the plane.) Rank the choices according to the magnitude of the normal force acting on the block from the plane, greatest first.

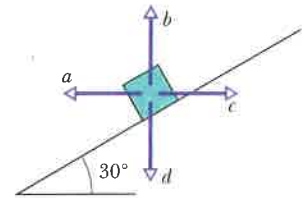


Figure 5-28 Question 12.

- 6 In a two-dimensional tug-of-war, Alex, Betty, and Charles pull horizontally on an automobile tire at the angles shown in the overhead view of Fig. 5-30. The tire remains stationary in spite of the three pulls. Alex pulls with force \vec{F}_A of magnitude 220 N, and Charles pulls with force \vec{F}_C of magnitude 170 N. Note that the direction of \vec{F}_C is not given. What is the magnitude of Betty's force \vec{F}_B ?
- 7 There are two forces on the 2.00 kg box in the overhead view of Fig. 5-31, but only one is shown. For $F_1 = 20.0 \text{ N}$, $a = 12.0 \text{ m/s}^2$, and $\theta = 30.0^\circ$, find the second force (a) in unit-vector notation and as (b) a magnitude and (c) an angle relative to the positive direction of the x axis.
- 8 A 2.00 kg object is subjected to three forces that give it an acceleration $\vec{a} = -(8.00 \text{ m/s}^2)\hat{i} + (6.00 \text{ m/s}^2)\hat{j}$. If two of the three forces are $\vec{F}_1 = (30.0 \text{ N})\hat{i} + (16.0 \text{ N})\hat{j}$ and $\vec{F}_2 = -(12.0 \text{ N})\hat{i} + (8.00 \text{ N})\hat{j}$, find the third force.
- 9 A 0.340 kg particle moves in an xy plane according to $x(t) = -15.00 + 2.00t - 4.00t^3$ and $y(t) = 25.00 + 7.00t - 9.00t^2$, with x and y in meters and t in seconds. At $t = 0.700 \text{ s}$, what are

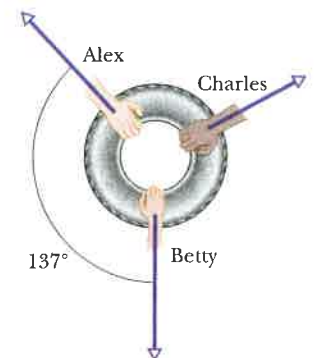


Figure 5-30 Problem 6.

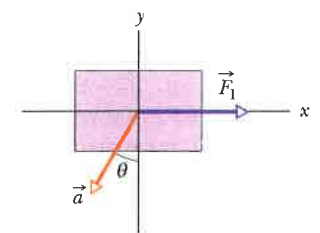


Figure 5-31 Problem 7.

(a) the magnitude and (b) the angle (relative to the positive direction of the x axis) of the net force on the particle, and (c) what is the angle of the particle's direction of travel?

••10 **GO** A 0.150 kg particle moves along an x axis according to $x(t) = -13.00 + 2.00t + 4.00t^2 - 3.00t^3$, with x in meters and t in seconds. In unit-vector notation, what is the net force acting on the particle at $t = 3.40$ s?

••11 A 2.0 kg particle moves along an x axis, being propelled by a variable force directed along that axis. Its position is given by $x = 3.0 \text{ m} + (4.0 \text{ m/s})t + ct^2 - (2.0 \text{ m/s}^3)t^3$, with x in meters and t in seconds. The factor c is a constant. At $t = 3.0$ s, the force on the particle has a magnitude of 36 N and is in the negative direction of the axis. What is c ?

••12 **GO** Two horizontal forces \vec{F}_1 and \vec{F}_2 act on a 4.0 kg disk that slides over frictionless ice, on which an xy coordinate system is laid out. Force \vec{F}_1 is in the positive direction of the x axis and has a magnitude of 7.0 N. Force \vec{F}_2 has a magnitude of 9.0 N. Figure 5-32 gives the x component v_x of the velocity of the disk as a function of time t during the sliding. What is the angle between the constant directions of forces \vec{F}_1 and \vec{F}_2 ?

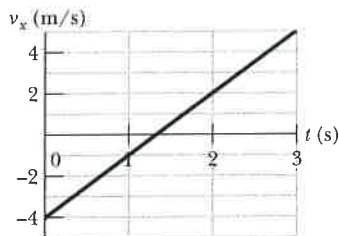


Figure 5-32 Problem 12.

Module 5-2 Some Particular Forces

•13 Figure 5-33 shows an arrangement in which four disks are suspended by cords. The longer, top cord loops over a frictionless pulley and pulls with a force of magnitude 98 N on the wall to which it is attached. The tensions in the three shorter cords are $T_1 = 58.8 \text{ N}$, $T_2 = 49.0 \text{ N}$, and $T_3 = 9.8 \text{ N}$. What are the masses of (a) disk A, (b) disk B, (c) disk C, and (d) disk D?

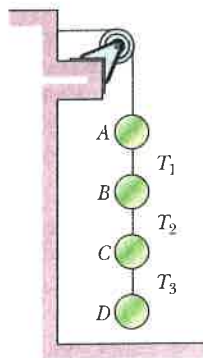


Figure 5-33 Problem 13.

•14 A block with a weight of 3.0 N is at rest on a horizontal surface. A 1.0 N upward force is applied to the block by means of an attached vertical string. What are the (a) magnitude and (b) direction of the force of the block on the horizontal surface?

•15 **SSM** (a) An 11.0 kg salami is supported by a cord that runs to a spring scale, which is supported by a cord hung from the ceiling (Fig. 5-34a). What is the reading on the scale, which is marked in SI weight units? (This is a way to measure weight by a deli owner.) (b) In Fig. 5-34b the salami is supported by a cord that runs around a pulley and to a scale. The opposite end of the scale is attached by a cord to a wall. What is the reading on the scale? (This is the way by a physics major.) (c) In Fig. 5-34c the wall has been replaced with a second 11.0 kg salami, and the assembly is stationary. What is the

reading on the scale? (This is the way by a deli owner who was once a physics major.)

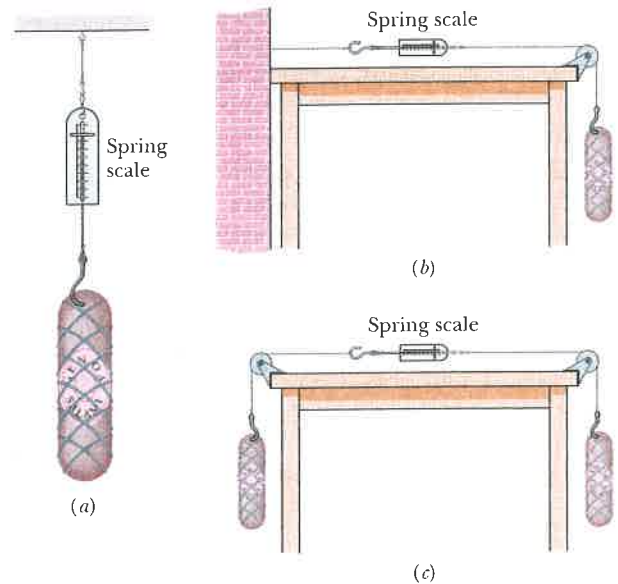


Figure 5-34 Problem 15.

••16 Some insects can walk below a thin rod (such as a twig) by hanging from it. Suppose that such an insect has mass m and hangs from a horizontal rod as shown in Fig. 5-35, with angle $\theta = 40^\circ$. Its six legs are all under the same tension, and the leg sections nearest the body are horizontal. (a) What is the ratio of the tension in each tibia (forepart of a leg) to the insect's weight? (b) If the insect straightens out its legs somewhat, does the tension in each tibia increase, decrease, or stay the same?

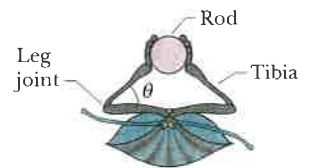


Figure 5-35 Problem 16.

Module 5-3 Applying Newton's Laws

•17 **SSM WWW** In Fig. 5-36, let the mass of the block be 8.5 kg and the angle θ be 30° . Find (a) the tension in the cord and (b) the normal force acting on the block. (c) If the cord is cut, find the magnitude of the resulting acceleration of the block.

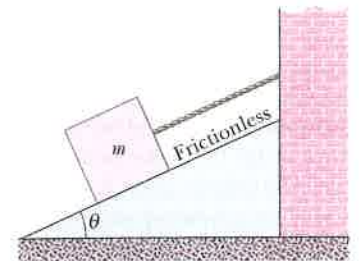


Figure 5-36 Problem 17.

•18 **SSM** In April 1974, John Massis of Belgium managed to move two passenger railroad cars. He did so by clamping his teeth down on a bit that was attached to the cars with a rope and then leaning backward while pressing his feet against the railway ties. The cars together weighed 700 kN (about 80 tons). Assume that he pulled with a constant force that was 2.5 times his body weight, at an upward angle θ of 30° from the horizontal. His mass was 80 kg, and he moved the cars by 1.0 m. Neglecting any retarding force from the wheel rotation, find the speed of the cars at the end of the pull.

•19 **SSM** A 500 kg rocket sled can be accelerated at a constant rate from rest to 1600 km/h in 1.8 s. What is the magnitude of the required net force?

•20 A car traveling at 53 km/h hits a bridge abutment. A passenger in the car moves forward a distance of 65 cm (with respect to the road) while being brought to rest by an inflated air bag. What magnitude of force (assumed constant) acts on the passenger's upper torso, which has a mass of 41 kg?

•21 A constant horizontal force \vec{F}_a pushes a 2.00 kg FedEx package across a frictionless floor on which an xy coordinate system has been drawn. Figure 5-37 gives the package's x and y velocity components versus time t . What are the (a) magnitude and (b) direction of \vec{F}_a ?

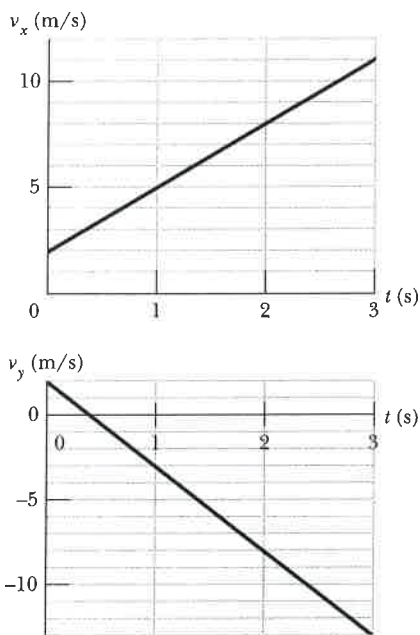


Figure 5-37 Problem 21.

•22 **SSM** A customer sits in an amusement park ride in which the compartment is to be pulled downward in the negative direction of a y axis with an acceleration magnitude of $1.24g$, with $g = 9.80 \text{ m/s}^2$. A 0.567 g coin rests on the customer's knee. Once the motion begins and in unit-vector notation, what is the coin's acceleration relative to (a) the ground and (b) the customer? (c) How long does the coin take to reach the compartment ceiling, 2.20 m above the knee? In unit-vector notation, what are (d) the actual force on the coin and (e) the apparent force according to the customer's measure of the coin's acceleration?

•23 Tarzan, who weighs 820 N, swings from a cliff at the end of a 20.0 m vine that hangs from a high tree limb and initially makes an angle of 22.0° with the vertical. Assume that an x axis extends horizontally away from the cliff edge and a y axis extends upward. Immediately after Tarzan steps off the cliff, the tension in the vine is 760 N. Just then, what are (a) the force on him from the vine in unit-vector notation and the net force on him (b) in unit-vector notation and as (c) a magnitude and (d) an angle relative to the positive direction of the x axis? What are the (e) magnitude and (f) angle of Tarzan's acceleration just then?

•24 There are two horizontal forces on the 2.0 kg box in the overhead view of Fig. 5-38 but only one (of magnitude $F_1 = 20 \text{ N}$) is shown. The box moves along the x axis. For each of the following values for the acceleration a_x of the box, find the second force in unit-vector notation: (a) 10 m/s^2 , (b) 20 m/s^2 , (c) 0, (d) -10 m/s^2 , and (e) -20 m/s^2 .



Figure 5-38 Problem 24.

•25 **Sunjamming.** A "sun yacht" is a spacecraft with a large sail that is pushed by sunlight. Although such a push is tiny in everyday circumstances, it can be large enough to send the spacecraft outward from the Sun on a cost-free but slow trip. Suppose that the spacecraft has a mass of 900 kg and receives a push of 20 N. (a) What is the magnitude of the resulting acceleration? If the craft starts from rest, (b) how far will it travel in 1 day and (c) how fast will it then be moving?

•26 The tension at which a fishing line snaps is commonly called the line's "strength." What minimum strength is needed for a line that is to stop a salmon of weight 85 N in 11 cm if the fish is initially drifting at 2.8 m/s? Assume a constant deceleration.

•27 **SSM** An electron with a speed of $1.2 \times 10^7 \text{ m/s}$ moves horizontally into a region where a constant vertical force of $4.5 \times 10^{-16} \text{ N}$ acts on it. The mass of the electron is $9.11 \times 10^{-31} \text{ kg}$. Determine the vertical distance the electron is deflected during the time it has moved 30 mm horizontally.

•28 A car that weighs $1.30 \times 10^4 \text{ N}$ is initially moving at 40 km/h when the brakes are applied and the car is brought to a stop in 15 m. Assuming the force that stops the car is constant, find (a) the magnitude of that force and (b) the time required for the change in speed. If the initial speed is doubled, and the car experiences the same force during the braking, by what factors are (c) the stopping distance and (d) the stopping time multiplied? (There could be a lesson here about the danger of driving at high speeds.)

•29 A firefighter who weighs 712 N slides down a vertical pole with an acceleration of 3.00 m/s^2 , directed downward. What are the (a) magnitude and (b) direction (up or down) of the vertical force on the firefighter from the pole and the (c) magnitude and (d) direction of the vertical force on the pole from the firefighter?

•30 **SSM** The high-speed winds around a tornado can drive projectiles into trees, building walls, and even metal traffic signs. In a laboratory simulation, a standard wood toothpick was shot by pneumatic gun into an oak branch. The toothpick's mass was 0.13 g, its speed before entering the branch was 220 m/s, and its penetration depth was 15 mm. If its speed was decreased at a uniform rate, what was the magnitude of the force of the branch on the toothpick?

•31 **SSM WWW** A block is projected up a frictionless inclined plane with initial speed $v_0 = 3.50 \text{ m/s}$. The angle of incline is $\theta = 32.0^\circ$. (a) How far up the plane does the block go? (b) How long does it take to get there? (c) What is its speed when it gets back to the bottom?

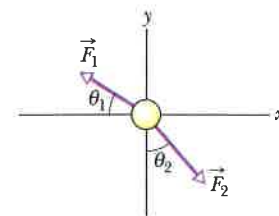



Figure 5-39 Problem 32.

•32 Figure 5-39 shows an overhead view of a 0.0250 kg lemon half and

two of the three horizontal forces that act on it as it is on a frictionless table. Force \vec{F}_1 has a magnitude of 6.00 N and is at $\theta_1 = 30.0^\circ$. Force \vec{F}_2 has a magnitude of 7.00 N and is at $\theta_2 = 30.0^\circ$. In unit-vector notation, what is the third force if the lemon half (a) is stationary, (b) has the constant velocity $\vec{v} = (13.0\hat{i} - 14.0\hat{j})$ m/s, and (c) has the varying velocity $\vec{v} = (13.0t\hat{i} - 14.0t\hat{j})$ m/s², where t is time?

••33 An elevator cab and its load have a combined mass of 1600 kg. Find the tension in the supporting cable when the cab, originally moving downward at 12 m/s, is brought to rest with constant acceleration in a distance of 42 m.

••34  In Fig. 5-40, a crate of mass $m = 100$ kg is pushed at constant speed up a frictionless ramp ($\theta = 30.0^\circ$) by a horizontal force \vec{F} . What are the magnitudes of (a) \vec{F} and (b) the force on the crate from the ramp?

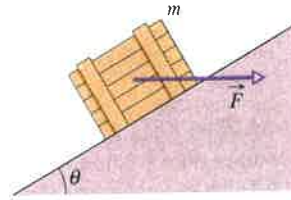



Figure 5-40 Problem 34.


••35 The velocity of a 3.00 kg particle is given by $\vec{v} = (8.00\hat{i} + 3.00t^2\hat{j})$ m/s, with time t in seconds. At the instant the net force on the particle has a magnitude of 35.0 N, what are the direction (relative to the positive direction of the x axis) of (a) the net force and (b) the particle's direction of travel?

••36 Holding on to a towrope moving parallel to a frictionless ski slope, a 50 kg skier is pulled up the slope, which is at an angle of 8.0° with the horizontal. What is the magnitude F_{rope} of the force on the skier from the rope when (a) the magnitude v of the skier's velocity is constant at 2.0 m/s and (b) $v = 2.0$ m/s as v increases at a rate of 0.10 m/s²?

••37 A 40 kg girl and an 8.4 kg sled are on the frictionless ice of a frozen lake, 15 m apart but connected by a rope of negligible mass. The girl exerts a horizontal 5.2 N force on the rope. What are the acceleration magnitudes of (a) the sled and (b) the girl? (c) How far from the girl's initial position do they meet?

••38 A 40 kg skier skis directly down a frictionless slope angled at 10° to the horizontal. Assume the skier moves in the negative direction of an x axis along the slope. A wind force with component F_x acts on the skier. What is F_x if the magnitude of the skier's velocity is (a) constant, (b) increasing at a rate of 1.0 m/s², and (c) increasing at a rate of 2.0 m/s²?

••39  A sphere of mass 3.0×10^{-4} kg is suspended from a cord. A steady horizontal breeze pushes the sphere so that the cord makes a constant angle of 37° with the vertical. Find (a) the push magnitude and (b) the tension in the cord.

••40  A dated box of dates, of mass 5.00 kg, is sent sliding up a frictionless ramp at an angle of θ to the horizontal. Figure 5-41 gives,

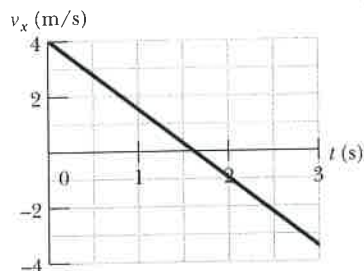



Figure 5-41 Problem 40.

as a function of time t , the component v_x of the box's velocity along an x axis that extends directly up the ramp. What is the magnitude of the normal force on the box from the ramp?

••41 Using a rope that will snap if the tension in it exceeds 387 N, you need to lower a bundle of old roofing material weighing 449 N from a point 6.1 m above the ground. Obviously if you hang the bundle on the rope, it will snap. So, you allow the bundle to accelerate downward. (a) What magnitude of the bundle's acceleration will put the rope on the verge of snapping? (b) At that acceleration, with what speed would the bundle hit the ground?

••42  In earlier days, horses pulled barges down canals in the manner shown in Fig. 5-42. Suppose the horse pulls on the rope with a force of 7900 N at an angle of $\theta = 18^\circ$ to the direction of motion of the barge, which is headed straight along the positive direction of an x axis. The mass of the barge is 9500 kg, and the magnitude of its acceleration is 0.12 m/s². What are the (a) magnitude and (b) direction (relative to positive x) of the force on the barge from the water?

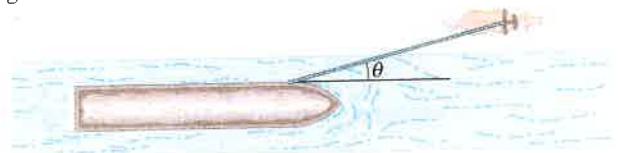



Figure 5-42 Problem 42.

••43  In Fig. 5-43, a chain consisting of five links, each of mass 0.100 kg, is lifted vertically with constant acceleration of magnitude $a = 2.50$ m/s². Find the magnitudes of (a) the force on link 1 from link 2, (b) the force on link 2 from link 3, (c) the force on link 3 from link 4, and (d) the force on link 4 from link 5. Then find the magnitudes of (e) the force \vec{F} on the top link from the person lifting the chain and (f) the net force accelerating each link.

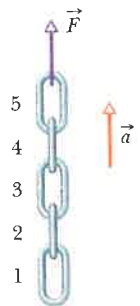




Figure 5-43 Problem 43.

••44 A lamp hangs vertically from a cord in a descending elevator that decelerates at 2.4 m/s². (a) If the tension in the cord is 89 N, what is the lamp's mass? (b) What is the cord's tension when the elevator ascends with an upward acceleration of 2.4 m/s²?

••45 An elevator cab that weighs 27.8 kN moves upward. What is the tension in the cable if the cab's speed is (a) increasing at a rate of 1.22 m/s² and (b) decreasing at a rate of 1.22 m/s²?

••46 An elevator cab is pulled upward by a cable. The cab and its single occupant have a combined mass of 2000 kg. When that occupant drops a coin, its acceleration relative to the cab is 8.00 m/s² downward. What is the tension in the cable?

••47   The Zacchini family was renowned for their human-cannonball act in which a family member was shot from a cannon using either elastic bands or compressed air. In one version of the act, Emanuel Zacchini was shot over three Ferris wheels to land in a net at the same height as the open end of the cannon and at a range of 69 m. He was propelled inside the barrel for 5.2 m and launched at an angle of 53° . If his mass was 85 kg and he underwent constant acceleration inside the barrel, what was the magnitude of the force propelling him? (Hint: Treat the launch as though it were along a ramp at 53° . Neglect air drag.)

••48 In Fig. 5-44, elevator cabs *A* and *B* are connected by a short cable and can be pulled upward or lowered by the cable above cab *A*. Cab *A* has mass 1700 kg; cab *B* has mass 1300 kg. A 12.0 kg box of catnip lies on the floor of cab *A*. The tension in the cable connecting the cabs is 1.91×10^4 N. What is the magnitude of the normal force on the box from the floor?

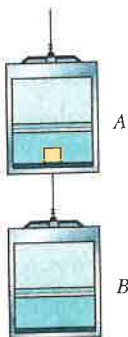


Figure 5-44 Problem 48.

••49 In Fig. 5-45, a block of mass $m = 5.00$ kg is pulled along a horizontal frictionless floor by a cord that exerts a force of magnitude $F = 12.0$ N at an angle $\theta = 25.0^\circ$. (a) What is the magnitude of the block's acceleration? (b) The force magnitude F is slowly increased. What is its value just before the block is lifted (completely) off the floor? (c) What is the magnitude of the block's acceleration just before it is lifted (completely) off the floor?

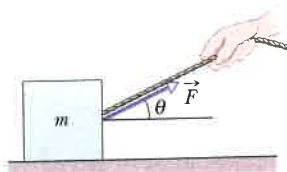


Figure 5-45 Problems 49 and 60.

••50 In Fig. 5-46, three ballot boxes are connected by cords, one of which wraps over a pulley having negligible friction on its axle and negligible mass. The three masses are $m_A = 30.0$ kg, $m_B = 40.0$ kg, and $m_C = 10.0$ kg. When the assembly is released from rest, (a) what is the tension in the cord connecting *B* and *C*, and (b) how far does *A* move in the first 0.250 s (assuming it does not reach the pulley)?



Figure 5-46 Problem 50.

••51 Figure 5-47 shows two blocks connected by a cord (of negligible mass) that passes over a frictionless pulley (also of negligible mass). The arrangement is known as *Atwood's machine*. One block has mass $m_1 = 1.30$ kg; the other has mass $m_2 = 2.80$ kg. What are (a) the magnitude of the blocks' acceleration and (b) the tension in the cord?

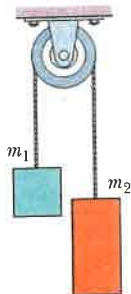


Figure 5-47 Problems 51 and 65.

••52 An 85 kg man lowers himself to the ground from a height of 10.0 m by holding onto a rope that runs over a frictionless pulley to a 65 kg sandbag. With what speed does the man hit the ground if he started from rest?

••53 In Fig. 5-48, three connected blocks are pulled to the right on a horizontal frictionless table by a force of magnitude $T_3 = 65.0$ N. If $m_1 = 12.0$ kg, $m_2 = 24.0$ kg, and $m_3 = 31.0$ kg, calculate (a) the magnitude of the system's acceleration, (b) the tension T_1 , and (c) the tension T_2 .

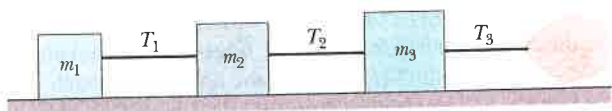


Figure 5-48 Problem 53.

••54 Figure 5-49 shows four penguins that are being playfully pulled along very slippery (frictionless) ice by a curator. The masses of three penguins and the tension in two of the cords are $m_1 = 12$ kg, $m_3 = 15$ kg, $m_4 = 20$ kg, $T_2 = 111$ N, and $T_4 = 222$ N. Find the penguin mass m_2 that is not given.



Figure 5-49 Problem 54.

••55 Two blocks are in contact on a frictionless table. A horizontal force is applied to the larger block, as shown in Fig. 5-50. (a) If $m_1 = 2.3$ kg, $m_2 = 1.2$ kg, and $F = 3.2$ N, find the magnitude of the force between the two blocks. (b) Show that if a force of the same magnitude F is applied to the smaller block but in the opposite direction, the magnitude of the force between the blocks is 2.1 N, which is not the same value calculated in (a). (c) Explain the difference.

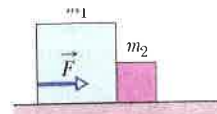


Figure 5-50 Problem 55.

••56 In Fig. 5-51a, a constant horizontal force \vec{F}_a is applied to block *A*, which pushes against block *B* with a 20.0 N force directed horizontally to the right. In Fig. 5-51b, the same force \vec{F}_a is applied to block *B*; now block *A* pushes on block *B* with a 10.0 N force directed horizontally to the left. The blocks have a combined mass of 12.0 kg. What are the magnitudes of (a) their acceleration in Fig. 5-51a and (b) force \vec{F}_a ?

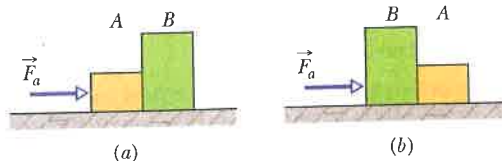


Figure 5-51 Problem 56.

••57 A block of mass $m_1 = 3.70$ kg on a frictionless plane inclined at angle $\theta = 30.0^\circ$ is connected by a cord over a massless, frictionless pulley to a second block of mass $m_2 = 2.30$ kg (Fig. 5-52). What are (a) the magnitude of the acceleration of each block, (b) the direction of the acceleration of the hanging block, and (c) the tension in the cord?

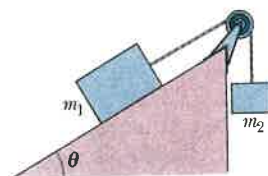


Figure 5-52 Problem 57.

••58 Figure 5-53 shows a man sitting in a bosun's chair that dangles from a massless rope, which runs over a massless, frictionless pulley and back down to the man's hand. The combined mass of man and chair is 95.0 kg. With what force magnitude must the man pull on the rope if he is to rise (a) with a constant velocity and

(b) with an upward acceleration of 1.30 m/s^2 ? (*Hint:* A free-body diagram can really help.) If the rope on the right extends to the ground and is pulled by a co-worker, with what force magnitude must the co-worker pull for the man to rise (c) with a constant velocity and (d) with an upward acceleration of 1.30 m/s^2 ? What is the magnitude of the force on the ceiling from the pulley system in (e) part a, (f) part b, (g) part c, and (h) part d?

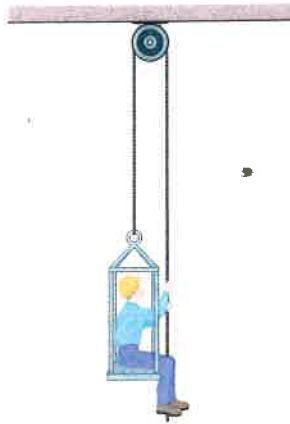


Figure 5-53 Problem 58.

••59 SSM A 10 kg monkey climbs up a massless rope that runs over a frictionless tree limb and back down to a 15 kg package on the ground (Fig. 5-54). (a) What is the magnitude of the least acceleration the monkey must have if it is to lift the package off the ground? If, after the package has been lifted, the monkey stops its climb and holds onto the rope, what are the (b) magnitude and (c) direction of the monkey's acceleration and (d) the tension in the rope?

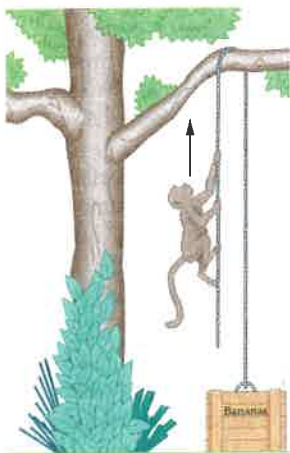


Figure 5-54 Problem 59.

••60 Figure 5-45 shows a 5.00 kg block being pulled along a frictionless floor by a cord that applies a force of constant magnitude 20.0 N but with an angle $\theta(t)$ that varies with time. When angle $\theta = 25.0^\circ$, at what rate is the acceleration of the block changing if (a) $\theta(t) = (2.00 \times 10^{-2} \text{ deg/s})t$ and (b) $\theta(t) = -(2.00 \times 10^{-2} \text{ deg/s})t$? (*Hint:* The angle should be in radians.)

••61 SSM ILW A hot-air balloon of mass M is descending vertically with downward acceleration of magnitude a . How much mass (ballast) must be thrown out to give the balloon an upward acceleration of magnitude a ? Assume that the upward force from the air (the lift) does not change because of the decrease in mass.

••62 In shot putting, many athletes elect to launch the shot at an angle that is smaller than the theoretical one (about 42°) at which the distance of a projected ball at the same speed and height is greatest. One reason has to do with the speed the athlete can give the shot during the acceleration phase of the throw. Assume that a 7.260 kg shot is accelerated along a straight path of length 1.650 m by a constant applied force of magnitude 380.0 N, starting with an initial speed of 2.500 m/s (due to the athlete's preliminary motion). What is the shot's speed at the end of the acceleration phase if the angle between the path and the horizontal is (a) 30.00° and (b) 42.00° ? (*Hint:* Treat the motion as though it were along a ramp at the given angle.) (c) By what percent is the launch speed decreased if the athlete increases the angle from 30.00° to 42.00° ?

••63 Figure 5-55 gives, as a function of time t , the force component F_x that acts on a 3.00 kg ice block that can move only along the x axis. At $t = 0$, the block is moving in the positive direction of

the axis, with a speed of 3.0 m/s. What are its (a) speed and (b) direction of travel at $t = 11 \text{ s}$?

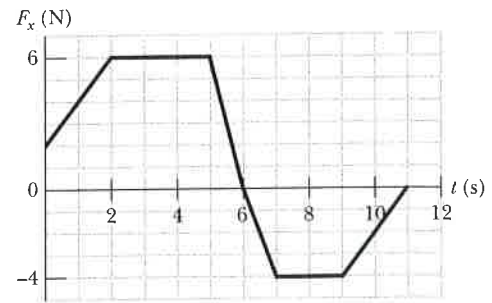


Figure 5-55 Problem 63.

••64 Figure 5-56 shows a box of mass $m_2 = 1.0 \text{ kg}$ on a frictionless plane inclined at angle $\theta = 30^\circ$. It is connected by a cord of negligible mass to a box of mass $m_1 = 3.0 \text{ kg}$ on a horizontal frictionless surface. The pulley is frictionless and massless. (a) If the magnitude of horizontal force \vec{F} is 2.3 N, what is the tension in the connecting cord? (b) What is the largest value the magnitude of \vec{F} may have without the cord becoming slack?

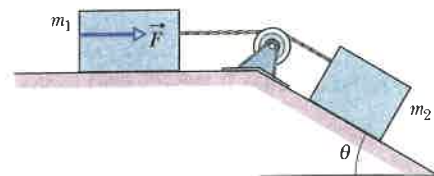


Figure 5-56 Problem 64.

••65 Figure 5-47 shows Atwood's machine, in which two containers are connected by a cord (of negligible mass) passing over a frictionless pulley (also of negligible mass). At time $t = 0$, container 1 has mass 1.30 kg and container 2 has mass 2.80 kg, but container 1 is losing mass (through a leak) at the constant rate of 0.200 kg/s. At what rate is the acceleration magnitude of the containers changing at (a) $t = 0$ and (b) $t = 3.00 \text{ s}$? (c) When does the acceleration reach its maximum value?

••66 Figure 5-57 shows a section of a cable-car system. The maximum permissible mass of each car with occupants is 2800 kg. The cars, riding on a support cable, are pulled by a second cable attached to the support tower on each car. Assume that the cables

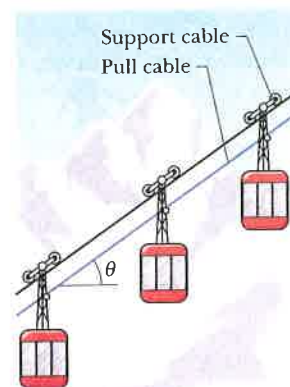


Figure 5-57 Problem 66.

are taut and inclined at angle $\theta = 35^\circ$. What is the difference in tension between adjacent sections of pull cable if the cars are at the maximum permissible mass and are being accelerated up the incline at 0.81 m/s^2 ?

•••67 Figure 5-58 shows three blocks attached by cords that loop over frictionless pulleys. Block B lies on a frictionless table; the masses are $m_A = 6.00 \text{ kg}$, $m_B = 8.00 \text{ kg}$, and $m_C = 10.0 \text{ kg}$. When the blocks are released, what is the tension in the cord at the right?

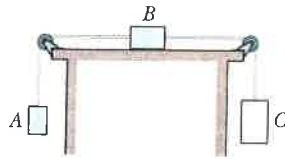


Figure 5-58 Problem 67.

•••68 A shot putter launches a 7.260 kg shot by pushing it along a straight line of length 1.650 m and at an angle of 34.10° from the horizontal, accelerating the shot to the launch speed from its initial speed of 2.500 m/s (which is due to the athlete's preliminary motion). The shot leaves the hand at a height of 2.110 m and at an angle of 34.10° , and it lands at a horizontal distance of 15.90 m . What is the magnitude of the athlete's average force on the shot during the acceleration phase? (*Hint:* Treat the motion during the acceleration phase as though it were along a ramp at the given angle.)

Additional Problems

69 In Fig. 5-59, 4.0 kg block A and 6.0 kg block B are connected by a string of negligible mass. Force $\vec{F}_A = (12 \text{ N})\hat{i}$ acts on block A ; force $\vec{F}_B = (24 \text{ N})\hat{i}$ acts on block B . What is the tension in the string?

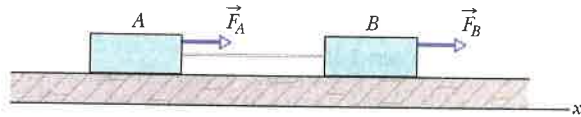


Figure 5-59 Problem 69.

70 An 80 kg man drops to a concrete patio from a window 0.50 m above the patio. He neglects to bend his knees on landing, taking 2.0 cm to stop. (a) What is his average acceleration from when his feet first touch the patio to when he stops? (b) What is the magnitude of the average stopping force exerted on him by the patio?

71 **SSM** Figure 5-60 shows a box of dirty money (mass $m_1 = 3.0 \text{ kg}$) on a frictionless plane inclined at angle $\theta_1 = 30^\circ$. The box is connected via a cord of negligible mass to a box of laundered money (mass $m_2 = 2.0 \text{ kg}$) on a frictionless plane inclined at angle $\theta_2 = 60^\circ$. The pulley is frictionless and has negligible mass. What is the tension in the cord?

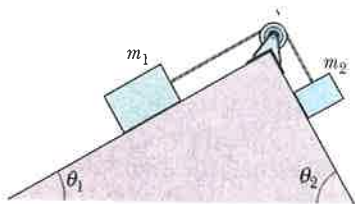


Figure 5-60 Problem 71.

72 Three forces act on a particle that moves with unchanging velocity $\vec{v} = (2 \text{ m/s})\hat{i} - (7 \text{ m/s})\hat{j}$. Two of the forces are $\vec{F}_1 = (2 \text{ N})\hat{i} + (3 \text{ N})\hat{j} + (-2 \text{ N})\hat{k}$ and $\vec{F}_2 = (-5 \text{ N})\hat{i} + (8 \text{ N})\hat{j} + (-2 \text{ N})\hat{k}$. What is the third force?

73 **SSM** In Fig. 5-61, a tin of antioxidants ($m_1 = 1.0 \text{ kg}$) on a frictionless inclined surface is connected to a tin of corned beef ($m_2 = 2.0 \text{ kg}$). The pulley is massless and frictionless. An upward force of magnitude $F = 6.0 \text{ N}$ acts on the corned beef tin, which has a downward acceleration of 5.5 m/s^2 . What are (a) the tension in the connecting cord and (b) angle β ?

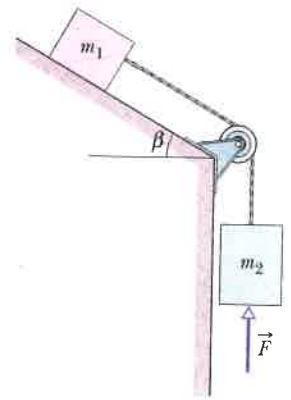


Figure 5-61 Problem 73.

74 The only two forces acting on a body have magnitudes of 20 N and 35 N and directions that differ by 80° . The resulting acceleration has a magnitude of 20 m/s^2 . What is the mass of the body?

75 Figure 5-62 is an overhead view of a 12 kg tire that is to be pulled by three horizontal ropes. One rope's force ($F_1 = 50 \text{ N}$) is indicated. The forces from the other ropes are to be oriented such that the tire's acceleration magnitude a is least. What is that least a if (a) $F_2 = 30 \text{ N}$, $F_3 = 20 \text{ N}$; (b) $F_2 = 30 \text{ N}$, $F_3 = 10 \text{ N}$; and (c) $F_2 = F_3 = 30 \text{ N}$?

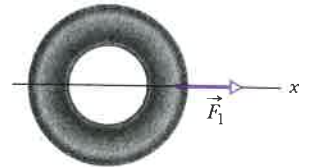


Figure 5-62 Problem 75.

76 A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m , as shown in Fig. 5-63. A horizontal force \vec{F} acts on one end of the rope.

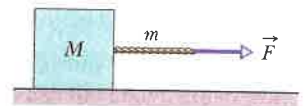


Figure 5-63 Problem 76.

(a) Show that the rope *must* sag, even if only by an imperceptible amount. Then, assuming that the sag is negligible, find (b) the acceleration of rope and block, (c) the force on the block from the rope, and (d) the tension in the rope at its midpoint.

77 **SSM** A worker drags a crate across a factory floor by pulling on a rope tied to the crate. The worker exerts a force of magnitude $F = 450 \text{ N}$ on the rope, which is inclined at an upward angle $\theta = 38^\circ$ to the horizontal, and the floor exerts a horizontal force of magnitude $f = 125 \text{ N}$ that opposes the motion. Calculate the magnitude of the acceleration of the crate if (a) its mass is 310 kg and (b) its weight is 310 N .

78 In Fig. 5-64, a force \vec{F} of magnitude 12 N is applied to a FedEx box of mass $m_2 = 1.0 \text{ kg}$. The force is directed up a plane tilted by $\theta = 37^\circ$. The box is connected by a cord to a UPS box of mass $m_1 = 3.0 \text{ kg}$ on the floor. The floor, plane, and pulley are frictionless, and the masses of the pulley and cord are negligible. What is the tension in the cord?

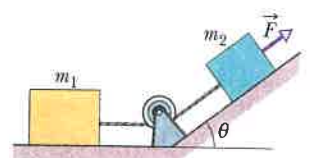


Figure 5-64 Problem 78.

79 A certain particle has a weight of 22 N at a point where $g = 9.8 \text{ m/s}^2$. What are its (a) weight and (b) mass at a point where $g = 4.9 \text{ m/s}^2$? What are its (c) weight and (d) mass if it is moved to a point in space where $g = 0$?

80 An 80 kg person is parachuting and experiencing a downward acceleration of 2.5 m/s^2 . The mass of the parachute is 5.0 kg . (a)

What is the upward force on the open parachute from the air? (b) What is the downward force on the parachute from the person?

81 A spaceship lifts off vertically from the Moon, where $g = 1.6 \text{ m/s}^2$. If the ship has an upward acceleration of 1.0 m/s^2 as it lifts off, what is the magnitude of the force exerted by the ship on its pilot, who weighs 735 N on Earth?

82 In the overhead view of Fig. 5-65, five forces pull on a box of mass $m = 4.0 \text{ kg}$. The force magnitudes are $F_1 = 11 \text{ N}$, $F_2 = 17 \text{ N}$, $F_3 = 3.0 \text{ N}$, $F_4 = 14 \text{ N}$, and $F_5 = 5.0 \text{ N}$, and angle θ_4 is 30° . Find the box's acceleration (a) in unit-vector notation and as (b) a magnitude and (c) an angle relative to the positive direction of the x axis.

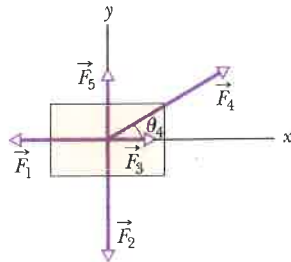


Figure 5-65 Problem 82.

83 SSM A certain force gives an object of mass m_1 an acceleration of 12.0 m/s^2 and an object of mass m_2 an acceleration of 3.30 m/s^2 . What acceleration would the force give to an object of mass (a) $m_2 - m_1$ and (b) $m_2 + m_1$?

84 You pull a short refrigerator with a constant force \vec{F} across a greased (frictionless) floor, either with \vec{F} horizontal (case 1) or with \vec{F} tilted upward at an angle θ (case 2). (a) What is the ratio of the refrigerator's speed in case 2 to its speed in case 1 if you pull for a certain time t ? (b) What is this ratio if you pull for a certain distance d ?

85 A 52 kg circus performer is to slide down a rope that will break if the tension exceeds 425 N. (a) What happens if the performer hangs stationary on the rope? (b) At what magnitude of acceleration does the performer just avoid breaking the rope?

86 Compute the weight of a 75 kg space ranger (a) on Earth, (b) on Mars, where $g = 3.7 \text{ m/s}^2$, and (c) in interplanetary space, where $g = 0$. (d) What is the ranger's mass at each location?

87 An object is hung from a spring balance attached to the ceiling of an elevator cab. The balance reads 65 N when the cab is standing still. What is the reading when the cab is moving upward (a) with a constant speed of 7.6 m/s and (b) with a speed of 7.6 m/s while decelerating at a rate of 2.4 m/s^2 ?

88 Imagine a landing craft approaching the surface of Callisto, one of Jupiter's moons. If the engine provides an upward force (thrust) of 3260 N, the craft descends at constant speed; if the engine provides only 2200 N, the craft accelerates downward at 0.39 m/s^2 . (a) What is the weight of the landing craft in the vicinity of Callisto's surface? (b) What is the mass of the craft? (c) What is the magnitude of the free-fall acceleration near the surface of Callisto?

89 A 1400 kg jet engine is fastened to the fuselage of a passenger jet by just three bolts (this is the usual practice). Assume that each bolt supports one-third of the load. (a) Calculate the force on each bolt as the plane waits in line for clearance to take off. (b) During flight, the plane encounters turbulence, which suddenly imparts an upward vertical acceleration of 2.6 m/s^2 to the plane. Calculate the force on each bolt now.

90 An interstellar ship has a mass of $1.20 \times 10^6 \text{ kg}$ and is initially at rest relative to a star system. (a) What constant acceleration is needed to bring the ship up to a speed of $0.10c$ (where c is the speed of light, $3.0 \times 10^8 \text{ m/s}$) relative to the star system in 3.0 days? (b) What is that

acceleration in g units? (c) What force is required for the acceleration? (d) If the engines are shut down when $0.10c$ is reached (the speed then remains constant), how long does the ship take (start to finish) to journey 5.0 light-months, the distance that light travels in 5.0 months?

91 SSM A motorcycle and 60.0 kg rider accelerate at 3.0 m/s^2 up a ramp inclined 10° above the horizontal. What are the magnitudes of (a) the net force on the rider and (b) the force on the rider from the motorcycle?

92 Compute the initial upward acceleration of a rocket of mass $1.3 \times 10^4 \text{ kg}$ if the initial upward force produced by its engine (the thrust) is $2.6 \times 10^5 \text{ N}$. Do not neglect the gravitational force on the rocket.

93 SSM Figure 5-66a shows a mobile hanging from a ceiling; it consists of two metal pieces ($m_1 = 3.5 \text{ kg}$ and $m_2 = 4.5 \text{ kg}$) that are strung together by cords of negligible mass. What is the tension in (a) the bottom cord and (b) the top cord? Figure 5-66b shows a mobile consisting of three metal pieces. Two of the masses are $m_3 = 4.8 \text{ kg}$ and $m_5 = 5.5 \text{ kg}$. The tension in the top cord is 199 N. What is the tension in (c) the lowest cord and (d) the middle cord?

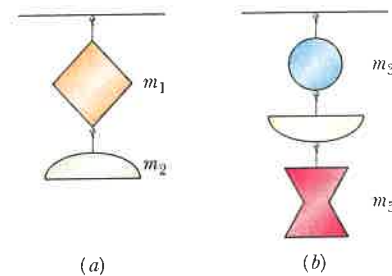


Figure 5-66 Problem 93.

94 For sport, a 12 kg armadillo runs onto a large pond of level, frictionless ice. The armadillo's initial velocity is 5.0 m/s along the positive direction of an x axis. Take its initial position on the ice as being the origin. It slips over the ice while being pushed by a wind with a force of 17 N in the positive direction of the y axis. In unit-vector notation, what are the animal's (a) velocity and (b) position vector when it has slid for 3.0 s?

95 Suppose that in Fig. 5-12, the masses of the blocks are 2.0 kg and 4.0 kg. (a) Which mass should the hanging block have if the magnitude of the acceleration is to be as large as possible? What then are (b) the magnitude of the acceleration and (c) the tension in the cord?

96 A nucleus that captures a stray neutron must bring the neutron to a stop within the diameter of the nucleus by means of the strong force. That force, which "glues" the nucleus together, is approximately zero outside the nucleus. Suppose that a stray neutron with an initial speed of $1.4 \times 10^7 \text{ m/s}$ is just barely captured by a nucleus with diameter $d = 1.0 \times 10^{-14} \text{ m}$. Assuming the strong force on the neutron is constant, find the magnitude of that force. The neutron's mass is $1.67 \times 10^{-27} \text{ kg}$.

97 If the 1 kg standard body is accelerated by only $\vec{F}_1 = (3.0 \text{ N})\hat{i} + (4.0 \text{ N})\hat{j}$ and $\vec{F}_2 = (-2.0 \text{ N})\hat{i} + (-6.0 \text{ N})\hat{j}$, then what is \vec{F}_{net} . (a) in unit-vector notation and as (b) a magnitude and (c) an angle relative to the positive x direction? What are the (d) magnitude and (e) angle of \vec{a} ?

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) $(8\text{ m/s}^2)\hat{i} + (1\text{ m/s})\hat{k}$; (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) $2.4 \times 10^{15}\text{ s}$ **123.** (a) 6.29°; (b) 83.7° **125.** (a) $3 \times 10^1\text{ m}$ **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) 2*M*; (e) 3*M* **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/s² **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/s²; (b) 116 N; (c) 21.0 m/s² **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.** $2Ma/(a + g)$ **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 θ* until it reaches *f_{s,max}*. Thereafter the force is kinetic friction directed up the ramp, with magnitude *f_k* (a constant value smaller than *f_{s,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