(2) free-fall motion in the vertical direction subject to a constant downward acceleration of magnitude $g = 9.80\ m/s^2$.

A particle moving in a circle of radius r with constant speed v is in **uniform circular motion**. It undergoes a radial acceleration $\mathbf{a}_r$ because the direction of $\mathbf{v}$ changes in time. The magnitude of $\mathbf{a}_r$ is the **centripetal acceleration** a_c:

$$a_c = \frac{v^2}{r} \tag{4.19}$$

and its direction is always toward the center of the circle.

If a particle moves along a curved path in such a way that both the magnitude and the direction of $\mathbf{v}$ change in time, then the particle has an acceleration vector that can be described by two component vectors: (1) a radial component vector $\mathbf{a}_r$ that causes the change in direction of $\mathbf{v}$ and (2) a tangential component vector $\mathbf{a}_t$ that causes the change in magnitude of $\mathbf{v}$. The magnitude of $\mathbf{a}_r$ is v^2/r, and the magnitude of $\mathbf{a}_t$ is $d|\mathbf{v}|/dt$.

The velocity $\mathbf{v}$ of a particle measured in a fixed frame of reference S can be related to the velocity $\mathbf{v}'$ of the same particle measured in a moving frame of reference S' by

$$\mathbf{v}' = \mathbf{v} - \mathbf{v}_0 \tag{4.22}$$

where $\mathbf{v}_0$ is the velocity of S' relative to S.

QUESTIONS

1. Can an object accelerate if its speed is constant? Can an object accelerate if its velocity is constant?

2. If you know the position vectors of a particle at two points along its path and also know the time it took to move from one point to the other, can you determine the particle's instantaneous velocity? Its average velocity? Explain.

3. Construct motion diagrams showing the velocity and acceleration of a projectile at several points along its path if (a) the projectile is launched horizontally and (b) the projectile is launched at an angle θ with the horizontal.

4. A baseball is thrown with an initial velocity of $(10\hat{\mathbf{i}} + 15\hat{\mathbf{j}})$ m/s. When it reaches the top of its trajectory, what are (a) its velocity and (b) its acceleration? Neglect the effect of air resistance.

5. A baseball is thrown such that its initial x and y components of velocity are known. Neglecting air resistance, describe how you would calculate, at the instant the ball reaches the top of its trajectory, (a) its position, (b) its velocity, and (c) its acceleration. How would these results change if air resistance were taken into account?

6. A spacecraft drifts through space at a constant velocity. Suddenly a gas leak in the side of the spacecraft gives it a constant acceleration in a direction perpendicular to the initial velocity. The orientation of the spacecraft does not change, so that the acceleration remains perpendicular to the original direction of the velocity. What is the shape of the path followed by the spacecraft in this situation?

7. A ball is projected horizontally from the top of a building. One second later another ball is projected horizontally from the same point with the same velocity. At what point in the motion will the balls be closest to each other? Will the first ball always be traveling faster than the second ball? What will be the time interval between when the balls hit the ground? Can the horizontal projection velocity of the second ball be changed so that the balls arrive at the ground at the same time?

8. A rock is dropped at the same instant that a ball, at the same initial elevation, is thrown horizontally. Which will have the greater speed when it reaches ground level?

9. Determine which of the following moving objects obey the equations of projectile motion developed in this chapter. (a) A ball is thrown in an arbitrary direction. (b) A jet airplane crosses the sky with its engines thrusting the plane forward. (c) A rocket leaves the launch pad. (d) A rocket moving through the sky after its engines have failed. (e) A stone is thrown under water.

10. How can you throw a projectile so that it has zero speed at the top of its trajectory? So that it has nonzero speed at the top of its trajectory?

11. Two projectiles are thrown with the same magnitude of initial velocity, one at an angle θ with respect to the level ground and the other at angle $90° - \theta$. Both projectiles will strike the ground at the same distance from the projection point. Will both projectiles be in the air for the same time interval?

12. A projectile is launched at some angle to the horizontal with some initial speed v_i, and air resistance is negligible. Is the projectile a freely falling body? What is its acceleration in the vertical direction? What is its acceleration in the horizontal direction?

13. State which of the following quantities, if any, remain constant as a projectile moves through its parabolic trajectory: (a) speed, (b) acceleration, (c) horizontal component of velocity, (d) vertical component of velocity.

14. A projectile is fired at an angle of 30° from the horizontal with some initial speed. Firing the projectile at what other angle results in the same horizontal range if the initial speed is the same in both cases? Neglect air resistance.

15. The maximum range of a projectile occurs when it is launched at an angle of 45.0° with the horizontal, if air resistance is neglected. If air resistance is not neglected, will the optimum angle be greater or less than 45.0°? Explain.

16. A projectile is launched on the Earth with some initial velocity. Another projectile is launched on the Moon with the same initial velocity. Neglecting air resistance, which projectile has the greater range? Which reaches the greater altitude? (Note that the free-fall acceleration on the Moon is about 1.6 m/s^2.)

17. A coin on a table is given an initial horizontal velocity such that it ultimately leaves the end of the table and hits the floor. At the instant the coin leaves the end of the table, a ball is released from the same height and falls to the floor. Explain why the two objects hit the floor simultaneously, even though the coin has an initial velocity.

[18.] Explain whether or not the following particles have an acceleration: (a) a particle moving in a straight line with constant speed and (b) a particle moving around a curve with constant speed.

19. Correct the following statement: "The racing car rounds the turn at a constant velocity of 90 miles per hour."

20. At the end of a pendulum's arc, its velocity is zero. Is its acceleration also zero at that point?

21. An object moves in a circular path with constant speed v. (a) Is the velocity of the object constant? (b) Is its acceleration constant? Explain.

22. Describe how a driver can steer a car traveling at constant speed so that (a) the acceleration is zero or (b) the magnitude of the acceleration remains constant.

23. An ice skater is executing a figure eight, consisting of two equal, tangent circular paths. Throughout the first loop she increases her speed uniformly, and during the second loop she moves at a constant speed. Draw a motion diagram showing her velocity and acceleration vectors at several points along the path of motion.

24. Based on your observation and experience, draw a motion diagram showing the position, velocity, and acceleration vectors for a pendulum that swings in an arc carrying it from an initial position 45° to the right of the central vertical line to a final position 45° to the left of the central vertical line. The arc is a quadrant of a circle, and you should use the center of the circle as the origin for the position vectors.

25. What is the fundamental difference between the unit vectors $\hat{\mathbf{r}}$ and $\hat{\boldsymbol{\theta}}$ and the unit vectors $\hat{\mathbf{i}}$ and $\hat{\mathbf{j}}$?

26. A sailor drops a wrench from the top of a sailboat's mast while the boat is moving rapidly and steadily in a straight line. Where will the wrench hit the deck? (Galileo posed this question.)

27. A ball is thrown upward in the air by a passenger on a train that is moving with constant velocity. (a) Describe the path of the ball as seen by the passenger. Describe the path as seen by an observer standing by the tracks outside the train. (b) How would these observations change if the train were accelerating along the track?

28. A passenger on a train that is moving with constant velocity drops a spoon. What is the acceleration of the spoon relative to (a) the train and (b) the Earth?

PROBLEMS

1, 2, 3 = straightforward, intermediate, challenging ☐ = full solution available in the *Student Solutions Manual and Study Guide*

= coached solution with hints available at http://www.pse6.com = computer useful in solving problem

= paired numerical and symbolic problems

Section 4.1 The Position, Velocity, and Acceleration Vectors

[1.] A motorist drives south at 20.0 m/s for 3.00 min, then turns west and travels at 25.0 m/s for 2.00 min, and finally travels northwest at 30.0 m/s for 1.00 min. For this 6.00-min trip, find (a) the total vector displacement, (b) the average speed, and (c) the average velocity. Let the positive x axis point east.

2. A golf ball is hit off a tee at the edge of a cliff. Its x and y coordinates as functions of time are given by the following expressions:

$$x = (18.0 \text{ m/s})t$$

and

$$y = (4.00 \text{ m/s})t - (4.90 \text{ m/s}^2)t^2$$

(a) Write a vector expression for the ball's position as a function of time, using the unit vectors $\hat{\mathbf{i}}$ and $\hat{\mathbf{j}}$. By taking derivatives, obtain expressions for (b) the velocity vector $\mathbf{v}$ as a function of time and (c) the acceleration vector $\mathbf{a}$ as a function of time. Next use unit-vector notation to write expressions for (d) the position, (e) the velocity, and (f) the acceleration of the golf ball, all at $t = 3.00$ s.

3. When the Sun is directly overhead, a hawk dives toward the ground with a constant velocity of 5.00 m/s at 60.0° below the horizontal. Calculate the speed of her shadow on the level ground.

4. The coordinates of an object moving in the xy plane vary with time according to the equations $x = -(5.00 \text{ m}) \sin(\omega t)$ and $y = (4.00 \text{ m}) - (5.00 \text{ m}) \cos(\omega t)$, where ω is a constant and t is in seconds. (a) Determine the components of velocity and components of acceleration at $t = 0$. (b) Write expressions for the position vector, the velocity vector, and the acceleration vector at any time $t > 0$. (c) Describe the path of the object in an xy plot.

flight (his "hang time"), (b) his horizontal and (c) vertical velocity components at the instant of takeoff, and (d) his takeoff angle. (e) For comparison, determine the hang time of a whitetail deer making a jump with center-of-mass elevations $y_i = 1.20$ m, $y_{max} = 2.50$ m, $y_f = 0.700$ m.

25. An archer shoots an arrow with a velocity of 45.0 m/s at an angle of 50.0° with the horizontal. An assistant standing on the level ground 150 m downrange from the launch point throws an apple straight up with the minimum initial speed necessary to meet the path of the arrow. (a) What is the initial speed of the apple? (b) At what time after the arrow launch should the apple be thrown so that the arrow hits the apple?

26. A fireworks rocket explodes at height h, the peak of its vertical trajectory. It throws out burning fragments in all directions, but all at the same speed v. Pellets of solidified metal fall to the ground without air resistance. Find the smallest angle that the final velocity of an impacting fragment makes with the horizontal.

Section 4.4 Uniform Circular Motion

Note: Problems 8, 10, 12, and 16 in Chapter 6 can also be assigned with this section.

27. The athlete shown in Figure P4.27 rotates a 1.00-kg discus along a circular path of radius 1.06 m. The maximum speed of the discus is 20.0 m/s. Determine the magnitude of the maximum radial acceleration of the discus.

Sam Sargent/Liaison International

Figure P4.27

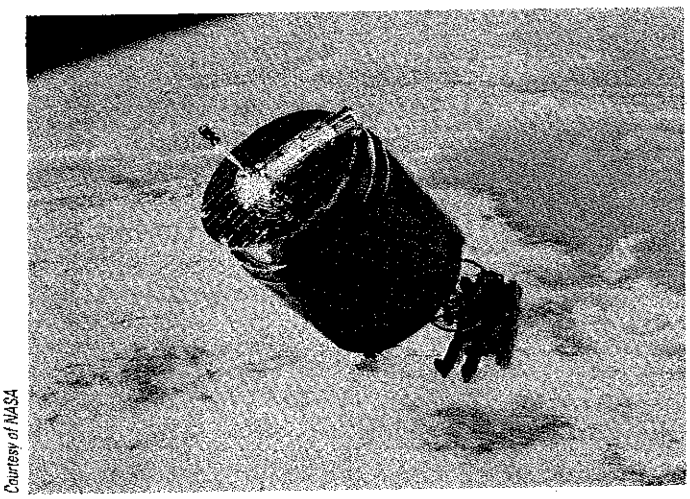
28. From information on the endsheets of this book, compute the radial acceleration of a point on the surface of the Earth at the equator, due to the rotation of the Earth about its axis.

29. A tire 0.500 m in radius rotates at a constant rate of 200 rev/min. Find the speed and acceleration of a small stone lodged in the tread of the tire (on its outer edge).

30. As their booster rockets separate, Space Shuttle astronauts typically feel accelerations up to $3g$, where $g = 9.80$ m/s^2. In their training, astronauts ride in a device where they experience such an acceleration as a centripetal acceleration. Specifically, the astronaut is fastened securely at the end of a mechanical arm that then turns at constant speed in a horizontal circle. Determine the rotation rate, in revolutions per second, required to give an astronaut a centripetal acceleration of $3.00g$ while in circular motion with radius 9.45 m.

31. Young David who slew Goliath experimented with slings before tackling the giant. He found that he could revolve a sling of length 0.600 m at the rate of 8.00 rev/s. If he increased the length to 0.900 m, he could revolve the sling only 6.00 times per second. (a) Which rate of rotation gives the greater speed for the stone at the end of the sling? (b) What is the centripetal acceleration of the stone at 8.00 rev/s? (c) What is the centripetal acceleration at 6.00 rev/s?

32. The astronaut orbiting the Earth in Figure P4.32 is preparing to dock with a Westar VI satellite. The satellite is in a circular orbit 600 km above the Earth's surface, where the free-fall acceleration is 8.21 m/s^2. Take the radius of the Earth as 6 400 km. Determine the speed of the satellite and the time interval required to complete one orbit around the Earth.



Courtesy of NASA

Figure P4.32

Section 4.5 Tangential and Radial Acceleration

33. A train slows down as it rounds a sharp horizontal turn, slowing from 90.0 km/h to 50.0 km/h in the 15.0 s that it takes to round the bend. The radius of the curve is 150 m. Compute the acceleration at the moment the train speed reaches 50.0 km/h. Assume it continues to slow down at this time at the same rate.

34. An automobile whose speed is increasing at a rate of 0.600 m/s^2 travels along a circular road of radius 20.0 m. When the instantaneous speed of the automobile is 4.00 m/s, find (a) the tangential acceleration component, (b) the centripetal acceleration component, and (c) the magnitude and direction of the total acceleration.

SUMMARY

Take a practice test for this chapter by clicking the Practice Test link at http://www.pse6.com.

An **inertial frame of reference** is one we can identify in which an object that does interact with other objects experiences zero acceleration. Any frame moving with c stant velocity relative to an inertial frame is also an inertial frame. **Newton's first** states that it is possible to find such a frame, or, equivalently, in the absence of an ex nal force, when viewed from an inertial frame, an object at rest remains at rest and object in uniform motion in a straight line maintains that motion.

Newton's second law states that the acceleration of an object is directly pro tional to the net force acting on it and inversely proportional to its mass. The net fo acting on an object equals the product of its mass and its acceleration: $\Sigma \mathbf{F} = m\mathbf{a}$. If object is either stationary or moving with constant velocity, then the object is in equi rium and the force vectors must cancel each other.

The **gravitational force** exerted on an object is equal to the product of its mas scalar quantity) and the free-fall acceleration: $\mathbf{F}_g = m\mathbf{g}$. The **weight** of an object is magnitude of the gravitational force acting on the object.

Newton's third law states that if two objects interact, the force exerted by obje on object 2 is equal in magnitude and opposite in direction to the force exerted by ject 2 on object 1. Thus, an isolated force cannot exist in nature.

The **maximum force of static friction** $\mathbf{f}_{s\,max}$ between an object and a surfac proportional to the normal force acting on the object. In general, $f_s \leq \mu_s n$, where μ the **coefficient of static friction** and n is the magnitude of the normal force. Wh an object slides over a surface, the direction of the **force of kinetic friction** $\mathbf{f}_k$ is op site the direction of motion of the object relative to the surface and is also pro tional to the magnitude of the normal force. The magnitude of this force is given $f_k = \mu_k n$, where μ_k is the **coefficient of kinetic friction**.

QUESTIONS

1. A ball is held in a person's hand. (a) Identify all the external forces acting on the ball and the reaction to each. (b) If the ball is dropped, what force is exerted on it while it is falling? Identify the reaction force in this case. (Neglect air resistance.)

2. If a car is traveling westward with a constant speed of 20 m/s, what is the resultant force acting on it?

3. What is wrong with the statement "Because the car is at rest, there are no forces acting on it"? How would you correct this sentence?

4. In the motion picture *It Happened One Night* (Columbia Pictures, 1934), Clark Gable is standing inside a stationary bus in front of Claudette Colbert who is seated. The bus suddenly starts moving forward and Clark falls into Claudette's lap. Why did this happen?

5. A passenger sitting in the rear of a bus claims that she was injured as the driver slammed on the brakes, causing a suitcase to come flying toward her from the front of the bus. If you were the judge in this case, what disposition would you make? Why?

6. A space explorer is moving through space far from any planet or star. She notices a large rock, taken as a specimen from an alien planet, floating around the cabin of the ship. Should she push it gently or kick it toward the st age compartment? Why?

7. A rubber ball is dropped onto the floor. What force cau the ball to bounce?

8. While a football is in flight, what forces act on it? What the action–reaction pairs while the football is being kic and while it is in flight?

9. The mayor of a city decides to fire some city employees cause they will not remove the obvious sags from the bles that support the city traffic lights. If you were a law what defense would you give on behalf of the employe Who do you think would win the case in court?

10. A weightlifter stands on a bathroom scale. He pump barbell up and down. What happens to the reading on t bathroom scale as this is done? **What if** he is stro enough to actually *throw* the barbell upward? How does t reading on the scale vary now?

11. Suppose a truck loaded with sand accelerates along a hi way. If the driving force on the truck remains consta what happens to the truck's acceleration if its trailer le sand at a constant rate through a hole in its bottom?

12. As a rocket is fired from a launching pad, its speed and celeration increase with time as its engines continue to

erate. Explain why this occurs even though the thrust of the engines remains constant.

13. What force causes an automobile to move? A propeller-driven airplane? A rowboat?

14. Identify the action–reaction pairs in the following situations: a man takes a step; a snowball hits a girl in the back; a baseball player catches a ball; a gust of wind strikes a window.

15. In a contest of National Football League behemoths, teams from the Rams and the 49ers engage in a tug-of-war, pulling in opposite directions on a strong rope. The Rams exert a force of 9 200 N and they are winning, making the center of the rope move steadily toward themselves. Is it possible to know the tension in the rope from the information stated? Is it larger or smaller than 9 200 N? How hard are the 49ers pulling on the rope? Would it change your answer if the 49ers were winning or if the contest were even? The stronger team wins by exerting a larger force—on what? Explain your answers.

16. Twenty people participate in a tug-of-war. The two teams of ten people are so evenly matched that neither team wins. After the game they notice that a car is stuck in the mud. They attach the tug-of-war rope to the bumper of the car, and all the people pull on the rope. The heavy car has just moved a couple of decimeters when the rope breaks. Why did the rope break in this situation when it did not break when the same twenty people pulled on it in a tug-of-war?

17. "When the locomotive in Figure Q5.17 broke through the wall of the train station, the force exerted by the locomotive on the wall was greater than the force the wall could exert on the locomotive." Is this statement true or in need of correction? Explain your answer.

18. An athlete grips a light rope that passes over a low-friction pulley attached to the ceiling of a gym. A sack of sand precisely equal in weight to the athlete is tied to the other end of the rope. Both the sand and the athlete are initially at rest. The athlete climbs the rope, sometimes speeding up and slowing down as he does so. What happens to the sack of sand? Explain.

19. If the action and reaction forces are always equal in magnitude and opposite in direction to each other, then doesn't the net vector force on any object necessarily add up to zero? Explain your answer.

20. Can an object exert a force on itself? Argue for your answer.

21. If you push on a heavy box that is at rest, you must exert some force to start its motion. However, once the box is sliding, you can apply a smaller force to maintain that motion. Why?

Roger Viollet, Mill Valley, CA, University Science Books, 1982

Figure Q5.17

22. The driver of a speeding empty truck slams on the brakes and skids to a stop through a distance d. (a) If the truck carried a load that doubled its mass, what would be the truck's "skidding distance"? (b) If the initial speed of the truck were halved, what would be the truck's skidding distance?

23. Suppose you are driving a classic car. Why should you avoid slamming on your brakes when you want to stop in the shortest possible distance? (Many cars have antilock brakes that avoid this problem.)

24. A book is given a brief push to make it slide up a rough incline. It comes to a stop and slides back down to the starting point. Does it take the same time to go up as to come down? **What if** the incline is frictionless?

25. A large crate is placed on the bed of a truck but not tied down. (a) As the truck accelerates forward, the crate remains at rest relative to the truck. What force causes the crate to accelerate forward? (b) If the driver slammed on the brakes, what could happen to the crate?

26. Describe a few examples in which the force of friction exerted on an object is in the direction of motion of the object.

PROBLEMS

1, 2, 3 = straightforward, intermediate, challenging □ = full solution available in the *Student Solutions Manual and Study Guide*
= coached solution with hints available at http://www.pse6.com = computer useful in solving problem
= paired numerical and symbolic problems

Sections 5.1 through 5.6

1. A force $\mathbf{F}$ applied to an object of mass m_1 produces an acceleration of 3.00 m/s^2. The same force applied to a second object of mass m_2 produces an acceleration of 1.00 m/s^2. (a) What is the value of the ratio m_1/m_2? (b) If m_1 and m_2 are combined, find their acceleration under the action of the force $\mathbf{F}$.

2. The largest-caliber antiaircraft gun operated by the German air force during World War II was the 12.8-cm Flak 40. This weapon fired a 25.8-kg shell with a muzzle speed of 880 m/s. What propulsive force was necessary to attain the muzzle speed within the 6.00-m barrel? (Assume the shell moves horizontally with constant acceleration and neglect friction.)

3. A 3.00-kg object undergoes an acceleration given by $\mathbf{a} = (2.00\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}})$ m/s^2. Find the resultant force acting on it and the magnitude of the resultant force.

4. The gravitational force on a baseball is $-F_g\hat{\mathbf{j}}$. A pitcher throws the baseball with velocity $v\hat{\mathbf{i}}$ by uniformly accelerating it straight forward horizontally for a time interval $\Delta t = t - 0 = t$. If the ball starts from rest, (a) through what distance does it accelerate before its release? (b) What force does the pitcher exert on the ball?

5. To model a spacecraft, a toy rocket engine is securely fastened to a large puck, which can glide with negligible friction over a horizontal surface, taken as the xy plane. The 4.00-kg puck has a velocity of $300\hat{\mathbf{i}}$ m/s at one instant. Eight seconds later, its velocity is to be $(800\hat{\mathbf{i}} + 10.0\hat{\mathbf{j}})$ m/s. Assuming the rocket engine exerts a constant horizontal force, find (a) the components of the force and (b) its magnitude.

6. The average speed of a nitrogen molecule in air is about 6.70×10^2 m/s, and its mass is 4.68×10^{-26} kg. (a) If it takes 3.00×10^{-13} s for a nitrogen molecule to hit a wall and rebound with the same speed but moving in the opposite direction, what is the average acceleration of the molecule during this time interval? (b) What average force does the molecule exert on the wall?

7. An electron of mass 9.11×10^{-31} kg has an initial speed of 3.00×10^5 m/s. It travels in a straight line, and its speed increases to 7.00×10^5 m/s in a distance of 5.00 cm. Assuming its acceleration is constant, (a) determine the force exerted on the electron and (b) compare this force with the weight of the electron, which we neglected.

8. A woman weighs 120 lb. Determine (a) her weight in newtons (N) and (b) her mass in kilograms (kg).

9. If a man weighs 900 N on the Earth, what would he weigh on Jupiter, where the acceleration due to gravity is 25.9 m/s^2?

10. The distinction between mass and weight was discovered after Jean Richer transported pendulum clocks from Paris to French Guyana in 1671. He found that they ran slower there quite systematically. The effect was reversed when the clocks returned to Paris. How much weight would you personally lose in traveling from Paris, where $g = 9.809\ 5$ m/s^2, to Cayenne, where $g = 9.780\ 8$ m/s^2? [We will consider how the free-fall acceleration influences the period of a pendulum in Section 15.5.]

11. Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a 5.00-kg object. If $F_1 = 20.0$ N and $F_2 = 15.0$ N, find the accelerations in (a) and (b) of Figure P5.11.

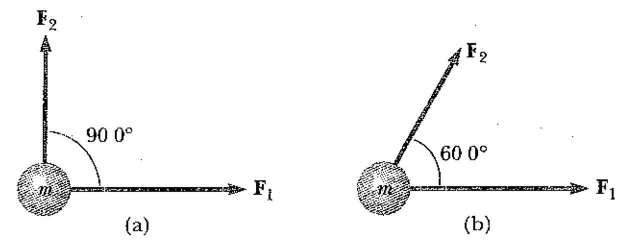


Figure P5.11

12. Besides its weight, a 2.80-kg object is subjected to one other constant force. The object starts from rest and in 1.20 s experiences a displacement of $(4.20\hat{\mathbf{i}} - 3.30\hat{\mathbf{j}})$ m, where the direction of $\hat{\mathbf{j}}$ is the upward vertical direction. Determine the other force.

13. You stand on the seat of a chair and then hop off. (a) During the time you are in flight down to the floor, the Earth is lurching up toward you with an acceleration of what order of magnitude? In your solution explain your logic. Model the Earth as a perfectly solid object. (b) The Earth moves up through a distance of what order of magnitude?

14. Three forces acting on an object are given by $\mathbf{F}_1 = (-2.00\hat{\mathbf{i}} + 2.00\hat{\mathbf{j}})$ N, $\mathbf{F}_2 = (5.00\hat{\mathbf{i}} - 3.00\hat{\mathbf{j}})$ N, and $\mathbf{F}_3 = (-45.0\hat{\mathbf{i}})$ N. The object experiences an acceleration of magnitude 3.75 m/s^2. (a) What is the direction of the acceleration? (b) What is the mass of the object? (c) If the object is initially at rest, what is its speed after 10.0 s? (d) What are the velocity components of the object after 10.0 s?

15. A 15.0-lb block rests on the floor. (a) What force does the floor exert on the block? (b) If a rope is tied to the block and run vertically over a pulley, and the other end is attached to a free-hanging 10.0-lb weight, what is the force exerted by the floor on the 15.0-lb block? (c) If we replace the 10.0-lb weight in part (b) with a 20.0-lb weight, what is the force exerted by the floor on the 15.0-lb block?

Section 5.7 Some Applications of Newton's Laws

16 A 3 00-kg object is moving in a plane, with its x and y coordinates given by $x = 5t^2 - 1$ and $y = 3t^3 + 2$, where x and y are in meters and t is in seconds. Find the magnitude of the net force acting on this object at $t = 2\ 00$ s.

17 The distance between two telephone poles is 50.0 m. When a 1.00-kg bird lands on the telephone wire midway between the poles, the wire sags 0 200 m. Draw a free-body diagram of the bird. How much tension does the bird produce in the wire? Ignore the weight of the wire.

18. A bag of cement of weight 325 N hangs from three wires as suggested in Figure P5.18. Two of the wires make angles $\theta_1 = 60.0°$ and $\theta_2 = 25.0°$ with the horizontal. If the system is in equilibrium, find the tensions T_1, T_2, and T_3 in the wires.

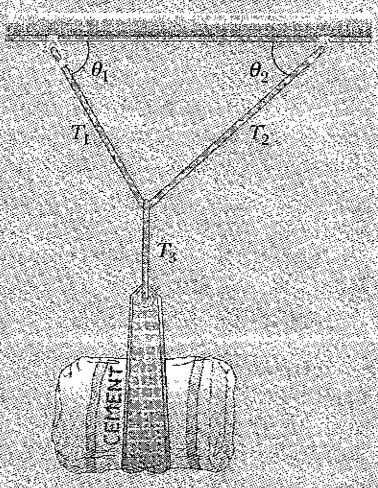


Figure P5.18 Problems 18 and 19.

19. A bag of cement of weight F_g hangs from three wires as shown in Figure P5.18. Two of the wires make angles θ_1 and θ_2 with the horizontal. If the system is in equilibrium, show that the tension in the left-hand wire is

$$T_1 = F_g \cos\theta_2 / \sin(\theta_1 + \theta_2)$$

20. You are a judge in a children's kite-flying contest, and two children will win prizes for the kites that pull most strongly and least strongly on their strings. To measure string tensions, you borrow a weight hanger, some slotted weights, and a protractor from your physics teacher, and use the following protocol, illustrated in Figure P5.20: Wait for a child to get her kite well controlled, hook the hanger onto the kite string about 30 cm from her hand, pile on weight until that section of string is horizontal, record the mass required, and record the angle between the horizontal and the string running up to the kite. (a) Explain how this method works. As you construct your explanation, imagine that the children's parents ask you about your method, that they might make false assumptions about your ability without concrete evidence, and that your explanation is an opportunity to give them confidence in your evaluation technique. (b) Find the string tension if the mass is 132 g and the angle of the kite string is 46.3°.

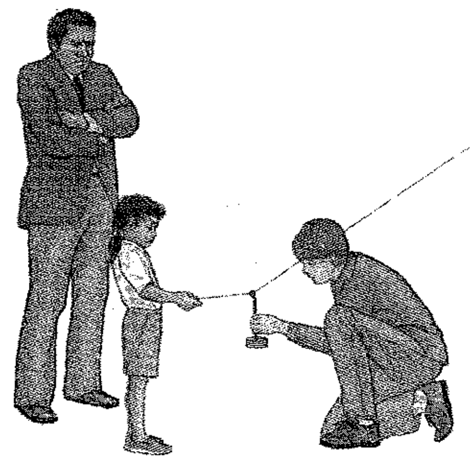


Figure P5.20

21. The systems shown in Figure P5.21 are in equilibrium. If the spring scales are calibrated in newtons, what do they read? (Neglect the masses of the pulleys and strings, and assume the incline in part (c) is frictionless.)

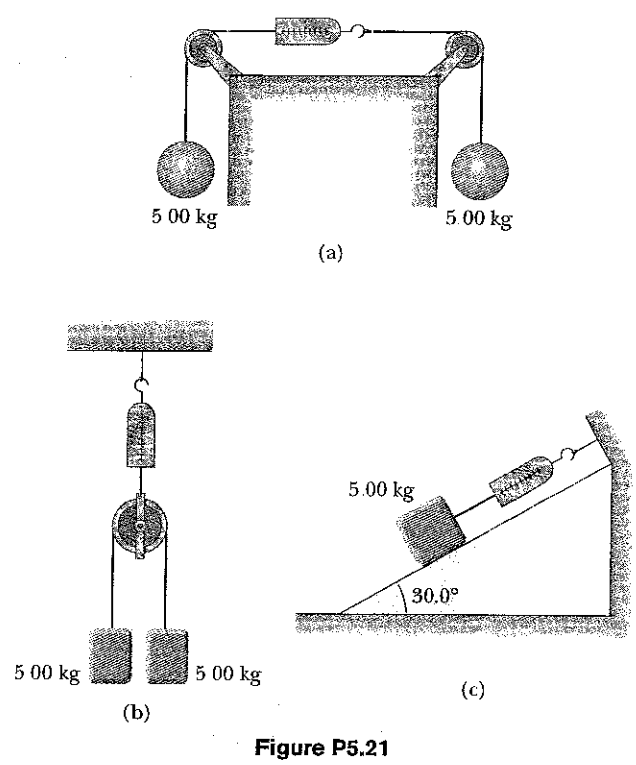


Figure P5.21

22. Draw a free-body diagram of a block which slides down a frictionless plane having an inclination of $\theta = 15\ 0°$ (Fig. P5 22). The block starts from rest at the top and the length of the incline is 2 00 m. Find (a) the acceleration of

the block and (b) its speed when it reaches the bottom of the incline.

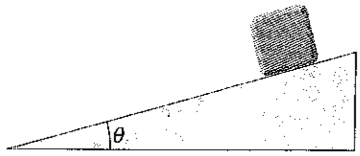


Figure P5.22 Problems 22 and 25

23. A 1.00-kg object is observed to have an acceleration of 10.0 m/s^2 in a direction 30.0° north of east (Fig. P5.23). The force $\mathbf{F}_2$ acting on the object has a magnitude of 5.00 N and is directed north. Determine the magnitude and direction of the force $\mathbf{F}_1$ acting on the object.

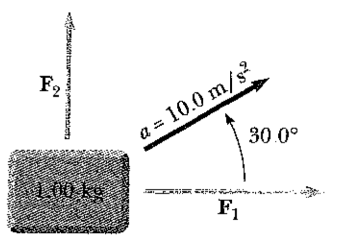


Figure P5.23

24. A 5.00-kg object placed on a frictionless, horizontal table is connected to a string that passes over a pulley and then is fastened to a hanging 9.00-kg object, as in Figure P5.24. Draw free-body diagrams of both objects. Find the acceleration of the two objects and the tension in the string.

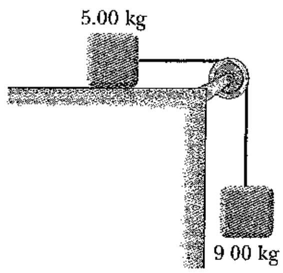


Figure P5.24 Problems 24 and 43

25. A block is given an initial velocity of 5.00 m/s up a frictionless 20.0° incline (Fig. P5.22). How far up the incline does the block slide before coming to rest?

26. Two objects are connected by a light string that passes over a frictionless pulley, as in Figure P5.26. Draw free-body diagrams of both objects. If the incline is frictionless and if $m_1 = 2.00$ kg, $m_2 = 6.00$ kg, and $\theta = 55.0°$, find (a) the accelerations of the objects, (b) the tension in the string, and (c) the speed of each object 2.00 s after being released from rest.

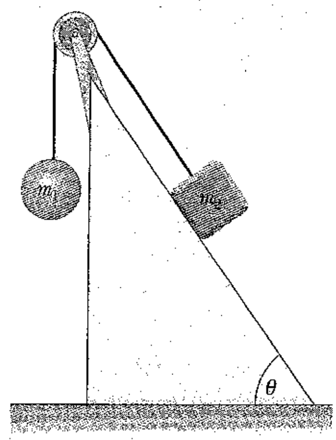


Figure P5.26

27. A tow truck pulls a car that is stuck in the mud, with a force of 2 500 N as in Fig. P5.27. The tow cable is under tension and therefore pulls downward and to the left on the pin at its upper end. The light pin is held in equilibrium by forces exerted by the two bars A and B. Each bar is a *strut*: that is, each is a bar whose weight is small compared to the forces it exerts, and which exerts forces only through hinge pins at its ends. Each strut exerts a force directed parallel to its length. Determine the force of tension or compression in each strut. Proceed as follows: Make a guess as to which way (pushing or pulling) each force acts on the top pin. Draw a free-body diagram of the pin. Use the condition for equilibrium of the pin to translate the free-body diagram into equations. From the equations calculate the forces exerted by struts A and B. If you obtain a positive answer, you correctly guessed the direction of the force. A negative answer means the direction should be reversed, but the absolute value correctly gives the magnitude of the force. If a strut pulls on a pin, it is in tension. If it pushes, the strut is in compression. Identify whether each strut is in tension or in compression.

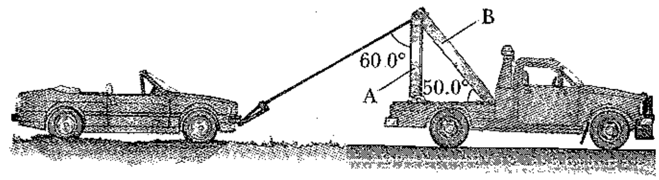


Figure P5.27

28. Two objects with masses of 3.00 kg and 5.00 kg are connected by a light string that passes over a light frictionless pulley to form an Atwood machine, as in Figure 5.14a. Determine (a) the tension in the string, (b) the acceleration of each object, and (c) the distance each object will move in the first second of motion if they start from rest.

29. In Figure P5.29, the man and the platform together weigh 950 N. The pulley can be modeled as frictionless. Determine how hard the man has to pull on the rope to lift himself steadily upward above the ground. (Or is it impossible? If so, explain why.)

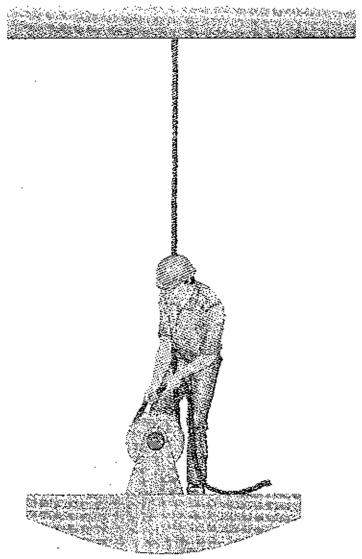


Figure P5.29

30. In the Atwood machine shown in Figure 5.14a, $m_1 = 2.00$ kg and $m_2 = 7.00$ kg. The masses of the pulley and string are negligible by comparison. The pulley turns without friction and the string does not stretch. The lighter object is released with a sharp push that sets it into motion at $v_i = 2.40$ m/s downward. (a) How far will m_1 descend below its initial level? (b) Find the velocity of m_1 after 1.80 seconds.

31. In the system shown in Figure P5.31, a horizontal force $\mathbf{F}_x$ acts on the 8.00-kg object. The horizontal surface is frictionless. (a) For what values of F_x does the 2.00-kg object accelerate upward? (b) For what values of F_x is the tension in the cord zero? (c) Plot the acceleration of the 8.00-kg object versus F_x. Include values of F_x from -100 N to $+100$ N.

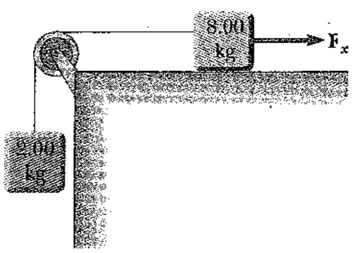


Figure P5.31

32. A frictionless plane is 10.0 m long and inclined at 35.0°. A sled starts at the bottom with an initial speed of 5.00 m/s up the incline. When it reaches the point at which it momentarily stops, a second sled is released from the top of this incline with an initial speed v_i. Both sleds reach the bottom of the incline at the same moment. (a) Determine the distance that the first sled traveled up the incline. (b) Determine the initial speed of the second sled.

33. A 72.0-kg man stands on a spring scale in an elevator. Starting from rest, the elevator ascends, attaining its maximum speed of 1.20 m/s in 0.800 s. It travels with this constant speed for the next 5.00 s. The elevator then undergoes a uniform acceleration in the negative y direction for 1.50 s and comes to rest. What does the spring scale register (a) before the elevator starts to move? (b) during the first 0.800 s? (c) while the elevator is traveling at constant speed? (d) during the time it is slowing down?

34. An object of mass m_1 on a frictionless horizontal table is connected to an object of mass m_2 through a very light pulley P_1 and a light fixed pulley P_2 as shown in Figure P5.34. (a) If a_1 and a_2 are the accelerations of m_1 and m_2, respectively, what is the relation between these accelerations? Express (b) the tensions in the strings and (c) the accelerations a_1 and a_2 in terms of the masses m_1 and m_2, and g.

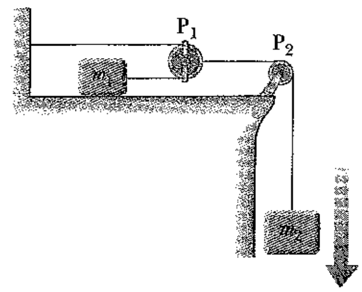


Figure P5.34

Section 5.8 Forces of Friction

35. The person in Figure P5.35 weighs 170 lb. As seen from the front, each light crutch makes an angle of 22.0° with the vertical. Half of the person's weight is supported by the crutches. The other half is supported by the vertical forces of the ground on his feet. Assuming the person is moving

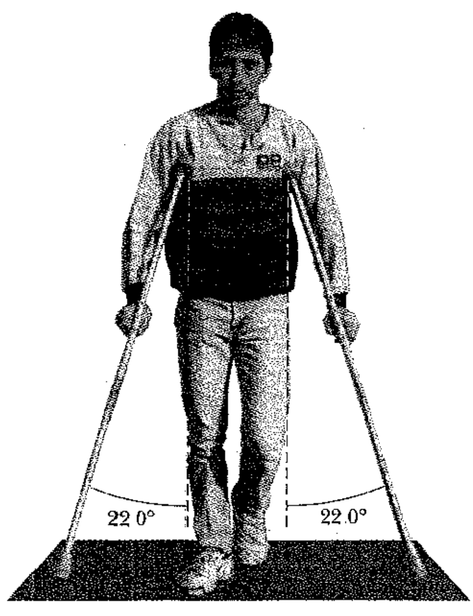


Figure P5.35

with constant velocity and the force exerted by the ground on the crutches acts along the crutches, determine (a) the smallest possible coefficient of friction between crutches and ground and (b) the magnitude of the compression force in each crutch

36. A 25.0-kg block is initially at rest on a horizontal surface. A horizontal force of 75 0 N is required to set the block in motion. After it is in motion, a horizontal force of 60.0 N is required to keep the block moving with constant speed. Find the coefficients of static and kinetic friction from this information.

37. A car is traveling at 50.0 mi/h on a horizontal highway. (a) If the coefficient of static friction between road and tires on a rainy day is 0.100, what is the minimum distance in which the car will stop? (b) What is the stopping distance when the surface is dry and $\mu_s = 0.600$?

38. Before 1960 it was believed that the maximum attainable coefficient of static friction for an automobile tire was less than 1. Then, about 1962, three companies independently developed racing tires with coefficients of 1 6. Since then, tires have improved, as illustrated in this problem. According to the 1990 Guinness Book of Records, the shortest time in which a piston-engine car initially at rest has covered a distance of one-quarter mile is 4 96 s. This record was set by Shirley Muldowney in September 1989. (a) Assume that, as in Figure P5 38, the rear wheels lifted the front wheels off the pavement. What minimum value of μ_s is necessary to achieve the record time? (b) Suppose Muldowney were able to double her engine power, keeping other things equal. How would this change affect the elapsed time?

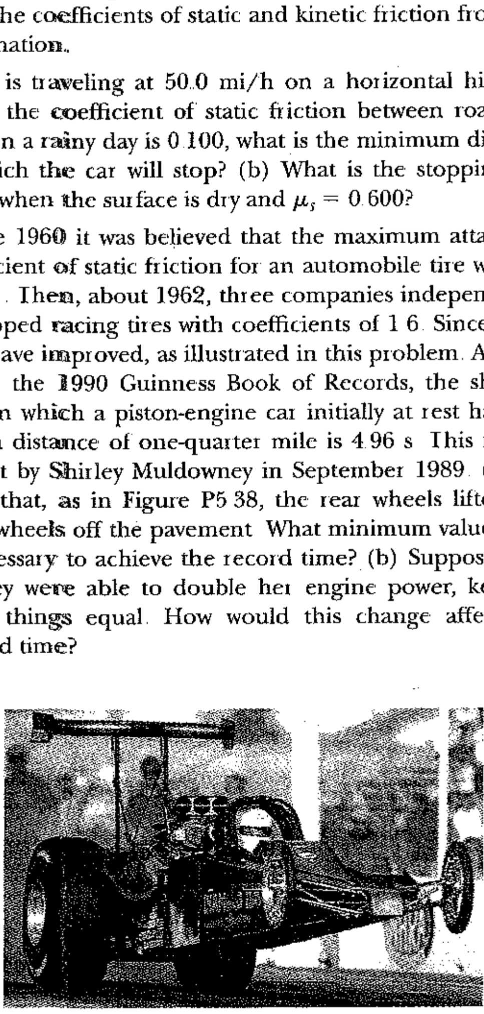

Mike Powell/Allsport USA/Getty

Figure P5.38

39. To meet a U S Postal Service requirement, footwear must have a coefficient of static friction of 0 5 or more on a specified tile surface. A typical athletic shoe has a coefficient of 0.800. In an emergency, what is the minimum time interval in which a person starting from rest can move 3.00 m on a tile surface if she is wearing (a) footwear meeting the Postal Service minimum? (b) a typical athletic shoe?

40. A woman at an airport is towing her 20.0-kg suitcase at constant speed by pulling on a strap at an angle θ above the horizontal (Fig. P5.40). She pulls on the strap with a 35.0-N force, and the friction force on the suitcase is 20.0 N. Draw a free-body diagram of the suitcase. (a) What angle does the strap make with the horizontal? (b) What normal force does the ground exert on the suitcase?

Figure P5.40

41. A 3.00-kg block starts from rest at the top of a 30.0° incline and slides a distance of 2 00 m down the incline in 1.50 s. Find (a) the magnitude of the acceleration of the block, (b) the coefficient of kinetic friction between block and plane, (c) the friction force acting on the block, and (d) the speed of the block after it has slid 2.00 m

42. A Chevrolet Corvette convertible can brake to a stop from a speed of 60.0 mi/h in a distance of 123 ft on a level roadway. What is its stopping distance on a roadway sloping downward at an angle of 10.0°?

43. A 9.00-kg hanging weight is connected by a string over a pulley to a 5.00-kg block that is sliding on a flat table (Fig. P5.24). If the coefficient of kinetic friction is 0 200, find the tension in the string

44. Three objects are connected on the table as shown in Figure P5.44. The table is rough and has a coefficient of kinetic friction of 0.350. The objects have masses of 4 00 kg, 1.00 kg, and 2 00 kg, as shown, and the pulleys are frictionless. Draw free-body diagrams of each of the objects. (a) Determine the acceleration of each object and their directions. (b) Determine the tensions in the two cords

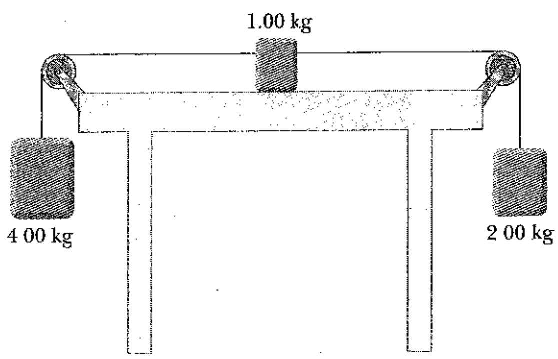


Figure P5.44

45. Two blocks connected by a rope of negligible mass are being dragged by a horizontal force **F** (Fig. P5 45). Suppose that $F = 68.0$ N, $m_1 = 12.0$ kg, $m_2 = 18.0$ kg, and the coefficient of kinetic friction between each block and the surface is 0 100. (a) Draw a free-body diagram for each block.

(b) Determine the tension T and the magnitude of the acceleration of the system.

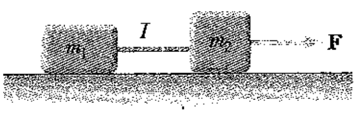


Figure P5.45

46. A block of mass 3.00 kg is pushed up against a wall by a force **P** that makes a 50.0° angle with the horizontal as shown in Figure P5.46. The coefficient of static friction between the block and the wall is 0.250. Determine the possible values for the magnitude of **P** that allow the block to remain stationary.

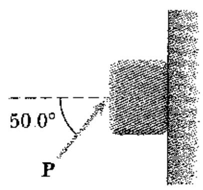


Figure P5.46

47. You and your friend go sledding. Out of curiosity, you measure the constant angle θ that the snow-covered slope makes with the horizontal. Next, you use the following method to determine the coefficient of friction μ_k between the snow and the sled. You give the sled a quick push up so that it will slide up the slope away from you. You wait for it to slide back down, timing the motion. It turns out that the sled takes twice as long to slide down as it does to reach the top point in the round trip. In terms of θ, what is the coefficient of friction?

48. The board sandwiched between two other boards in Figure P5.48 weighs 95.5 N. If the coefficient of friction between the boards is 0.663, what must be the magnitude of the compression forces (assume horizontal) acting on both sides of the center board to keep it from slipping?

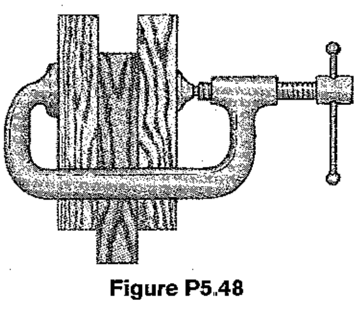


Figure P5.48

49. A block weighing 75.0 N rests on a plane inclined at 25.0° to the horizontal. A force F is applied to the object at 40.0° to the horizontal, pushing it upward on the plane. The coefficients of static and kinetic friction between the block and the plane are, respectively, 0.363 and 0.156. (a) What is the minimum value of F that will prevent the block from slipping down the plane? (b) What is the minimum value of F that will start the block moving up the plane? (c) What value of F will move the block up the plane with constant velocity?

Review problem. One side of the roof of a building slopes up at 37.0°. A student throws a Frisbee onto the roof. It strikes with a speed of 15.0 m/s and does not bounce, but slides straight up the incline. The coefficient of kinetic friction between the plastic and the roof is 0.400. The Frisbee slides 10.0 m up the roof to its peak, where it goes into free fall, following a parabolic trajectory with negligible air resistance. Determine the maximum height the Frisbee reaches above the point where it struck the roof.

Additional Problems

51. An inventive child named Pat wants to reach an apple in a tree without climbing the tree. Sitting in a chair connected to a rope that passes over a frictionless pulley (Fig. P5.51), Pat pulls on the loose end of the rope with such a force that the spring scale reads 250 N. Pat's true weight is 320 N, and the chair weighs 160 N. (a) Draw free-body diagrams for Pat and the chair considered as separate systems, and another diagram for Pat and the chair considered as one system. (b) Show that the acceleration of the system is *upward* and find its magnitude. (c) Find the force Pat exerts on the chair.

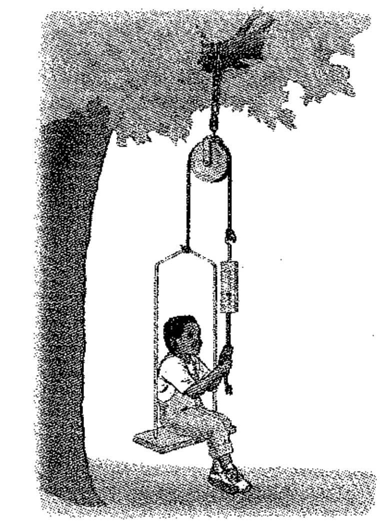


Figure P5.51

52. A time-dependent force, $\mathbf{F} = (8.00\hat{\mathbf{i}} - 4.00t\hat{\mathbf{j}})$ N, where t is in seconds, is exerted on a 2.00-kg object initially at rest. (a) At what time will the object be moving with a speed of 15.0 m/s? (b) How far is the object from its initial position when its speed is 15.0 m/s? (c) Through what total displacement has the object traveled at this time?

53. To prevent a box from sliding down an inclined plane, student A pushes on the box in the direction parallel to the incline, just hard enough to hold the box stationary. In an identical situation student B pushes on the box horizontally. Regard as known the mass m of the box, the coefficient of static friction μ_s between box and incline, and the inclination angle θ. (a) Determine the force A

ticle rotating in a vertical circle, the gravitational force provides the tangential component of acceleration and part or all of the radial component of acceleration

An observer in a noninertial (accelerating) frame of reference must introduce **fictitious forces** when applying Newton's second law in that frame If these fictitious forces are properly defined, the description of motion in the noninertial frame is equivalent to that made by an observer in an inertial frame. However, the observers in the two frames do not agree on the causes of the motion

An object moving through a liquid or gas experiences a speed-dependent **resistive force.** This resistive force, which opposes the motion relative to the medium, generally increases with speed. The magnitude of the resistive force depends on the size and shape of the object and on the properties of the medium through which the object is moving. In the limiting case for a falling object, when the magnitude of the resistive force equals the object's weight, the object reaches its **terminal speed**. **Euler's method** provides a means for analyzing the motion of a particle under the action of a force that is not simple

Kap. 6

QUESTIONS

1. Why does mud fly off a rapidly turning automobile tire?
2. Imagine that you attach a heavy object to one end of a spring, hold onto the other end of the spring, and then whirl the object in a horizontal circle. Does the spring stretch? If so, why? Discuss this in terms of the force causing the motion to be circular
3. Describe a situation in which the driver of a car can have a centripetal acceleration but no tangential acceleration
4. Describe the path of a moving body in the event that its acceleration is constant in magnitude at all times and (a) perpendicular to the velocity; (b) parallel to the velocity
5. An object executes circular motion with constant speed whenever a net force of constant magnitude acts perpendicular to the velocity. What happens to the speed if the force is not perpendicular to the velocity?
6. Explain why the Earth is not spherical in shape and bulges at the equator
7. Because the Earth rotates about its axis, it is a noninertial frame of reference. Assume the Earth is a uniform sphere. Why would the apparent weight of an object be greater at the poles than at the equator?
8. What causes a rotary lawn sprinkler to turn?
9. If someone told you that astronauts are weightless in orbit because they are beyond the pull of gravity, would you accept the statement? Explain
10. It has been suggested that rotating cylinders about 10 mi in length and 5 mi in diameter be placed in space and used as colonies The purpose of the rotation is to simulate gravity for the inhabitants. Explain this concept for producing an effective imitation of gravity
11. Consider a rotating space station, spinning with just the right speed such that the centripetal acceleration on the inner surface is g. Thus, astronauts standing on this inner surface would feel pressed to the surface as if they were pressed into the floor because of the Earth's gravitational force Suppose an astronaut in this station holds a ball above her head and "drops" it to the floor. Will the ball fall just like it would on the Earth?
12. A pail of water can be whirled in a vertical path such that none is spilled. Why does the water stay in the pail, even when the pail is above your head?
13. How would you explain the force that pushes a rider toward the side of a car as the car rounds a corner?
14. Why does a pilot tend to black out when pulling out of a steep dive?
15. The observer in the accelerating elevator of Example 5.8 would claim that the "weight" of the fish is T, the scale reading. This is obviously wrong. Why does this observation differ from that of a person outside the elevator, at rest with respect to the Earth?
16. If you have ever taken a ride in an express elevator of a high-rise building, you may have experienced a nauseating sensation of heaviness or lightness depending on the direction of the acceleration. Explain these sensations Are we truly weightless in free-fall?
17. A falling sky diver reaches terminal speed with her parachute closed After the parachute is opened, what parameters change to decrease this terminal speed?
18. Consider a small raindrop and a large raindrop falling through the atmosphere. Compare their terminal speeds. What are their accelerations when they reach terminal speed?
19. On long journeys, jet aircraft usually fly at high altitudes of about 30 000 ft. What is the main advantage of flying at these altitudes from an economic viewpoint?
20. Analyze the motion of a rock falling through water in terms of its speed and acceleration as it falls. Assume that the resistive force acting on the rock increases as the speed increases
21. "If the current position and velocity of every particle in the Universe were known, together with the laws describing the forces that particles exert on one another, then the whole future of the Universe could be calculated The future is determinate and preordained. Free will is an illusion." Do you agree with this thesis? Argue for or against it

PROBLEMS

1, 2, 3 = straightforward, intermediate, challenging ☐ = full solution available in the *Student Solutions Manual and Study Guide*
= coached solution with hints available at http://www.pse6 com ▣ = computer useful in solving problem
= paired numerical and symbolic problems

Section 6.1 Newton's Second Law Applied to Uniform Circular Motion

1. A light string can support a stationary hanging load of 25 0 kg before breaking A 3.00-kg object attached to the string rotates on a horizontal, frictionless table in a circle of radius 0 800 m, while the other end of the string is held fixed What range of speeds can the object have before the string breaks?

2. A curve in a road forms part of a horizontal circle. As a car goes around it at constant speed 14 0 m/s, the total force on the driver has magnitude 130 N. What is the total vector force on the driver if the speed is 18.0 m/s instead?

3. In the Bohr model of the hydrogen atom, the speed of the electron is approximately 2.20×10^6 m/s. Find (a) the force acting on the electron as it revolves in a circular orbit of radius $0\ 530 \times 10^{-10}$ m and (b) the centripetal acceleration of the electron.

4. In a cyclotron (one type of particle accelerator), a deuteron (of atomic mass 2 00 u) reaches a final speed of 10.0% of the speed of light while moving in a circular path of radius 0.480 m The deuteron is maintained in the circular path by a magnetic force What magnitude of force is required?

5. A coin placed 30.0 cm from the center of a rotating, horizontal turntable slips when its speed is 50 0 cm/s. (a) What force causes the centripetal acceleration when the coin is stationary relative to the turntable? (b) What is the coefficient of static friction between coin and turntable?

6. Whenever two *Apollo* astronauts were on the surface of the Moon, a third astronaut orbited the Moon Assume the orbit to be circular and 100 km above the surface of the Moon, where the acceleration due to gravity is 1 52 m/s^2. The radius of the Moon is $1\ 70 \times 10^6$ m. Determine (a) the astronaut's orbital speed, and (b) the period of the orbit.

7. A crate of eggs is located in the middle of the flat bed of a pickup truck as the truck negotiates an unbanked curve in the road The curve may be regarded as an arc of a circle of radius 35.0 m. If the coefficient of static friction between crate and truck is 0 600, how fast can the truck be moving without the crate sliding?

8. The cornering performance of an automobile is evaluated on a skidpad, where the maximum speed that a car can maintain around a circular path on a dry, flat surface is measured. Then the centripetal acceleration, also called the lateral acceleration, is calculated as a multiple of the free-fall acceleration g The main factors affecting the performance are the tire characteristics and the suspension system of the car A Dodge Viper GTS can negotiate a skidpad of radius 61 0 m at 86.5 km/h Calculate its maximum lateral acceleration

9. Consider a conical pendulum with an 80.0-kg bob on a 10.0-m wire making an angle of 5 00° with the vertical (Fig. P6 9) Determine (a) the horizontal and vertical components of the force exerted by the wire on the pendulum and (b) the radial acceleration of the bob

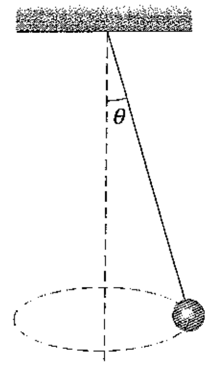


Figure P6.9

10. A car initially traveling eastward turns north by traveling in a circular path at uniform speed as in Figure P6.10 The length of the arc ABC is 235 m, and the car completes the turn in 36 0 s. (a) What is the acceleration when the car is at B located at an angle of 35.0°? Express your answer in terms of the unit vectors $\hat{\mathbf{i}}$ and $\hat{\mathbf{j}}$. Determine (b) the car's average speed and (c) its average acceleration during the 36 0-s interval

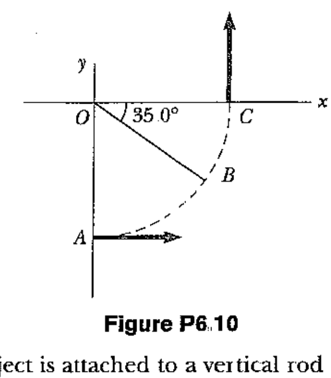


Figure P6.10

11. A 4 00-kg object is attached to a vertical rod by two strings, as in Figure P6 11. The object rotates in a horizontal circle at constant speed 6 00 m/s. Find the tension in (a) the upper string and (b) the lower string

12. Casting of molten metal is important in many industrial processes. *Centrifugal casting* is used for manufacturing pipes, bearings and many other structures. A variety of sophisticated techniques have been invented, but the basic idea is as illustrated in Figure P6 12 A cylindrical enclosure is rotated rapidly and steadily about a horizontal axis Molten metal is poured into the rotating cylinder and then cooled, forming the finished product. Turning the cylin-

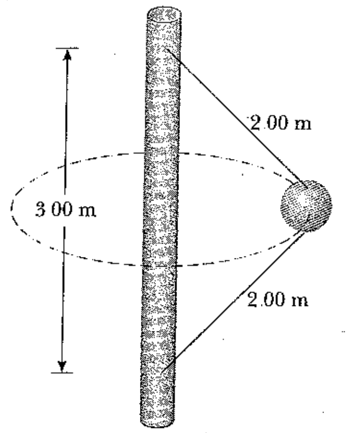


Figure P6.11

der at a high rotation rate forces the solidifying metal strongly to the outside. Any bubbles are displaced toward the axis, so unwanted voids will not be present in the casting. Sometimes it is desirable to form a composite casting, such as for a bearing. Here a strong steel outer surface is poured, followed by an inner lining of special low-friction metal. In some applications a very strong metal is given a coating of corrosion-resistant metal. Centrifugal casting results in strong bonding between the layers.

Suppose that a copper sleeve of inner radius 2.10 cm and outer radius 2.20 cm is to be cast. To eliminate bubbles and give high structural integrity, the centripetal acceleration of each bit of metal should be $100g$. What rate of rotation is required? State the answer in revolutions per minute.

Section 6.2 Nonuniform Circular Motion

13. A 40.0-kg child swings in a swing supported by two chains, each 3.00 m long. If the tension in each chain at the lowest point is 350 N, find (a) the child's speed at the lowest point and (b) the force exerted by the seat on the child at the lowest point. (Neglect the mass of the seat.)

14. A child of mass m swings in a swing supported by two chains, each of length R. If the tension in each chain at the lowest point is T, find (a) the child's speed at the lowest point and (b) the force exerted by the seat on the child at the lowest point. (Neglect the mass of the seat.)

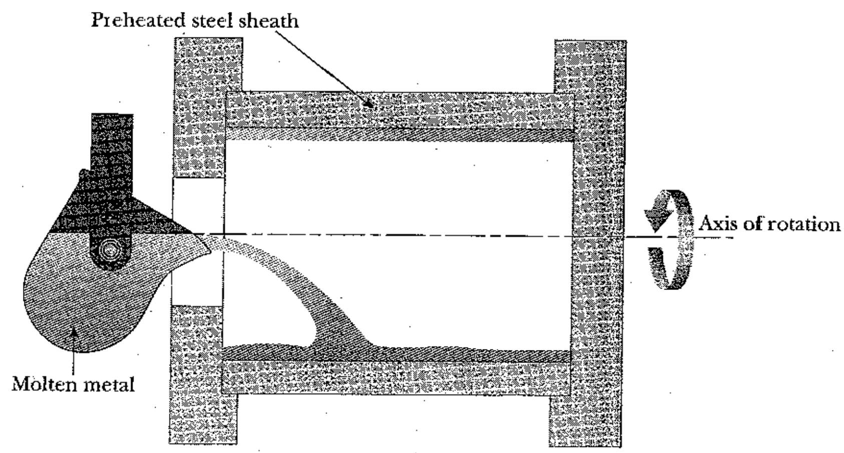


Figure P6.12

15. Tarzan (m = 85.0 kg) tries to cross a river by swinging from a vine. The vine is 10.0 m long, and his speed at the bottom of the swing (as he just clears the water) will be 8.00 m/s. Tarzan doesn't know that the vine has a breaking strength of 1 000 N. Does he make it safely across the river?

16. A hawk flies in a horizontal arc of radius 12.0 m at a constant speed of 4.00 m/s. (a) Find its centripetal acceleration. (b) It continues to fly along the same horizontal arc but increases its speed at the rate of 1.20 m/s^2. Find the acceleration (magnitude and direction) under these conditions.

17. A pail of water is rotated in a vertical circle of radius 1.00 m. What is the minimum speed of the pail at the top of the circle if no water is to spill out?

18. A 0.400-kg object is swung in a vertical circular path on a string 0.500 m long. If its speed is 4.00 m/s at the top of the circle, what is the tension in the string there?

19. A roller coaster car (Fig. P6.19) has a mass of 500 kg when fully loaded with passengers. (a) If the vehicle has a speed of 20.0 m/s at point Ⓐ, what is the force exerted by the track on the car at this point? (b) What is the maximum speed the vehicle can have at Ⓑ and still remain on the track?

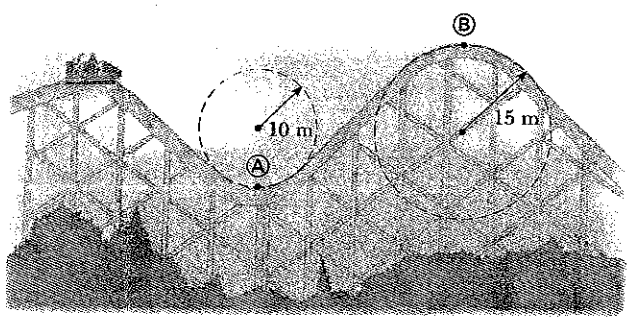


Figure P6.19

20. A roller coaster at the Six Flags Great America amusement park in Gurnee, IL, incorporates some clever design technology and some basic physics. Each vertical loop, instead of being circular, is shaped like a teardrop (Fig. P6.20). The cars ride on the inside of the loop at the top, and the speeds are high enough to ensure that the cars remain on the track. The biggest loop is 40.0 m high, with a maximum speed of 31.0 m/s (nearly 70 mi/h) at the bottom. Suppose

the speed at the top is 13.0 m/s and the corresponding centripetal acceleration is $2g$. (a) What is the radius of the arc of the teardrop at the top? (b) If the total mass of a car plus the riders is M, what force does the rail exert on the car at the top? (c) Suppose the roller coaster had a circular loop of radius 20.0 m. If the cars have the same speed, 13.0 m/s at the top, what is the centripetal acceleration at the top? Comment on the normal force at the top in this situation.

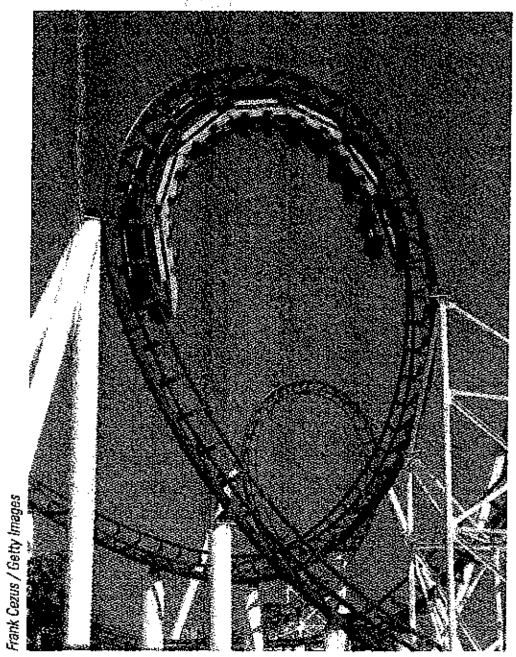


Figure P6.20

Section 6.3 Motion in Accelerated Frames

21. An object of mass 5.00 kg, attached to a spring scale, rests on a frictionless, horizontal surface as in Figure P6.21. The spring scale, attached to the front end of a boxcar, has a constant reading of 18.0 N when the car is in motion. (a) If the spring scale reads zero when the car is at rest, determine the acceleration of the car. (b) What constant reading will the spring scale show if the car moves with constant velocity? (c) Describe the forces on the object as observed by someone in the car and by someone at rest outside the car.

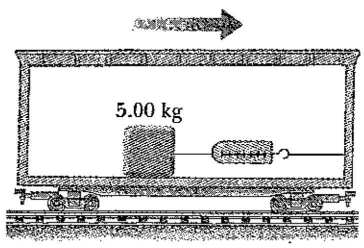


Figure P6.21

22. If the coefficient of static friction between your coffee cup and the horizontal dashboard of your car is $\mu_s = 0.800$, how fast can you drive on a horizontal roadway around a right turn of radius 30.0 m before the cup starts to slide? If you go too fast, in what direction will the cup slide relative to the dashboard?

23. A 0.500-kg object is suspended from the ceiling of an accelerating boxcar as in Figure 6.13. If $a = 3.00$ m/s^2, find (a) the angle that the string makes with the vertical and (b) the tension in the string.

24. A small container of water is placed on a carousel inside a microwave oven, at a radius of 12.0 cm from the center. The turntable rotates steadily, turning through one revolution in each 7.25 s. What angle does the water surface make with the horizontal?

25. A person stands on a scale in an elevator. As the elevator starts, the scale has a constant reading of 591 N. As the elevator later stops, the scale reading is 391 N. Assume the magnitude of the acceleration is the same during starting and stopping, and determine (a) the weight of the person, (b) the person's mass, and (c) the acceleration of the elevator.

26. The Earth rotates about its axis with a period of 24.0 h. Imagine that the rotational speed can be increased. If an object at the equator is to have zero apparent weight, (a) what must the new period be? (b) By what factor would the speed of the object be increased when the planet is rotating at the higher speed? Note that the apparent weight of the object becomes zero when the normal force exerted on it is zero.

27. A small block is at rest on the floor at the front of a railroad boxcar that has length ℓ. The coefficient of kinetic friction between the floor of the car and the block is μ_k. The car, originally at rest, begins to move with acceleration a. The block slides back horizontally until it hits the back wall of the car. At that moment, what is its speed (a) relative to the car? (b) relative to Earth?

28. A student stands in an elevator that is continuously accelerating upward with acceleration a. Her backpack is sitting on the floor next to the wall. The width of the elevator car is L. The student gives her backpack a quick kick at $t = 0$, imparting to it speed v, and making it slide across the elevator floor. At time t, the backpack hits the opposite wall. Find the coefficient of kinetic friction μ_k between the backpack and the elevator floor.

29. A child on vacation wakes up. She is lying on her back. The tension in the muscles on both sides of her neck is 55.0 N as she raises her head to look past her toes and out the motel window. Finally it is not raining! Ten minutes later she is screaming feet first down a water slide at terminal speed 5.70 m/s, riding high on the outside wall of a horizontal curve of radius 2.40 m (Figure P6.29). She raises her head to look forward past her toes; find the tension in the muscles on both sides of her neck.

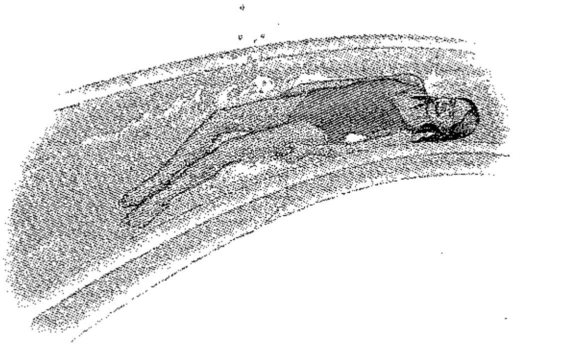


Figure P6.29

30 One popular design of a household juice machine is a conical, perforated stainless steel basket 3 30 cm high with a closed bottom of diameter 8.00 cm and open top of diameter 13.70 cm that spins at 20 000 revolutions per minute about a vertical axis (Figure P6 30) Solid pieces of fruit are chopped into granules by cutters at the bottom of the spinning cone Then the fruit granules rapidly make their way to the sloping surface where the juice is extracted to the outside of the cone through the mesh perforations. The dry pulp spirals upward along the slope to be ejected from the top of the cone. The juice is collected in an enclosure immediately surrounding the sloped surface of the cone. (a) What centripetal acceleration does a bit of fruit experience when it is spinning with the basket at a point midway between the top and bottom? Express the answer as a multiple of g. (b) Observe that the weight of the fruit is a negligible force. What is the normal force on 2.00 g of fruit at that point? (c) If the effective coefficient of kinetic friction between the fruit and the cone is 0 600, with what acceleration relative to the cone will the bit of fruit start to slide up the wall of the cone at that point, after being temporarily stuck?

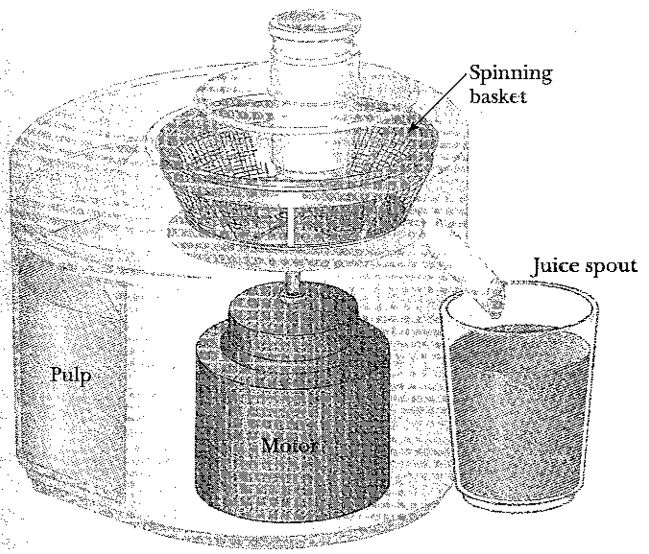


Figure P6.30

31. A plumb bob does not hang exactly along a line directed to the center of the Earth's rotation. How much does the plumb bob deviate from a radial line at 35 0° north latitude? Assume that the Earth is spherical.

Section 6.4 Motion in the Presence of Resistive Forces

32. A sky diver of mass 80 0 kg jumps from a slow-moving aircraft and reaches a terminal speed of 50 0 m/s. (a) What is the acceleration of the sky diver when her speed is 30 0 m/s? What is the drag force on the diver when her speed is (b) 50.0 m/s? (c) 30 0 m/s?

33. A small piece of Styrofoam packing material is dropped from a height of 2 00 m above the ground Until it reaches terminal speed, the magnitude of its acceleration is given by $a = g - bv$ After falling 0 500 m, the Styrofoam effectively reaches terminal speed, and then takes 5 00 s more to reach the ground (a) What is the value of the constant b? (b) What is the acceleration at $t = 0$? (c) What is the acceleration when the speed is 0 150 m/s?

34. (a) Estimate the terminal speed of a wooden sphere (density 0 830 g/cm^3) falling through air if its radius is 8 00 cm and its drag coefficient is 0.500 (b) From what height would a freely falling object reach this speed in the absence of air resistance?

35. Calculate the force required to pull a copper ball of radius 2.00 cm upward through a fluid at the constant speed 9.00 cm/s. Take the drag force to be proportional to the speed, with proportionality constant 0.950 kg/s. Ignore the buoyant force.

36. A fire helicopter carries a 620-kg bucket at the end of a cable 20 0 m long as in Figure P6 36 As the helicopter flies to a fire at a constant speed of 40.0 m/s, the cable makes an angle of 40.0° with respect to the vertical. The bucket presents a cross-sectional area of 3.80 m^2 in a plane perpendicular to the air moving past it. Determine the drag coefficient assuming that the resistive force is proportional to the square of the bucket's speed.

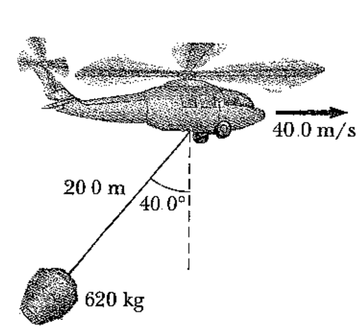


Figure P6.36

37. A small, spherical bead of mass 3 00 g is released from rest at $t = 0$ in a bottle of liquid shampoo The terminal speed is observed to be $v_T = 2\ 00$ cm/s. Find (a) the value of the constant b in Equation 6 2, (b) the time τ at which the bead reaches $0.632v_T$, and (c) the value of the resistive force when the bead reaches terminal speed.

38. The mass of a sports car is 1 200 kg The shape of the body is such that the aerodynamic drag coefficient is 0 250 and the frontal area is 2.20 m^2 Neglecting all other sources of friction, calculate the initial acceleration of the car if it has been traveling at 100 km/h and is now shifted into neutral and allowed to coast.

39. A motorboat cuts its engine when its speed is 10.0 m/s and coasts to rest The equation describing the motion of the motorboat during this period is $v = v_i e^{-ct}$, where v is the speed at time t, v_i is the initial speed, and c is a constant. At $t = 20.0$ s, the speed is 5.00 m/s (a) Find the constant c. (b) What is the speed at $t = 40.0$ s? (c) Differentiate the expression for $v(t)$ and thus show that the acceleration of the boat is proportional to the speed at any time.

40. Consider an object on which the net force is a resistive force proportional to the square of its speed. For example, assume that the resistive force acting on a speed skater is $f = -kmv^2$, where k is a constant and m is the skater's mass The skater crosses the finish line of a straight-line race with

speed v_0 and then slows down by coasting on his skates Show that the skater's speed at any time t after crossing the finish line is $v(t) = v_0/(1 + ktv_0)$ This problem also provides the background for the two following problems

41. (a) Use the result of Problem 40 to find the position x as a function of time for an object of mass m, located at $x = 0$ and moving with velocity $v_0\hat{\mathbf{i}}$ at time $t = 0$ and thereafter experiencing a net force $-kmv^2\hat{\mathbf{i}}$. (b) Find the object's velocity as a function of position.

42. At major league baseball games it is commonplace to flash on the scoreboard a speed for each pitch. This speed is determined with a radar gun aimed by an operator positioned behind home plate. The gun uses the Doppler shift of microwaves reflected from the baseball, as we will study in Chapter 39. The gun determines the speed at some particular point on the baseball's path, depending on when the operator pulls the trigger. Because the ball is subject to a drag force due to air, it slows as it travels 18 3 m toward the plate. Use the result of Problem 41(b) to find how much its speed decreases Suppose the ball leaves the pitcher's hand at 90.0 mi/h = 40 2 m/s. Ignore its vertical motion. Use data on baseballs from Example 6 13 to determine the speed of the pitch when it crosses the plate

43. You can feel a force of air drag on your hand if you stretch your arm out of the open window of a speeding car [*Note*: Do not endanger yourself.] What is the order of magnitude of this force? In your solution state the quantities you measure or estimate and their values.

Section 6.5 Numerical Modeling in Particle Dynamics

44. A 3 00-g leaf is dropped from a height of 2.00 m above the ground. Assume the net downward force exerted on the leaf is $F = mg - bv$, where the drag factor is $b = 0.030\ 0$ kg/s (a) Calculate the terminal speed of the leaf (b) Use Euler's method of numerical analysis to find the speed and position of the leaf, as functions of time, from the instant it is released until 99% of terminal speed is reached. (*Suggestion*: Try $\Delta t = 0.005$ s.)

45. A hailstone of mass 4.80×10^{-4} kg falls through the air and experiences a net force given by

$$F = -mg + Cv^2$$

where $C = 2.50 \times 10^{-5}$ kg/m. (a) Calculate the terminal speed of the hailstone (b) Use Euler's method of numerical analysis to find the speed and position of the hailstone at 0 2-s intervals, taking the initial speed to be zero. Continue the calculation until the hailstone reaches 99% of terminal speed

46. A 0 142-kg baseball has a terminal speed of 42 5 m/s (95 mi/h). (a) If a baseball experiences a drag force of magnitude $R = Cv^2$, what is the value of the constant C? (b) What is the magnitude of the drag force when the speed of the baseball is 36 0 m/s? (c) Use a computer to determine the motion of a baseball thrown vertically upward at an initial speed of 36 m/s. What maximum height does the ball reach? How long is it in the air? What is its speed just before it hits the ground?

47. A 50.0-kg parachutist jumps from an airplane and falls to Earth with a drag force proportional to the square of the speed, $R = Cv^2$ Take $C = 0.200$ kg/m (with the parachute closed) and $C = 20.0$ kg/m (with the chute open) (a) Determine the terminal speed of the parachutist in both configurations, before and after the chute is opened (b) Set up a numerical analysis of the motion and compute the speed and position as functions of time, assuming the jumper begins the descent at 1 000 m above the ground and is in free fall for 10.0 s before opening the parachute. (*Suggestion*: When the parachute opens, a sudden large acceleration takes place; a smaller time step may be necessary in this region)

48. Consider a 10 0-kg projectile launched with an initial speed of 100 m/s, at an elevation angle of 35 0° The resistive force is $\mathbf{R} = -b\mathbf{v}$, where $b = 10\ 0$ kg/s (a) Use a numerical method to determine the horizontal and vertical coordinates of the projectile as functions of time (b) What is the range of this projectile? (c) Determine the elevation angle that gives the maximum range for the projectile (*Suggestion*: Adjust the elevation angle by trial and error to find the greatest range)

49. A professional golfer hits her 5-iron 155 m (170 yd) A 46.0-g golf ball experiences a drag force of magnitude $R = Cv^2$, and has a terminal speed of 44 0 m/s (a) Calculate the drag constant C for the golf ball (b) Use a numerical method to calculate the trajectory of this shot. If the initial velocity of the ball makes an angle of 31.0° (the loft angle) with the horizontal, what initial speed must the ball have to reach the 155-m distance? (c) If this same golfer hits her 9-iron (47.0° loft) a distance of 119 m, what is the initial speed of the ball in this case? Discuss the differences in trajectories between the two shots

Additional Problems

50. In a home laundry dryer, a cylindrical tub containing wet clothes is rotated steadily about a horizontal axis, as shown in Figure P6 50. So that the clothes will dry uniformly, they are made to tumble The rate of rotation of the smooth-walled tub is chosen so that a small piece of cloth will lose contact with the tub when the cloth is at an angle of 68 0°

Figure P6 50

above the horizontal. If the radius of the tub is 0.330 m, what rate of revolution is needed?

51. We will study the most important work of Nobel laureate Arthur Compton in Chapter 40. Disturbed by speeding cars outside the physics building at Washington University in St. Louis, Compton designed a speed bump and had it installed. Suppose that a 1 800-kg car passes over a bump in a roadway that follows the arc of a circle of radius 20.4 m as in Figure P6.51. (a) What force does the road exert on the car as the car passes the highest point of the bump if the car travels at 30.0 km/h? (b) **What If?** What is the maximum speed the car can have as it passes this highest point without losing contact with the road?

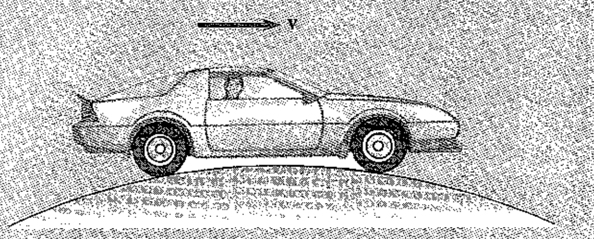


Figure P6.51 Problems 51 and 52.

52. A car of mass m passes over a bump in a road that follows the arc of a circle of radius R as in Figure P6.51. (a) What force does the road exert on the car as the car passes the highest point of the bump if the car travels at a speed v? (b) **What If?** What is the maximum speed the car can have as it passes this highest point without losing contact with the road?

53. Interpret the graph in Figure 6.18(b). Proceed as follows: (a) Find the slope of the straight line, including its units. (b) From Equation 6.6, $R = \frac{1}{2}D\rho Av^2$, identify the theoretical slope of a graph of resistive force versus squared speed. (c) Set the experimental and theoretical slopes equal to each other and proceed to calculate the drag coefficient of the filters. Use the value for the density of air listed on the book's endpapers. Model the cross-sectional area of the filters as that of a circle of radius 10.5 cm. (d) Arbitrarily choose the eighth data point on the graph and find its vertical separation from the line of best fit. Express this scatter as a percentage. (e) In a short paragraph state what the graph demonstrates and compare it to the theoretical prediction. You will need to make reference to the quantities plotted on the axes, to the shape of the graph line, to the data points, and to the results of parts (c) and (d).

54. A student builds and calibrates an accelerometer, which she uses to determine the speed of her car around a certain unbanked highway curve. The accelerometer is a plumb bob with a protractor that she attaches to the roof of her car. A friend riding in the car with her observes that the plumb bob hangs at an angle of 15.0° from the vertical when the car has a speed of 23.0 m/s. (a) What is the centripetal acceleration of the car rounding the curve? (b) What is the radius of the curve? (c) What is the speed of the car if the plumb bob deflection is 9.00° while rounding the same curve?

55. Suppose the boxcar of Figure 6.13 is moving with constant acceleration a up a hill that makes an angle ϕ with the horizontal. If the pendulum makes a constant angle θ with the perpendicular to the ceiling, what is a?

56. (a) A luggage carousel at an airport has the form of a section of a large cone, steadily rotating about its vertical axis. Its metallic surface slopes downward toward the outside, making an angle of 20.0° with the horizontal. A piece of luggage having mass 30.0 kg is placed on the carousel, 7.46 m from the axis of rotation. The travel bag goes around once in 38.0 s. Calculate the force of static friction between the bag and the carousel. (b) The drive motor is shifted to turn the carousel at a higher constant rate of rotation, and the piece of luggage is bumped to another position, 7.94 m from the axis of rotation. Now going around once in every 34.0 s, the bag is on the verge of slipping. Calculate the coefficient of static friction between the bag and the carousel.

57. Because the Earth rotates about its axis, a point on the equator experiences a centripetal acceleration of 0.033 7 m/s², while a point at the poles experiences no centripetal acceleration. (a) Show that at the equator the gravitational force on an object must exceed the normal force required to support the object. That is, show that the object's true weight exceeds its apparent weight. (b) What is the apparent weight at the equator and at the poles of a person having a mass of 75.0 kg? (Assume the Earth is a uniform sphere and take g = 9.800 m/s².)

58. An air puck of mass m_1 is tied to a string and allowed to revolve in a circle of radius R on a frictionless horizontal table. The other end of the string passes through a hole in the center of the table, and a counterweight of mass m_2 is tied to it (Fig. P6.58). The suspended object remains in equilibrium while the puck on the tabletop revolves. What is (a) the tension in the string? (b) the radial force acting on the puck? (c) the speed of the puck?

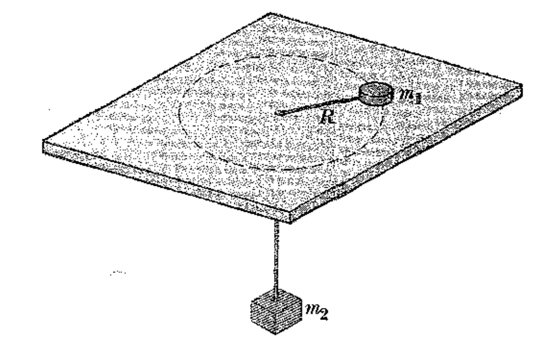


Figure P6.58

59. The pilot of an airplane executes a constant-speed loop-the-loop maneuver in a vertical circle. The speed of the airplane is 300 mi/h, and the radius of the circle is 1 200 ft. (a) What is the pilot's apparent weight at the lowest point if his true weight is 160 lb? (b) What is his apparent weight at the highest point? (c) **What If?** Describe how the pilot could experience weightlessness if both the radius and the speed can be varied. (*Note:* His apparent weight is equal to the magnitude of the force exerted by the seat on his body.)

60. A penny of mass 3.10 g rests on a small 20.0-g block supported by a spinning disk (Fig. P6.60). The coefficients of friction between block and disk are 0.750 (static) and

0 640 (kinetic) while those for the penny and block are 0.520 (static) and 0 450 (kinetic) What is the maximum rate of rotation in revolutions per minute that the disk can have, without the block or penny sliding on the disk?

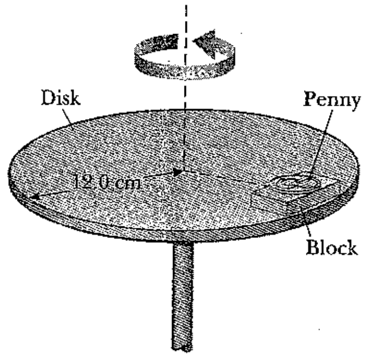


Figure P6.60

61. Figure P6 61 shows a Ferris wheel that rotates four times each minute. It carries each car around a circle of diameter 18 0 m (a) What is the centripetal acceleration of a rider? What force does the seat exert on a 40.0-kg rider (b) at the lowest point of the ride and (c) at the highest point of the ride? (d) What force (magnitude and direction) does the seat exert on a rider when the rider is halfway between top and bottom?

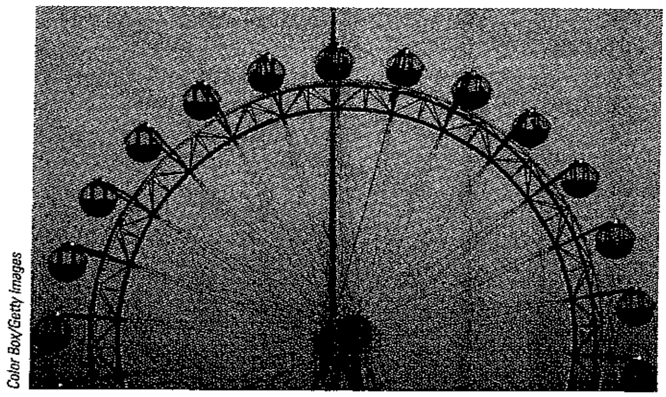


Figure P6.61

62. A space station, in the form of a wheel 120 m in diameter, rotates to provide an "artificial gravity" of 3 00 m/s^2 for persons who walk around on the inner wall of the outer rim. Find the rate of rotation of the wheel (in revolutions per minute) that will produce this effect.

63. An amusement park ride consists of a rotating circular platform 8.00 m in diameter from which 10.0-kg seats are suspended at the end of 2 50-m massless chains (Fig. P6.63). When the system rotates, the chains make an angle $\theta = 28.0°$ with the vertical (a) What is the speed of each seat? (b) Draw a free-body diagram of a 40.0-kg child riding in a seat and find the tension in the chain.

64. A piece of putty is initially located at point A on the rim of a grinding wheel rotating about a horizontal axis The putty is dislodged from point A when the diameter through A is horizontal. It then rises vertically and returns to A at the instant the wheel completes one revolution

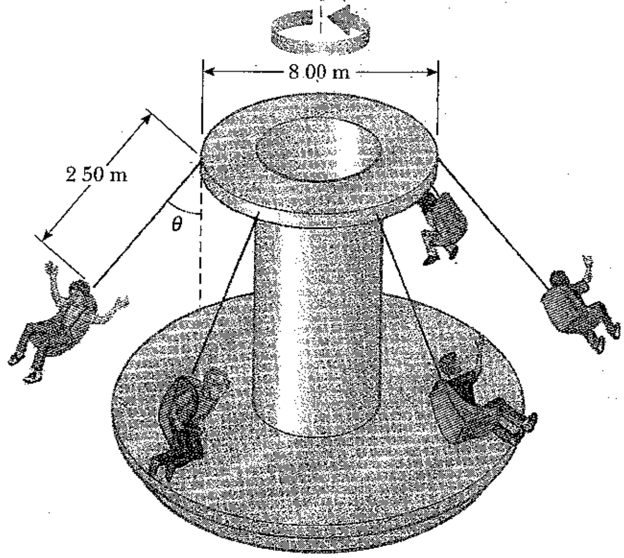


Figure P6.63

(a) Find the speed of a point on the rim of the wheel in terms of the acceleration due to gravity and the radius R of the wheel (b) If the mass of the putty is m, what is the magnitude of the force that held it to the wheel?

65. An amusement park ride consists of a large vertical cylinder that spins about its axis fast enough such that any person inside is held up against the wall when the floor drops away (Fig. P6 65). The coefficient of static friction between person and wall is μ_s, and the radius of the cylinder is R (a) Show that the maximum period of revolution necessary to keep the person from falling is $T = (4\pi^2 R\mu_s/g)^{1/2}$. (b) Obtain a numerical value for T if $R = 4\ 00$ m and $\mu_s = 0\ 400$ How many revolutions per minute does the cylinder make?

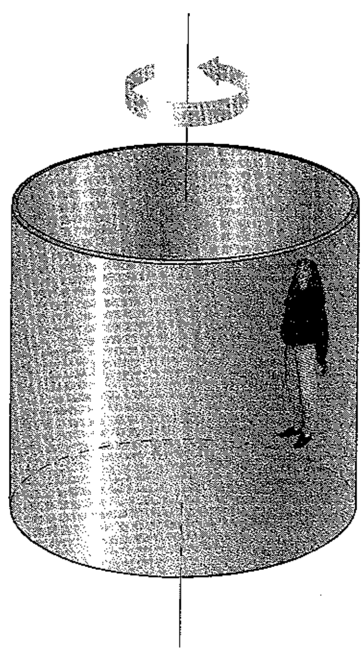


Figure P6.65

66. *An example of the Coriolis effect* Suppose air resistance is negligible for a golf ball A golfer tees off from a location precisely at $\phi_i = 35.0°$ north latitude. He hits the ball due south, with range 285 m. The ball's initial velocity is at 48.0° above the horizontal (a) For how long is the ball in flight? The cup is due south of the golfer's location, and he would have a hole-in-one if the Earth were not rotating The Earth's rotation makes the tee move in a circle of radius $R_E \cos \phi_i = (6.37 \times 10^6 \text{ m}) \cos 35.0°$, as shown in Figure P6.66. The tee completes one revolution each day. (b) Find the eastward speed of the tee, relative to the stars. The hole is also moving east, but it is 285 m farther south, and thus at a slightly lower latitude ϕ_f. Because the hole moves in a slightly larger circle, its speed must be greater than that of the tee. (c) By how much does the hole's speed exceed that of the tee? During the time the ball is in flight, it moves upward and downward as well as southward with the projectile motion you studied in Chapter 4, but it also moves eastward with the speed you found in part (b). The hole moves to the east at a faster speed, however, pulling ahead of the ball with the relative speed you found in part (c). (d) How far to the west of the hole does the ball land?

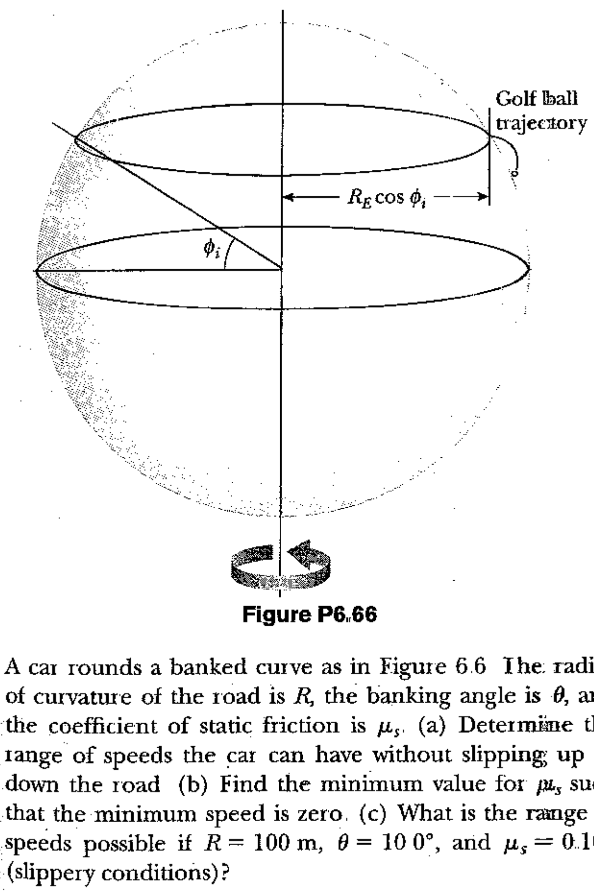


Figure P6.66

67. A car rounds a banked curve as in Figure 6.6 The radius of curvature of the road is R, the banking angle is θ, and the coefficient of static friction is μ_s. (a) Determine the range of speeds the car can have without slipping up or down the road (b) Find the minimum value for μ_s such that the minimum speed is zero. (c) What is the range of speeds possible if $R = 100$ m, $\theta = 10.0°$, and $\mu_s = 0.100$ (slippery conditions)?

68. A single bead can slide with negligible friction on a wire that is bent into a circular loop of radius 15.0 cm, as in Figure P6.68. The circle is always in a vertical plane and rotates steadily about its vertical diameter with (a) a period of 0.450 s The position of the bead is described by the angle θ that the radial line, from the center of the loop to the bead, makes with the vertical. At what angle up from the bottom of the circle can the bead stay motionless relative to the turning circle? (b) **What If?** Repeat the problem if the period of the circle's rotation is 0.850 s.

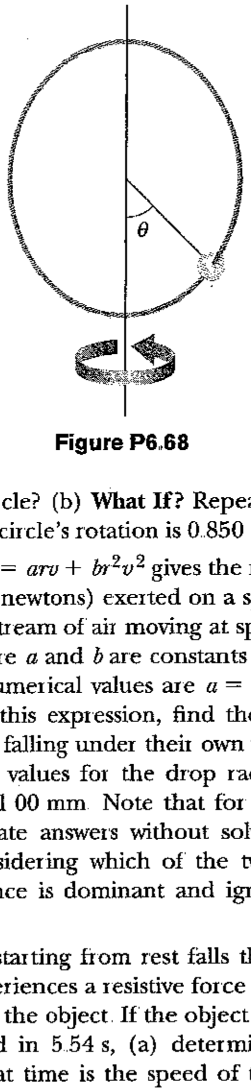


Figure P6.68

69. The expression $F = arv + br^2v^2$ gives the magnitude of the resistive force (in newtons) exerted on a sphere of radius r (in meters) by a stream of air moving at speed v (in meters per second), where a and b are constants with appropriate SI units. Their numerical values are $a = 3.10 \times 10^{-4}$ and $b = 0.870$. Using this expression, find the terminal speed for water droplets falling under their own weight in air, taking the following values for the drop radii: (a) 10.0 μm, (b) 100 μm, (c) 1.00 mm. Note that for (a) and (c) you can obtain accurate answers without solving a quadratic equation, by considering which of the two contributions to the air resistance is dominant and ignoring the lesser contribution.

70. A 9.00-kg object starting from rest falls through a viscous medium and experiences a resistive force $\mathbf{R} = -b\mathbf{v}$, where $\mathbf{v}$ is the velocity of the object. If the object reaches one-half its terminal speed in 5.54 s, (a) determine the terminal speed. (b) At what time is the speed of the object three-fourths the terminal speed? (c) How far has the object traveled in the first 5.54 s of motion?

71. A model airplane of mass 0.750 kg flies in a horizontal circle at the end of a 60.0-m control wire, with a speed of 35.0 m/s. Compute the tension in the wire if it makes a constant angle of 20.0° with the horizontal. The forces exerted on the airplane are the pull of the control wire, the gravitational force, and aerodynamic lift, which acts at 20.0° inward from the vertical as shown in Figure P6.71

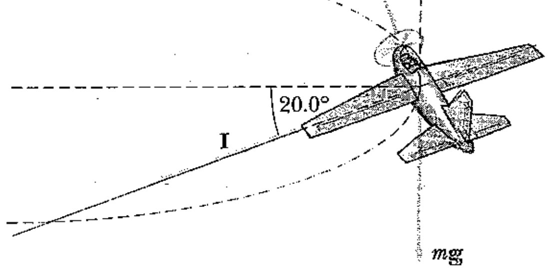


Figure P6.71

69. (a) 3.00 s (b) -15.3 m/s (c) 31 4 m/s down and 34 8 m/s down

71. (c) v_{boy}^2/h, 0 (d) v_{boy}, 0

73. (a) 5 46 s (b) 73.0 m
(c) $v_{\text{Stan}} = 22.6$ m/s, $v_{\text{Kathy}} = 26.7$ m/s

75. $0.577v$

CHAPTER 3

1. $(-2\ 75, -4\ 76)$ m

3. (a) 2.24 m (b) 2.24 m at 26 6°

5. $y = 1.15$; $r = 2\ 31$

7. 70 0 m

9. 310 km at 57° S of W

11. (a) 10 0 m (b) 15 7 m (c) 0

13. (a) $\sim 10^5$ m vertically upward (b) $\sim 10^3$ m vertically upward

15. (a) 5.2 m at 60° (b) 3.0 m at 330° (c) 3 0 m at 150° (d) 5.2 m at 300°

17. approximately 420 ft at $-3°$

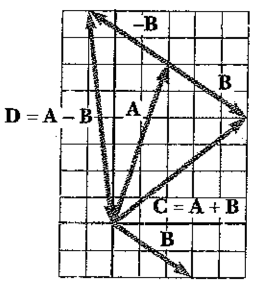
19. 47 2 units at 122°

21. (a) $(-11.1\hat{\mathbf{i}} + 6\ 40\hat{\mathbf{j}})$ m (b) $(1.65\hat{\mathbf{i}} + 2.86\hat{\mathbf{j}})$ cm
(c) $(-18.0\hat{\mathbf{i}} - 12\ 6\hat{\mathbf{j}})$ in.

23. (a) 5.00 blocks at 53.1° N of E (b) 13 0 blocks

25. 358 m at 2.00° S of E

27. (a)



(b) $\mathbf{C} = 5.00\hat{\mathbf{i}} + 4\ 00\hat{\mathbf{j}}$ or 6.40 at 38.7°; $\mathbf{D} = -1.00\hat{\mathbf{i}} + 8.00\hat{\mathbf{j}}$ or 8.06 at 97.2°

29. 196 cm at 345°

31. (a) $2.00\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}}$ (b) $4.00\hat{\mathbf{i}} + 2.00\hat{\mathbf{j}}$ (c) 6.32
(d) 4.47 (e) 288°; 26 6°

33. 9.48 m at 166°

35. (a) 185 N at 77.8° from the $+x$ axis
(b) $(-39.3\hat{\mathbf{i}} - 181\hat{\mathbf{j}})$ N

37. $\mathbf{A} + \mathbf{B} = (2\ 60\hat{\mathbf{i}} + 4\ 50\hat{\mathbf{j}})$ m

39. $|\mathbf{B}| = 7.81$, $\theta_x = 59.2°$, $\theta_y = 39.8°$, $\theta_z = 67\ 4°$

41. (a) $8\ 00\hat{\mathbf{i}} + 12.0\hat{\mathbf{j}} - 4.00\hat{\mathbf{k}}$ (b) $2.00\hat{\mathbf{i}} + 3\ 00\hat{\mathbf{j}} - 1\ 00\hat{\mathbf{k}}$
(c) $-24.0\hat{\mathbf{i}} - 36\ 0\hat{\mathbf{j}} + 12.0\hat{\mathbf{k}}$

43. (a) 5 92 m is the magnitude of $(5\ 00\hat{\mathbf{i}} - 1\ 00\hat{\mathbf{j}} - 3.00\hat{\mathbf{k}})$ m
(b) 19.0 m is the magnitude of $(4.00\hat{\mathbf{i}} - 11\ 0\hat{\mathbf{j}} - 15.0\hat{\mathbf{k}})$ m

45. 157 km

47. (a) $-3.00\hat{\mathbf{i}} + 2.00\hat{\mathbf{j}}$ (b) 3 61 at 146°
(c) $3.00\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}}$

49. (a) $49.5\hat{\mathbf{i}} + 27.1\hat{\mathbf{j}}$ (b) 56.4 units at 28.7°

51. 1.15°

53. (a) 2.00, 1 00, 3.00 (b) 3 74 (c) $\theta_x = 57.7°$, $\theta_y = 74\ 5°$, $\theta_z = 36\ 7°$

55. 2 29 km

57. (a) 11.2 m (b) 12 9 m at 36.4°

59. 240 m at 237°

61. 390 mi/h at 7.37° north of east

63. (a) zero (b) zero

65. 106°

CHAPTER 4

1. (a) 4 87 km at 209° from east (b) 23.3 m/s
(c) 13 5 m/s at 209°

3. 2.50 m/s

5. (a) $(2.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}})$ m/s^2
(b) $(3.00t + t^2)\hat{\mathbf{i}}$ m $+ (1\ 50t^2 - 2\ 00t)\hat{\mathbf{j}}$ m

7. (a) $(0.800\hat{\mathbf{i}} - 0.300\hat{\mathbf{j}})$ m/s^2 (b) 339°
(c) $(360\hat{\mathbf{i}} - 72\ 7\hat{\mathbf{j}})$ m, $-15.2°$

9. (a) $x = 0.010\ 0$ m, $y = 2.41 \times 10^{-4}$ m
(b) $\mathbf{v} = (1\ 84 \times 10^7\hat{\mathbf{i}} + 8\ 78 \times 10^5\hat{\mathbf{j}})$ m/s
(c) $v = 1.85 \times 10^7$ m/s
(d) $\theta = 2.73°$

11. (a) $3.34\hat{\mathbf{i}}$ m/s (b) $-50\ 9°$

13. (a) 20.0° (b) 3.05 s

15. 53.1°

17. (a) 22.6 m (b) 52.3 m (c) 1 18 s

19. (a) The ball clears by 0 889 m while
(b) descending

21. (a) 18.1 m/s (b) 1 13 m (c) 2.79 m

23. 9.91 m/s

25. (a) 30.3 m/s (b) 2 09 s

27. 377 m/s^2

29. 10.5 m/s, 219 m/s^2 inward

31. (a) 6.00 rev/s (b) 1.52 km/s^2
(c) 1.28 km/s^2

33. 1.48 m/s^2 inward and 29.9° backward

35. (a) 13.0 m/s^2 (b) 5 70 m/s (c) 7.50 m/s^2

37. $\theta = \tan^{-1}(1/4\pi) = 4\ 55°$

39. (a) 57.7 km/h at 60 0° west of vertical
(b) 28.9 km/h downward

41. $2\ 02 \times 10^3$ s; 21.0% longer

43. $t_{\text{Alan}} = \dfrac{2L/c}{1 - v^2/c^2}$, $t_{\text{Beth}} = \dfrac{2L/c}{\sqrt{1 - v^2/c^2}}$
Beth returns first.

45. 15 3 m

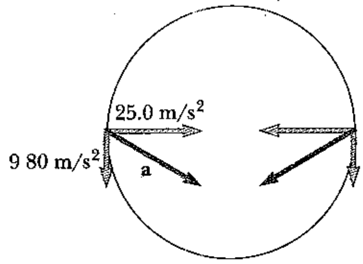
47. (a) 101 m/s (b) 32 700 ft (c) 20.6 s
(d) 180 m/s

49. 54.4 m/s^2

51. (a) 41.7 m/s (b) 3.81 s (c) $(34.1\hat{\mathbf{i}} - 13.4\hat{\mathbf{j}})$ m/s; 36.7 m/s

53. (a) 25 0 m/s^2; 9 80 m/s^2

(b)



(c) 26.8 m/s^2 inward at 21.4° below the horizontal

55. (a) 26.6° (b) 0.949

57. (a) 0.600 m (b) 0.402 m (c) 1.87 m/s^2 toward center (d) 9.80 m/s^2 down

59. (a) 6.80 km (b) 3.00 km vertically above the impact point (c) 66.2°

61. (a) 46.5 m/s (b) −77.6° (c) 6.34 s

63. (a) 20.0 m/s, 5.00 s (b) $(16.0\hat{\mathbf{i}} - 27.1\hat{\mathbf{j}})$ m/s (c) 6.53 s (d) $24.5\hat{\mathbf{i}}$ m

65. (a) 22.9 m/s (b) 360 m from the base of the cliff (c) $\mathbf{v} = (114\hat{\mathbf{i}} - 44.3\hat{\mathbf{j}})$ m/s

67. (a) 43.2 m (b) $(9.66\hat{\mathbf{i}} - 25.5\hat{\mathbf{j}})$ m/s

69. (a) 4.00 km/h (b) 4.00 km/h

71. Safe distances are less than 270 m or greater than 3.48×10^3 m from the western shore.

CHAPTER 5

1. (a) 1/3 (b) 0.750 m/s^2

3. $(6.00\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}})$ N; 16.2 N

5. (a) $(2.50\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}})$ N (b) 5.59 N

7. (a) 3.64×10^{-18} N (b) 8.93×10^{-30} N is 408 billion times smaller

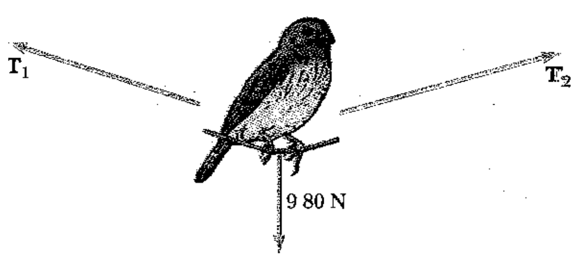
9. 2.38 kN

11. (a) 5.00 m/s^2 at 36.9° (b) 6.08 m/s^2 at 25.3°

13. (a) $\sim 10^{-22}$ m/s^2 (b) $\sim 10^{-23}$ m

15. (a) 15.0 lb up (b) 5.00 lb up (c) 0

17. 613 N



21. (a) 49.0 N (b) 98.0 N (c) 24.5 N

23. 8.66 N east

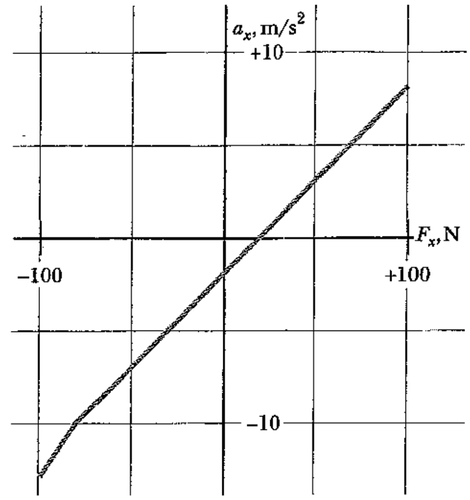
25. 3.73 m

27. A is in compression 3.83 kN and B is in tension 3.37 kN

29. 950 N

31. (a) $F_x > 19.6$ N (b) $F_x \leq -78.4$ N

(c)



33. (a) 706 N (b) 814 N (c) 706 N (d) 648 N

35. (a) 0.404 (b) 45.8 lb

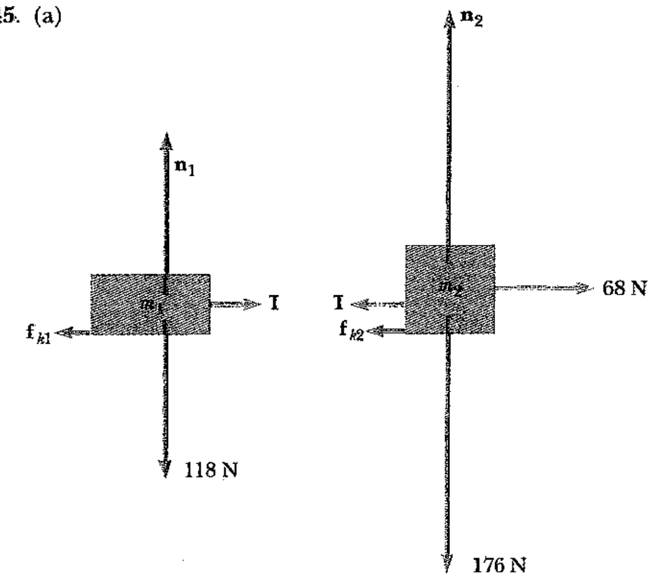
37. (a) 256 m (b) 42.7 m

39. (a) 1.10 s (b) 0.875 s

41. (a) 1.78 m/s^2 (b) 0.368 (c) 9.37 N (d) 2.67 m/s

43. 37.8 N

45. (a)

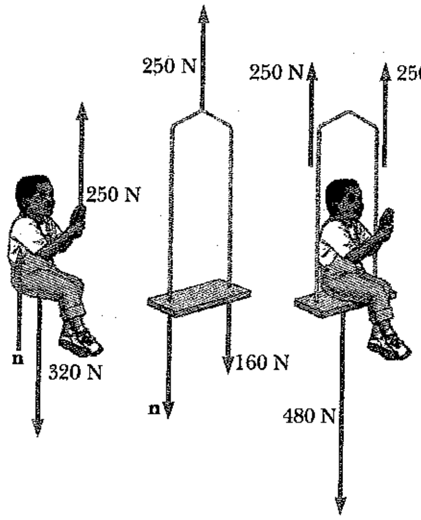


(b) 27.2 N, 1.29 m/s^2

47. $\mu_k = (3/5)\tan\theta$

49. (a) 8.05 N (b) 53.2 N (c) 42.0 N

51. (a)



(b) 0.408 m/s^2 (c) 83.3 N

53. (a) $F_A = mg(\sin\theta - \mu_s \cos\theta)$
(b) $F_B = mg(\sin\theta - \mu_s \cos\theta)/(\cos\theta + \mu_s \sin\theta)$
(c) A's job is easier
(d) B's job is easier

55. (a) $Mg/2$, $Mg/2$, $Mg/2$, $3Mg/2$, Mg (b) $Mg/2$

57. (b)

θ	0	15°	30°	45°	60°
P(N)	40.0	46.4	60.1	94.3	260

59. (a) 19.3° (b) 4.21 N

61. $(M + m_1 + m_2)(m_2 g/m_1)$

63. (a) $m_2 g\left[\dfrac{m_1 M}{m_1 M + m_2(m_1 + M)}\right]$
(b) $\dfrac{m_2 g(M + m_1)}{m_1 M + m_2(m_1 + M)}$
(c) $\dfrac{m_1 m_2 g}{m_1 M + m_2(m_1 + M)}$
(d) $\dfrac{M m_2 g}{m_1 M + m_2(m_1 + M)}$

65. (c) 3.56 N

67. (a) $T = f/(2\sin\theta)$ (b) 410 N

69. (a) 30.7° (b) 0.843 N

71. 0.060 0 m

73. (a) $T_1 = \dfrac{2mg}{\sin\theta_1}$

$T_2 = \dfrac{mg}{\sin\theta_2} = \dfrac{mg}{\sin[\tan^{-1}(\frac{1}{2}\tan\theta_1)]}$

$T_3 = 2mg/\tan\theta_1$

(b) $\theta_2 = \tan^{-1}\left(\dfrac{\tan\theta_1}{2}\right)$

CHAPTER 6

1. Any speed up to 8.08 m/s

3. (a) 8.32×10^{-8} N toward the nucleus
(b) 9.13×10^{22} m/s^2 inward

5. (a) static friction (b) 0.085 0

7. $v \leq 14.3$ m/s

9. (a) 68.6 N toward the center of the circle and 784 N up
(b) 0.857 m/s^2

11. (a) 108 N (b) 56.2 N

13. (a) 4.81 m/s (b) 700 N up

15. No. The jungle lord needs a vine of tensile strength 1.38 kN

17. 3.13 m/s

19. (a) 2.49×10^4 N up (b) 12.1 m/s

21. (a) 3.60 m/s^2 (b) zero (c) An observer in the car (a noninertial frame) claims an 18.0-N force toward the left and an 18.0-N force toward the right. An inertial observer (outside the car) claims only an 18.0-N force toward the right.

23. (a) 17.0° (b) 5.12 N

25. (a) 491 N (b) 50.1 kg (c) 2.00 m/s^2

27. (a) $v = [2(a - \mu_k g)\ell]^{1/2}$; (b) $v' = (2\mu_k g\ell/v)$, where $v = [2(a - \mu_k g)\ell]^{1/2}$

29. 93.8 N

31. 0.092 7°

33. (a) 32.7 s^{-1} (b) 9.80 m/s^2 down (c) 4.90 m/s^2 down

35. 3.01 N up

37. (a) 1.47 N·s/m (b) 2.04×10^{-3} s (c) 2.94×10^{-2} N

39. (a) 0.034 7 s^{-1} (b) 2.50 m/s (c) $a = -cv$

41. (a) $x = k^{-1}\ln(1 + kv_0 t)$ (b) $v = v_0 e^{-kx}$

43. $\sim 10^1$ N

45. (a) 13.7 m/s down
(b)

t (s)	x (m)	v (m/s)
0	0	0
0.2	0	−1.96
0.4	−0.392	−3.88
1.0	−3.77	−8.71
2.0	−14.4	−12.56
4.0	−41.0	−13.67

47. (a) 49.5 m/s down and 4.95 m/s down
(b)

t (s)	y (m)	v (m/s)
0	1 000	0
1	995	−9.7
2	980	−18.6
10	674	−47.7
10.1	671	−16.7
12	659	−4.95
145	0	−4.95

49. (a) 2.33×10^{-4} kg/m (b) 57.0 m/s (c) 44.9 m/s. The second trajectory is higher and shorter than the first. In both cases, the ball attains maximum height when it has covered 56% of its horizontal range, and attains minimum speed a little later. The impact speeds are also similar, 30 m/s and 29 m/s.

51. (a) 11.5 kN (b) 14.1 m/s = 50.9 km/h

53. (a) 0.016 2 kg/m (b) $\frac{1}{2}D\rho A$ (c) 0.778 (d) 1.5% (e) For stacked coffee filters falling in air at terminal speed, the graph of resistive force as a function of squared speed demonstrates that the force is proportional to the speed squared, within the experimental uncertainty, estimated as ± 2%. This proportionality agrees with that predicted by the theoretical equation $R = \frac{1}{2}D\rho Av^2$. The value of the constant slope of the graph implies that the drag coefficient for coffee filters is $D = 0.78 \pm 2\%$.

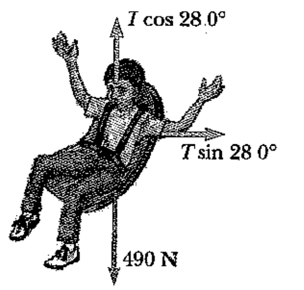
55. $g(\cos\phi \tan\theta - \sin\phi)$

57. (b) 732 N down at the equator and 735 N down at the poles

59. (a) 967 lb (b) − 647 lb (pilot must be strapped in) (c) Speed and radius of path can be adjusted so that $v^2 = gR$

61. (a) 1.58 m/s² (b) 455 N (c) 329 N (d) 397 N upward and 9.15° inward

63. (a) 5.19 m/s (b) T = 555 N



65. (b) 2.54 s; 23.6 rev/min

67. (a) $v_{\min} = \sqrt{\dfrac{Rg(\tan\theta - \mu_s)}{1 + \mu_s \tan\theta}}$, $v_{\max} = \sqrt{\dfrac{Rg(\tan\theta + \mu_s)}{1 - \mu_s \tan\theta}}$ (b) $\mu_s = \tan\theta$ (c) 8.57 m/s ≤ v ≤ 16.6 m/s

69. (a) 0.013 2 m/s (b) 1.03 m/s (c) 6.87 m/s

71. 12.8 N

73. $\Sigma\mathbf{F} = -km\mathbf{v}$

CHAPTER 7

1. (a) 31.9 J (b) 0 (c) 0 (d) 31.9 J

3. − 4.70 kJ

5. 28.9

7. (a) 16.0 J (b) 36.9°

9. (a) 11.3° (b) 156° (c) 82.3°

11. (a) 24.0 J (b) − 3.00 J (c) 21.0 J

13. (a) 7.50 J (b) 15.0 J (c) 7.50 J (d) 30.0 J

15. (a) 0.938 cm (b) 1.25 J

17. (a) 0.768 m (b) 1.68×10^5 J

19. 12.0 J

21. (a) 0.020 4 m (b) 720 N/m

23. kg/s²

25. (a) 33.8 J (b) 135 J

27. 878 kN up

29. (a) 4.56 kJ (b) 6.34 kN (c) 422 km/s² (d) 6.34 kN

31. (a) 650 J (b) 588 J (c) 0 (d) 0 (e) 62.0 J (f) 1.76 m/s

33. (a) − 168 J (b) 184 J (c) 500 J (d) 148 J (e) 5.65 m/s

35. 2.04 m

37. 875 W

39. (a) 20.6 kJ (b) 686 W

41. $46.2

43. (a) 423 mi/gal (b) 776 mi/gal

45. (a) 0.013 5 gal (b) 73.8 (c) 8.08 kW

47. 2.92 m/s

49. (a) $(2 + 24t^2 + 72t^4)$ J (b) $12t$ m/s²; $48t$ N (c) $(48t + 288t^3)$ W (d) 1 250 J

51. $k_1 x_{\max}^2/2 + k_2 x_{\max}^3/3$

53. (a) $\sqrt{2W/m}$ (b) W/d

55. (b) 240 W

57. (a) 1.38×10^4 J (b) 3.02×10^4 W

59. (a) $\mathcal{P} = 2Mgv_T$ (b) $\mathcal{P} = 24Mgv_T$

61. (a) 4.12 m (b) 3.35 m

63. 1.68 m/s

65. -1.37×10^{-21} J

67. 0.799 J

69. (b) For a block of weight w pushed over a rough horizontal surface at constant velocity, $b = \mu_k$. For a load pulled vertically upward at constant velocity, $b = 1$.

CHAPTER 8

1. (a) 259 kJ, 0, − 259 kJ (b) 0, − 259 kJ, − 259 kJ

3. 22.0 kW

5. (a) $v = (3gR)^{1/2}$ (b) 0.098 0 N down

7. (a) 1.47 m/s (b) 1.35 m/s

9. (a) 2.29 m/s (b) 1.98 m/s

11. 10.2 m

13. (a) 4.43 m/s (b) 5.00 m

15. 5.49 m/s

17. (a) 18.5 km, 51.0 km (b) 10.0 MJ

19. (a) 25.8 m (b) 27.1 m/s²

21. (a) − 196 J (b) − 196 J (c) − 196 J The force is conservative.

23. (a) 125 J (b) 50.0 J (c) 66.7 J (d) Nonconservative. The results differ.

25. (a) − 9.00 J; no; the force is conservative (b) 3.39 m/s (c) 9.00 J

27. 26.5 m/s