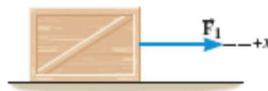


PROBLEMS

WileyPLUS

Section 4.3 Newton's Second Law of Motion

1. An airplane has a mass of 3.1×10^4 kg and takes off under the influence of a constant net force of 3.7×10^4 N. What is the net force that acts on the plane's 78-kg pilot?
2. **mmh** A boat has a mass of 6800 kg. Its engines generate a drive force of 4100 N due west, while the wind exerts a force of 800 N due east and the water exerts a resistive force of 1200 N due east. What are the magnitude and direction of the boat's acceleration?
3. **GO** Two horizontal forces, \vec{F}_1 and \vec{F}_2 , are acting on a box, but only \vec{F}_1 is shown in the drawing. \vec{F}_2 can point either to the right or to the left. The box moves only along the x axis. There is no friction between the box and the surface. Suppose that $\vec{F}_1 = +9.0$ N and the mass of the box is 3.0 kg. Find the magnitude and direction of \vec{F}_2 when the acceleration of the box is (a) $+5.0$ m/s², (b) -5.0 m/s², and (c) 0 m/s².

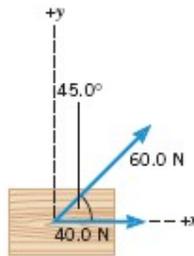


4. In the amusement park ride known as Magic Mountain Superman, powerful magnets accelerate a car and its riders from rest to 45 m/s (about 100 mi/h) in a time of 7.0 s. The combined mass of the car and riders is 5.5×10^3 kg. Find the average net force exerted on the car and riders by the magnets.
5. **ssm** A person in a kayak starts paddling, and it accelerates from 0 to 0.60 m/s in a distance of 0.41 m. If the combined mass of the person and the kayak is 73 kg, what is the magnitude of the net force acting on the kayak?
6. Scientists are experimenting with a kind of gun that may eventually be used to fire payloads directly into orbit. In one test, this gun accelerates a 5.0-kg projectile from rest to a speed of 4.0×10^3 m/s. The net force accelerating the projectile is 4.9×10^5 N. How much time is required for the projectile to come up to speed?
7. **ssm mmh** A 1580-kg car is traveling with a speed of 15.0 m/s. What is the magnitude of the horizontal net force that is required to bring the car to a halt in a distance of 50.0 m?
8. **GO** The space probe *Deep Space 1* was launched on October 24, 1998. Its mass was 474 kg. The goal of the mission was to test a new kind of engine called an ion propulsion drive. This engine generated only a weak thrust, but it could do so over long periods of time with the consumption of only small amounts of fuel. The mission was spectacularly successful. At a thrust of 56 mN how many days were required for the probe to attain a velocity of 805 m/s (1800 mi/h), assuming that the probe started from rest and that the mass remained nearly constant?
- *9. **ssm** Two forces \vec{F}_A and \vec{F}_B are applied to an object whose mass is 8.0 kg. The larger force is \vec{F}_A . When both forces point due east, the object's acceleration has a magnitude of 0.50 m/s². However, when \vec{F}_A points due east and \vec{F}_B points due west, the acceleration is 0.40 m/s², due east. Find (a) the magnitude of \vec{F}_A and (b) the magnitude of \vec{F}_B .
- *10. **PII** An electron is a subatomic particle ($m = 9.11 \times 10^{-31}$ kg) that is subject to electric forces. An electron moving in the $+x$ direction accelerates from an initial velocity of $+5.40 \times 10^5$ m/s to a final velocity of $+2.10 \times 10^6$ m/s while traveling a distance of 0.038 m. The electron's acceleration is due to two electric forces parallel to the x axis: $\vec{F}_1 = +7.50 \times 10^{-17}$ N, and \vec{F}_2 , which points in the $-x$ direction. Find the magnitudes of (a) the net force acting on the electron and (b) the electric force \vec{F}_2 .

Section 4.4 The Vector Nature of Newton's Second Law of Motion,

Section 4.5 Newton's Third Law of Motion

11. Only two forces act on an object (mass = 3.00 kg), as in the drawing. Find the magnitude and direction (relative to the x axis) of the acceleration of the object.
12. At an instant when a soccer ball is in contact with the foot of a player kicking it, the horizontal or x component of the ball's acceleration is 810 m/s^2 and the vertical or y component of its acceleration is 1100 m/s^2 . The ball's mass is 0.43 kg. What is the magnitude of the net force acting on the soccer ball at this instant?



Problem 11

13. **ssm mmh** A rocket of mass $4.50 \times 10^5 \text{ kg}$ is in flight. Its thrust is directed at an angle of 55.0° above the horizontal and has a magnitude of $7.50 \times 10^6 \text{ N}$. Find the magnitude and direction of the rocket's acceleration. Give the direction as an angle above the horizontal.
14. **GO** A billiard ball strikes and rebounds from the cushion of a pool table perpendicularly. The mass of the ball is 0.38 kg. The ball approaches the cushion with a velocity of $+2.1 \text{ m/s}$ and rebounds with a velocity of -2.0 m/s . The ball remains in contact with the cushion for a time of $3.3 \times 10^{-3} \text{ s}$. What is the average net force (magnitude and direction) exerted on the ball by the cushion?
15. When a parachute opens, the air exerts a large drag force on it. This upward force is initially greater than the weight of the sky diver and, thus, slows him down. Suppose the weight of the sky diver is 915 N and the drag force has a magnitude of 1027 N. The mass of the sky diver is 93.4 kg. What are the magnitude and direction of his acceleration?
16. **GO** Two skaters, a man and a woman, are standing on ice. Neglect any friction between the skate blades and the ice. The mass of the man is 82 kg, and the mass of the woman is 48 kg. The woman pushes on the man with a force of 45 N due east. Determine the acceleration (magnitude and direction) of (a) the man and (b) the woman.
- *17. **GO** A space probe has two engines. Each generates the same amount of force when fired, and the directions of these forces can be independently adjusted. When the engines are fired simultaneously and each applies its force in the same direction, the probe, starting from rest, takes 28 s to travel a certain distance. How long does it take to travel the same distance, again starting from rest, if the engines are fired simultaneously and the forces that they apply to the probe are perpendicular?
- **18. At a time when mining asteroids has become feasible, astronauts have connected a line between their 3500-kg space tug and a 6200-kg asteroid. Using their tug's engine, they pull on the asteroid with a force of 490 N. Initially the tug and the asteroid are at rest, 450 m apart. How much time does it take for the tug and the asteroid to meet?
- **19. **ssm** A 325-kg boat is sailing 15.0° north of east at a speed of 2.00 m/s. Thirty seconds later, it is sailing 35.0° north of east at a speed of 4.00 m/s. During this time, three forces act on the boat: a 31.0-N force directed 15.0° north of east (due to an auxiliary engine), a 23.0-N force directed 15.0° south of west (resistance due to the water), and \vec{F}_w (due to the wind). Find the magnitude and direction of the force \vec{F}_w . Express the direction as an angle with respect to due east.

Section 4.7 The Gravitational Force

20. **GO** A 5.0-kg rock and a 3.0×10^{-4} -kg pebble are held near the surface of the earth. (a) Determine the magnitude of the gravitational force exerted on each by the earth. (b) Calculate the magnitude of the acceleration of each object when released.
21. Mars has a mass of $6.46 \times 10^{23} \text{ kg}$ and a radius of $3.39 \times 10^6 \text{ m}$. (a) What is the acceleration due to gravity on Mars? (b) How much would a 65-kg person weigh on this planet?
22. On earth, two parts of a space probe weigh 11 000 N and 3400 N. These parts are separated by a center-to-

center distance of 12 m and may be treated as uniform spherical objects. Find the magnitude of the gravitational force that each part exerts on the other out in space, far from any other objects.

23.  A raindrop has a mass of 5.2×10^{-7} kg and is falling near the surface of the earth. Calculate the magnitude of the gravitational force exerted **(a)** on the raindrop by the earth and **(b)** on the earth by the raindrop.

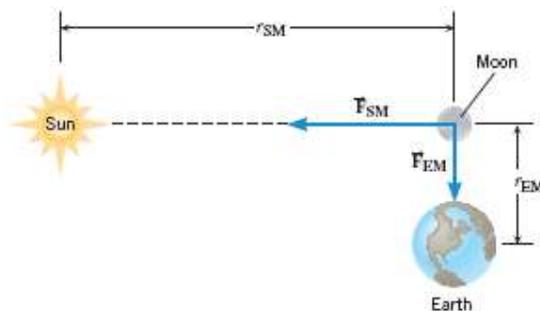
24. The weight of an object is the same on two different planets. The mass of planet A is only sixty percent that of planet B. Find the ratio r_A/r_B of the radii of the planets.

25. ssm A bowling ball (mass = 7.2 kg, radius = 0.11 m) and a billiard ball (mass = 0.38 kg, radius = 0.028 m) may each be treated as uniform spheres. What is the magnitude of the maximum gravitational force that each can exert on the other?

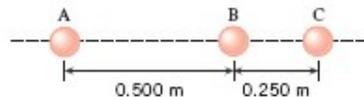
26. Review Conceptual Example 7 in preparation for this problem. In tests on earth a lunar surface exploration vehicle (mass = 5.90×10^3 kg) achieves a forward acceleration of 0.220 m/s². To achieve this same acceleration on the moon, the vehicle's engines must produce a drive force of 1.43×10^3 N. What is the magnitude of the frictional force that acts on the vehicle on the moon?

27. ssm Synchronous communications satellites are placed in a circular orbit that is 3.59×10^7 m above the surface of the earth. What is the magnitude of the acceleration due to gravity at this distance?

28. The drawing (not to scale) shows one alignment of the sun, earth, and moon. The gravitational force \vec{F}_{SM} that the sun exerts on the moon is perpendicular to the force \vec{F}_{EM} that the earth exerts on the moon. The masses are: mass of sun = 1.99×10^{30} kg, mass of earth = 5.98×10^{24} kg, mass of moon = 7.35×10^{22} kg. The distances shown in the drawing are $r_{SM} = 1.50 \times 10^{11}$ m and $r_{EM} = 3.85 \times 10^8$ m. Determine the magnitude of the net gravitational force on the moon.



29. The drawing shows three particles far away from any other objects and located on a straight line. The masses of these particles are $m_A = 363$ kg, $m_B = 517$ kg, and $m_C = 154$ kg. Find the magnitude and direction of the net gravitational force acting on **(a)** particle A, **(b)** particle B, and **(c)** particle C.



30. A space traveler weighs 540.0 N on earth. What will the traveler weigh on another planet whose radius is twice that of earth and whose mass is three times that of earth?

31. ssm The mass of a robot is 5450 kg. This robot weighs 3620 N more on planet A than it does on planet B. Both planets have the same radius of 1.33×10^7 m. What is the difference $M_A - M_B$ in the masses of these planets?

***32.**   A spacecraft is on a journey to the moon. At what point, as measured from the center of the earth, does the gravitational force exerted on the spacecraft by the earth balance that exerted by the moon? This point lies on a line between the centers of the earth and the moon. The distance between the earth and the moon is 3.85×10^8 m, and the mass of the earth is 81.4 times as great as that of the moon.

***33.**   As a moon follows its orbit around a planet, the maximum gravitational force exerted on the moon by the planet exceeds the minimum gravitational force by 11%. Find the ratio r_{\max}/r_{\min} , where r_{\max} is the moon's maximum distance from the center of the planet and r_{\min} is the minimum distance.

***34.**  A neutron star has a mass of 2.0×10^{30} kg (about the mass of our sun) and a radius of 5.0×10^3 m (about the height of a good-sized mountain). Suppose an object falls from rest near the surface of such a star.

How fast would this object be moving after it had fallen a distance of 0.010 m? (Assume that the gravitational force is constant over the distance of the fall and that the star is not rotating.)

***35. ssm** The sun is more massive than the moon, but the sun is farther from the earth. Which one exerts a greater gravitational force on a person standing on the earth? Give your answer by determining the ratio $F_{\text{sun}}/F_{\text{moon}}$ of the magnitudes of the gravitational forces. Use the data on the inside of the front cover.

***36.** At a distance H above the surface of a planet, the true weight of a remote probe is one percent less than its true weight on the surface. The radius of the planet is R . Find the ratio H/R .

****37.** Two particles are located on the x axis. Particle 1 has a mass m and is at the origin. Particle 2 has a mass $2m$ and is at $x = +L$. A third particle is placed between particles 1 and 2. Where on the x axis should the third particle be located so that the magnitude of the gravitational force on *both* particle 1 and particle 2 doubles? Express your answer in terms of L .

Section 4.8 The Normal Force,

Section 4.9 Static and Kinetic Frictional Forces

38. A 35-kg crate rests on a horizontal floor, and a 65-kg person is standing on the crate. Determine the magnitude of the normal force that (a) the floor exerts on the crate and (b) the crate exerts on the person.

39. ssm A 60.0-kg crate rests on a level floor at a shipping dock. The coefficients of static and kinetic friction are 0.760 and 0.410, respectively. What horizontal pushing force is required to (a) just start the crate moving and (b) slide the crate across the dock at a constant speed?

40. A rocket blasts off from rest and attains a speed of 45 m/s in 15 s. An astronaut has a mass of 57 kg. What is the astronaut's apparent weight during takeoff?

41. GO A car is traveling up a hill that is inclined at an angle θ above the horizontal. Determine the ratio of the magnitude of the normal force to the weight of the car when (a) $\theta = 15^\circ$ and (b) $\theta = 35^\circ$.

42. A woman stands on a scale in a moving elevator. Her mass is 60.0 kg, and the combined mass of the elevator and scale is an additional 815 kg. Starting from rest, the elevator accelerates upward. During the acceleration, the hoisting cable applies a force of 9410 N. What does the scale read during the acceleration?

43. A Mercedes-Benz 300SL ($m = 1700$ kg) is parked on a road that rises 15° above the horizontal. What are the magnitudes of (a) the normal force and (b) the static frictional force that the ground exerts on the tires?

44. GO Consult Multiple-Concept Example 9 to explore a model for solving this problem. A person pushes on a 57-kg refrigerator with a horizontal force of -267 N; the minus sign indicates that the force points in the $-x$ direction. The coefficient of static friction is 0.65. (a) If the refrigerator does not move, what are the magnitude and direction of the static frictional force that the floor exerts on the refrigerator? (b) What is the magnitude of the largest pushing force that can be applied to the refrigerator before it just begins to move?

45. ssm A 6.00-kg box is sliding across the horizontal floor of an elevator. The coefficient of kinetic friction between the box and the floor is 0.360. Determine the kinetic frictional force that acts on the box when the elevator is (a) stationary, (b) accelerating upward with an acceleration whose magnitude is 1.20 m/s², and (c) accelerating downward with an acceleration whose magnitude is 1.20 m/s².

46. GO A cup of coffee is on a table in an airplane flying at a constant altitude and a constant velocity. The coefficient of static friction between the cup and the table is 0.30. Suddenly, the plane accelerates forward, its altitude remaining constant. What is the maximum acceleration that the plane can have without the cup sliding backward on the table?

47. mmh An 81-kg baseball player slides into second base. The coefficient of kinetic friction between the player and the ground is 0.49. (a) What is the magnitude of the frictional force? (b) If the player comes to rest after 1.6 s, what was his initial velocity?

***48. II** Consult Multiple-Concept Example 10 in preparation for this problem. Traveling at a speed of 16.1 m/s, the driver of an automobile suddenly locks the wheels by slamming on the brakes. The coefficient of kinetic friction between the tires and the road is 0.720. What is the speed of the automobile after 1.30 s have elapsed? Ignore the effects of air resistance.

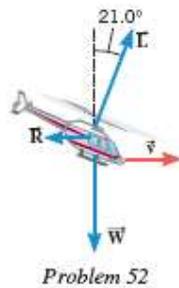
***49. ssm** A person is trying to judge whether a picture (mass = 1.10 kg) is properly positioned by temporarily pressing it against a wall. The pressing force is perpendicular to the wall. The coefficient of static friction between the picture and the wall is 0.660. What is the minimum amount of pressing force that must be used?

***50.**  Air rushing over the wings of high-performance race cars generates unwanted horizontal air resistance but also causes a vertical *downforce*, which helps the cars hug the track more securely. The coefficient of static friction between the track and the tires of a 690-kg race car is 0.87. What is the magnitude of the maximum acceleration at which the car can speed up without its tires slipping when a 4060-N downforce and an 1190-N horizontal-air-resistance force act on it?

****51.** While moving in, a new homeowner is pushing a box across the floor at a constant velocity. The coefficient of kinetic friction between the box and the floor is 0.41. The pushing force is directed downward at an angle θ below the horizontal. When θ is greater than a certain value, it is not possible to move the box, no matter how large the pushing force is. Find that value of θ .

Section 4.10 The Tension Force, Section 4.11 Equilibrium Applications of Newton's Laws of Motion

52. mmh The helicopter in the drawing is moving horizontally to the right at a constant velocity \vec{v} . The weight of the helicopter is $W = 53\,800\text{ N}$. The lift force \vec{L} generated by the rotating blade makes an angle of 21.0° with respect to the vertical. **(a)** What is the magnitude of the lift force? **(b)** Determine the magnitude of the air resistance \vec{R} that opposes the motion.

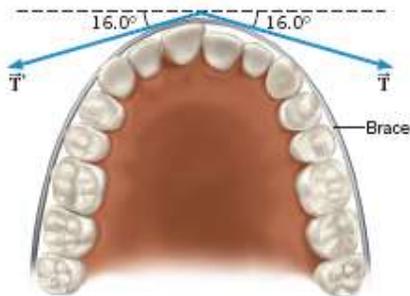


53. ssm Three forces act on a moving object. One force has a magnitude of 80.0 N and is directed due north. Another has a magnitude of 60.0 N and is directed due west. What must be the magnitude and direction of the third force, such that the object continues to move with a constant velocity?

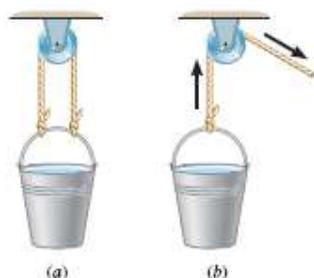
54. The steel I-beam in the drawing has a weight of 8.00 kN and is being lifted at a constant velocity. What is the tension in each cable attached to its ends?



55.  The drawing shows a wire tooth brace used by orthodontists. The topmost tooth is protruding slightly, and the tension in the wire exerts two forces \vec{T} and \vec{T}' on this tooth in order to bring it back into alignment. If the forces have the same magnitude of 21.0 N, what is the magnitude of the net force exerted on the tooth by these forces?



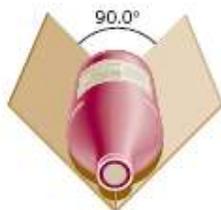
56. Part *a* of the drawing shows a bucket of water suspended from the pulley of a well; the tension in the rope is 92.0 N. Part *b* shows the same bucket of water being pulled up from the well at a constant velocity. What is the tension in the rope in part *b*?



57. **ssm** A worker stands still on a roof sloped at an angle of 36° above the horizontal. He is prevented from slipping by a static frictional force of 390 N. Find the mass of the worker.

58. A stuntman is being pulled along a rough road at a constant velocity by a cable attached to a moving truck. The cable is parallel to the ground. The mass of the stuntman is 109 kg, and the coefficient of kinetic friction between the road and him is 0.870. Find the tension in the cable.

59. **go** A 1.40-kg bottle of vintage wine is lying horizontally in a rack, as shown in the drawing. The two surfaces on which the bottle rests are 90.0° apart, and the right surface makes an angle of 45.0° with respect to the horizontal. Each surface exerts a force on the bottle that is perpendicular to the surface. Both forces have the same magnitude F . Find the value of F .

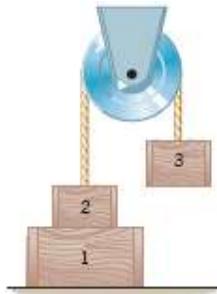


60. **go** The drawing shows a circus clown who weighs 890 N. The coefficient of static friction between the clown's feet and the ground is 0.53. He pulls vertically downward on a rope that passes around three pulleys and is tied around his feet. What is the minimum pulling force that the clown must exert to yank his feet out from under himself?



*61. **go** The drawing shows box 1 resting on a table, with box 2 resting on top of box 1. A massless rope passes over a massless, frictionless pulley. One end of the rope is connected to box 2, and the other end is connected to box 3. The weights of the three boxes are $W_1 = 55$ N, $W_2 = 35$ N, and $W_3 = 28$ N. Determine the

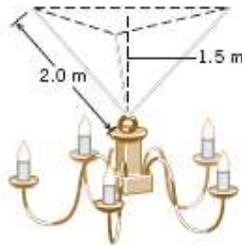
magnitude of the normal force that the table exerts on box 1.



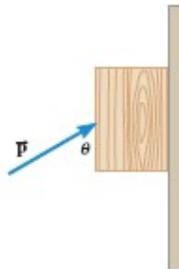
Problem 61

*62.   During a storm, a tree limb breaks off and comes to rest across a barbed wire fence at a point that is not in the middle between two fence posts. The limb exerts a downward force of 151 N on the wire. The left section of the wire makes an angle of 14.0° relative to the horizontal and sustains a tension of 447 N. Find the magnitude and direction of the tension that the right section of the wire sustains.

*63.  A 44-kg chandelier is suspended 1.5 m below a ceiling by three wires, each of which has the same tension and the same length of 2.0 m (see the drawing). Find the tension in each wire.



*64.  A block is pressed against a vertical wall by a force \vec{P} , as the drawing shows. This force can either push the block upward at a constant velocity or allow it to slide downward at a constant velocity. The magnitude of the force is different in the two cases, while the directional angle θ is the same. Kinetic friction exists between the block and the wall, and the coefficient of kinetic friction is 0.250. The weight of the block is 39.0 N, and the directional angle for the force \vec{P} is $\theta = 30.0^\circ$. Determine the magnitude of \vec{P} when the block slides (a) up the wall and (b) down the wall.



*65.   A toboggan slides down a hill and has a constant velocity. The angle of the hill is 8.00° with respect to the horizontal. What is the coefficient of kinetic friction between the surface of the hill and the toboggan?

*66.   The person in the drawing is standing on crutches. Assume that the force exerted on each crutch by the ground is directed along the crutch, as the force vectors in the drawing indicate. If the coefficient of static friction between a crutch and the ground is 0.90, determine the largest angle θ^{MAX} that the crutch can have just before it slips on the floor.



Problem 66

****67. ssm** A bicyclist is coasting straight down a hill at a constant speed. The combined mass of the rider and bicycle is 80.0 kg, and the hill is inclined at 15.0° with respect to the horizontal. Air resistance opposes the motion of the cyclist. Later, the bicyclist climbs the same hill at the same constant speed. How much force (directed parallel to the hill) must be applied to the bicycle in order for the bicyclist to climb the hill?

****68. mmh** A kite is hovering over the ground at the end of a straight 43-m line. The tension in the line has a magnitude of 16 N. Wind blowing on the kite exerts a force of 19 N, directed 56° above the horizontal. Note that the line attached to the kite is *not* oriented at an angle of 56° above the horizontal. Find the height of the kite, relative to the person holding the line.

****69.** A damp washcloth is hung over the edge of a table to dry. Thus, part (mass = m_{on}) of the washcloth rests on the table and part (mass = m_{off}) does not. The coefficient of static friction between the table and the washcloth is 0.40. Determine the maximum fraction $[m_{\text{off}}/(m_{\text{on}} + m_{\text{off}})]$ that can hang over the edge without causing the whole washcloth to slide off the table.

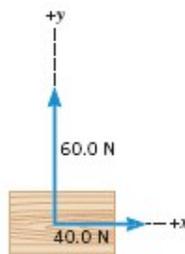
Section 4.12 Nonequilibrium Applications of Newton's Laws of Motion

70. A 1450-kg submarine rises straight up toward the surface. Seawater exerts both an upward buoyant force of 16 140 N on the submarine and a downward resistive force of 1030 N. What is the submarine's acceleration?

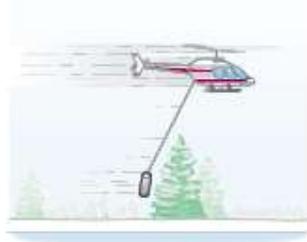
71. ssm A 15-g bullet is fired from a rifle. It takes 2.50×10^{-3} s for the bullet to travel the length of the barrel, and it exits the barrel with a speed of 715 m/s. Assuming that the acceleration of the bullet is constant, find the average net force exerted on the bullet.

72. A fisherman is fishing from a bridge and is using a "45-N test line." In other words, the line will sustain a maximum force of 45 N without breaking. What is the weight of the heaviest fish that can be pulled up vertically when the line is reeled in (a) at a constant speed and (b) with an acceleration whose magnitude is 2.0 m/s^2 ?

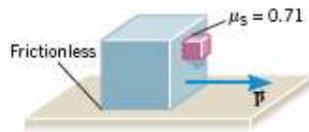
73. ssm Only two forces act on an object (mass = 4.00 kg), as in the drawing. Find the magnitude and direction (relative to the x axis) of the acceleration of the object.



74. A helicopter flies over the arctic ice pack at a constant altitude, towing an airborne 129-kg laser sensor that measures the thickness of the ice (see the drawing). The helicopter and the sensor both move only in the horizontal direction and have a horizontal acceleration of magnitude 2.84 m/s^2 . Ignoring air resistance, find the tension in the cable towing the sensor.

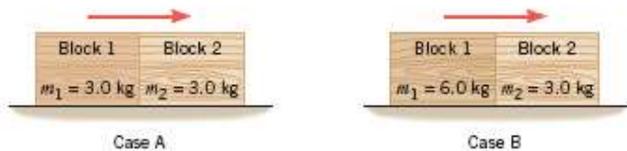


75. Review Conceptual Example 16 as background for this problem. The water skier there has a mass of 73 kg. Find the magnitude of the net force acting on the skier when (a) she is accelerated from rest to a speed of 11 m/s in 8.0 s and (b) she lets go of the tow rope and glides to a halt in 21 s.
76. A rescue helicopter is lifting a man (weight = 822 N) from a capsized boat by means of a cable and harness. (a) What is the tension in the cable when the man is given an initial upward acceleration of 1.10 m/s^2 ? (b) What is the tension during the remainder of the rescue when he is pulled upward at a constant velocity?
77. A car is towing a boat on a trailer. The driver starts from rest and accelerates to a velocity of $+11 \text{ m/s}$ in a time of 28 s. The combined mass of the boat and trailer is 410 kg. The frictional force acting on the trailer can be ignored. What is the tension in the hitch that connects the trailer to the car?
78. **GO** A 292-kg motorcycle is accelerating up along a ramp that is inclined 30.0° above the horizontal. The propulsion force pushing the motorcycle up the ramp is 3150 N, and air resistance produces a force of 250 N that opposes the motion. Find the magnitude of the motorcycle's acceleration.
79. **ssm** A student is skateboarding down a ramp that is 6.0 m long and inclined at 18° with respect to the horizontal. The initial speed of the skateboarder at the top of the ramp is 2.6 m/s. Neglect friction and find the speed at the bottom of the ramp.
80. A man seeking to set a world record wants to tow a 109 000-kg airplane along a runway by pulling horizontally on a cable attached to the airplane. The mass of the man is 85 kg, and the coefficient of static friction between his shoes and the runway is 0.77. What is the greatest acceleration the man can give the airplane? Assume that the airplane is on wheels that turn without any frictional resistance.
- *81. **GO** A 205-kg log is pulled up a ramp by means of a rope that is parallel to the surface of the ramp. The ramp is inclined at 30.0° with respect to the horizontal. The coefficient of kinetic friction between the log and the ramp is 0.900, and the log has an acceleration of magnitude 0.800 m/s^2 . Find the tension in the rope.
- *82. **GO** To hoist himself into a tree, a 72.0-kg man ties one end of a nylon rope around his waist and throws the other end over a branch of the tree. He then pulls downward on the free end of the rope with a force of 358 N. Neglect any friction between the rope and the branch, and determine the man's upward acceleration.
- *83. **GO** **ssm** Two objects (45.0 and 21.0 kg) are connected by a massless string that passes over a massless, frictionless pulley. The pulley hangs from the ceiling. Find (a) the acceleration of the objects and (b) the tension in the string.
- *84. **GO** A train consists of 50 cars, each of which has a mass of $6.8 \times 10^3 \text{ kg}$. The train has an acceleration of $+8.0 \times 10^{-2} \text{ m/s}^2$. Ignore friction and determine the tension in the coupling (a) between the 30th and 31st cars and (b) between the 49th and 50th cars.
- *85. In Problem 80, an 85-kg man plans to tow a 109 000-kg airplane along a runway by pulling horizontally on a cable attached to it. Suppose that he instead attempts the feat by pulling the cable at an angle of 9.0° above the horizontal. The coefficient of static friction between his shoes and the runway is 0.77. What is the greatest acceleration the man can give the airplane? Assume that the airplane is on wheels that turn without any frictional resistance.
- *86. **mmh** The drawing shows a large cube (mass = 25 kg) being accelerated across a horizontal frictionless surface by a horizontal force \vec{P} . A small cube (mass = 4.0 kg) is in contact with the front surface of the large cube and will slide downward unless \vec{P} is sufficiently large. The coefficient of static friction between the cubes is 0.71. What is the smallest magnitude that \vec{P} can have in order to keep the small cube from sliding downward?



***87.** The alarm at a fire station rings and an 86-kg fireman, starting from rest, slides down a pole to the floor below (a distance of 4.0 m). Just before landing, his speed is 1.4 m/s. What is the magnitude of the kinetic frictional force exerted on the fireman as he slides down the pole?

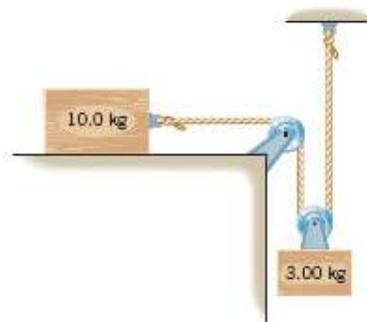
***88.** Two blocks are sliding to the right across a horizontal surface, as the drawing shows. In Case A the mass of each block is 3.0 kg. In Case B the mass of block 1 (the block behind) is 6.0 kg, and the mass of block 2 is 3.0 kg. No frictional force acts on block 1 in either Case A or Case B. However, a kinetic frictional force of 5.8 N does act on block 2 in both cases and opposes the motion. For both Case A and Case B determine (a) the magnitude of the forces with which the blocks push against each other and (b) the magnitude of the acceleration of the blocks.



***89. ssm** A person whose weight is 5.20×10^2 N is being pulled up vertically by a rope from the bottom of a cave that is 35.1 m deep. The maximum tension that the rope can withstand without breaking is 569 N. What is the shortest time, starting from rest, in which the person can be brought out of the cave?

***90.** A girl is sledding down a slope that is inclined at 30.0° with respect to the horizontal. The wind is aiding the motion by providing a steady force of 105 N that is parallel to the motion of the sled. The combined mass of the girl and the sled is 65.0 kg, and the coefficient of kinetic friction between the snow and the runners of the sled is 0.150. How much time is required for the sled to travel down a 175-m slope, starting from rest?

****91.** In the drawing, the rope and the pulleys are massless, and there is no friction. Find (a) the tension in the rope and (b) the acceleration of the 10.0-kg block. (Hint: The larger mass moves twice as far as the smaller mass.)



****92.** A small sphere is hung by a string from the ceiling of a van. When the van is stationary, the sphere hangs vertically. However, when the van accelerates, the sphere swings backward so that the string makes an angle of θ with respect to the vertical. (a) Derive an expression for the magnitude a of the acceleration of the van in terms of the angle θ and the magnitude g of the acceleration due to gravity. (b) Find the acceleration of the van when $\theta = 10.0^\circ$. (c) What is the angle θ when the van moves with a constant velocity?

****93. ssm** A penguin slides at a constant velocity of 1.4 m/s down an icy incline. The incline slopes above the horizontal at an angle of 6.9° . At the bottom of the incline, the penguin slides onto a horizontal patch of ice. The coefficient of kinetic friction between the penguin and the ice is the same for the incline as for the horizontal patch. How much time is required for the penguin to slide to a halt after entering the horizontal patch of ice?

****94.** A 5.00-kg block is placed on top of a 12.0-kg block that rests on a frictionless table. The coefficient of static friction between the two blocks is 0.600. What is the maximum horizontal force that can be applied before the 5.00-kg block begins to slip relative to the 12.0-kg block, if the force is applied to (a) the more

massive block and **(b)** the less massive block?

ADDITIONAL PROBLEMS

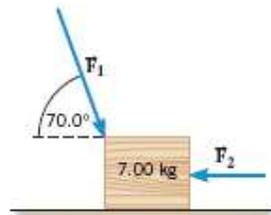
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95. ssm A 55-kg bungee jumper has fallen far enough that her bungee cord is beginning to stretch and resist her downward motion. Find the force (magnitude and direction) exerted on her by the bungee cord at an instant when her downward acceleration has a magnitude of 7.6 m/s^2 . Ignore the effects of air resistance.

96. GO A person with a black belt in karate has a fist that has a mass of 0.70 kg. Starting from rest, this fist attains a velocity of 8.0 m/s in 0.15 s. What is the magnitude of the average net force applied to the fist to achieve this level of performance?

97. ssm A 95.0-kg person stands on a scale in an elevator. What is the apparent weight when the elevator is **(a)** accelerating upward with an acceleration of 1.80 m/s^2 , **(b)** moving upward at a constant speed, and **(c)** accelerating downward with an acceleration of 1.30 m/s^2 ?

98. mmh Two forces, \vec{F}_1 and \vec{F}_2 , act on the 7.00-kg block shown in the drawing. The magnitudes of the forces are $F_1 = 59.0 \text{ N}$ and $F_2 = 33.0 \text{ N}$. What is the horizontal acceleration (magnitude and direction) of the block?



Problem 98

99. ssm A student presses a book between his hands, as the drawing indicates. The forces that he exerts on the front and back covers of the book are perpendicular to the book and are horizontal. The book weighs 31 N. The coefficient of static friction between his hands and the book is 0.40. To keep the book from falling, what is the magnitude of the minimum pressing force that each hand must exert?



100. mmh The speed of a bobsled is increasing because it has an acceleration of 2.4 m/s^2 . At a given instant in time, the forces resisting the motion, including kinetic friction and air resistance, total 450 N. The combined mass of the bobsled and its riders is 270 kg. **(a)** What is the magnitude of the force propelling the bobsled forward? **(b)** What is the magnitude of the net force that acts on the bobsled?

101. A 1.14×10^4 -kg lunar landing craft is about to touch down on the surface of the moon, where the acceleration due to gravity is 1.60 m/s^2 . At an altitude of 165 m the craft's downward velocity is 18.0 m/s. To slow down the craft, a retrorocket is firing to provide an upward thrust. Assuming the descent is vertical, find the magnitude of the thrust needed to reduce the velocity to zero at the instant when the craft touches the lunar surface.

102. In a European country a bathroom scale displays its reading in kilograms. When a man stands on this scale, it reads 92.6 kg. When he pulls down on a chin-up bar installed over the scale, the reading decreases to 75.1 kg. What is the magnitude of the force he exerts on the chin-up bar?

103. ssm A 1380-kg car is moving due east with an initial speed of 27.0 m/s. After 8.00 s the car has slowed down to 17.0 m/s. Find the magnitude and direction of the net force that produces the deceleration.

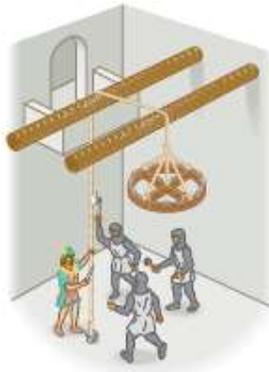
104. When a 58-g tennis ball is served, it accelerates from rest to a speed of 45 m/s. The impact with the racket gives the ball a constant acceleration over a distance of 44 cm. What is the magnitude of the net force acting on the ball?

105. In preparation for this problem, review Conceptual Example 7. A space traveler whose mass is 115 kg

leaves earth. What are his weight and mass **(a)** on earth and **(b)** in interplanetary space where there are no nearby planetary objects?

106. (a) Calculate the magnitude of the gravitational force exerted on a 425-kg satellite that is a distance of two earth radii from the center of the earth. **(b)** What is the magnitude of the gravitational force exerted on the earth by the satellite? **(c)** Determine the magnitude of the satellite's acceleration. **(d)** What is the magnitude of the earth's acceleration?

***107. ssm mmh** The drawing shows Robin Hood (mass = 77.0 kg) about to escape from a dangerous situation. With one hand, he is gripping the rope that holds up a chandelier (mass = 195 kg). When he cuts the rope where it is tied to the floor, the chandelier will fall, and he will be pulled up toward a balcony above. Ignore the friction between the rope and the beams over which it slides, and find **(a)** the acceleration with which Robin is pulled upward and **(b)** the tension in the rope while Robin escapes.



Problem 107

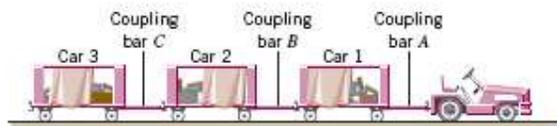
***108. GO** A skater with an initial speed of 7.60 m/s stops propelling himself and begins to coast across the ice, eventually coming to rest. Air resistance is negligible. **(a)** The coefficient of kinetic friction between the ice and the skate blades is 0.100. Find the deceleration caused by kinetic friction. **(b)** How far will the skater travel before coming to rest?

***109. PII** The central ideas in this problem are reviewed in Multiple-Concept Example 9. One block rests upon a horizontal surface. A second identical block rests upon the first one. The coefficient of static friction between the blocks is the same as the coefficient of static friction between the lower block and the horizontal surface. A horizontal force is applied to the upper block, and the magnitude of the force is slowly increased. When the force reaches 47.0 N, the upper block just begins to slide. The force is then removed from the upper block, and the blocks are returned to their original configuration. What is the magnitude of the horizontal force that should be applied to the lower block so that it just begins to slide out from under the upper block?

***110. GO** A mountain climber, in the process of crossing between two cliffs by a rope, pauses to rest. She weighs 535 N. As the drawing shows, she is closer to the left cliff than to the right cliff, with the result that the tensions in the left and right sides of the rope are not the same. Find the tensions in the rope to the left and to the right of the mountain climber.



***111. ssm** At an airport, luggage is unloaded from a plane into the three cars of a luggage carrier, as the drawing shows. The acceleration of the carrier is 0.12 m/s^2 , and friction is negligible. The coupling bars have negligible mass. By how much would the tension in *each* of the coupling bars *A*, *B*, and *C* change if 39 kg of luggage were removed from car 2 and placed in **(a)** car 1 and **(b)** car 3? If the tension changes, specify whether it increases or decreases.



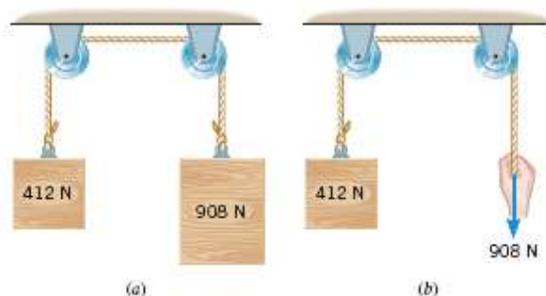
***112.** Consult Multiple-Concept Example 10 for insight into solving this type of problem. A box is sliding up an incline that makes an angle of 15.0° with respect to the horizontal. The coefficient of kinetic friction between the box and the surface of the incline is 0.180. The initial speed of the box at the bottom of the incline is 1.50 m/s. How far does the box travel along the incline before coming to rest?

***113.** A duck has a mass of 2.5 kg. As the duck paddles, a force of 0.10 N acts on it in a direction due east. In addition, the current of the water exerts a force of 0.20 N in a direction of 52° south of east. When these forces begin to act, the velocity of the duck is 0.11 m/s in a direction due east. Find the magnitude and direction (relative to due east) of the displacement that the duck undergoes in 3.0 s while the forces are acting.

***114.** Three uniform spheres are located at the corners of an equilateral triangle. Each side of the triangle has a length of 1.20 m. Two of the spheres have a mass of 2.80 kg each. The third sphere (mass unknown) is released from rest. Considering only the gravitational forces that the spheres exert on each other, what is the magnitude of the initial acceleration of the third sphere?

***115. ssm** Refer to Multiple-Concept Example 10 for help in solving problems like this one. An ice skater is gliding horizontally across the ice with an initial velocity of $+6.3$ m/s. The coefficient of kinetic friction between the ice and the skate blades is 0.081, and air resistance is negligible. How much time elapses before her velocity is reduced to $+2.8$ m/s?

****116.** As part *a* of the drawing shows, two blocks are connected by a rope that passes over a set of pulleys. One block has a weight of 412 N, and the other has a weight of 908 N. The rope and the pulleys are massless and there is no friction. **(a)** What is the acceleration of the lighter block? **(b)** Suppose that the heavier block is removed, and a downward force of 908 N is provided by someone pulling on the rope, as part *b* of the drawing shows. Find the acceleration of the remaining block. **(c)** Explain why the answers in (a) and (b) are different.

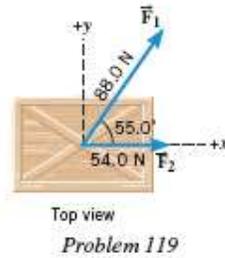


****117. ssm** The three objects in the drawing are connected by strings that pass over massless and friction-free pulleys. The objects move, and the coefficient of kinetic friction between the middle object and the surface of the table is 0.100. **(a)** What is the acceleration of the three objects? **(b)** Find the tension in each of the two strings.

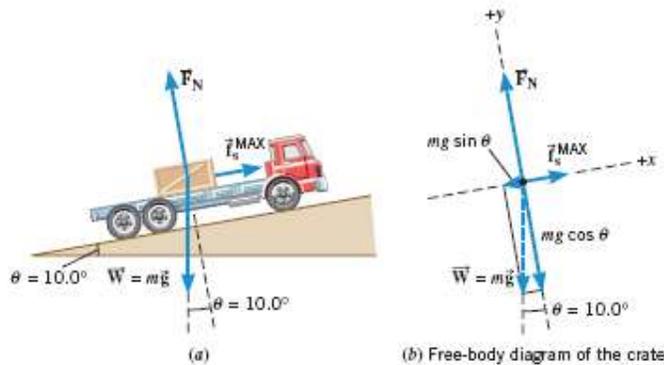


****118.** The basic concepts in this problem are presented in Multiple-Concept Example 9. A 225-kg crate rests on a surface that is inclined above the horizontal at an angle of 20.0° . A horizontal force (magnitude = 535 N and parallel to the ground, not the incline) is required to start the crate moving down the incline. What is the coefficient of static friction between the crate and the incline?

****119.** The drawing shows a 25.0-kg crate that is initially at rest. Note that the view is one looking down on the top of the crate. Two forces, \vec{F}_1 and \vec{F}_2 , are applied to the crate, and it begins to move. The coefficient of kinetic friction between the crate and the floor is $\mu_k = 0.350$. Determine the magnitude and direction (relative to the x axis) of the acceleration of the crate.



***120.** A flatbed truck is carrying a crate up a hill of angle of inclination $\theta = 10.0^\circ$, as the figure illustrates. The coefficient of static friction between the truck bed and the crate is $\mu_s = 0.350$. Find the maximum acceleration that the truck can attain before the crate begins to slip backward relative to the truck.



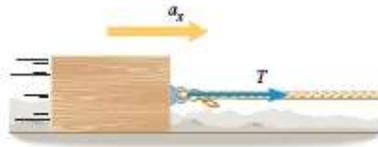
CONCEPTS AND CALCULATIONS PROBLEMS

Newton's three laws of motion provide the basis for understanding the effect of forces on the motion of an object. The second law is especially important, because it provides the quantitative relationship between net force and acceleration. The following problems serve as a review of the essential features of this relationship.

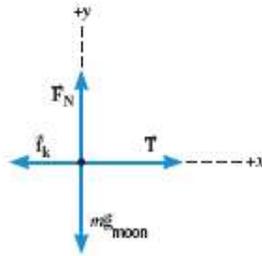
***121.** The figure shows two forces, $\vec{F}_1 = +3000\text{ N}$ and $\vec{F}_2 = +5000\text{ N}$ acting on a spacecraft; the plus signs indicate that the forces are directed along the $+x$ axis. A third force \vec{F}_3 also acts on the spacecraft but is not shown in the drawing. *Concepts:* (i) Suppose the spacecraft were stationary. What would be the direction of \vec{F}_3 ? (ii) When the spacecraft is moving at a constant velocity of $+850\text{ m/s}$, what is the direction of \vec{F}_3 ? *Calculations:* Find the direction and magnitude of \vec{F}_3 .



***122.** On earth a block has a weight of 88 N. This block is sliding on a horizontal surface on the moon, where the acceleration due to gravity is 1.60 m/s^2 . As the figure shows, the block is being pulled by a horizontal rope in which the tension is $T = 24\text{ N}$. The coefficient of kinetic friction between the block and the surface is $\mu_k = 0.20$. *Concepts:* (i) Which of Newton's laws of motion provides the best way to determine the acceleration of the block? (ii) Does the net force in the x direction equal the tension T ? *Calculations:* Determine the acceleration of the block.



(a)



(b) Free-body diagram for the block