

4-9 Problem Solving—A General Approach

A basic part of a physics course is solving problems effectively. The approach discussed here, though emphasizing Newton's laws, can be applied generally for other topics discussed throughout this book.

PROBLEM SOLVING In General

- 1. Read** and reread written problems carefully. A common error is to skip a word or two when reading, which can completely change the meaning of a problem.
- 2. Draw** an accurate picture or diagram of the situation. (This is probably the most overlooked, yet most crucial, part of solving a problem.) Use arrows to represent vectors such as velocity or force, and label the vectors with appropriate symbols. When dealing with forces and applying Newton's laws, make sure to include all forces on a given object, including unknown ones, and make clear what forces act on what object (otherwise you may make an error in determining the *net force* on a particular object). A separate **free-body diagram** needs to be drawn for each object involved, and it must show *all* the forces acting on a given object (and only on that object). Do not show forces that act on other objects.
- 3.** Choose a convenient *xy* **coordinate system** (one that makes your calculations easier, such as one axis in the direction of the acceleration). Vectors are to be resolved into components along the coordinate axes. When using Newton's second law, apply $\Sigma \vec{F} = m\vec{a}$ separately to *x* and *y* components, remembering that *x* direction forces are related to a_x , and similarly for *y*. If more than one object is involved, you can choose different (convenient) coordinate systems for each.
- 4.** List the knowns and the unknowns (what you are trying to determine), and decide what you need in order to find the unknowns. For problems in the present Chapter, we use Newton's laws. More generally, it may help to see if one or more **relationships** (or **equations**) relate the unknowns to the knowns. But be sure each relationship is applicable in the given case. It is very important to know the limitations of each formula or relationship—when it is valid and when not. In this book, the more general equations have been given numbers, but even these can have a limited range of validity (often stated in brackets to the right of the equation).
- 5.** Try to solve the problem approximately, to see if it is doable (to check if enough information has been given) and reasonable. Use your intuition, and make **rough calculations**—see “Order of Magnitude Estimating” in Section 1-7. A rough calculation, or a reasonable guess about what the range of final answers might be, is very useful. And a rough calculation can be checked against the final answer to catch errors in calculation, such as in a decimal point or the powers of 10.
- 6. Solve** the problem, which may include algebraic manipulation of equations and/or numerical calculations. Recall the mathematical rule that you need as many independent equations as you have unknowns; if you have three unknowns, for example, then you need three independent equations. It is usually best to work out the algebra symbolically before putting in the numbers. Why? Because (a) you can then solve a whole class of similar problems with different numerical values; (b) you can check your result for cases already understood (say, $\theta = 0^\circ$ or 90°); (c) there may be cancellations or other simplifications; (d) there is usually less chance for numerical error; and (e) you may gain better insight into the problem.
- 7.** Be sure to keep track of **units**, for they can serve as a check (they must balance on both sides of any equation).
- 8.** Again consider if your answer is **reasonable**. The use of dimensional analysis, described in Section 1-8, can also serve as a check for many problems.

Summary

Newton's three laws of motion are the basic classical laws describing motion.

Newton's first law (the **law of inertia**) states that if the net force on an object is zero, an object originally at rest remains at rest, and an object in motion remains in motion in a straight line with constant velocity.

Newton's second law states that the acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass:

$$\Sigma \vec{F} = m\vec{a}. \quad (4-1)$$

Newton's second law is one of the most important and fundamental laws in classical physics.

Newton's third law states that whenever one object exerts a force on a second object, the second object always exerts a force on the first object which is equal in magnitude but opposite in direction:

$$\vec{F}_{AB} = -\vec{F}_{BA} \quad (4-2)$$

where \vec{F}_{BA} is the force on object B exerted by object A.

The tendency of an object to resist a change in its motion is called **inertia**. **Mass** is a measure of the inertia of an object.

Weight refers to the **gravitational force** on an object, and is equal to the product of the object's mass m and the acceleration of gravity \vec{g} :

$$\vec{F}_G = m\vec{g}. \quad (4-3)$$

Force, which is a vector, can be considered as a push or pull; or, from Newton's second law, force can be defined as an

action capable of giving rise to acceleration. The **net force** on an object is the vector sum of all forces acting on it.

When two objects slide over one another, the force of friction that each object exerts on the other can be written approximately as $F_{fr} = \mu_k F_N$, where F_N is the **normal force** (the force each object exerts on the other perpendicular to their contact surfaces), and μ_k is the coefficient of **kinetic friction**. If the objects are at rest relative to each other, then F_{fr} is just large enough to hold them at rest and satisfies the inequality $F_{fr} < \mu_s F_N$, where μ_s is the coefficient of **static friction**.

For solving problems involving the forces on one or more objects, it is essential to draw a **free-body diagram** for each object, showing all the forces acting on only that object. Newton's second law can be applied to the vector components for each object.

Questions

- Why does a child in a wagon seem to fall backward when you give the wagon a sharp pull forward?
- A box rests on the (frictionless) bed of a truck. The truck driver starts the truck and accelerates forward. The box immediately starts to slide toward the rear of the truck bed. Discuss the motion of the box, in terms of Newton's laws, as seen (a) by Mary standing on the ground beside the truck, and (b) by Chris who is riding on the truck (Fig. 4-35).

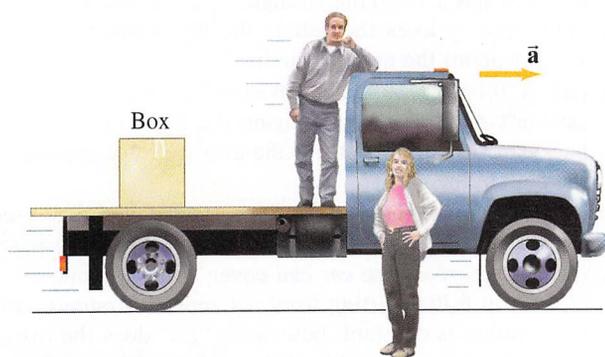


FIGURE 4-35 Question 2.

- A stone hangs by a fine thread from the ceiling, and a section of the same thread dangles from the bottom of the stone (Fig. 4-36). If a person gives a sharp pull on the dangling thread, where is the thread likely to break: below the stone or above it? What if the person gives a slow and steady pull? Explain your answers.

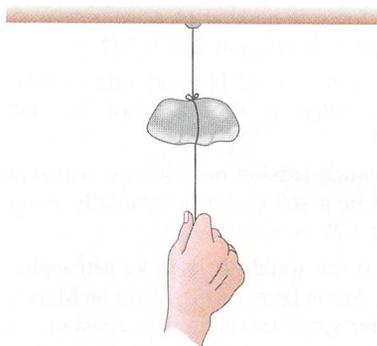


FIGURE 4-36 Question 9.

- If the acceleration of an object is zero, are no forces acting on it? Explain.
- Only one force acts on an object. Can the object have zero acceleration? Can it have zero velocity? Explain.
- When a golf ball is dropped to the pavement, it bounces back up. (a) Is a force needed to make it bounce back up? (b) If so, what exerts the force?
- If you walk along a log floating on a lake, why does the log move in the opposite direction?
- Why might your foot hurt if you kick a heavy desk or a wall?
- When you are running and want to stop quickly, you must decelerate quickly. (a) What is the origin of the force that causes you to stop? (b) Estimate (using your own experience) the maximum rate of deceleration of a person running at top speed to come to rest.
- The force of gravity on a 2-kg rock is twice as great as that on a 1-kg rock. Why then doesn't the heavier rock fall faster?
- Would a spring scale carried to the Moon give accurate results if the scale had been calibrated (a) in pounds, or (b) in kilograms?
- You pull a box with a constant force across a frictionless table using an attached rope held horizontally. If you now pull the rope with the same force at an angle to the horizontal (with the box remaining flat on the table), does the acceleration of the box (a) remain the same, (b) increase, or (c) decrease? Explain.
- When an object falls freely under the influence of gravity there is a net force mg exerted on it by the Earth. Yet by Newton's third law the object exerts an equal and opposite force on the Earth. Why doesn't the Earth move?
- Compare the effort (or force) needed to lift a 10-kg object when you are on the Moon with the force needed to lift it on Earth. Compare the force needed to throw a 2-kg object horizontally with a given speed on the Moon and on Earth.

15. According to Newton's third law, each team in a tug of war (Fig. 4–37) pulls with equal force on the other team. What, then, determines which team will win?



FIGURE 4–37 Question 15. A tug of war. Describe the forces on each of the teams and on the rope.

16. A person exerts an upward force of 40 N to hold a bag of groceries. Describe the “reaction” force (Newton's third law) by stating (a) its magnitude, (b) its direction, (c) on what object it is exerted, and (d) by what object it is exerted.

17. When you stand still on the ground, how large a force does the ground exert on you? Why doesn't this force make you rise up into the air?
18. Whiplash sometimes results from an automobile accident when the victim's car is struck violently from the rear. Explain why the head of the victim seems to be thrown backward in this situation. Is it really?
19. A heavy crate rests on the bed of a flatbed truck. When the truck accelerates, the crate remains where it is on the truck, so it, too, accelerates. What force causes the crate to accelerate?
20. A block is given a push so that it slides up a ramp. After the block reaches its highest point, it slides back down but the magnitude of its acceleration is less on the descent than on the ascent. Why?
21. What would your bathroom scale read if you weighed yourself on an inclined plane? Assume the mechanism functions properly, even at an angle.

Problems

4–4 to 4–6 Newton's Laws, Gravitational Force, Normal Force

- (I) What force is needed to accelerate a child on a sled (total mass = 60.0 kg) at 1.25 m/s^2 ?
- (I) A net force of 265 N accelerates a bike and rider at 2.30 m/s^2 . What is the mass of the bike and rider together?
- (I) How much tension must a rope withstand if it is used to accelerate a 960-kg car horizontally along a frictionless surface at 1.20 m/s^2 ?
- (I) What is the weight of a 76-kg astronaut (a) on Earth, (b) on the Moon ($g = 1.7 \text{ m/s}^2$), (c) on Mars ($g = 3.7 \text{ m/s}^2$), (d) in outer space traveling with constant velocity?
- (II) A 20.0-kg box rests on a table. (a) What is the weight of the box and the normal force acting on it? (b) A 10.0-kg box is placed on top of the 20.0-kg box, as shown in Fig. 4–38. Determine the normal force that the table exerts on the 20.0-kg box and the normal force that the 20.0-kg box exerts on the 10.0-kg box.

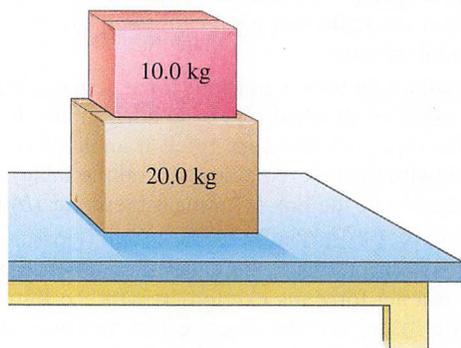


FIGURE 4–38 Problem 5.

- (II) What average force is needed to accelerate a 7.00-gram pellet from rest to 125 m/s over a distance of 0.800 m along the barrel of a rifle?
- (II) A fisherman yanks a fish vertically out of the water with an acceleration of 2.5 m/s^2 using very light fishing line that has a breaking strength of 22 N. The fisherman unfortunately loses the fish as the line snaps. What can you say about the mass of the fish?
- (II) A 0.140-kg baseball traveling 35.0 m/s strikes the catcher's mitt, which, in bringing the ball to rest, recoils backward 11.0 cm. What was the average force applied by the ball on the glove?
- (II) How much tension must a rope withstand if it is used to accelerate a 1200-kg car vertically upward at 0.80 m/s^2 ?
- (II) A particular race car can cover a quarter-mile track (402 m) in 6.40 s starting from a standstill. Assuming the acceleration is constant, how many “g's” does the driver experience? If the combined mass of the driver and race car is 485 kg, what horizontal force must the road exert on the tires?
- (II) A 12.0-kg bucket is lowered vertically by a rope in which there is 163 N of tension at a given instant. What is the acceleration of the bucket? Is it up or down?
- (II) An elevator (mass 4850 kg) is to be designed so that the maximum acceleration is $0.0680g$. What are the maximum and minimum forces the motor should exert on the supporting cable?
- (II) A 75-kg petty thief wants to escape from a third-story jail window. Unfortunately, a makeshift rope made of sheets tied together can support a mass of only 58 kg. How might the thief use this “rope” to escape? Give a quantitative answer.
- (II) A person stands on a bathroom scale in a motionless elevator. When the elevator begins to move, the scale briefly reads only 0.75 of the person's regular weight. Calculate the acceleration of the elevator, and find the direction of acceleration.

16. (II) The cable supporting a 2125-kg elevator has a maximum strength of 21,750 N. What maximum upward acceleration can it give the elevator without breaking?
17. (II) (a) What is the acceleration of two falling sky divers (mass 132 kg including parachute) when the upward force of air resistance is equal to one-fourth of their weight? (b) After popping open the parachute, the divers descend leisurely to the ground at constant speed. What now is the force of air resistance on the sky divers and their parachute? See Fig. 4–39.



FIGURE 4–39 Problem 17.

18. (III) A person jumps from the roof of a house 3.9-m high. When he strikes the ground below, he bends his knees so that his torso decelerates over an approximate distance of 0.70 m. If the mass of his torso (excluding legs) is 42 kg, find (a) his velocity just before his feet strike the ground, and (b) the average force exerted on his torso by his legs during deceleration.

4–7 Newton's Laws and Vectors

19. (I) A box weighing 77.0 N rests on a table. A rope tied to the box runs vertically upward over a pulley and a weight is hung from the other end (Fig. 4–40). Determine the force that the table exerts on the box if the weight hanging on the other side of the pulley weighs (a) 30.0 N, (b) 60.0 N, and (c) 90.0 N.

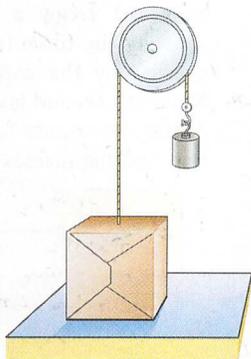


FIGURE 4–40
Problem 19.

20. (I) Draw the free-body diagram for a basketball player (a) just before leaving the ground on a jump, and (b) while in the air. See Fig. 4–41.



FIGURE 4–41
Problem 20.

21. (I) Sketch the free-body diagram of a baseball (a) at the moment it is hit by the bat, and again (b) after it has left the bat and is flying toward the outfield.
22. (I) A 650-N force acts in a northwesterly direction. A second 650-N force must be exerted in what direction so that the resultant of the two forces points westward? Illustrate your answer with a vector diagram.
23. (II) Arlene is to walk across a “high wire” strung horizontally between two buildings 10.0 m apart. The sag in the rope when she is at the midpoint is 10.0°, as shown in Fig. 4–42. If her mass is 50.0 kg, what is the tension in the rope at this point?

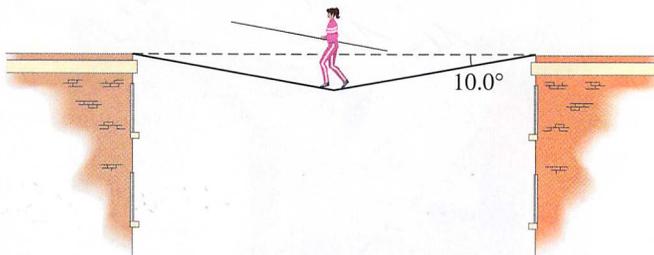


FIGURE 4–42 Problem 23.

24. (II) The two forces \vec{F}_1 and \vec{F}_2 shown in Fig. 4–43a and b (looking down) act on a 27.0-kg object on a frictionless tabletop. If $F_1 = 10.2$ N and $F_2 = 16.0$ N, find the net force on the object and its acceleration for (a) and (b).

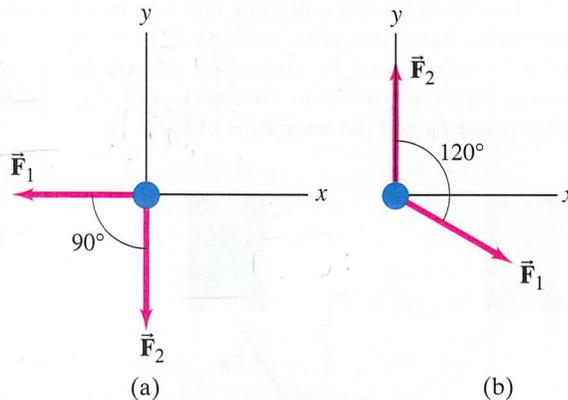


FIGURE 4–43 Problem 24.

25. (II) One 3.2-kg paint bucket is hanging by a massless cord from another 3.2-kg paint bucket, also hanging by a massless cord, as shown in Fig. 4–44. (a) If the buckets are at rest, what is the tension in each cord? (b) If the two buckets are pulled upward with an acceleration of 1.60 m/s^2 by the upper cord, calculate the tension in each cord.

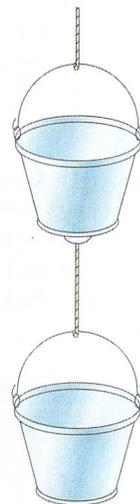


FIGURE 4–44
Problem 25.

26. (II) A person pushes a 14.0-kg lawn mower at constant speed with a force of $F = 88.0\text{ N}$ directed along the handle, which is at an angle of 45.0° to the horizontal (Fig. 4-45). (a) Draw the free-body diagram showing all forces acting on the mower. Calculate (b) the horizontal friction force on the mower, then (c) the normal force exerted vertically upward on the mower by the ground. (d) What force must the person exert on the lawn mower to accelerate it from rest to 1.5 m/s in 2.5 seconds, assuming the same friction force?

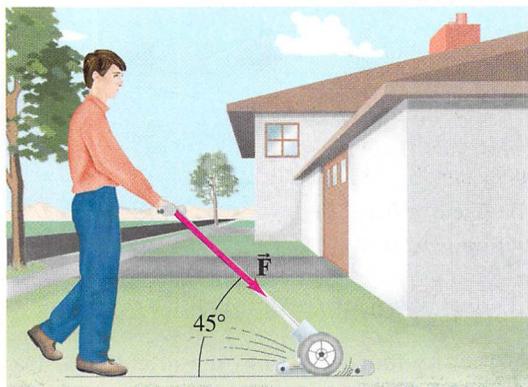


FIGURE 4-45 Problem 26.

27. (II) Two snowcats tow a housing unit to a new location at McMurdo Base, Antarctica, as shown in Fig. 4-46. The sum of the forces \vec{F}_A and \vec{F}_B exerted on the unit by the horizontal cables is parallel to the line L , and $F_A = 4500\text{ N}$. Determine F_B and the magnitude of $\vec{F}_A + \vec{F}_B$.

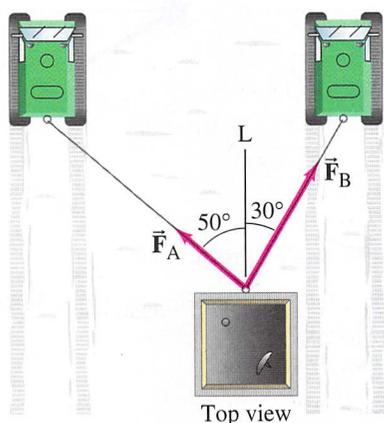


FIGURE 4-46 Problem 27.

28. (II) A train locomotive is pulling two cars of the same mass behind it, Fig. 4-47. Determine the ratio of the tension in the coupling between the locomotive and the first car (F_{T1}), to that between the first car and the second car (F_{T2}), for any nonzero acceleration of the train.

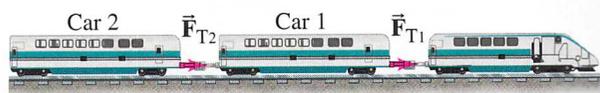


FIGURE 4-47 Problem 28.

29. (II) A window washer pulls herself upward using the bucket-pulley apparatus shown in Fig. 4-48. (a) How hard must she pull downward to raise herself slowly at constant speed? (b) If she increases this force by 15%, what will her acceleration be? The mass of the person plus the bucket is 65 kg .

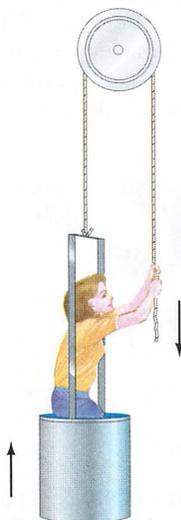


FIGURE 4-48 Problem 29.

30. (II) At the instant a race began, a 65-kg sprinter exerted a force of 720 N on the starting block at a 22° angle with respect to the ground. (a) What was the horizontal acceleration of the sprinter? (b) If the force was exerted for 0.32 s , with what speed did the sprinter leave the starting block?
31. (II) Figure 4-49 shows a block (mass m_A) on a smooth horizontal surface, connected by a thin cord that passes over a pulley to a second block (m_B), which hangs vertically. (a) Draw a free-body diagram for each block, showing the force of gravity on each, the force (tension) exerted by the cord, and any normal force. (b) Apply Newton's second law to find formulas for the acceleration of the system and for the tension in the cord. Ignore friction and the masses of the pulley and cord.

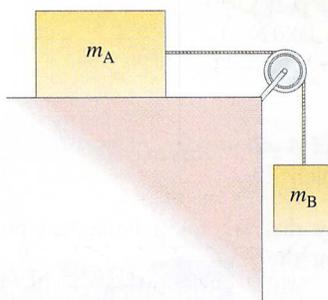


FIGURE 4-49 Problem 31. Mass m_A rests on a smooth horizontal surface, m_B hangs vertically.

32. (II) A pair of fuzzy dice is hanging by a string from your rearview mirror. While you are accelerating from a stoplight to 28 m/s in 6.0 s , what angle θ does the string make with the vertical? See Fig. 4-50.

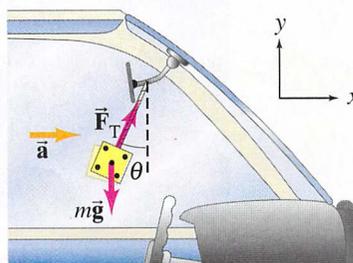


FIGURE 4-50 Problem 32.

33. (III) Three blocks on a frictionless horizontal surface are in contact with each other, as shown in Fig. 4–51. A force \vec{F} is applied to block A (mass m_A). (a) Draw a free-body diagram for each block. Determine (b) the acceleration of the system (in terms of m_A , m_B , and m_C), (c) the net force on each block, and (d) the force of contact that each block exerts on its neighbor. (e) If $m_A = m_B = m_C = 12.0$ kg and $F = 96.0$ N, give numerical answers to (b), (c), and (d). Do your answers make sense intuitively?

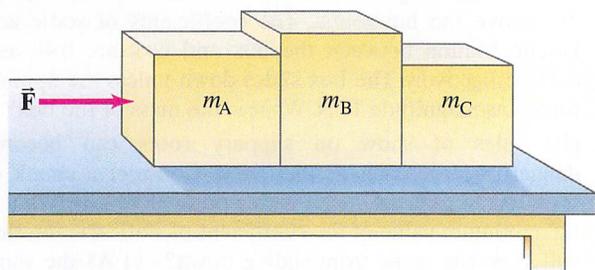


FIGURE 4–51 Problem 33.

34. (III) The two masses shown in Fig. 4–52 are each initially 1.80 m above the ground, and the massless frictionless pulley is 4.8 m above the ground. What maximum height does the lighter object reach after the system is released? [Hint: First determine the acceleration of the lighter mass and then its velocity at the moment the heavier one hits the ground. This is its “launch” speed. Assume it doesn’t hit the pulley.]

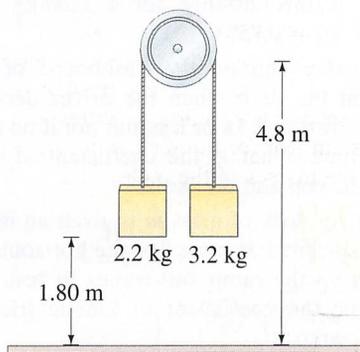


FIGURE 4–52 Problem 34.

35. (III) Suppose two boxes on a frictionless table are connected by a heavy cord of mass 1.0 kg. Calculate the acceleration of each box and the tension at each end of the cord, using the free-body diagrams shown in Fig. 4–53. Assume $F_P = 40.0$ N, and ignore sagging of the cord. Compare your results to Example 4–12 and Fig. 4–22.

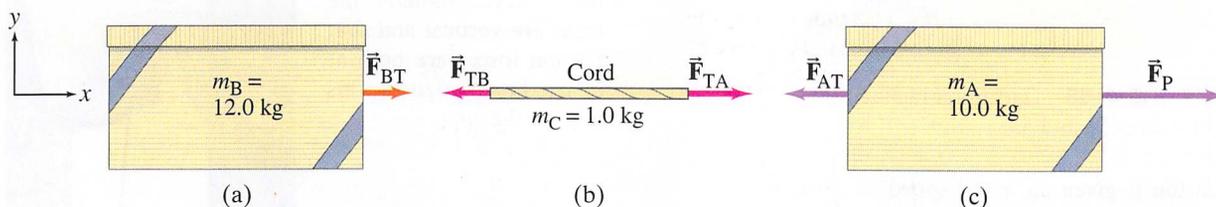


FIGURE 4–53 Problem 35. Free-body diagrams for two boxes on a table connected by a heavy cord, and being pulled to the right as in Fig. 4–22a. Vertical forces, \vec{F}_N and \vec{F}_G , are not shown.

4–8 Newton’s Laws with Friction; Inclines

36. (I) If the coefficient of kinetic friction between a 35-kg crate and the floor is 0.30, what horizontal force is required to move the crate at a steady speed across the floor? What horizontal force is required if μ_k is zero?
37. (I) A force of 48.0 N is required to start a 5.0-kg box moving across a horizontal concrete floor. (a) What is the coefficient of static friction between the box and the floor? (b) If the 48.0-N force continues, the box accelerates at 0.70 m/s². What is the coefficient of kinetic friction?
38. (I) Suppose that you are standing on a train accelerating at $0.20g$. What minimum coefficient of static friction must exist between your feet and the floor if you are not to slide?
39. (I) What is the maximum acceleration a car can undergo if the coefficient of static friction between the tires and the ground is 0.80?
40. (II) The coefficient of static friction between hard rubber and normal street pavement is about 0.8. On how steep a hill (maximum angle) can you leave a car parked?
41. (II) A 15.0-kg box is released on a 32° incline and accelerates down the incline at 0.30 m/s². Find the friction force impeding its motion. What is the coefficient of kinetic friction?
42. (II) A car can decelerate at -4.80 m/s² without skidding when coming to rest on a level road. What would its deceleration be if the road were inclined at 13° uphill? Assume the same static friction coefficient.
43. (II) (a) A box sits at rest on a rough 30° inclined plane. Draw the free-body diagram, showing all the forces acting on the box. (b) How would the diagram change if the box were sliding down the plane? (c) How would it change if the box were sliding up the plane after an initial shove?
44. (II) Drag-race tires in contact with an asphalt surface have a very high coefficient of static friction. Assuming a constant acceleration and no slipping of tires, estimate the coefficient of static friction needed for a drag racer to cover 1.0 km in 12 s, starting from rest.
45. (II) The coefficient of kinetic friction for a 22-kg bobsled on a track is 0.10. What force is required to push it down a 6.0° incline and achieve a speed of 60 km/h at the end of 75 m?
46. (II) For the system of Fig. 4–32 (Example 4–20) how large a mass would box A have to have to prevent any motion from occurring? Assume $\mu_s = 0.30$.
47. (II) A box is given a push so that it slides across the floor. How far will it go, given that the coefficient of kinetic friction is 0.20 and the push imparts an initial speed of 4.0 m/s?

48. (II) Two crates, of mass 75 kg and 110 kg, are in contact and at rest on a horizontal surface (Fig. 4–54). A 620-N force is exerted on the 75-kg crate. If the coefficient of kinetic friction is 0.15, calculate (a) the acceleration of the system, and (b) the force that each crate exerts on the other. (c) Repeat with the crates reversed.

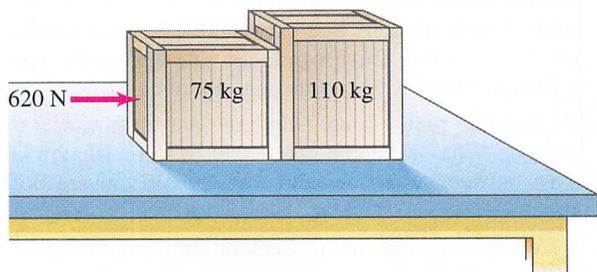


FIGURE 4–54 Problem 48.

49. (II) A flatbed truck is carrying a heavy crate. The coefficient of static friction between the crate and the bed of the truck is 0.75. What is the maximum rate at which the driver can decelerate and still avoid having the crate slide against the cab of the truck?
50. (II) On an icy day, you worry about parking your car in your driveway, which has an incline of 12° . Your neighbor's driveway has an incline of 9.0° , and the driveway across the street is at 6.0° . The coefficient of static friction between tire rubber and ice is 0.15. Which driveway(s) will be safe to park in?
51. (II) A child slides down a slide with a 28° incline, and at the bottom her speed is precisely half what it would have been if the slide had been frictionless. Calculate the coefficient of kinetic friction between the slide and the child.
52. (II) The carton shown in Fig. 4–55 lies on a plane tilted at an angle $\theta = 22.0^\circ$ to the horizontal, with $\mu_k = 0.12$. (a) Determine the acceleration of the carton as it slides down the plane. (b) If the carton starts from rest 9.30 m up the plane from its base, what will be the carton's speed when it reaches the bottom of the incline?

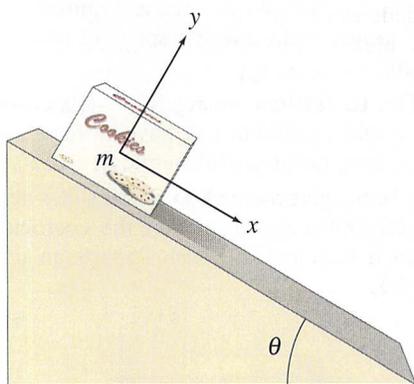


FIGURE 4–55 Carton on inclined plane. Problems 52 and 53.

53. (II) A carton is given an initial speed of 3.0 m/s up the 22.0° plane shown in Fig. 4–55. (a) How far up the plane will it go? (b) How much time elapses before it returns to its starting point? Ignore friction.

54. (II) A roller coaster reaches the top of the steepest hill with a speed of 6.0 km/h. It then descends the hill, which is at an average angle of 45° and is 45.0 m long. Estimate its speed when it reaches the bottom. Assume $\mu_k = 0.18$.
55. (II) An 18.0-kg box is released on a 37.0° incline and accelerates down the incline at 0.270 m/s^2 . Find the friction force impeding its motion. How large is the coefficient of kinetic friction?
56. (II) A small box is held in place against a rough wall by someone pushing on it with a force directed upward at 28° above the horizontal. The coefficients of static and kinetic friction between the box and wall are 0.40 and 0.30, respectively. The box slides down unless the applied force has magnitude 13 N. What is the mass of the box?
57. (II) Piles of snow on slippery roofs can become dangerous projectiles as they melt. Consider a chunk of snow at the ridge of a roof with a pitch of 30° . (a) What is the minimum value of the coefficient of static friction that will keep the snow from sliding down? (b) As the snow begins to melt, the coefficient of static friction decreases and the snow eventually slips. Assuming that the distance from the chunk to the edge of the roof is 5.0 m and the coefficient of kinetic friction is 0.20, calculate the speed of the snow chunk when it slides off the roof. (c) If the edge of the roof is 10.0 m above ground, what is the speed of the snow when it hits the ground?
58. (III) (a) Show that the minimum stopping distance for an automobile traveling at speed v is equal to $v^2/2\mu_s g$, where μ_s is the coefficient of static friction between the tires and the road, and g is the acceleration of gravity. (b) What is this distance for a 1200-kg car traveling 95 km/h if $\mu_s = 0.75$?
59. (III) A coffee cup on the dashboard of a car slides forward on the dash when the driver decelerates from 45 km/h to rest in 3.5 s or less, but not if he decelerates in a longer time. What is the coefficient of static friction between the cup and the dash?
60. (III) A small block of mass m is given an initial speed v_0 up a ramp inclined at angle θ to the horizontal. It travels a distance d up the ramp and comes to rest. Determine a formula for the coefficient of kinetic friction between block and ramp.

61. (III) The 75-kg climber in Fig. 4–56 is supported in the “chimney” by the friction forces exerted on his shoes and back. The static coefficients of friction between his shoes and the wall, and between his back and the wall, are 0.80 and 0.60, respectively. What is the minimum normal force he must exert? Assume the walls are vertical and that friction forces are both at a maximum. Ignore his grip on the rope.



FIGURE 4–56 Problem 61.

62. (III) Boxes are moved on a conveyor belt from where they are filled to the packing station 11.0 m away. The belt is initially stationary and must finish with zero speed. The most rapid transit is accomplished if the belt accelerates for half the distance, then decelerates for the final half of the trip. If the coefficient of static friction between a box and the belt is 0.60, what is the minimum transit time for each box?
63. (III) A block (mass m_1) lying on a frictionless inclined plane is connected to a mass m_2 by a massless cord passing over a pulley, as shown in Fig. 4–57. (a) Determine a formula for the acceleration of the system of the two blocks in terms of m_1 , m_2 , θ and g . (b) What conditions apply to masses m_1 and m_2 for the acceleration to be in one direction (say, m_1 down the plane), or in the opposite direction?
64. (III) (a) Suppose the coefficient of kinetic friction between m_1 and the plane in Fig. 4–57 is $\mu_k = 0.15$, and that $m_1 = m_2 = 2.7$ kg. As m_2 moves down, determine the magnitude of the acceleration of m_1 and m_2 , given $\theta = 25^\circ$. (b) What smallest value of μ_k will keep this system from accelerating?
65. (III) A bicyclist of mass 65 kg (including the bicycle) can coast down a 6.0° hill at a steady speed of 6.0 km/h because of air resistance. How much force must be applied to climb the hill at the same speed and same air resistance?

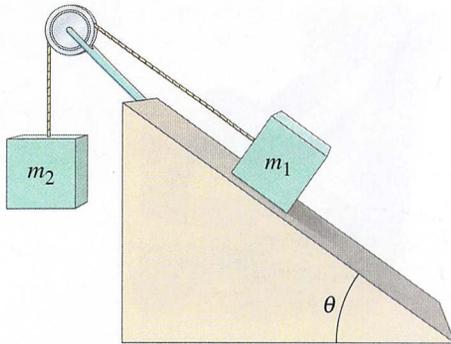


FIGURE 4–57
Problems 63
and 64.

General Problems

66. According to a simplified model of a mammalian heart, at each pulse approximately 20 g of blood is accelerated from 0.25 m/s to 0.35 m/s during a period of 0.10 s. What is the magnitude of the force exerted by the heart muscle?
67. A person has a reasonable chance of surviving an automobile crash if the deceleration is no more than 30 “g’s.” Calculate the force on a 70-kg person undergoing this acceleration. What distance is traveled if the person is brought to rest at this rate from 100 km/h?
68. (a) If the horizontal acceleration produced by an earthquake is a , and if an object is going to “hold its place” on the ground, show that the coefficient of static friction with the ground must be at least $\mu_s = a/g$. (b) The famous Loma Prieta earthquake that stopped the 1989 World Series produced ground accelerations of up to 4.0 m/s^2 in the San Francisco Bay Area. Would a chair have started to slide on a linoleum floor with coefficient of static friction 0.25?
69. An 1150-kg car pulls a 450-kg trailer. The car exerts a horizontal force of $3.8 \times 10^3 \text{ N}$ against the ground in order to accelerate. What force does the car exert on the trailer? Assume an effective friction coefficient of 0.15 for the trailer.
70. Police investigators, examining the scene of an accident involving two cars, measure 72-m-long skid marks of one of the cars, which nearly came to a stop before colliding. The coefficient of kinetic friction between rubber and the pavement is about 0.80. Estimate the initial speed of that car assuming a level road.
71. A car starts rolling down a 1-in-4 hill (1-in-4 means that for each 4 m traveled along the road, the elevation change is 1 m). How fast is it going when it reaches the bottom after traveling 55 m? (a) Ignore friction. (b) Assume an effective coefficient of friction equal to 0.10.
72. A 2.0-kg purse is dropped from the top of the Leaning Tower of Pisa and falls 55 m before reaching the ground with a speed of 29 m/s. What was the average force of air resistance?
73. A cyclist is coasting at a steady speed of 12 m/s but enters a muddy stretch where the effective coefficient of friction is 0.60. Will the cyclist emerge from the muddy stretch without having to pedal if the mud lasts for 11 m? If so, what will be the speed upon emerging?
74. A city planner is working on the redesign of a hilly portion of a city. An important consideration is how steep the roads can be so that even low-powered cars can get up the hills without slowing down. A particular small car, with a mass of 1100 kg, can accelerate on a level road from rest to 21 m/s (75 km/h) in 14.0 s. Using these data, calculate the maximum steepness of a hill.
75. Francesca, who likes physics experiments, dangles her watch from a thin piece of string while the jetliner she is in takes off from JFK Airport (Fig. 4–58). She notices that the string makes an angle of 25° with respect to the vertical as the aircraft accelerates for takeoff, which takes about 18 s. Estimate the takeoff speed of the aircraft.

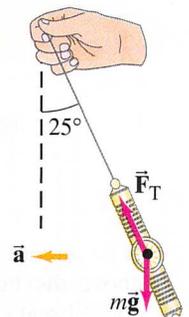


FIGURE 4–58
Problem 75.

76. A 28.0-kg block is connected to an empty 1.35-kg bucket by a cord running over a frictionless pulley (Fig. 4–59). The coefficient of static friction between the table and the block is 0.450 and the coefficient of kinetic friction between the table and the block is 0.320. Sand is gradually added to the bucket until the system just begins to move. (a) Calculate the mass of sand added to the bucket. (b) Calculate the acceleration of the system.

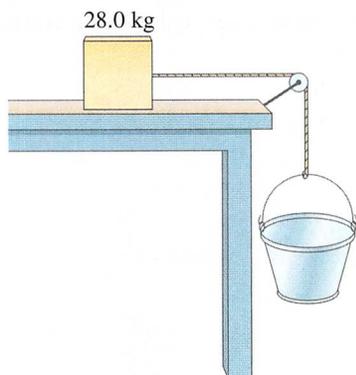


FIGURE 4–59 Problem 76.

77. In the design of a supermarket, there are to be several ramps connecting different parts of the store. Customers will have to push grocery carts up the ramps and it is obviously desirable that this not be too difficult. The engineer has done a survey and found that almost no one complains if the force directed up the ramp is no more than 20 N. Ignoring friction, at what maximum angle θ should the ramps be built, assuming a full 30-kg grocery cart?
78. (a) What minimum force F is needed to lift the piano (mass M) using the pulley apparatus shown in Fig. 4–60? (b) Determine the tension in each section of rope: F_{T1} , F_{T2} , F_{T3} , and F_{T4} .

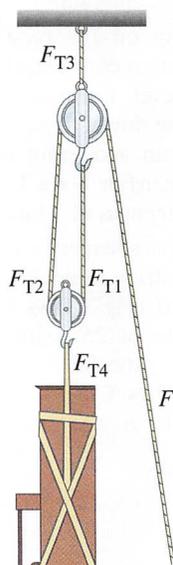


FIGURE 4–60 Problem 78.

79. A jet aircraft is accelerating at 3.5 m/s^2 at an angle of 45° above the horizontal. What is the total force that the cockpit seat exerts on the 75-kg pilot?

80. In the design process for a child-restraint chair, an engineer considers the following set of conditions: A 12-kg child is riding in the chair, which is securely fastened to the seat of an automobile (Fig. 4–61). Assume the automobile is involved in a head-on collision with another vehicle. The initial speed v_0 of the car is 45 km/h, and this speed is reduced to zero during the collision time of 0.20 s. Assume a constant car deceleration during the collision and estimate the net horizontal force F that the straps of the restraint chair must exert on the child in order to keep her fixed to the chair. Treat the child as a particle and state any additional assumptions made during your analysis.



FIGURE 4–61 Problem 80.

81. A 7650-kg helicopter accelerates upward at 0.80 m/s^2 while lifting a 1250-kg frame at a construction site, Fig. 4–62. (a) What is the lift force exerted by the air on the helicopter rotors? (b) What is the tension in the cable (ignore its mass) that connects the frame to the helicopter? (c) What force does the cable exert on the helicopter?

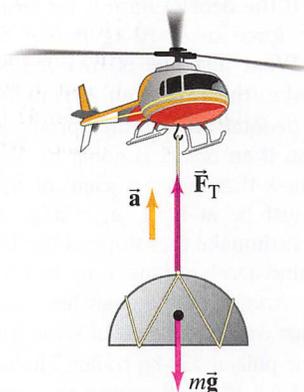


FIGURE 4–62 Problem 81.

82. A super high-speed 12-car Italian train has a mass of 660 metric tons (660,000 kg). It can exert a maximum force of 400 kN horizontally against the tracks, whereas at maximum velocity (300 km/h), it exerts a force of about 150 kN. Calculate (a) its maximum acceleration, and (b) estimate the force of air resistance at top speed.
83. A 65-kg ice skater coasts with no effort for 75 m until she stops. If the coefficient of kinetic friction between her skates and the ice is $\mu_k = 0.10$, how fast was she moving at the start of her coast?

84. Two rock climbers, Bill and Karen, use safety ropes of similar length. Karen's rope is more elastic, called a *dynamic rope* by climbers. Bill has a *static rope*, not recommended for safety purposes in pro climbing. Karen falls freely about 2.0 m and then the rope stops her over a distance of 1.0 m (Fig. 4–63). (a) Estimate, assuming that the force is constant, how large a force she will feel from the rope. (Express the result in multiples of her weight.) (b) In a similar fall, Bill's rope stretches by 30 cm only. How many times his weight will the rope pull on him? Which climber is more likely to be hurt?

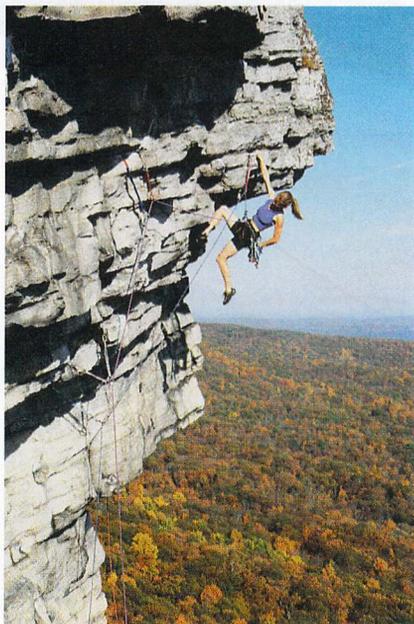


FIGURE 4–63
Problem 84.

85. A fisherman in a boat is using a “10-lb test” fishing line. This means that the line can exert a force of 45 N without breaking ($1 \text{ lb} = 4.45 \text{ N}$). (a) How heavy a fish can the fisherman land if he pulls the fish up vertically at constant speed? (b) If he accelerates the fish upward at 2.0 m/s^2 , what maximum weight fish can he land? (c) Is it possible to land a 15-lb trout on 10-lb test line? Why or why not?

86. An elevator in a tall building is allowed to reach a maximum speed of 3.5 m/s going down. What must the tension be in the cable to stop this elevator over a distance of 2.6 m if the elevator has a mass of 1300 kg including occupants?
87. Two boxes, $m_1 = 1.0 \text{ kg}$ with a coefficient of kinetic friction of 0.10, and $m_2 = 2.0 \text{ kg}$ with a coefficient of 0.20, are placed on a plane inclined at $\theta = 30^\circ$. (a) What acceleration does each box experience? (b) If a taut string is connected to the boxes (Fig. 4–64), with m_2 initially farther down the slope, what is the acceleration of each box? (c) If the initial configuration is reversed with m_1 starting lower with a taut string, what is the acceleration of each box?

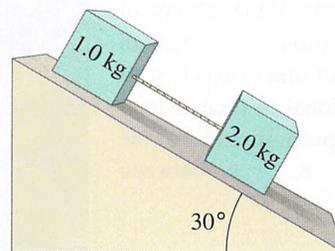


FIGURE 4–64 Problem 87.

88. A 75.0-kg person stands on a scale in an elevator. What does the scale read (in N and in kg) when the elevator is (a) at rest, (b) ascending at a constant speed of 3.0 m/s, (c) falling at 3.0 m/s, (d) accelerating upward at 3.0 m/s^2 , (e) accelerating downward at 3.0 m/s^2 ?
89. Three mountain climbers who are roped together are ascending an icefield inclined at 21.0° to the horizontal. The last climber slips, pulling the second climber off his feet. The first climber is able to hold them both. If each climber has a mass of 75 kg, calculate the tension in each of the two sections of rope between the three climbers. Ignore friction between the ice and the fallen climbers.

Answers to Exercises

- A:** (a) The same; (b) the sports car; (c) third law for part (a), second law for part (b).
B: The force applied by the person is insufficient to keep the box moving.

- C:** No; yes.
D: Yes; no.