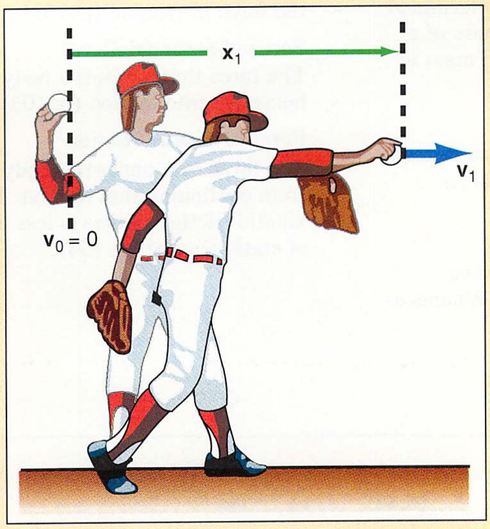


Figure 2
The process of throwing a ball.

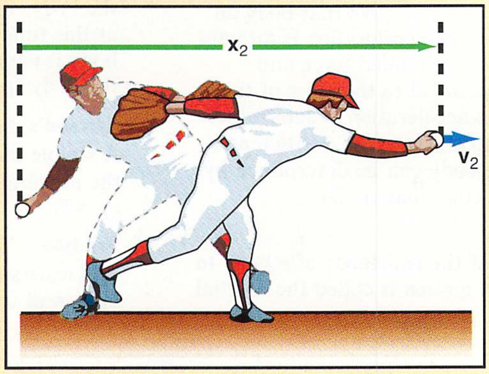


Figure 3
A pitcher throwing a baseball.

Taking the ratio of these two velocities we obtain

$$\frac{v_2}{v_1} = \frac{\sqrt{2(F/m)x_2}}{\sqrt{2(F/m)x_1}}$$

which simplifies to

$$\frac{v_2}{v_1} = \sqrt{\frac{x_2}{x_1}}$$

The velocity v_2 becomes

$$v_2 = \sqrt{\frac{x_2}{x_1}}\, v_1 \qquad \text{(H4.5)}$$

Hence, by going through that long windup, the pitcher has increased the distance to x_2, thereby increasing the value of the velocity that he can throw the baseball to v_2. For example, for an average person, x_1 is about 50 in., while x_2 is about 125 in. Therefore, the velocity becomes

$$v_2 = \sqrt{\frac{125}{50}}\, v_1$$
$$= 1.58\, v_1$$

Thus, if a pitcher is normally capable of throwing a baseball at a speed of 60 mph, by going through the long windup, the speed of the ball becomes

$$v_2 = 1.58(60 \text{ mph}) = 95 \text{ mph}$$

The long windup has allowed the pitcher to throw the baseball at 95 mph, much faster than the 60 mph that he could normally throw the ball. So this is why the pitcher goes through all those gyrations.

The Language of Physics

Dynamics
That branch of mechanics concerned with the forces that change or produce the motions of bodies. The foundation of dynamics is Newton's laws of motion (p. 79).

Newton's first law of motion
A body at rest will remain at rest, and a body in motion at a constant velocity will continue in motion at that constant velocity, unless acted on by some unbalanced external force. This is sometimes referred to as the law of inertia (p. 80).

Force
The simplest definition of a force is a push or a pull that acts on a body. Force can also be defined in a more general way by Newton's second law, that is, a force is that which causes a mass *m* to have an acceleration *a* (p. 80).

Inertia
The characteristic of matter that causes it to resist a change in motion is called inertia (p. 80).

Inertial coordinate system
A coordinate system that is either at rest or moving at a constant velocity with respect to another coordinate system that is either at rest or also moving at some constant velocity. Newton's first law of motion defines an inertial coordinate system. That is, if a body is at rest or moving at a constant velocity in a coordinate system where there are no unbalanced forces acting on the body, the coordinate system is an inertial coordinate system. Newton's first law must be applied in an inertial coordinate system (p. 81).

Newton's third law of motion
If there are two bodies, *A* and *B*, and if body *A* exerts a force on body *B*, then body *B* exerts an equal but opposite force on body *A* (p. 81).

Newton's second law of motion
If an unbalanced external force **F** acts on a body of mass m, it will give that body an acceleration **a**. The acceleration is directly proportional to the applied force and inversely proportional to the mass of the body. Once the acceleration is determined by Newton's second law, the position and velocity of the body can be determined by the kinematic equations (p. 84).

Inertial mass
The measure of the resistance of a body to a change in its motion is called the inertial mass of the body. The mass of a body in Newton's second law is the inertial mass of the body. The best that can be determined at this time is that the inertial mass of a body is equal to the gravitational mass of the body (p. 92).

Atwood's machine
A simple pulley device that is used to study the acceleration of a system of bodies (p. 97).

Friction
The resistance offered to the relative motion of two bodies in contact. Whenever we try to slide one body over another body, the force that opposes the motion is called the force of friction (p. 101).

Force of static friction
The force that opposes a body at rest from being put into motion (p. 103).

Force of kinetic friction
The force that opposes a body in motion from continuing that motion. The force of kinetic friction is always less than the force of static friction (p. 103).

Summary of Important Equations

Newton's second law
$$\mathbf{F} = m\mathbf{a} \tag{4.9}$$

The weight of a body
$$w = mg \tag{4.12}$$

Definition of inertial mass
$$m_2 = \frac{a_1}{a_2} m_1 \tag{4.22}$$

Force of static friction
$$f_s \leq \mu_s F_N \tag{4.44}$$

Force of kinetic friction
$$f_k = \mu_k F_N \tag{4.45}$$

Coefficient of static friction
$$\mu_s = \tan \theta_s \tag{4.71}$$

Coefficient of kinetic friction
$$\mu_k = \tan \theta_k \tag{4.73}$$

Questions for Chapter 4

1. A force was originally defined as a push or a pull. Define the concept of force dynamically using Newton's laws of motion.
2. Discuss the difference between the ancient Greek philosophers' requirement of a constantly applied force as a condition for motion with Galileo's and Newton's concept of a force to initiate an acceleration.
3. Is a coordinate system that is accelerated in a straight line an inertial coordinate system? Describe the motion of a projectile in one dimension in a horizontally accelerated system.
4. If you drop an object near the surface of the earth it is accelerated downward to the earth. By Newton's third law, can you also assume that a force is exerted on the earth and the earth should be accelerated upward toward the object? Can you observe such an acceleration? Why or why not?

†5. Discuss an experiment that could be performed on a tilted air track whereby changing the angle of the track would allow you to prove that the acceleration of a body is proportional to the applied force. Why could you not use this same experiment to show that the acceleration is inversely proportional to the mass?

†6. Discuss the concept of mass as a quantity of matter, a measure of the resistance of matter to being put into motion, and a measure of the gravitational force acting on the mass. Has the original platinum-iridium cylinder, which is stored in Paris, France, and defined as the standard of mass, ever been accelerated so that mass can be defined in terms of its inertial characteristics? Does it have to? Which is the most fundamental definition of mass?

7. From the point of view of the different concepts of mass, discuss why all bodies fall with the same acceleration near the surface of the earth.
8. Discuss why the normal force F_N is not always equal to the weight of the body that is in contact with a surface.
9. In the discussion of Atwood's machine, we assumed that the tension in the string is the same on both sides of the pulley. Can a pulley rotate if the tension is the same on both sides of the pulley?

†10. You are riding in an elevator and the cable breaks. The elevator goes into free fall. The instant before the elevator hits the ground, you jump upward about 3 ft. Will this do you any good? Discuss your motion with respect to the elevator and with respect to the ground. What will happen to you?

†11. Discuss the old saying: "If a horse pulls on a cart with a force F, then by Newton's third law the cart pulls backward on the horse with the same force F, therefore the horse can not move the cart."

12. A football is filled with mercury and taken into space where it is weightless. Will it hurt to kick this football since it is weightless?

†13. A 110-lb lady jumps out of a plane to go skydiving. She extends her body to obtain maximum frictional resistance from the air. After a while, she descends at a constant speed, called her terminal speed. At this time, what is the value of the frictional force of the air?

14. When a baseball player catches a ball he always pulls his glove backward. Why does he do this?

Problems for Chapter 4

In all problems assume that all objects are initially at rest, i.e., $v_0 = 0$, unless otherwise stated.

4.4 Newton's Second Law of Motion

1. What is the mass of a 200-lb person?

2. What is the weight of a 100-kg person at the surface of the earth? What would the person weigh on Mars where $g = 3.84\ m/s^2$?

3. What horizontal force must be applied to a 15.0-kg body in order to give it an acceleration of 5.00 m/s^2?

4. A constant force accelerates a 3200-lb car from 0 to 60.0 mph in 12.0 s. Find (a) the acceleration of the car and (b) the force acting on the car that produces the acceleration.

5. A 3200-lb car is traveling along a highway at 60.0 mph. If the driver immediately applies his brakes and the car comes to rest in a distance of 250 ft, what average force acted on the car during the deceleration?

6. A 910-kg car is traveling along a highway at 88.0 km/hr. If the driver immediately applies his brakes and the car comes to rest in a distance of 70.0 m, what average force acted on the car during the deceleration?

7. A car is traveling at 60.0 mph when it collides with a stone wall. The car comes to rest after the first foot of the car is crushed. What was the average horizontal force acting on a 150-lb driver while the car came to rest? If five cardboard boxes, each 4 ft wide and filled with sand had been placed in front of the wall, and the car moved through all that sand before coming to rest, what would the average force acting on the driver have been then?

8. A rifle bullet of mass 12.0 g has a muzzle velocity of 750 m/s. What is the average force acting on the bullet when the rifle is fired, if the bullet is accelerated over the entire 1.00-m length of the rifle?

9. A car is to tow a 5000-lb truck with a rope. How strong should the rope be so that it will not break when accelerating the truck from rest to 10.0 ft/s in 12.0 s?

10. A force of 200 lb acts on a body that weighs 60.0 lb. (a) What is the mass of the body? (b) What is the acceleration of the body? (c) If the body starts from rest, how fast will it be going after it has moved 10.0 ft?

11. A cable supports an elevator that weighs 8000 N. (a) What is the tension T in the cable when the elevator accelerates upward at 1.50 m/s^2? (b) What is the tension when the elevator accelerates downward at 1.50 m/s^2?

12. A rope breaks when the tension exceeds 30.0 N. What is the minimum acceleration downward that a 60.0-N load can have without breaking the rope?

13. A 5.00-g bullet is fired at a speed of 100 m/s into a fixed block of wood and it comes to rest after penetrating 6.00 cm into the wood. What is the average force stopping the bullet?

14. A rope breaks when the tension exceeds 100 lb. What is the maximum vertical acceleration that can be given to an 80.0-lb load to lift it with this rope without breaking the rope?

15. What horizontal force must a locomotive exert on a 1000-ton train to increase its speed from 15.0 mph to 30.0 mph in moving 200 ft along a level track?

16. A steady force of 10.0 lb, exerted 30.0° above the horizontal, acts on a 50.0-lb sled on level snow. How far will the sled move in 10.0 s? (Neglect friction.)

17. A steady force of 70.0 N, exerted 43.5° above the horizontal, acts on a 30.0-kg sled on level snow. How far will the sled move in 8.50 s? (Neglect friction.)

18. A helicopter rescues a person at sea by pulling him upward with a cable. If the person weighs 180 lb and is accelerated upward at 1.00 ft/s^2, what is the tension in the cable?

4.5 Applications of Newton's Second Law

19. A force of 10.0 N acts horizontally on a 20.0-kg mass that is at rest on a smooth table. Find (a) the acceleration, (b) the velocity at 5.00 s, and (c) the position of the body at 5.00 s. (d) If the force is removed at 7.00 s, what is the body's velocity at 7.00, 8.00, 9.00, and 10.0 s?

20. A 50.0-lb box slides down a frictionless inclined plane that makes an angle of 37.0° with the horizontal. (a) What unbalanced force acts on the block? (b) What is the acceleration of the block?

21. A 20.0-kg block slides down a smooth inclined plane. The plane is 10.0 m long and is inclined at an angle of 30.0° with the horizontal. Find (a) the acceleration of the block, and (b) the velocity of the block at the bottom of the plane.

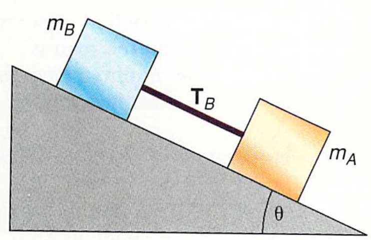
22. A 180-lb person stands on a scale in an elevator. What does the scale read when (a) the elevator is ascending with an acceleration of 4.00 ft/s^2, (b) it is ascending at a constant velocity of 8.00 ft/s, (c) it decelerates at 4.00 ft/s^2, (d) it descends at a constant velocity of 8.00 ft/s, and (e) the cable breaks and the elevator is in free-fall?

23. A 90.0-kg person stands on a scale in an elevator. What does the scale read when (a) the elevator is ascending with an acceleration of 1.50 m/s^2, (b) it is ascending at a constant velocity of 3.00 m/s, (c) it decelerates at 1.50 m/s^2, (d) it descends at a constant velocity of 3.00 m/s, and (e) the cable breaks and the elevator is in free-fall?

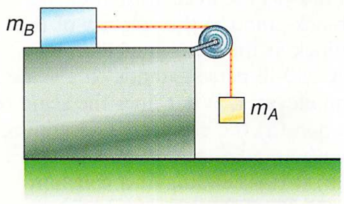
24. A spring scale is attached to the ceiling of an elevator. If a mass of 2.00 kg is placed in the pan of the scale, what will the scale read when (a) the elevator is accelerated upward at 1.50 m/s^2, (b) it is decelerated at 1.50 m/s^2, (c) it is moving at constant velocity, and (d) the cable breaks and the elevator is in free-fall?

†25. A block is propelled up a 48.0° frictionless inclined plane with an initial velocity $v_0 = 1.20$ m/s. (a) How far up the plane does the block go before coming to rest? (b) How long does it take to move to that position?

†26. In the diagram m_A is equal to 3.00 kg and m_B is equal to 1.50 kg. The angle of the inclined plane is 38.0°. (a) Find the acceleration of the system of two blocks. (b) Find the tension T_B in the connecting string.

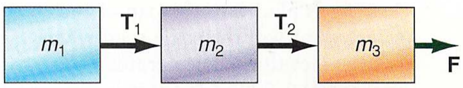


27. The two masses $m_A = 2.00$ kg and $m_B = 20.0$ kg are connected as shown. The table is frictionless. Find (a) the acceleration of the system, (b) the velocity of m_B at $t = 3.00$ s, and (c) the position of m_B at $t = 3.00$ s.

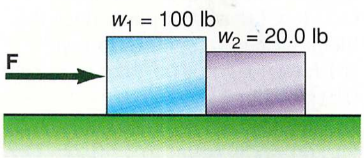


28. A 30.0-g mass and a 50.0-g mass are placed on an Atwood machine. Find (a) the acceleration of the system, (b) the velocity of the 50.0-g block at 4.00 s, (c) the position of the 50.0-g mass at the end of the fourth second, (d) the tension in the connecting string.

†29. Three blocks of mass $m_1 = 100$ g, $m_2 = 200$ g, and $m_3 = 300$ g are connected by strings as shown. (a) What force F is necessary to give the masses a horizontal acceleration of 4 m/s²? Find the tensions T_1 and T_2.



†30. A force of 20.0 lb acts as shown on the two blocks. If the blocks are on a frictionless surface, find the acceleration of each block and the horizontal force exerted on each block.



4.7 Applications of Newton's Second Law Taking Friction into Account

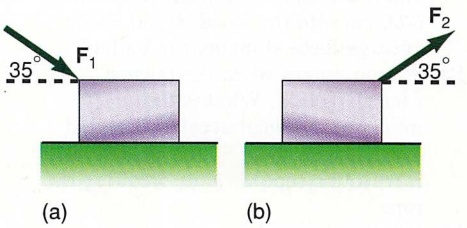
31. If the coefficient of friction between the tires of a car and the road is 0.300, what is the minimum stopping distance of a car traveling at 60.0 mph?

32. If the coefficient of friction between the tires of a car and the road is 0.300, what is the minimum stopping distance of a car traveling at 85.0 km/hr?

33. A 200-N container is to be pushed across a rough floor. The coefficient of static friction is 0.500 and the coefficient of kinetic friction is 0.400. What force is necessary to start the container moving, and what force is necessary to keep it moving at a constant velocity?

34. A 2.00-kg toy accelerates from rest to 3.00 m/s in 8.00 s on a rough surface of $\mu_k = 0.300$. Find the applied force F.

35. A 50.0-lb box is to be moved along a rough floor at a constant velocity. The coefficient of friction is $\mu_k = 0.300$. (a) What force F_1 must you exert if you push downward on the box as shown? (b) What force F_2 must you exert if you pull upward on the box as shown? (c) Which is the better way to move the box?



36. A 5.00-lb book is held against a rough vertical wall. If the coefficient of static friction between the book and the wall is 0.300, what force perpendicular to the wall is necessary to keep the book from sliding?

37. A block slides along a wooden table with an initial speed of 50.0 cm/s. If the block comes to rest in 150 cm, find the coefficient of kinetic friction between the block and the table.

38. What force must act horizontally on a 20.0-kg mass moving at a constant speed of 4.00 m/s on a rough table of coefficient of kinetic friction of 0.300? If the force is removed, when will the body come to rest? Where will it come to rest?

39. A 10.0-kg package slides down an inclined mail chute 15.0 m long. The top of the chute is 6.00 m above the floor. What is the speed of the package at the bottom of the chute if (a) the chute is frictionless and (b) the coefficient of kinetic friction is 0.300?

40. In order to place a 200-lb air conditioner in a window, a plank is laid between the window and the floor, making an angle of 40.0° with the horizontal. How much force is necessary to push the air conditioner up the plank at a constant speed if the coefficient of kinetic friction between the air conditioner and the plank is 0.300?

41. If a 4.00-kg container has a velocity of 3.00 m/s after sliding down a 2.00-m plane inclined at an angle of 30.0°, what is (a) the force of friction acting on the container and (b) the coefficient of kinetic friction between the container and the plane?

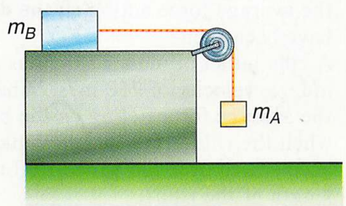
†42. A 100-lb crate sits on the floor of a truck. If $\mu_s = 0.300$, what is the maximum acceleration of the truck before the crate starts to slip?

43. A skier starts from rest and slides a distance of 200 ft down the ski slope. The slope makes an angle of 35.0° with the horizontal. (a) If the coefficient of friction between the skis and the slope is 0.100, find the speed of the skier at the bottom of the slope. (b) At the bottom of the slope the skier continues to move on level snow. Where does the skier come to a stop?

44. A skier starts from rest and slides a distance of 85.0 m down the ski slope. The slope makes an angle of 23.0° with the horizontal. (a) If the coefficient of friction between the skis and the slope is 0.100, find the speed of the skier at the bottom of the slope. (b) At the bottom of the slope, the skier continues to move on level snow. Where does the skier come to a stop?

†45. A mass of 2.00 kg is pushed up an inclined plane that makes an angle of 50.0° with the horizontal. If the coefficient of kinetic friction between the mass and the plane is 0.400, and a force of 50.0 N is applied parallel to the plane, what is (a) the acceleration of the mass and (b) its velocity after moving 3.00 m up the plane?

46. The two masses $m_A = 20$ kg and $m_B = 20$ kg are connected as shown on a rough table. If the coefficient of friction between block B and the table is 0.45, find (a) the acceleration of each block and (b) the tension in the connecting string.

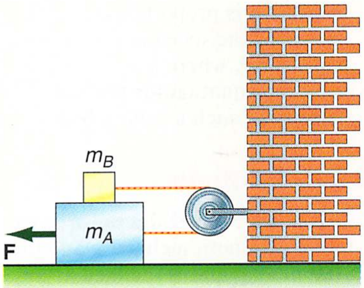


47. To determine the coefficient of static friction, the following system is set up. A mass, $m_B = 2.50$ kg, is placed on a rough horizontal table such as in the diagram for problem 46. When mass m_A is increased to the value of 1.50 kg the system just starts into motion. Determine the coefficient of static friction.

48. To determine the coefficient of kinetic friction, the following system is set up. A mass, $m_B = 2.50$ kg, is placed on a rough horizontal table such as in the diagram for problem 46. Mass m_A has the value of 1.85 kg, and the system goes into accelerated motion with a value a_1. While mass m_A falls to the floor, a distance $x_1 = 30.0$ cm below its starting point, mass m_B will also move through a distance x_1 and will have acquired a velocity v_1 at x_1. When m_A hits the floor, the acceleration a_1 becomes zero. From this point on, the only acceleration m_B experiences is the deceleration a_2 caused by the force of kinetic friction acting on m_B. Mass m_B moves on the rough surface until it comes to rest at the distance $x_2 = 20.0$ cm. From this information, determine the coefficient of kinetic friction.

Additional Problems

†49. Find the force F that is necessary for the system shown to move at constant velocity if $\mu_k = 0.300$ for all surfaces. The masses are $m_A = 6.00$ kg and $m_B = 2.00$ kg.

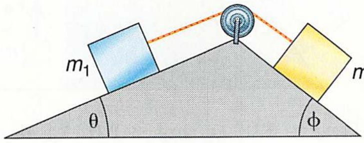


50. A pendulum is placed in a car at rest and hangs vertically. The car then accelerates forward and the pendulum bob is observed to move backward, the string making an angle of 15.0° with the vertical. Find the acceleration of the car.

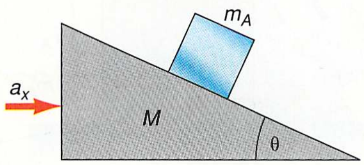
51. Two gliders are tied together by a string after they are connected together by a compressed spring and placed on an air track. Glider A has a mass of 200 g and the mass of glider B is unknown. The string is now cut and the gliders fly apart. If glider B has an acceleration of 5.00 cm/s² to the right, and the acceleration of glider A to the left is 20.0 cm/s², find the mass of glider B.

52. A mass of 1.87 kg is pushed up a smooth inclined plane with an applied force of 3.50 N parallel to the plane. If the plane makes an angle of 35.8° with the horizontal, find (a) the acceleration of the mass and (b) its velocity after moving 1.50 m up the plane.

†53. Two blocks $m_1 = 20.0$ kg and $m_2 = 10.0$ kg are connected as shown on a frictionless plane. The angle $\theta = 25.0°$ and $\phi = 35.0°$. Find the acceleration of each block and the tension in the connecting string.



†54. What horizontal acceleration a_x must the inclined block M have in order for the smaller block m_A not to slide down the frictionless inclined plane? What force must be applied to the system to keep the block from sliding down the frictionless plane? $M = 10.0$ kg, $m_A = 1.50$ kg, and $\theta = 43°$.



†55. If the acceleration of the system is 3.00 m/s² when it is lifted, and $m_A = 5.00$ kg, $m_B = 3.00$ kg, and $m_C = 2.00$ kg, find the tensions T_A, T_B, and T_C.

†56. Consider the double Atwood's machine as shown. If $m_1 = 50.0$ g, $m_2 = 20.0$ g, and $m_3 = 25.0$ g, what is the acceleration of m_3?

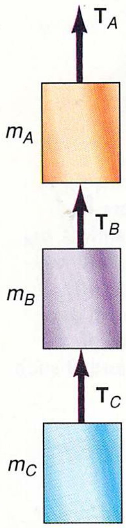


Diagram for problem 55

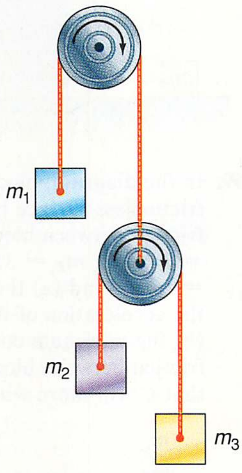
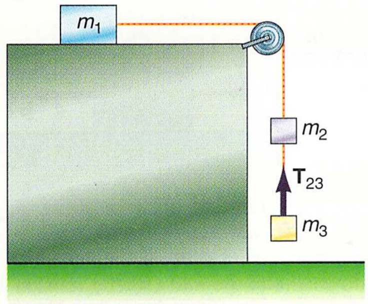
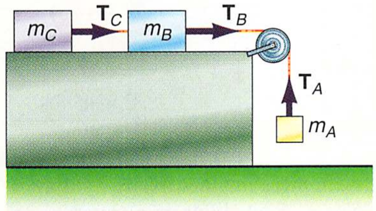


Diagram for problem 56

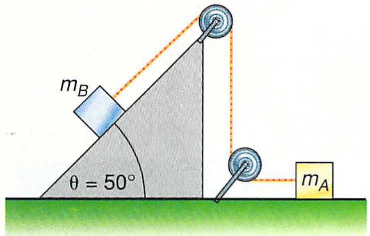
†57. Find the tension T_{23} in the string between mass m_2 and m_3, if $m_1 = 10.0$ kg, $m_2 = 2.00$ kg, and $m_3 = 1.00$ kg.



†58. If $m_A = 6.00$ kg, $m_B = 3.00$ kg, and $m_C = 2.00$ kg in the diagram, find the magnitude of the acceleration of the system and the tensions $\mathbf{T}_A$, $\mathbf{T}_B$, and $\mathbf{T}_C$.



†59. Find (a) the acceleration of mass m_A in the diagram. All surfaces are frictionless. (b) Find the displacement of block A at $t = 0.500$ s. The value of the masses are $m_A = 3.00$ kg and $m_B = 5.00$ kg.

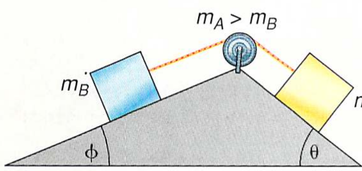


60. A force of 5.00 N acts on a body of mass $m = 2.00$ kg at an angle of 35.0° above the horizontal. If the coefficient of friction between the body and the surface upon which it is resting is 0.250, find the acceleration of the mass.

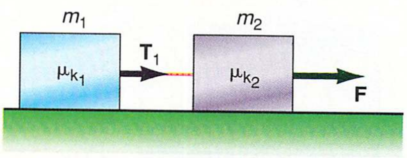
†61. Derive the formula for the magnitude of the acceleration of the system shown in the diagram.

(a) What problem does this reduce to if $\phi = 90°$?

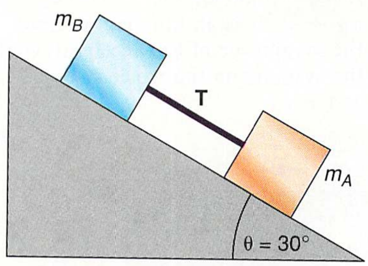
(b) What problem does this reduce to if both θ and ϕ are equal to 90°?



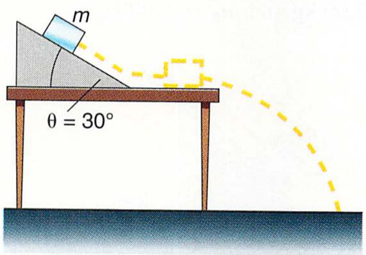
†62. What force is necessary to pull the two masses at constant speed if $m_1 = 2.00$ kg, $m_2 = 5.00$ kg, $\mu_{k_1} = 0.300$, and $\mu_{k_2} = 0.200$? What is the tension T_1 in the connecting string?



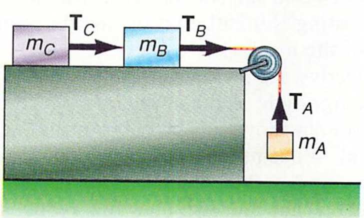
†63. If $m_A = 4.00$ kg, $m_B = 2.00$ kg, $\mu_{k_A} = 0.300$, and $\mu_{k_B} = 0.400$, find (a) the acceleration of the system down the plane and (b) the tension in the connecting string.



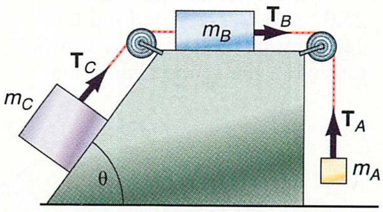
†64. A block $m = 0.500$ kg slides down a frictionless inclined plane 2.00 m long. It then slides on a rough horizontal table surface of $\mu_k = 0.300$ for 0.500 m. It then leaves the top of the table, which is 1.00 m high. How far from the base of the table does the block land?



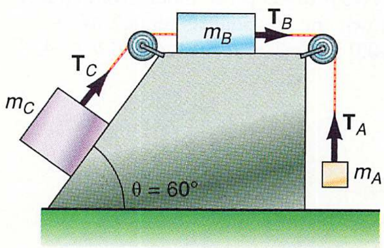
†65. In the diagram $m_A = 6.00$ kg, $m_B = 3.00$ kg, $m_C = 2.00$ kg, $\mu_{k_C} = 0.400$, and $\mu_{k_B} = 0.300$. Find the magnitude of the acceleration of the system and the tension in each string.



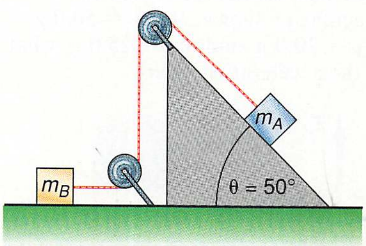
†66. In the diagram $m_A = 4.00$ kg, $m_B = 2.00$ kg, $m_C = 4.00$ kg, and $\theta = 58°$. If all the surfaces are frictionless, find the magnitude of the acceleration of the system.



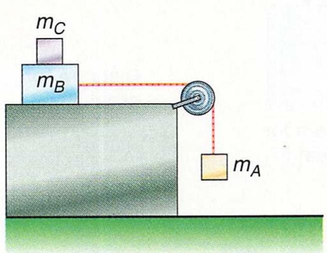
†67. If $m_A = 6.00$ kg, $m_B = 2.00$ kg, $m_C = 4.00$ kg, and the coefficient of kinetic friction for the surfaces are $\mu_{k_B} = 0.300$ and $\mu_{k_C} = 0.200$ find the magnitude of the acceleration of the system shown in the diagram and the tension in each string.



†68. Find (a) the magnitude of the acceleration of the system shown if $\mu_{k_B} = 0.300$, $\mu_{k_A} = 0.200$, $m_B = 3.00$ kg, and $m_A = 5.00$ kg, (b) the velocity of block A at 0.500 s.



†69. In the diagram, block B rests on a frictionless surface but there is friction between blocks B and C. $m_A = 2.00$ kg, $m_B = 3.00$ kg, and $m_C = 1$ kg. Find (a) the magnitude of the acceleration of the system and (b) the minimum coefficient of friction between blocks C and B such that C will move with B.



†70. When a body is moving through the air, the effect of air resistance can be taken into account. If the speed of the body is not too great, the force associated with the retarding force of air friction is proportional to the first power of the velocity of the moving body. This retarding force causes the velocity of a falling body at any time t to be

$$v = \frac{mg}{k}(1 - e^{-(k/m)t})$$

where m is the mass of the falling body and k is a constant that depends on the shape of the body. Show that this reduces to the case of a freely falling body if t and k are both small. (*Hint:* expand the term $e^{-(k/m)t}$ in a power series.)

71. Repeat problem 70, but now let the time t be very large (assume it is infinite). What does the velocity of the falling body become now? Discuss this result with Aristotle's statement that heavier objects fall faster than lighter objects. Clearly distinguish between the concepts of velocity and acceleration.

†72. If a body moves through the air at very large speeds the retarding force of friction is proportional to the square of the speed of the body, that is, $f = kv^2$, where k is a constant. Find the equation for the terminal velocity of such a falling body.

Interactive Tutorials

73. A 20.0-kg block slides down from the top of a smooth inclined plane that is 10.0 m long and is inclined at an angle θ of 30° with the horizontal. Find the acceleration a of the block and its velocity v at the bottom of the plane. Assume the initial velocity $v_0 = 0$.

74. Two masses $m_A = 40.0$ kg and $m_B = 30.0$ kg are connected by a massless string that hangs over a massless, frictionless pulley in an Atwood's machine arrangement as shown in figure 4.14. Calculate the acceleration a of the system and the tension T in the string.

75. A mass $m_A = 40.0$ kg hangs over a table connected by a massless string to a mass $m_B = 20.0$ kg that is on a rough horizontal table, with a coefficient of friction $\mu_k = 0.400$, that is similar to figure 4.25. Calculate the acceleration a of the system and the tension T in the string.

76. Generalization of problem 61 that also includes friction. Derive the formula for the magnitude of the acceleration of the system shown in the diagram for problem 61. As a general case, assume that the coefficient of kinetic friction between block A and the surface in μ_{k_A} and between block B and the surface is μ_{k_B}. Identify and solve for all the special cases that you can think of.

77. Free fall with friction—variable acceleration—terminal velocity. In the freely falling body studied in chapter 3, we assumed that the resistance of the air could be considered negligible. Let us now remove that constraint. Assume that there is frictional force caused by the motion through the air, and let us further assume that the frictional force is proportional to the square of the velocity of the moving body and is given by

$$f = kv^2$$

Find the displacement, velocity, and acceleration of the falling body and compare it to the displacement, velocity, and acceleration of a freely falling body without friction.

78. The mass of the connecting string is not negligible. In the problem of the combined motion of a block on a frictionless horizontal plane and a block falling vertically, as shown in figure 4.12, it was assumed that the mass of the connecting string was negligible and had no effect on the problem. Let us now remove that constraint. Assume that the string is a massive string. The string has a linear mass density of 0.050 kg/m and is 1.25 m long. Find the acceleration, velocity, and displacement y of the system as a function of time, and compare it to the acceleration, velocity, and displacement of the system with the string of negligible mass.