Then use the equation $v_f^2 = v_i^2 + 2a(d_f - d_i)$ to find the distance.

Let $d_i = 0$ and solve for d_f.

$$d_f = \frac{v_f^2 - v_i^2}{2a}$$

$$= \frac{v_f^2 - v_i^2}{(2)(-\mu_k g)}$$

$$= \frac{(0.0\text{ m/s})^2 - (5.8\text{ m/s})^2}{(2)(-0.31)(9.80\text{ m/s}^2)}$$

$$= 5.5\text{ m}$$

25. Consider the force pushing the box in Example Problem 4. How long would it take for the velocity of the box to double to 2.0 m/s?

The initial velocity is 1.0 m/s, the final velocity is 2.0 m/s, and the acceleration is 2.0 m/s², so

$a = \frac{v_f - v_i}{t_f - t_i}$; let $t_i = 0$ and solve for t_f.

$$t_f = \frac{v_f - v_i}{a}$$

$$= \frac{2.0\text{ m/s} - 1.0\text{ m/s}}{2.0\text{ m/s}^2}$$

$$= 0.50\text{ s}$$

26. Ke Min is driving along on a rainy night at 23 m/s when he sees a tree branch lying across the road and slams on the brakes when the branch is 60.0 m in front of him. If the coefficient of kinetic friction between the car's locked tires and the road is 0.41, will the car stop before hitting the branch? The car has a mass of 2400 kg.

Choose positive direction as direction of car's movement.

$$F_{net} = -\mu_k F_N = -\mu_k mg = ma$$

$$a = -\mu_k g$$

Then use the equation $v_f^2 = v_i^2 + 2a(d_f - d_i)$ to find the distance.

Let $d_i = 0$ and solve for d_f.

$$d_f = \frac{v_f^2 - v_i^2}{2a}$$

$$= \frac{v_f^2 - v_i^2}{(2)(-\mu_k g)}$$

$$= \frac{(0.0\text{ m/s}) - (23\text{ m/s})^2}{(2)(-0.41)(9.80\text{ m/s}^2)}$$

= 66 m, so he hits the branch before he can stop.

Section Review

5.2 Friction pages 126–130

page 130

27. Friction In this section, you learned about static and kinetic friction. How are these two types of friction similar? What are the differences between static and kinetic friction?

They are similar in that they both act in a direction opposite to the motion (or intended motion) and they both result from two surfaces rubbing against each other. Both are dependent on the normal force between these two surfaces. Static friction applies when there is no relative motion between the two surfaces. Kinetic friction is the type of friction when there is relative motion. The coefficient of static friction between two surfaces is greater than the coefficient of kinetic friction between those same two surfaces.

28. Friction At a wedding reception, you notice a small boy who looks like his mass is about 25 kg, running part way across the dance floor, then sliding on his knees until he stops. If the kinetic coefficient of friction between the boy's pants and the floor is 0.15, what is the frictional force acting on him as he slides?

$$F_{friction} = \mu_k F_N$$

$$= \mu_k mg$$

$$= (0.15)(25\text{ kg})(9.80\text{ m/s}^2)$$

$$= 37\text{ N}$$

29. Velocity Derek is playing cards with his friends, and it is his turn to deal. A card has a mass of 2.3 g, and it slides 0.35 m along the table before it stops. If the coefficient of kinetic friction between the card and the table is 0.24, what was the initial speed of the card as it left Derek's hand?

Identify the direction of the card's movement as positive

$F_{net} = -\mu_k F_N = -\mu_k mg = ma$

$a = -\mu_k g$

$v_f^2 = v_i^2 + 2a(d_f - d_i)$; $v_f = d_i = 0$ so

$v_i = \sqrt{-2ad_f}$

$= \sqrt{-2(-\mu_k g)d_f}$

$= \sqrt{-2(-0.24)(9.80\ m/s^2)(0.35\ m)}$

$= 1.3\ m/s$

30. Force The coefficient of static friction between a 40.0-kg picnic table and the ground below it is 0.43 m. What is the greatest horizontal force that could be exerted on the table while it remains stationary?

$F_f = \mu_s F_N$

$= \mu_s mg$

$= (0.43)(40.0\ kg)(9.80\ m/s^2)$

$= 1.7\times10^2\ N$

31. Acceleration Ryan is moving to a new apartment and puts a dresser in the back of his pickup truck. When the truck accelerates forward, what force accelerates the dresser? Under what circumstances could the dresser slide? In which direction?

Friction between the dresser and the truck accelerates the dresser forward. If the force of the truck on the dresser exceeds $\mu_s mg$, the dresser will slide backward.

32. Critical Thinking You push a 13-kg table in the cafeteria with a horizontal force of 20 N, but it does not move. You then push it with a horizontal force of 25 N, and it accelerates at 0.26 m/s². What, if anything, can you conclude about the coefficients of static and kinetic friction?

From the sliding portion of your experiment you can determine that the coefficient of kinetic friction between the table and the floor is

$F_f = F_{on\ table} - F_2$

$\mu_k F_N = F_{on\ table} - ma$

$\mu_k = \dfrac{F_{on\ table} - ma}{mg}$

$= \dfrac{25\ N - (13\ kg)(0.26\ m/s)}{(13\ kg)(9.80\ m/s^2)}$

$= 0.17$

All you can conclude about the coefficient of static friction is that it is between

$\mu_s = \dfrac{F_{on\ table}}{mg}$

$= \dfrac{20\ N}{(13\ kg)(9.80\ m/s^2)}$

$= 0.16$

and $\mu_s = \dfrac{F_{on\ table}}{mg}$

$= \dfrac{25\ N}{(13\ kg)(9.80\ m/s^2)}$

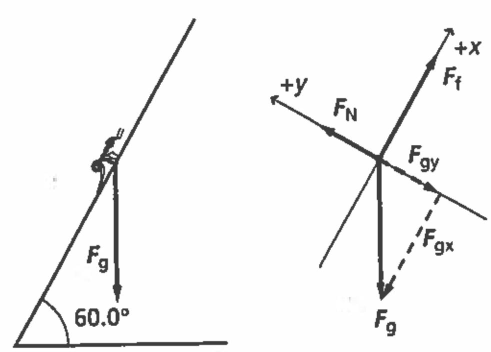
$= 0.20$

Practice Problems

5.3 Force and Motion in Two Dimensions pages 131–135

page 133

33. An ant climbs at a steady speed up the side of its anthill, which is inclined 30.0° from the vertical. Sketch a free-body diagram for the ant.

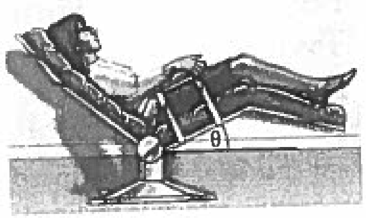


34. Scott and Becca are moving a folding table out of the sunlight. A cup of lemonade, with a mass of 0.44 kg, is on the table. Scott lifts his end of the table before Becca does, and as a result, the table makes an angle of 15.0° with the horizontal. Find the components of the cup's weight that are parallel and perpendicular to the plane of the table.

$$F_{g,\text{ parallel}} = F_g \sin\theta$$
$$= (0.44\text{ kg})(9.80\text{ m/s}^2)(\sin 15.0°)$$
$$= 1.1\text{ N}$$

$$F_{g,\text{ perpendicular}} = F_g \cos\theta$$
$$= (0.44\text{ kg})(9.80\text{ m/s}^2)(\cos 15.0°)$$
$$= 4.2\text{ N}$$

35. Kohana, who has a mass of 50.0 kg, is at the dentist's office having her teeth cleaned, as shown in **Figure 5-14.** If the component of her weight perpendicular to the plane of the seat of the chair is 449 N, at what angle is the chair tilted?



■ **Figure 5-14**

$$F_{g,\text{ perpendicular}} = F_g \cos\theta = mg\cos\theta$$

$$\theta = \cos^{-1}\left(\frac{F_{g,\text{ perpendicular}}}{mg}\right)$$
$$= \cos^{-1}\left(\frac{449\text{ N}}{(50.0\text{ kg})(9.80\text{ m/s}^2)}\right)$$
$$= 23.6°$$

36. Fernando, who has a mass of 43.0 kg, slides down the banister at his grandparents' house. If the banister makes an angle of 35.0° with the horizontal, what is the normal force between Fernando and the banister?

$$F_N = mg\cos\theta$$
$$= (43.0\text{ kg})(9.80\text{ m/s}^2)(\cos 35.0°)$$
$$= 345\text{ N}$$

37. A suitcase is on an inclined plane. At what angle, relative to the vertical, will the component of the suitcase's weight parallel to the plane be equal to half the perpendicular component of its weight?

$F_{g,\text{ parallel}} = F_g \sin\theta$, when the angle is with respect to the horizontal

$F_{g,\text{ perpendicular}} = F_g \cos\theta$, when the angle is with respect to the horizontal

$$F_{g,\text{ perpendicular}} = 2F_{g,\text{ parallel}}$$

$$2 = \frac{F_{g,\text{ perpendicular}}}{F_{g,\text{ parallel}}}$$
$$= \frac{F_g\cos\theta}{F_g\sin\theta}$$
$$= \frac{1}{\tan\theta}$$

$$\theta = \tan^{-1}\left(\frac{1}{2}\right)$$

= 26.6° relative to the horizontal, or 63.4° relative to the vertical

page 135

38. Consider the crate on the incline in Example Problem 5.

a. Calculate the magnitude of the acceleration.

$$a = \frac{F}{m}$$
$$= \frac{F_g\sin\theta}{m}$$
$$= \frac{mg\sin\theta}{m}$$
$$= g\sin\theta$$
$$= (9.80\text{ m/s}^2)(\sin 30.0°)$$
$$= 4.90\text{ m/s}^2$$

b. After 4.00 s, how fast will the crate be moving?

$$a = \frac{v_f - v_i}{t_f - t_i};\ \text{let } v_i = t_i = 0.$$

Solve for v_f.

$$v_f = at_f$$
$$= (4.90\text{ m/s}^2)(4.00\text{ s})$$
$$= 19.6\text{ m/s}$$

39. If the skier in Example Problem 6 were on a 31° downhill slope, what would be the magnitude of the acceleration?

Since $a = g(\sin\theta - \mu\cos\theta)$,

$a = (9.80\ m/s^2)(\sin 31° - (0.15)(\cos 31°))$

$= 3.8\ m/s^2$

40. Stacie, who has a mass of 45 kg, starts down a slide that is inclined at an angle of 45° with the horizontal. If the coefficient of kinetic friction between Stacie's shorts and the slide is 0.25, what is her acceleration?

$$F_{\text{Stacie's weight parallel with slide}} - F_f = ma$$

$$a = \frac{F_{\text{Stacie's weight parallel with slide}} - F_f}{m}$$

$$= \frac{mg\sin\theta - \mu_k F_N}{m}$$

$$= \frac{mg\sin\theta - \mu_k mg\cos\theta}{m}$$

$$= g(\sin\theta - \mu_k\cos\theta)$$

$$= (9.80\ m/s^2)[\sin 45° - (0.25)(\cos 45°)]$$

$$= 5.2\ m/s^2$$

41. After the skier on the 37° hill in Example Problem 6 had been moving for 5.0 s, the friction of the snow suddenly increased and made the net force on the skier zero. What is the new coefficient of friction?

$$a = g(\sin\theta - \mu_k\cos\theta)$$

$$a = g\sin\theta - g\mu_k\cos\theta$$

If $a = 0$,

$$0 = g\sin\theta - g\mu_k\cos\theta$$

$$\mu_k\cos\theta = \sin\theta$$

$$\mu_k = \frac{\sin\theta}{\cos\theta}$$

$$\mu_k = \frac{\sin 37°}{\cos 37°}$$

$$= 0.75$$

Section Review

5.3 Force and Motion in Two Dimensions pages 131–135

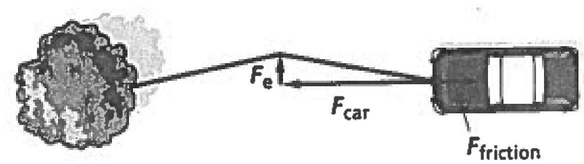
page 135

42. Forces One way to get a car unstuck is to tie one end of a strong rope to the car and the other end to a tree, then push the rope at its midpoint at right angles to the rope. Draw a free-body diagram and explain why even a small force on the rope can exert a large force on the car.

The vectors shown in the free body diagram indicate that even a small force perpendicular to the rope can increase the tension in the rope enough to overcome the friction force. Since $F = 2T\sin\theta$ (where θ is the angle between the rope's original position and its displaced position),

$$T = \frac{F}{2\sin\theta}$$

For smaller values of θ, the tension, T, will increase greatly.



43. Mass A large scoreboard is suspended from the ceiling of a sports arena by 10 strong cables. Six of the cables make an angle of 8.0° with the vertical while the other four make an angle of 10.0°. If the tension in each cable is 1300.0 N, what is the scoreboard's mass?

$F_{net,y} = ma_y = 0$

$F_{net,y} = F_{cables\ on\ board} - F_g$

$= 6F_{cable} \cos \theta_6 + 4F_{cable} \cos \theta_4 - mg = 0$

$m = \frac{6F_{cable} \cos \theta_6 + 4F_{cable} \cos \theta_4}{g}$

$= \frac{6(1300.0\ N)(\cos 8.0°) + 4(1300.0\ N)(\cos 10.0°)}{9.80\ m/s^2}$

$= 1.31 \times 10^3$ kg

44. Acceleration A 63-kg water skier is pulled up a 14.0° incline by a rope parallel to the incline with a tension of 512 N. The coefficient of kinetic friction is 0.27. What are the magnitude and direction of the skier's acceleration?

$F_N = mg \cos \theta$

$F_{rope\ on\ skier} - F_g - F_f = ma$

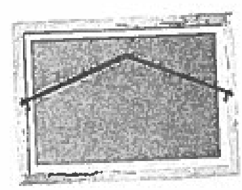
$F_{rope\ on\ skier} - mg \sin \theta - \mu_k mg \cos \theta = ma$

$a = \frac{F_{rope\ on\ skier} - mg \sin \theta - \mu_k mg \cos \theta}{m}$

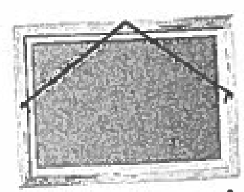
$= \frac{512\ N - (63\ kg)(9.80\ m/s^2)(\sin 14.0°) - (0.27)(63\ kg)(9.80\ m/s^2)(\cos 14.0°)}{63\ kg}$

$= 3.2\ m/s^2$, up the incline

45. Equilibrium You are hanging a painting using two lengths of wire. The wires will break if the force is too great. Should you hang the painting as shown in **Figures 5-15a** or **5-15b?** Explain.



■ **Figure 5-15a**



■ **Figure 5-15b**

Figure 5-15b; $F_T = \frac{F_g}{2 \sin \theta}$, so F_T gets smaller as θ gets larger, and θ is larger in 5-15b.

46. Critical Thinking Can the coefficient of friction ever have a value such that a skier would be able to slide uphill at a constant velocity? Explain why or why not. Assume there are no other forces acting on the skier.

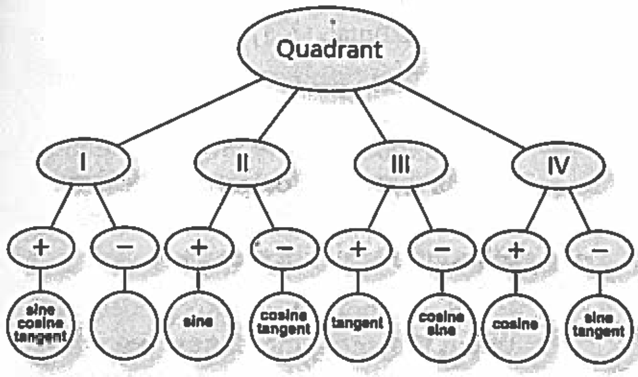
No, because if the skier moves uphill, both the frictional force opposing the motion of the skier and the component of Earth's gravity parallel to the slope point downhill, not uphill.

Chapter Assessment

Concept Mapping

page 140

47. Complete the concept map below by labeling the circles with *sine, cosine,* or *tangent* to indicate whether each function is positive or negative in each quadrant.



Mastering Concepts

page 140

48. Describe how you would add two vectors graphically. (5.1)

Make scale drawings of arrows representing the vector quantities. Place the arrows for the quantities to be added tip-to-tail. Draw an arrow from the tail of the first to the tip of the last. Measure the length of that arrow and find its direction.

49. Which of the following actions is permissible when you graphically add one vector to another: moving the vector, rotating the vector, or changing the vector's length? (5.1)

allowed: moving the vector without changing length or direction

50. In your own words, write a clear definition of the resultant of two or more vectors. Do not explain how to find it; explain what it represents. (5.1)

The resultant is the vector sum of two or more vectors. It represents the quantity that results from adding the vectors.

51. How is the resultant displacement affected when two displacement vectors are added in a different order? (5.1)

It is not affected.

52. Explain the method that you would use to subtract two vectors graphically. (5.1)

Reverse the direction of the second vector and then add them.

53. Explain the difference between these two symbols: **A** and *A*. (5.1)

***A* is the symbol for the vector quantity. *A* is the signed magnitude (length) of the vector.**

54. The Pythagorean theorem usually is written $c^2 = a^2 + b^2$. If this relationship is used in vector addition, what do *a, b,* and *c* represent? (5.1)

***a* and *b* represent the lengths of two vectors that are at the right angles to one another. *c* represents the length of the sum of the two vectors.**

55. When using a coordinate system, how is the angle or direction of a vector determined with respect to the axes of the coordinate system? (5.1)

The angle is measured counterclockwise from the *x*-axis.

56. What is the meaning of a coefficient of friction that is greater than 1.0? How would you measure it? (5.2)

The frictional force is greater than the normal force. You can pull the object along the surface, measuring the force needed to move it at constant speed. Also measure the weight of the object.

57. **Cars** Using the model of friction described in this textbook, would the friction between a tire and the road be increased by a wide rather than a narrow tire? Explain. (5.2)

It would make no difference. Friction does not depend upon surface area.

58. Describe a coordinate system that would be suitable for dealing with a problem in which a ball is thrown up into the air. (5.3)

One axis is vertical, with the positive direction either up or down.

88. Space Exploration A descent vehicle landing on Mars has a vertical velocity toward the surface of Mars of 5.5 m/s. At the same time, it has a horizontal velocity of 3.5 m/s.

a. At what speed does the vehicle move along its descent path?

$$R^2 = A^2 + B^2$$

$$R = \sqrt{(5.5\text{ m/s})^2 + (3.5\text{ m/s})^2}$$

$$v = R = 6.5\text{ m/s}$$

b. At what angle with the vertical is this path?

$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$

$$= \tan^{-1}\left(\frac{5.5}{3.5}\right)$$

$= 58°$ **from horizontal, which is 32° from vertical**

89. Navigation Alfredo leaves camp and, using a compass, walks 4 km E, then 6 km S, 3 km E, 5 km N, 10 km W, 8 km N, and, finally, 3 km S. At the end of three days, he is lost. By drawing a diagram, compute how far Alfredo is from camp and which direction he should take to get back to camp.

Take north and east to be positive directions. North: −6 km + 5 km + 8 km − 3 km = 4 km. East: 4 km + 3 km − 10 km = −3 km. The hiker is 4 km north and 3 km west of camp. To return to camp, the hiker must go 3 km east and 4 km south.

$$R^2 = A^2 + B^2$$

$$R = \sqrt{(3\text{ km})^2 + (4\text{ km})^2}$$

$$= 5\text{ km}$$

$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$

$$= \tan^{-1}\left(\frac{4\text{ km}}{3\text{ km}}\right)$$

$$= 53°$$

$R = 5$ **km, 53° south of east**

5.2 Friction

page 142

Level 1

90. If you use a horizontal force of 30.0 N to slide a 12.0-kg wooden crate across a floor at a constant velocity, what is the coefficient of kinetic friction between the crate and the floor?

$$F_f = \mu_k F_N = \mu_k mg = F_{horizontal}$$

$$\mu_k = \frac{F_{horizontal}}{mg}$$

$$= \frac{30.0\text{ N}}{(12.0\text{ kg})(9.80\text{ m/s}^2)}$$

$$= 0.255$$

91. A 225-kg crate is pushed horizontally with a force of 710 N. If the coefficient of friction is 0.20, calculate the acceleration of the crate.

$$ma = F_{net} = F_{appl} - F_f$$

where $F_f = \mu_k F_N = \mu_k mg$

Therefore

$$a = \frac{F_{appl} - \mu_k mg}{m}$$

$$= \frac{710\text{ N} - (0.20)(225\text{ kg})(9.80\text{ m/s}^2)}{225\text{ kg}}$$

$$= 1.2\text{ m/s}^2$$

Level 2

92. A force of 40.0 N accelerates a 5.0-kg block at 6.0 m/s^2 along a horizontal surface.

a. How large is the frictional force?

$$ma = F_{net} = F_{appl} - F_f$$

so $F_f = F_{appl} - ma$

$$= 40.0\text{ N} - (5.0\text{ kg})(6.0\text{ m/s}^2)$$

$$= 1.0\times10^1\text{ N}$$

b. What is the coefficient of friction?

$$F_f = \mu_k F_N = \mu_k mg$$

so $\mu_k = \frac{F_f}{mg}$

$$= \frac{1.0\times10^1\text{ N}}{(5.0\text{ kg})(9.80\text{ m/s}^2)}$$

$$= 0.20$$

93. **Moving Appliances** Your family just had a new refrigerator delivered. The delivery man has left and you realize that the refrigerator is not quite in the right position, so you plan to move it several centimeters. If the refrigerator has a mass of 180 kg, the coefficient of kinetic friction between the bottom of the refrigerator and the floor is 0.13, and the static coefficient of friction between these same surfaces is 0.21, how hard do you have to push horizontally to get the refrigerator to start moving?

$F_{\text{on fridge}} = F_{\text{friction}}$

$= \mu_s F_N$

$= \mu_s mg$

$= (0.21)(180\ \text{kg})(9.80\ \text{m/s}^2)$

$= 370\ \text{N}$

Level 3

94. **Stopping at a Red Light** You are driving a 2500.0-kg car at a constant speed of 14.0 m/s along a wet, but straight, level road. As you approach an intersection, the traffic light turns red. You slam on the brakes. The car's wheels lock, the tires begin skidding, and the car slides to a halt in a distance of 25.0 m. What is the coefficient of kinetic friction between your tires and the wet road?

$F_f = \mu_k F_N = ma$

$-\mu_k mg = \dfrac{m(v_f^2 - v_i^2)}{2\Delta d}$ where $v_f = 0$

(The minus sign indicates the force is acting opposite to the direction of motion.)

$\mu_k = \dfrac{v_i^2}{2dg}$

$= \dfrac{(14.0\ \text{m/s})^2}{2(25.0\ \text{m})(9.80\ \text{m/s}^2)}$

$= 0.400$

5.3 Force and Motion in Two Dimensions

pages 142–143

Level 1

95. An object in equilibrium has three forces exerted on it. A 33.0-N force acts at 90.0° from the *x*-axis and a 44.0-N force acts at 60.0° from the *x*-axis. What are the magnitude and direction of the third force?

First, find the magnitude of the sum of these two forces. The equilibrant will have the same magnitude but opposite direction.

$F_1 = 33.0\ \text{N}, 90.0°$

$F_2 = 44.0\ \text{N}, 60.0°$

$F_3 = ?$

$F_{1x} = F_1 \cos \theta_1$

$= (33.0\ \text{N})(\cos 90.0°)$

$= 0.0\ \text{N}$

$F_{1y} = F_1 \sin \theta_1$

$= (33.0\ \text{N})(\sin 90.0°)$

$= 33.0\ \text{N}$

$F_{2x} = F_2 \cos \theta_2$

$= (44.0\ \text{N})(\cos 60.0°)$

$= 22.0\ \text{N}$

$F_{2y} = F_2 \sin \theta_2$

$= (44.0\ \text{N})(\sin 60.0°)$

$= 38.1\ \text{N}$

$F_{3x} = F_1x + F_2x$

$= 0.0\ \text{N} + 22.0\ \text{N}$

$= 22.0\ \text{N}$

$F_{3y} = F_1y + F_2y$

$= 33.0\ \text{N} + 38.1\ \text{N}$

$= 71.1\ \text{N}$

$F_3 = \sqrt{F_{3x}^2 + F_{3y}^2}$

$= \sqrt{(22.0\ \text{N})^2 + (71.1\ \text{N})^2}$

$= 74.4\ \text{N}$

For equilibrium, the sum of the components must equal zero, so

$\theta = \tan^{-1}\left(\frac{F_{3y}}{F_{3x}}\right) + 180.0°$

$= \tan^{-1}\left(\frac{71.1\text{ N}}{22.0\text{ N}}\right) + 180.0°$

$= 253°$

$F_3 = 74.4\text{ N}, 253°$

Level 2

96. Five forces act on an object: (1) 60.0 N at 90.0°, (2) 40.0 N at 0.0°, (3) 80.0 N at 270.0°, (4) 40.0 N at 180.0°, and (5) 50.0 N at 60.0°. What are the magnitude and direction of a sixth force that would produce equilibrium?

Solutions by components

$F_1 = 60.0\text{ N}, 90.0°$

$F_2 = 40.0\text{ N}, 0.0°$

$F_3 = 80.0\text{ N}, 270.0°$

$F_4 = 40.0\text{ N}, 180.0°$

$F_5 = 50.0\text{ N}, 60.0°$

$F_6 = ?$

$F_{1x} = F_1 \cos\theta_1$

$= (60.0\text{ N})(\cos 90.0°) = 0.0\text{ N}$

$F_{1y} = F_1 \sin\theta_1 = (60.0\text{ N})(\sin 90.0°)$

$= 60.0\text{ N}$

$F_{2x} = F_2 \cos\theta_2 = (40.0\text{ N})(\cos 0.0°)$

$= 40.0\text{ N}$

$F_{2y} = F_2 \sin\theta_2 = (40.0\text{ N})(\sin 0.0°)$

$= 0.0\text{ N}$

$F_{3x} = F_3 \cos\theta_3 = (80.0\text{ N})(\cos 270.0°)$

$= 0.0\text{ N}$

$F_{3y} = F_3 \sin\theta_3 = (80.0\text{ N})(\sin 270.0°)$

$= -80.0\text{ N}$

$F_{4x} = F_4 \cos\theta_4 = (40.0\text{ N})(\cos 180.0°)$

$= -40.0\text{ N}$

$F_{4y} = F_4 \sin\theta_4 = (40.0\text{ N})(\sin 180.0°)$

$= 0.0\text{ N}$

$F_{5x} = F_5 \cos\theta_5 = (50.0\text{ N})(\cos 60.0°)$

$= 25.0\text{ N}$

$F_{5y} = F_5 \sin\theta_5 = (50.0\text{ N})(\sin 60.0°)$

$= 43.3\text{ N}$

$F_{6x} = F_{1x} + F_{2x} + F_{3x} + F_{4x} + F_{5x}$

$= 0.0\text{ N} + 40.0\text{ N} + 0.0\text{ N} + (-40.0\text{ N}) + 25.0\text{ N}$

$= 25.0\text{ N}$

$F_{6y} = F_{1y} + F_{2y} + F_{3y} + F_{4y} + F_{5y}$

$= 60.0\text{ N} + 0.0\text{ N} + (-80.0\text{ N}) + 0.0\text{ N} + 43.3\text{ N}$

$= 23.3\text{ N}$

$F_6 = \sqrt{{F_{6x}}^2 + {F_{6y}}^2}$

$= \sqrt{(25.0\text{ N})^2 + (23.3\text{ N})^2}$

$= 34.2\text{ N}$

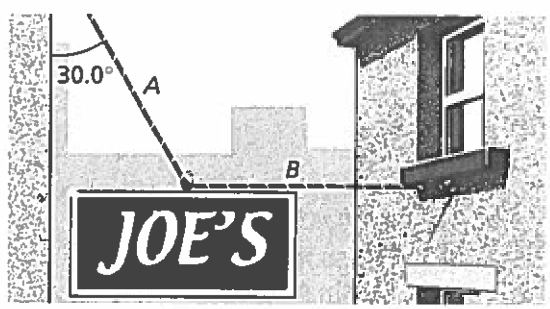
$\theta_6 = \tan^{-1}\left(\frac{F_{6y}}{F_{6x}}\right) + 180.0°$

$= \tan^{-1}\left(\frac{23.3\text{ N}}{25.0\text{ N}}\right) + 180.0°$

$= 223°$

$F_6 = 34.2\text{ N}, 223°$

97. Advertising Joe wishes to hang a sign weighing 7.50×10^2 N so that cable *A*, attached to the store, makes a 30.0° angle, as shown in **Figure 5-20.** Cable *B* is horizontal and attached to an adjoining building. What is the tension in cable *B*?



■ **Figure 5-20**

Solution by components. The sum of the components must equal zero, so

$F_{Ay} - F_g = 0$

so $F_{Ay} = F_g$

$= 7.50\times10^2$ N

$F_{Ay} = F_A \sin 60.0°$

so $F_A = \frac{F_{Ay}}{\sin 60.0°}$

$= \frac{7.50\times10^2 \text{ N}}{\sin 60.0°}$

$= 866$ N

Also, $F_B - F_A = 0$, so

$F_B = F_A$

$= F_A \cos 60.0°$

$= (866 \text{ N})(\cos 60.0°)$

$= 433$ N, right

98. A street lamp weighs 150 N. It is supported by two wires that form an angle of 120.0° with each other. The tensions in the wires are equal.

a. What is the tension in each wire supporting the street lamp?

$F_g = 2T \sin \theta$

so $T = \frac{F_g}{2 \sin \theta}$

$= \frac{150 \text{ N}}{(2)(\sin 30.0°)}$

$= 1.5\times10^2$ N

b. If the angle between the wires supporting the street lamp is reduced to 90.0°, what is the tension in each wire?

$T = \frac{F_g}{2 \sin \theta}$

$= \frac{150 \text{ N}}{(2)(\sin 45°)}$

$= 1.1\times10^2$ N

99. A 215-N box is placed on an inclined plane that makes a 35.0° angle with the horizontal. Find the component of the weight force parallel to the plane's surface.

$F_{parallel} = F_g \sin \theta$

$= (215 \text{ N})(\sin 35.0°)$

$= 123$ N

Level 3

100. Emergency Room You are shadowing a nurse in the emergency room of a local hospital. An orderly wheels in a patient who has been in a very serious accident and has had severe bleeding. The nurse quickly explains to you that in a case like this, the patient's bed will be tilted with the head downward to make sure the brain gets enough blood. She tells you that, for most patients, the largest angle that the bed can be tilted without the patient beginning to slide off is 32.0° from the horizontal.

a. On what factor or factors does this angle of tilting depend?

The coefficient of static friction between the patient and the bed's sheets.

b. Find the coefficient of static friction between a typical patient and the bed's sheets.

$F_{g \text{ parallel to bed}} = mg \sin \theta$

$= F_f$

$= \mu_s F_N$

$= \mu_s mg \cos \theta$

so $\mu_s = \frac{mg \sin \theta}{mg \cos \theta}$

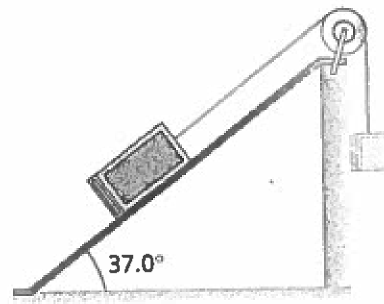
$= \frac{\sin \theta}{\cos \theta}$

$= \tan \theta$

$= \tan 32.0°$

$= 0.625$

101. Two blocks are connected by a string over a frictionless, massless pulley such that one is resting on an inclined plane and the other is hanging over the top edge of the plane, as shown in **Figure 5-21.** The hanging block has a mass of 16.0 kg, and the one on the plane has a mass of 8.0 kg. The coefficient of kinetic friction between the block and the inclined plane is 0.23. The blocks are released from rest.



■ **Figure 5-21**

a. What is the acceleration of the blocks?

$F = m_{both}a = F_{g\ hanging} - F_{\parallel plane} + F_{f\ plane}$

$$\text{so } a = \frac{m_{hanging}g - F_{g\ plane}\sin\theta + \mu_k F_{g\ plane}\cos\theta}{m_{both}}$$

$$= \frac{m_{hanging}g - m_{plane}g\sin\theta + \mu_k m_{plane}g\cos\theta}{m_{both}}$$

$$= \frac{g(m_{hanging} - m_{plane}\sin\theta + \mu_k m_{plane}\cos\theta)}{m_{hanging} + m_{plane}}$$

$$= \frac{(9.80\ \text{m/s}^2)(16.0\ \text{kg} - (8.0\ \text{kg})(\sin 37.0^\circ) + (0.23)(8.0\ \text{kg})(\cos 37.0^\circ))}{(16.0\ \text{kg} + 8.0\ \text{kg})}$$

$= 1.3\ \text{m/s}^2$

b. What is the tension in the string connecting the blocks?

$F_T = F_g - F_a$

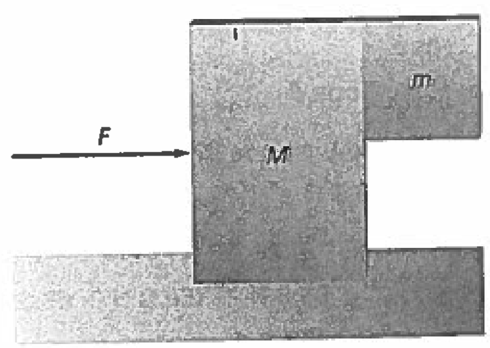
$= mg - ma$

$= m(g - a)$

$= (16.0\ \text{kg})(9.80\ \text{m/s}^2 - 1.3\ \text{m/s}^2)$

$= 140\ \text{N}$

102. In **Figure 5-22,** a block of mass M is pushed with such a force, F, that the smaller block of mass m does not slide down the front of it. There is no friction between the larger block and the surface below it, but the coefficient of static friction between the two blocks is μ_s. Find an expression for F in terms of M, m, μ_s, and g.



■ **Figure 5-22**

Smaller block:

$F_{f,\ M\ on\ m} = \mu_s F_{N,\ M\ on\ m} = mg$

$$F_{N,\ M\ on\ m} = \frac{mg}{\mu_s} = ma$$

$$a = \frac{g}{\mu_s}$$

Larger block:

$F - F_{N,\,m\ on\ M} = Ma$

$F - \frac{mg}{\mu_s} = \frac{Mg}{\mu_s}$

$F = \frac{g}{\mu_s}(m + M)$

Mixed Review

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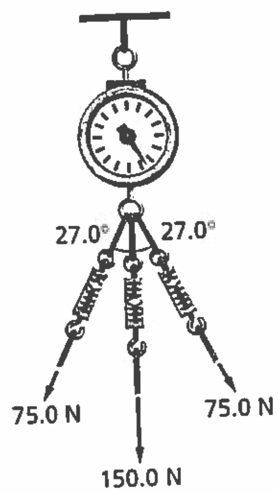
Level 1

103. The scale in **Figure 5-23** is being pulled on by three ropes. What net force does the scale read?



■ **Figure 5-7**

Find the *y*-component of the two side ropes and then add them to the middle rope.

$F_y = F\cos\theta$

$= (75.0\ N)(\cos 27.0°)$

$= 66.8\ N$

$F_{y,\,total} = F_{y,\,left} + F_{y,\,middle} + F_{y,\,right}$

$= 66.8\ N + 150.0\ N + 66.8\ N$

$= 283.6\ N$

104. Sledding A sled with a mass of 50.0 kg is pulled along flat, snow-covered ground. The static friction coefficient is 0.30, and the kinetic friction coefficient is 0.10.

a. What does the sled weigh?

$F_g = mg = (50.0\ kg)(9.80\ m/s^2)$

$= 4.90\times10^2\ N$

b. What force will be needed to start the sled moving?

$F_f = \mu_s F_N$

$= \mu_s F_g$

$= (0.30)(4.90\times10^2\ N)$

$= 1.5\times10^2\ N$

c. What force is needed to keep the sled moving at a constant velocity?

$F_f = \mu_k F_N$

$= \mu_k F_g$

$= (0.10)(4.90\times10^2\ N)$

$= 49\ N$

d. Once moving, what total force must be applied to the sled to accelerate it at 3.0 m/s²?

$ma = F_{net} = F_{appl} - F_f$

so $F_{appl} = ma + F_f$

$= (50.0\ kg)(3.0\ m/s^2) + 49\ N$

$= 2.0\times10^2\ N$

Level 2

105. Mythology Sisyphus was a character in Greek mythology who was doomed in Hades to push a boulder to the top of a steep mountain. When he reached the top, the boulder would slide back down the mountain and he would have to start all over again. Assume that Sisyphus slides the boulder up the mountain without being able to roll it, even though in most versions of the myth, he rolled it.

a. If the coefficient of kinetic friction between the boulder and the mountainside is 0.40, the mass of the boulder is 20.0 kg, and the slope of the mountain is a constant 30.0°, what is the force that Sisyphus must exert on the boulder to move it up the mountain at a constant velocity?

$F_{S\ on\ rock} - F_{g\parallel to\ slope} - F_f$

$= F_{S\ on\ rock} - mg\sin\theta -$

$\mu_k mg\cos\theta = ma = 0$

$F_{S\ on\ rock} = mg\sin\theta + \mu_k mg\cos\theta$

$= mg(\sin\theta + \mu_k \cos\theta)$

$= (20.0\ \text{kg})(9.80\ \text{m/s}^2)$
$(\sin 30.0° + (0.40)(\cos 30.0°))$

$= 166\ \text{N}$

b. If Sisyphus pushes the boulder at a velocity of 0.25 m/s and it takes him 8.0 h to reach the top of the mountain, what is the mythical mountain's vertical height?

$h = d\sin\theta$

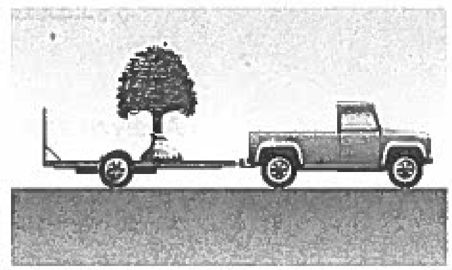
$= vt\sin\theta$

$= (0.25\ \text{m/s})(8.0\ \text{h})(3600\ \text{s/h})(\sin 30.0°)$

$= 3.6\times10^3\ \text{m} = 3.6\ \text{km}$

Level 3

106. Landscaping A tree is being transported on a flatbed trailer by a landscaper, as shown in **Figure 5-24.** If the base of the tree slides on the trailer, the tree will fall over and be damaged. If the coefficient of static friction between the tree and the trailer is 0.50, what is the minimum stopping distance of the truck, traveling at 55 km/h, if it is to accelerate uniformly and not have the tree slide forward and fall on the trailer?



■ **Figure 5-24**

$F_{truck} = -F_f = -\mu_s F_N = -\mu_s mg = ma$

$a = \dfrac{-\mu_s mg}{m} = -\mu_s g$

$= -(0.50)(9.80\ \text{m/s}^2)$

$= -4.9\ \text{m/s}^2$

$v_f^2 = v_i^2 + 2a\Delta d$ with $v_f = 0$,

so $\Delta d = -\dfrac{v_i^2}{2a}$

$= \dfrac{-\left((55\ \text{km/h})\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\right)^2}{(2)(-4.9\ \text{m/s}^2)}$

$= 24\ \text{m}$