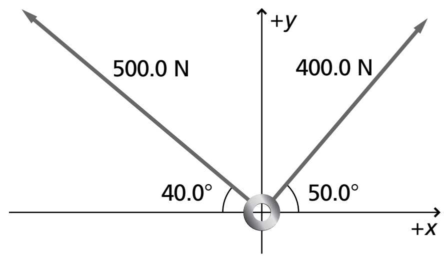
85. What is the net force acting on the ring in **Figure 5-18?**



■ **Figure 5-18**

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

$R = \sqrt{A^2 + B^2}$

$= \sqrt{(500.0\ \text{N})^2 + (400.0\ \text{N})^2}$

$= 640.3\ \text{N}$

$\tan\theta = \frac{A}{B}$

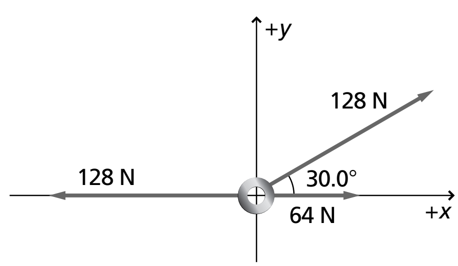
$\theta = \tan^{-1}\left(\frac{A}{B}\right)$

$= \tan^{-1}\left(\frac{500.0}{400.0}\right)$

$= 51.34°$ from B

The net force is 640.3 N at 51.34°

86. What is the net force acting on the ring in **Figure 5-19?**



■ **Figure 5-19**

$A = -128\ \text{N} + 64\ \text{N}$

$= -64\ \text{N}$

$A_x = A\cos\theta_A$

$= (-64\ \text{N})(\cos 180°)$

$= -64\ \text{N}$

$A_y = A\sin\theta_A$

$= (-64\ \text{N})(\sin 180°)$

$= 0\ \text{N}$

$B_x = B\cos\theta_B$

$= (128\ \text{N})(\cos 30.0°)$

$= 111\ \text{N}$

$B_y = B\sin\theta_B$

$= (128\ \text{N})(\sin 30.0°)$

$= 64\ \text{N}$

$R_x = A_x + B_x$

$= -64\ \text{N} + 111\ \text{N}$

$= 47\ \text{N}$

$R_y = A_y + B_y$

$= 0\ \text{N} + 64\ \text{N}$

$= 64\ \text{N}$

$R = \sqrt{R_x{}^2 + R_y{}^2}$

$= \sqrt{(47\ \text{N})^2 + (64\ \text{N})^2}$

$= 79\ \text{N}$

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

$= \tan^{-1}\left(\frac{64}{47}\right)$

$= 54°$

Level 3

87. A Ship at Sea A ship at sea is due into a port 500.0 km due south in two days. However, a severe storm comes in and blows it 100.0 km due east from its original position. How far is the ship from its destination? In what direction must it travel to reach its destination?

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

$R = \sqrt{(100.0\ \text{km})^2 + (500.0\ \text{km})^2}$

$= 509.9\ \text{km}$

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

$= \tan^{-1}\left(\frac{500.0}{100.0}\right)$

$= 78.69°$

$R = 509.9\ \text{km}, 78.69°$ **south of west**

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?

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

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

$$= 58° \text{ from horizontal, which is } 32° \text{ from vertical}$$

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.

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

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

$$= 5\text{ km}$$

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

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

$$= 53°$$

$$R = 5\text{ km, } 53° \text{ south of east}$$

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 $\mu_k = \dfrac{F_f}{mg}$

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

$$= 0.20$$

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?

$$\begin{aligned} F_{\text{on fridge}} &= F_{\text{friction}} \\ &= \mu_s F_N \\ &= \mu_s mg \\ &= (0.21)(180\ \text{kg})(9.80\ \text{m/s}^2) \\ &= 370\ \text{N} \end{aligned}$$

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?

$$F_f = \mu_k F_N = ma$$

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

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

$$\begin{aligned} \mu_k &= \frac{v_i^2}{2dg} \\ &= \frac{(14.0\ \text{m/s})^2}{2(25.0\ \text{m})(9.80\ \text{m/s}^2)} \\ &= 0.400 \end{aligned}$$

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.

$F_1 = 33.0\ \text{N}, 90.0°$

$F_2 = 44.0\ \text{N}, 60.0°$

$F_3 = ?$

$$\begin{aligned} F_{1x} &= F_1 \cos \theta_1 \\ &= (33.0\ \text{N})(\cos 90.0°) \\ &= 0.0\ \text{N} \end{aligned}$$

$$\begin{aligned} F_{1y} &= F_1 \sin \theta_1 \\ &= (33.0\ \text{N})(\sin 90.0°) \\ &= 33.0\ \text{N} \end{aligned}$$

$$\begin{aligned} F_{2x} &= F_2 \cos \theta_2 \\ &= (44.0\ \text{N})(\cos 60.0°) \\ &= 22.0\ \text{N} \end{aligned}$$

$$\begin{aligned} F_{2y} &= F_2 \sin \theta_2 \\ &= (44.0\ \text{N})(\sin 60.0°) \\ &= 38.1\ \text{N} \end{aligned}$$

$$\begin{aligned} F_{3x} &= F_1x + F_2x \\ &= 0.0\ \text{N} + 22.0\ \text{N} \\ &= 22.0\ \text{N} \end{aligned}$$

$$\begin{aligned} F_{3y} &= F_1y + F_2y \\ &= 33.0\ \text{N} + 38.1\ \text{N} \\ &= 71.1\ \text{N} \end{aligned}$$

$$\begin{aligned} F_3 &= \sqrt{F_{3x}^2 + F_{3y}^2} \\ &= \sqrt{(22.0\ \text{N})^2 + (71.1\ \text{N})^2} \\ &= 74.4\ \text{N} \end{aligned}$$

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

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

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

$$= 253°$$

$F_3 = 74.4$ **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

$F_1 = 60.0\text{ N}, 90.0°$

$F_2 = 40.0\text{ N}, 0.0°$

$F_3 = 80.0\text{ N}, 270.0°$

$F_4 = 40.0\text{ N}, 180.0°$

$F_5 = 50.0\text{ N}, 60.0°$

$F_6 = ?$

$$F_{1x} = F_1 \cos\theta_1 = (60.0\text{ N})(\cos 90.0°) = 0.0\text{ N}$$

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

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

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

$$F_{3x} = F_3 \cos\theta_3 = (80.0\text{ N})(\cos 270.0°) = 0.0\text{ N}$$

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

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

$$F_{4y} = F_4 \sin\theta_4 = (40.0\text{ N})(\sin 180.0°) = 0.0\text{ N}$$

$$F_{5x} = F_5 \cos\theta_5 = (50.0\text{ N})(\cos 60.0°) = 25.0\text{ N}$$

$$F_{5y} = F_5 \sin\theta_5 = (50.0\text{ N})(\sin 60.0°) = 43.3\text{ N}$$

$$F_{6x} = F_{1x} + F_{2x} + F_{3x} + F_{4x} + F_{5x}$$
$$= 0.0\text{ N} + 40.0\text{ N} + 0.0\text{ N} + (-40.0\text{ N}) + 25.0\text{ N}$$
$$= 25.0\text{ N}$$

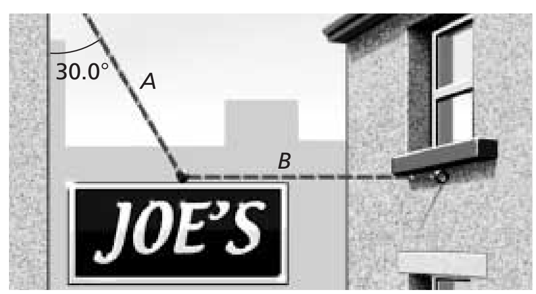
$$F_{6y} = F_{1y} + F_{2y} + F_{3y} + F_{4y} + F_{5y}$$
$$= 60.0\text{ N} + 0.0\text{ N} + (-80.0\text{ N}) + 0.0\text{ N} + 43.3\text{ N}$$
$$= 23.3\text{ N}$$

$$F_6 = \sqrt{F_{6x}^2 + F_{6y}^2}$$
$$= \sqrt{(25.0\text{ N})^2 + (23.3\text{ N})^2}$$
$$= 34.2\text{ N}$$

$$\theta_6 = \tan^{-1}\left(\frac{F_{6y}}{F_{6x}}\right) + 180.0°$$
$$= \tan^{-1}\left(\frac{23.3\text{ N}}{25.0\text{ N}}\right) + 180.0°$$
$$= 223°$$

$F_6 = 34.2\text{ N}, 223°$

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.

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

$= (215 \text{ N})(\sin 35.0°)$

$= 123$ 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 $\mu_s = \frac{mg \sin \theta}{mg \cos \theta}$

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

$= \tan \theta$

$= \tan 32.0°$

$= 0.625$