19. **REASONING AND SOLUTION** We know that $\mu_s = 2.0 \mu_k$ for a crate in contact with a cement floor. The maximum force of static friction is $f_s^{\text{MAX}} = \mu_s F_N$ while the force of kinetic friction is $f_k = \mu_k F_N$. As long as the crate is on the cement floor, we can conclude that the magnitude of the maximum static frictional force acting on the crate will always be twice the magnitude of the kinetic frictional force on the moving crate, once the crate has begun moving. However, the force of static friction may not have its maximum value. Thus, the magnitude of the static frictional force is not always twice the magnitude of the kinetic frictional force.
24. **REASONING AND SOLUTION**  A circus performer hangs from a stationary rope. Since there is no acceleration, the tension in the rope must be equal in magnitude to the weight of the performer. She then begins to climb upward by pulling herself up, hand-over-hand. Whether the tension in the rope is greater than or equal to the tension when she hangs stationary depends on whether or not she accelerates as she moves upward. When she moves upward at constant velocity, the tension in the rope will be the same. When she accelerates upward, the rope must support the net upward force in addition to her weight; therefore, in this case, the tension in the rope will be greater than when she hangs stationary.
There are three forces that act on the ring as shown in the figure below. The weight of the block, which acts downward, and two forces of tension that act along the rope away from the ring. Since the ring is at rest, the net force on the ring is zero. The weight of the block is balanced by the vertical components of the tension in the rope. Clearly, the rope can never be made horizontal, for then there would be no vertical components of the tension forces to balance the weight of the block.
34. **REASONING** In each case the object is in equilibrium. According to Equation 4.9b, \( \sum F_y = 0 \), the net force acting in the \( y \) (vertical) direction must be zero. The net force is composed of the weight of the object(s) and the normal force exerted on them.

**SOLUTION**

a. There are three vertical forces acting on the crate: an upward normal force \( +F_N \) that the floor exerts, the weight \(-m_1 g\) of the crate, and the weight \(-m_2 g\) of the person standing on the crate. Since the weights act downward, they are assigned negative numbers. Setting the sum of these forces equal to zero gives

\[
\sum F_y = F_N + (-m_1 g) + (-m_2 g) = 0
\]

The magnitude of the normal force is

\[
F_N = m_1 g + m_2 g = (35 \text{ kg} + 65 \text{ kg})(9.80 \text{ m/s}^2) = 980 \text{ N}
\]

b. There are only two vertical forces acting on the person: an upward normal force \( +F_N \) that the crate exerts and the weight \(-m_2 g\) of the person. Setting the sum of these forces equal to zero gives

\[
\sum F_y = F_N + (-m_2 g) = 0
\]

The magnitude of the normal force is

\[
F_N = m_2 g = (65 \text{ kg})(9.80 \text{ m/s}^2) = 640 \text{ N}
\]
The block will move only if the applied force is greater than the maximum static frictional force acting on the block. That is, if

\[ F > \mu_s F_N = \mu_s mg = (0.650)(45.0 \text{ N}) = 29.2 \text{ N} \]

The applied force is given to be \( F = 36.0 \text{ N} \) which is greater than the maximum static frictional force, so the block will move.

The block's acceleration is found from Newton's second law.

\[
a = \frac{\Sigma F}{m} = \frac{F - f_k}{m} = \frac{F - \mu_k mg}{m} = 3.72 \text{ m/s}^2
\]
Since the sled is pulled at constant velocity, its acceleration is zero, and Newton's second law in the direction of motion is (with right chosen as the positive direction)

\[ \sum F_x = P \cos \theta - f_k = ma_x = 0 \]

From Equation 4.8, we know that \( f_k = \mu_k F_N \), so that the above expression becomes

\[ P \cos \theta - \mu_k F_N = 0 \]  \hspace{1cm} (1)

In the vertical direction,

\[ \sum F_y = P \sin \theta + F_N - mg = ma_y = 0 \]  \hspace{1cm} (2)

Solving Equation (2) for the normal force, and substituting into Equation (1), we obtain

\[ P \cos \theta - \mu_k (mg - P \sin \theta) = 0 \]

Solving for \( \mu_k \), the coefficient of kinetic friction, we find

\[ \mu_k = \frac{P \cos \theta}{mg - P \sin \theta} = \frac{(80.0 \text{ N}) \cos 30.0^\circ}{(20.0 \text{ kg})(9.80 \text{ m/s}^2) - (80.0 \text{ N}) \sin 30.0^\circ} = 0.444 \]
47. **REASONING AND SOLUTION**
   
a. In the horizontal direction the thrust, $F$, is balanced by the resistive force, $f_r$, of the water. That is,
   
   \[ \Sigma F_x = 0 \]
   
or
   
   \[ f_r = F = 7.40 \times 10^5 \text{ N} \]
   
b. In the vertical direction, the weight, $mg$, is balanced by the buoyant force, $F_b$. So
   
   \[ \Sigma F_y = 0 \]
   
gives
   
   \[ F_b = mg = (1.70 \times 10^8 \text{ kg})(9.80 \text{ m/s}^2) = 1.67 \times 10^9 \text{ N} \]
50. **REASONING** The drawing shows the I-beam and the three forces that act on it, its weight $\mathbf{W}$ and the tension $\mathbf{T}$ in each of the cables. Since the I-beam is moving upward at a constant velocity, its acceleration is zero and it is in vertical equilibrium. According to Equation 4.9b, $\Sigma F_y = 0$, the net force in the vertical (or $y$) direction must be zero. This relation will allow us to find the magnitude of the tension.

**SOLUTION** Taking up as the $+y$ direction, Equation 4.9b becomes

$$\Sigma F_y = T \sin 70.0^\circ + T \sin 70.0^\circ - 8.00 \times 10^3 \text{ N} = 0$$

Solving this equation for the tension gives $T = \boxed{4260 \text{ N}}$.
54. **REASONING** The free-body diagram in the drawing at the right shows the forces that act on the clown (weight = $W$). In this drawing, note that $P$ denotes the pulling force. Since the rope passes around three pulleys, forces of magnitude $P$ are applied both to the clown’s hands and his feet. The normal force due to the floor is $F_N$, and the maximum static frictional force is $f_s^{MAX}$.

At the instant just before the clown’s feet move, the net vertical and net horizontal forces are zero, according to Newton’s second law, since there is no acceleration at this instant.

**SOLUTION** According to Newton’s second law, with upward and to the right chosen as the positive directions, we have

$$F_N + P - W = 0 \quad \text{and} \quad f_s^{MAX} - P = 0$$

From the horizontal-force equation we find $P = f_s^{MAX}$. But $f_s^{MAX} = \mu_s F_N$. From the vertical-force equation, the normal force is $F_N = W - P$. With these substitutions, it follows that

$$P = f_s^{MAX} = \mu_s F_N = \mu_s (W - P)$$

Solving for $P$ gives

$$P = \frac{\mu_s W}{1 + \mu_s} = \frac{(0.53)(890 \text{ N})}{1 + 0.53} = 310 \text{ N}$$
58. **REASONING** Since the mountain climber is at rest, she is in equilibrium and the net force acting on her must be zero. Three forces comprise the net force, her weight, and the tension forces from the left and right sides of the rope. We will resolve the forces into components and set the sum of the x components and the sum of the y components separately equal to zero. In so doing we will obtain two equations containing the unknown quantities, the tension $T_L$ in the left side of the rope and the tension $T_R$ in the right side. These two equations will be solved simultaneously to give values for the two unknowns.

**SOLUTION** Using $W$ to denote the weight of the mountain climber and choosing right and upward to be the positive directions, we have the following free-body diagram for the climber:

For the $x$ components of the forces we have

$$\Sigma F_x = T_R \sin 80.0^\circ - T_L \sin 65.0^\circ = 0$$

For the $y$ components of the forces we have

$$\Sigma F_y = T_R \cos 80.0^\circ + T_L \cos 65.0^\circ - W = 0$$

Solving the first of these equations for $T_R$, we find that

$$T_R = T_L \frac{\sin 65.0^\circ}{\sin 80.0^\circ}$$

Substituting this result into the second equation gives

$$T_L \frac{\sin 65.0^\circ}{\sin 80.0^\circ} \cos 80.0^\circ + T_L \cos 65.0^\circ - W = 0 \quad \text{or} \quad T_L = 1.717 W$$

Using this result in the expression for $T_R$ reveals that

$$T_R = T_L \frac{\sin 65.0^\circ}{\sin 80.0^\circ} = (1.717W) \frac{\sin 65.0^\circ}{\sin 80.0^\circ} = 1.580 W$$

Since the weight of the climber is $W = 535$ N, we find that

$$T_L = 1.717 W = 1.717 (535 \text{ N}) = 919 \text{ N}$$

$$T_R = 1.580 W = 1.580 (535 \text{ N}) = 845 \text{ N}$$