5.6. **Visualize:** Please refer to Figure Ex5.6.

**Solve:** For the diagram on the left, three of the vectors lie along the axes of the tilted coordinate system. Notice that the angle between the 3 N force and the $-y$-axis is the same $20^\circ$ by which the coordinates are tilted. Applying Newton’s second law,

\[
a_x = \frac{\vec{F}_{\text{net}}_x}{m} = \frac{5 \text{ N} - 1 \text{ N} - (3 \sin 20^\circ) \text{ N}}{2 \text{ kg}} = 1.49 \text{ m/s}^2
\]

\[
a_y = \frac{\vec{F}_{\text{net}}_y}{m} = \frac{2.82 \text{ N} - (3 \cos 20^\circ) \text{ N}}{2 \text{ kg}} = 0 \text{ m/s}^2
\]

For the diagram on the right, the 2-newton force in the first quadrant makes an angle of $15^\circ$ with the positive $x$-axis. The other 2-newton force makes an angle of $15^\circ$ with the negative $y$-axis. The accelerations are

\[
a_x = \frac{\vec{F}_{\text{net}}_x}{m} = \frac{(2 \cos 15^\circ) \text{ N} + (2 \sin 15^\circ) \text{ N} - 3 \text{ N}}{2 \text{ kg}} = -0.28 \text{ m/s}^2
\]

\[
a_y = \frac{\vec{F}_{\text{net}}_y}{m} = \frac{1.414 \text{ N} + (2 \sin 15^\circ) \text{ N} - (2 \cos 15^\circ) \text{ N}}{2 \text{ kg}} = 0 \text{ m/s}^2
\]
5.14. Model: We assume that the passenger is a particle acted on by only two vertical forces: the downward pull of gravity and the upward force of the elevator floor.

Visualize: Please refer to Figure Ex5.14. The graph has three segments corresponding to different conditions: (1) increasing velocity, meaning an upward acceleration, (2) a period of constant upward velocity, and (3) decreasing velocity, indicating a period of deceleration (negative acceleration).

Solve: Given the assumptions of our model, we can calculate the acceleration for each segment of the graph and then apply Equation 5.10. The acceleration for the first segment is

\[ a_y = \frac{v_y - v_0}{t_1 - t_0} = \frac{8 \text{ m/s} - 0 \text{ m/s}}{2 \text{ s} - 0 \text{ s}} = 4 \text{ m/s}^2 \]

\[ \Rightarrow w_{app} = \left(1 + \frac{a_y}{g}\right) = (mg)\left(1 + \frac{4 \text{ m/s}^2}{9.8 \text{ m/s}^2}\right) = (75 \text{ kg})(9.8 \text{ m/s}^2)\left(1 + \frac{4}{9.8}\right) = 1035 \text{ N} \]

For the second segment, \( a_y = 0 \text{ m/s}^2 \) and the apparent weight is

\[ w_{app} = w\left(1 + \frac{0 \text{ m/s}^2}{g}\right) = mg = (75 \text{ kg})(9.8 \text{ m/s}^2) = 740 \text{ N} \]

For the third segment,

\[ a_y = \frac{v_y - v_0}{t_3 - t_2} = \frac{0 \text{ m/s} - 8 \text{ m/s}}{10 \text{ s} - 6 \text{ s}} = -2 \text{ m/s}^2 \]

\[ \Rightarrow w_{app} = w\left(1 + \frac{-2 \text{ m/s}^2}{9.8 \text{ m/s}^2}\right) = (75 \text{ kg})(9.8 \text{ m/s}^2)(1 - 0.2) = 590 \text{ N} \]

Assess: As expected, the apparent weight is greater than normal when the elevator is accelerating upward and lower than normal when the acceleration is downward. When there is no acceleration the weight is normal. In all three cases the magnitudes are reasonable, given the mass of the passenger and the accelerations of the elevator.
5.16. Model: We assume that the truck is a particle in equilibrium, and use the model of static friction.

Visualize:

Solve: The truck is not accelerating, so it is in equilibrium, and we can apply Newton’s first law. The normal force has no component in the $x$-direction, so we can ignore it here. For the other two forces:

$$\sum_{x} F = f - w = 0 \Rightarrow f_x = w_x = mg \sin \theta = (4000 \text{ kg})(9.8 \text{ m/s}^2)(\sin 15^\circ) = 10,145 \text{ N}$$

Assess: The truck’s weight ($mg$) is roughly 40,000 N. A friction force that is $\approx 25\%$ of the truck’s weight seems reasonable.
5.33. Model: We can assume the foot is a single particle in equilibrium under the combined effects of gravity, the tensions in the upper and lower sections of the traction rope, and the opposing traction force of the leg itself. We can also treat the hanging mass as a particle in equilibrium. Since the pulleys are frictionless, the tension is the same everywhere in the rope. Because all pulleys are in equilibrium, their net force is zero. So they do not contribute to $T$.

Visualize:

Solve: (a) From the free-body diagram for the mass, the tension in the rope is

$$T = w = mg = (6 \text{ kg})(9.8 \text{ m/s}^2) = 58.8 \text{ N}$$

(b) Using Newton’s first law for the vertical direction on the pulley attached to the foot,

$$\begin{align*}
\{F_{\text{net}}\}_y &= \Sigma F_y = T \sin \theta - T \sin 15^\circ - w_{\text{foot}} = 0 \text{ N} \\
\Rightarrow \sin \theta &= \frac{T \sin 15^\circ + w_{\text{foot}}}{T} = \sin 15^\circ + \frac{m_{\text{foot}}g}{T} = 0.259 + \frac{(4 \text{ kg})(9.8 \text{ m/s}^2)}{58.8 \text{ N}} = 0.259 + 0.667 = 0.926 \\
\Rightarrow \theta &= \sin^{-1} 0.926 = 67.8^\circ
\end{align*}$$

(c) Using Newton’s first law for the horizontal direction,

$$\begin{align*}
\{F_{\text{net}}\}_x &= \Sigma F_x = T \cos \theta + T \cos 15^\circ - F_{\text{traction}} = 0 \text{ N} \\
\Rightarrow F_{\text{traction}} &= T \cos \theta + T \cos 15^\circ = T (\cos 67.8^\circ + \cos 15^\circ) \\
&= (58.8 \text{ N})(0.3778 + 0.9659) = (58.8 \text{ N})(1.344) = 79.0 \text{ N}
\end{align*}$$

Assess: Since the tension in the upper segment of the rope must support the foot and counteract the downward pull of the lower segment of the rope, it makes sense that its angle is larger (a more direct upward pull). The magnitude of the traction force, roughly one-tenth the weight of a human body, seems reasonable.
5.51. **Model:** The box will be treated as a particle. Because the box slides down a vertical wood wall, we will also use the model of kinetic friction.

**Visualize:**

![Physical representation](image)

**Solve:** The normal force due to the wall, which is perpendicular to the wall, is here to the right. The box slides down the wall at constant speed, so $\ddot{a} = 0$ and the box is in dynamic equilibrium. Thus, $\vec{F}_{\text{net}} = 0$. Newton’s second law for this equilibrium situation is

$$(F_{\text{net}})_x = 0 \text{ N} = n - F_{\text{push}} \cos 45^\circ$$

$$(F_{\text{net}})_y = 0 \text{ N} = f_k + F_{\text{push}} \sin 45^\circ - w = f_k + F_{\text{push}} \sin 45^\circ - mg$$

The friction force is $f_k = \mu_k n$. Using the $x$-equation to get an expression for $n$, we see that $f_k = \mu_k F_{\text{push}} \cos 45^\circ$.

Substituting this into the $y$-equation and using Table 5.1 to find $\mu_k = 0.20$ gives,

$$\mu_k F_{\text{push}} \cos 45^\circ + F_{\text{push}} \sin 45^\circ - mg = 0 \text{ N}$$

$$\Rightarrow F_{\text{push}} = \frac{mg}{\mu_k \cos 45^\circ + \sin 45^\circ} = \frac{(2 \text{ kg})(9.8 \text{ m/s}^2)}{0.20 \cos 45^\circ + \sin 45^\circ} = 23.1 \text{ N}$$
Homework 5. Problem 6:

What horizontal force must be applied to the cart shown in Figure so that the blocks remain stationary relative to the cart? Assume all surfaces, wheels and pulley are frictionless. (Hint: Note that the force exerted by the string accelerates $m_1$.) Draw separate free body diagrams for blocks $m_1$, $m_2$ and the combined blocks $(m_1 + m_2 + M)$.

**Free Body Diagrams**

\[ \sum F = ma \]

For $m_1$: $T = m_1 a$ \hspace{1cm} $a = \frac{m_2 g}{m_1}$

For $m_2$: $T - m_2 g = 0$

For all 3 blocks: $F = (M + m_1 + m_2) a = \left( M + m_1 + m_2 \right) \left( \frac{m_2 g}{m_1} \right)$