A box weighing 67 N rests on a table. A rope tied to the box runs vertically upward over a pulley and a weight is hung from the other end. Determine the force that the table exerts on the box if the weight hangs from the other side of the pulley weighing:

- a) 25 N
- b) 57 N
- c) 101 N

First, we notice that cases a) and b) have a counterweight smaller than the weight of the box. Case c) must be treated differently since the box will accelerate upwards.

\[ (F_{net})_y = T + F(N) - m_{box}g \]
\[ (F_{net})_y = m_w a \]

\[ T + F(N) - m_{box}g = m_{box}a \]
\[ m_wg - T = m_wa \]

or

\[ F(N) = m_{box}g + m_{box}g - T \]
\[ T = m_w(g-a) \]

For cases a) and b), we have \( a = 0 \) so

\[ F(N) = m_{box}g - T \]
\[ F(N) = m_{box}g - m_wg \]

\[ a) \quad F(N) = 67N - 25N \]
\[ F(N) = 42N \]
\[ b) \quad F(N) = 67N - 57N \]
\[ F(N) = 10N \]

\[ c) \quad \text{For case c), the box is raised off the surface so } F(N) = 0 \]
4-23 A hiker is to walk across a high wire strung horizontally between two buildings 13.0 m apart. The sag in the rope when he is at the midpoint is 10.0°. If her mass is 50.0 kg, what is the tension in the rope at this point?

1. 

2. Force diagram of section of rope under her feet:

3. 

4. Both \( a_x \) and \( a_y \) are equal to zero (since she is not falling):

\[
(F_{net})_x = m g \cos(10°) \\
(F_{net})_y = m g \\
0 = 0
\]

\[
T_1 = \sqrt{T_1^2 + T_2^2}
\]

\[
T_1 = \frac{mg}{\sin(170°) + \sin(10°)}
\]

\[
T_2 = \frac{mg}{\sin(170°) + \sin(10°)}
\]

\[
T = 1410 N
\]
One 3.1 kg point bucket is hanging by a massless cord from another 3.1 kg point bucket also hanging by a massless cord. If the buckets are at rest, what is the tension in each cord?

\[ T_u \]
\[ T_u \]
\[ T_u \]
\[ T_u \]
\[ T_u \]

\[ \text{Forces Diagram for:} \]
\[ \text{Upper bucket} \]
\[ \begin{align*}
T_u & - mg = 0 \\
T_u & - T_l - mg = 0
\end{align*} \]

\[ \text{Lower bucket} \]
\[ \begin{align*}
F_{net}y &= T_u - T_l - mg \\
F_{net}y &= mg
\end{align*} \]

\[ T_u - T_l - mg = 0 \]
\[ T_u - mg - mg = 0 \]
\[ T_u = 2mg = 60.8N \]

\[ T_l - mg = 0 \]
\[ T_l = mg \]
\[ T_l = (3.1 \text{ kg})(9.8 \text{ m/s}^2) \]
\[ T_l = 30.4N \]

If the two buckets are pulled upward with an acceleration of 1.70 m/s^2 by the upper cord, calculate the tension in each cord. We redo step 4 above.

\[ \text{Upper bucket} \]
\[ T_u - T_l - mg = m(1.70 \text{ m/s}^2) \]
\[ T_u - T_l = m(g + 1.70 \text{ m/s}^2) \]
\[ T_u = 35.2N + (3.1 \text{ kg})(9.8 \text{ m/s}^2 + 1.70 \text{ m/s}^2) \]
\[ T_u = 71.3N \]

\[ \text{Lower bucket} \]
\[ T_l - mg = m(1.70 \text{ m/s}^2) \]
\[ T_l = m(g + 1.70 \text{ m/s}^2) \]
\[ T_l = 35.2N \]
Two snowcats tow a housing unit to a new location at McMurdo Base, Antarctica. The sum of the forces \( \vec{F}_A \) and \( \vec{F}_B \) exerted on the unit by the horizontal cables is parallel to the line \( l \), and \(|\vec{F}_A| = 5900 \text{N}\). Determine \(|\vec{F}_B|\) and \(|\vec{F}_A + \vec{F}_B|\).

\[ |\vec{F}_A| = 3200 \text{N} \]
\[ |\vec{F}_B| = ? \]
\[ \theta_A = 140^\circ \]
\[ \theta_B = 60^\circ \]

\[ (2) \text{ The forces on the housing unit are} \]
\[ \vec{F}_A \parallel \vec{F}_B \]

In rectangular components:

\[ \vec{F}_A: \]
\[ F_{Ax} = |\vec{F}_A| \cos(140^\circ) \]
\[ F_{Ax} = 3200 \text{N} \cos(140^\circ) \]
\[ F_{Ax} = -2451 \text{N} \]

\[ F_{Ay} = |\vec{F}_A| \sin(140^\circ) \]
\[ F_{Ay} = 3200 \text{N} \sin(140^\circ) \]
\[ F_{Ay} = 2056 \text{N} \]
\[ F_0 = \begin{align*} F_{0x} &= |F_0| \cos(60^\circ) \\ F_{0y} &= |F_0| \sin(60^\circ) \end{align*} \]

\( (F_{\text{net}})_x = F_{Ax} + F_{0x} \)

\( (F_{\text{net}})_x = -2451 + |F_0| \cos(60^\circ) \)

\( (F_{\text{net}})_y = F_{Ay} + F_{0y} \)

\( (F_{\text{net}})_y = 2056N + |F_0| \sin(60^\circ) \)

\( \text{We know that there will be no acceleration in the x direction} \Rightarrow \text{so } a_x = 0. \text{ Any will be } \text{non-zero}. \)

\( (F_{\text{net}})_x = mg \frac{\uparrow}{\xrightarrow{x}} \)

\(-2451N + |F_0| \cos(60^\circ) = 0 \)

\[ |F_0| = \frac{2451N}{\cos(60^\circ)} \]

\[ |F_0| = 4902N \]

\[ |F_A + F_0| = \sqrt{(F_{Ax} + F_{0x})^2 + (F_{Ay} + F_{0y})^2} \]

\[ = \sqrt{0^2 + (2056N + (4902N) \sin(60^\circ))^2} \]

\[ |F_A + F_0| = 11,600N \]
A window washer pulls herself upward using the bucket pulley apparatus shown. The mass of the person plus the bucket is 63 kg.

a) How hard must she pull downwards to raise herself slowly?

b) If she increases this force by 8%, what will her acceleration be?

\[ (F_{net})_x = 0 \]
\[ (F_{net})_y = T + F_{rope} - mg \]
\[ (F_{net})_y = F_{rope} + F_{rope} - mg \]

We assume that "raise herself slowly" means no acceleration, so

\[ (F_{net})_x = mg \]
\[ 0 = 0 \]
\[ (F_{net})_y = mg \]
\[ F_{rope} - mg = 0 \]
\[ 2F_{rope} = mg \]
\[ F_{rope} = \frac{mg}{2} \]

She pulls down on the rope so Newton's 3rd Law says the rope pulls up on her with the same force.

It's all one force so the tension T is equal to how hard she's pulling. For
b) We re-do step 4 with:

\[
\text{F}_{\text{rope}} = 309\text{N} + 0.08(309\text{N})
\]

\[
\text{F}_{\text{rope}} = 334\text{N}
\]

So,

\[
(y) \quad (F_{\text{net}})_y = m\ddot{y}
\]

\[
2F_{\text{rope}} - mg = m\ddot{y}
\]

\[
\ddot{y} = \frac{2(334\text{N}) - (63\text{kg})(9.8\text{m/s}^2)}{(63\text{kg})}
\]

\[
\ddot{y} = 0.803\text{ m/s}^2
\]
Three blocks on a frictionless surface are in contact with each other. A force \( F \) is applied to block 1.

a) Draw a free body diagram for each block.

b) Determine the acceleration of the system.

c) What is the net force on each block?

d) Find the force of contact each block exerts on its neighbor.

\[ F \rightarrow \text{m}_1 \quad \text{m}_2 \quad \text{m}_3 \]

We'll call the force exerted on box 1 by box 2 \( F_{21} \).

a)

b) To find the acceleration of "The system," we approach the problem as if all three boxes were glued together into one object.

Then, \( F = (m_1 + m_2 + m_3) \cdot a \)

\[ a = \frac{F}{m_1 + m_2 + m_3} \]

c) The net force on each block will be the force necessary to cause each block to accelerate at the "a" given in part b.
For block 1

\[ F_{\text{net}1} = m_1 \left( \frac{F}{m_1 + m_2 + m_3} \right) \]

For block 2

\[ F_{\text{net}2} = m_2 \left( \frac{F}{m_1 + m_2 + m_3} \right) \]

For block 3

\[ F_{\text{net}3} = m_2 \left( \frac{F}{m_1 + m_2 + m_3} \right) \]

\[ d) \quad \text{From the free body diagram for } m, \text{ we see} \]

\[ (F_{\text{net}})_x = F - F_{21} \]

Using the result for \( F_{\text{net}} \), from part c

\[ m_1 \left( \frac{F}{m_1 + m_2 + m_3} \right) = F - F_{21} \]

Rearranging,

\[ F_{21} = F - \frac{m_1 F}{m_1 + m_2 + m_3} \]

\[ F_{21} = \frac{F(m_1 + m_2 + m_3)}{(m_1 + m_2 + m_3)} - \frac{m_1 F}{(m_1 + m_2 + m_3)} \]
\[ F_{21} = \frac{m_1 F + m_2 F + m_3 F - m_1 F}{m_1 + m_2 + m_3} \]

\[ |F_{12}| = |F_{21}| = \frac{(m_2 + m_3)}{(m_1 + m_2 + m_3)} F \]

From the free body diagram for \( m_2 \)

\[ (F_{\text{net}2})_x = F_{12} - F_{32} \]

Using the result from part C for \( (F_{\text{net}2})_x \)

\[ \frac{m_2 F}{m_1 + m_2 + m_3} = F_{12} - F_{32} \]

Using the result for \( F_{21} \) (and Newton's 3rd Law tells us that \( |F_{21}| = |F_{12}| \))

\[ \frac{m_2 F}{m_1 + m_2 + m_3} = \frac{(m_1 + m_2)}{m_1 + m_2 + m_3} F - F_{32} \]

Rearranging we find

\[ F_{32} = \frac{(m_2 + m_3) F}{m_1 + m_2 + m_3} - \frac{m_2 F}{m_1 + m_2 + m_3} \]

\[ |F_{23}| = |F_{32}| = \frac{m_3 F}{m_1 + m_2 + m_3} \]
e) \( m_1 = m_2 = m_3 = 10.0 \text{kg} \) and \( F = 88.0 \text{N} \) Then

\[
\alpha = \frac{88.0 \text{N}}{10 \text{kg} + 10 \text{kg} + 10 \text{kg}}
\]

\[
\alpha = 2.93 \text{ m/s}^2
\]

\[
|F_{12}| = |F_{21}| = \frac{10 \text{kg} \times 10 \text{kg}}{10 \text{kg} + 10 \text{kg} + 10 \text{kg}} \quad (88.0 \text{N})
\]

\[
|F_{21}| = |F_{31}| = 58.7 \text{N}
\]

\[
|F_{23}| = |F_{32}| = \frac{10 \text{kg}}{10 \text{kg} + 10 \text{kg} + 10 \text{kg}} \quad (88.0 \text{N})
\]

\[
|F_{23}| = |F_{32}| = 29.3 \text{N}
\]

\[
(F_{\text{net},1})_x = \frac{(10 \text{kg}) \times (88.0 \text{N})}{(10 \text{kg} + 10 \text{kg} + 10 \text{kg})} = 29.3 \text{ N}
\]

\[
(F_{\text{net},2})_x = \frac{(10 \text{kg}) \times (88.0 \text{N})}{(10 \text{kg} + 10 \text{kg} + 10 \text{kg})}
\]

\[
(F_{\text{net},3})_x = \frac{(10 \text{kg}) \times (88.0 \text{N})}{(10 \text{kg} + 10 \text{kg} + 10 \text{kg})}
\]
Suppose two boxes on a frictionless table are connected by a heavy cord of mass 1.0 kg. Calculate the magnitude of the acceleration of each box and the magnitude of the tension in the cord.

Assume $F_p = 35.0 \text{ N}$, $m_a = 8.0 \text{ kg}$, and $m_b = 12.0 \text{ kg}$, and ignore sagging cord.

Boxes A and B are tied together and so will have the same acceleration. We find the acceleration by treating both boxes and the cord as one object of mass $(m_A + m_B + 1kg$).

So,

$$F_{net} = m_{total} \cdot a$$

$$F_p = (m_A + m_B + m_{cord}) \cdot a$$

$$a = \frac{F_p}{(m_A + m_B + m_{cord})}$$

$$a = \frac{35.0 \text{ N}}{(8k_2 + 12k_2 + 1k_2)}$$

$$a = 1.67 \text{ m/s}^2$$
The cord has different tensions at each end because it has mass (we usually assume it is massless).

We find those tensions by examining the free body diagrams for box A and then box B.

2) Box A

\[ T_A \]
\[ F_{NA} \]
\[ \sqrt{m_A g} \]
\[ F_p \]

3) \((F_{net_A})_x = F_p - T_A\)

4) \((F_{net_A})_x = m_A a\)

\[
T_A = F_p - m_A a
\]

\[
T_A = 35.0 N - (8 kg)(1.67 m/s^2)
\]

\[
T_A = 21.6 N
\]

2) Box B

\[ F_{NB} \]
\[ \sqrt{m_B g} \]
\[ T_B \]

3) \((F_{net_B})_x = T_B\)

4) \((F_{net_B})_x = m_B a\)

\[
T_B = m_B a
\]

\[
T_B = (12 kg)(1.67 m/s^2)
\]

\[
T_B = 20.6 N
\]