Problem P4.17: The trough of concrete weighs 800 lb. (a) Draw a free body diagram of the cable's ring $A$. (b) Treating the ring as a particle, determine the tension in cables $AB$ and $AC$.

![Free body diagram](image)

**Approach:**
The three tension forces act along the cables. Sum the forces on a vector polygon using the head–to–tail rule. Assuming the suspension system is in static equilibrium, the polygon's start and end points are the same since there is zero resultant force acting on the ring. The weights of the cables and ring are not considered.

**Solution:**
(a) See diagram
(b) Using symmetry and summing horizontal force components, $AB = AC$. The vector polygon is a graphical way of writing $\Sigma F = 0$:

$$AB \sin 30^\circ = 400 \text{ lb}$$
$$AB = 800 \text{ lb}$$
$$\frac{AB}{4} = AC = 800 \text{ lb}$$

**Discussion:**
This answer is reasonable because only $\frac{1}{2}$ of the tension in these cables is being used to support the vertical weight of the trough. Therefore each cable supports $\frac{1}{2}$ of the weight of the trough, or 400 lb. The horizontal components of the tension are present because of the placement of the cables on the trough. These horizontal components are equal in magnitude but opposite in direction, offsetting each other.
Problem P4.18: Cable $AB$ of the boom truck is hoisting the 2500–lb section of precast concrete. A second cable is under tension $P$, and workers use it to pull and adjust the position of the concrete as it is being raised, (a) Draw a free body diagram of hook $A$, treating it as a particle, (b) Determine $P$ and the tension in cable $AB$.

Approach:
The two tension forces act along the cables. Sum the forces on a vector polygon using the head–to–tail rule. Assuming the hook is in static equilibrium, the polygon's start and end points are the same since there is zero resultant force acting on the hook. The weights of the cable and hook are not considered.

Solution:
(a) See diagram
(b) Find $AB$ and $P$ by applying the law of sines (Equation B.17 in Appendix B) to the vector polygon. The polygon is a graphical way of writing $\Sigma F = 0$.

$$\frac{AB}{\sin115^\circ} = \frac{2500 \text{ lb}}{\sin60^\circ}$$

$AB = 2616 \text{ lb}$

$$\frac{P}{\sin5^\circ} = \frac{2500 \text{ lb}}{\sin60^\circ}$$

$P = 251.6 \text{ lb}$

$[AB = 2616 \text{ lb and } P = 252 \text{ lb}]$

Discussion:
It makes sense that the tension in $AB$ is much larger than $P$ because $AB$ is supporting all the weight of the concrete section. The angle between $AB$ and $P$ in the vector polygon can also be found by $(90^\circ - 5^\circ - 25^\circ) = 60^\circ$. When workers are positioning the concrete, the hook may not be in static equilibrium, but may be accelerating or decelerating. In this case, the behavior is governed by Newton’s Second Law of Motion.
Problem P4.20: The front loader with mass 4.5 Mg is shown in side–view as it lifts a 0.75 Mg load of gravel, (a) Draw a free body diagram of the front loader, (b) Determine the contact forces between the wheels and the ground, (c) How heavy a load can be carried before the loader will start to tip about its front wheels?

**Approach:**
Let \( F \) and \( R \) be the contact forces on one front and one rear tire. There are two unknowns. Assuming the system is in static equilibrium, write a force balance in the vertical direction and a moment balance about the front wheels.

**Solution:**
(a) See sketch above for the FBD
(b) The two unknowns are \( F \) and \( R \). The weights are:

\[
\begin{align*}
    w_1 &= (0.75 \text{ Mg}) \left( 1000 \frac{\text{kg}}{\text{Mg}} \right) \left( 9.81 \frac{\text{m}}{\text{s}^2} \right) = 7357 \text{ N} = 7.357 \text{kN} \\
    w_2 &= (4.5 \text{ Mg}) \left( 1000 \frac{\text{kg}}{\text{Mg}} \right) \left( 9.81 \frac{\text{m}}{\text{s}^2} \right) = 44.145 \text{ N} = 44.15 \text{kN}
\end{align*}
\]

Apply \( \sum M_d = 0 \) to eliminate \( F \) and find \( R \):

\[
7.357 \text{ kN} (2.0 \text{ m}) - 44.15 \text{ kN} (1.8 \text{ m}) + (2R) (3.4 \text{ m}) = 0
\]

\( R = 9.523 \text{ kN} \)

Substitute for \( R \) and apply \( \sum F_y = 0 \) to find \( F \):

\[
-7.357 \text{ kN} + 2F - 44.15 \text{ kN} + 2(9.523 \text{ kN}) = 0
\]

\( F = 16.23 \text{ kN} \)

Front wheel: 16.2 kN
Rear wheel: 9.52 kN
(c) The two unknowns are \( w_1 \) and \( F \). At the condition of tipping, \( R = 0 \). Apply \( \Sigma M_A = 0 \) to eliminate \( F \) and find \( w_1 \):

\[
+ w_1(2.0 \text{ m}) - (44.15 \text{ kN})(1.8 \text{ m}) = 0
\]

\[
w_1 = 39.74 \text{ kN}
\]

39.7 kN

Discussion:
The front contact force is larger than the rear because of the gravel load positioned at the front of the loader. If the load is lowered, creating a longer moment arm, then the required load to cause the loader to start tipping would decrease.