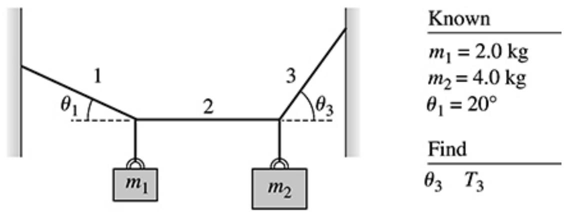
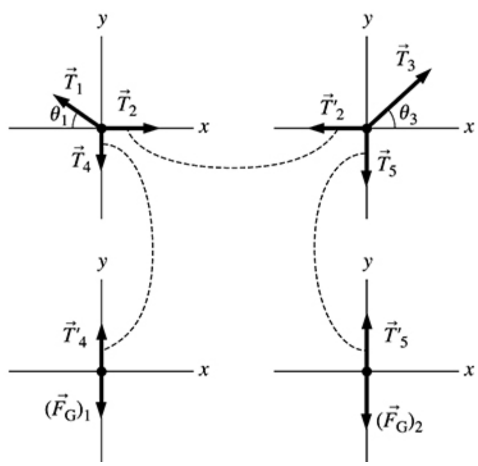
7.17. Model: The two hanging blocks, which can be modeled as particles, together with the two knots where rope 1 meets with rope 2 and rope 2 meets with rope 3 form a system. All the four objects in the system are in static equilibrium. The ropes are assumed to be massless.

Visualize:

Pictorial representation





Solve: **(a)** We will consider both the two hanging blocks *and* the two knots. The blocks are in static equilibrium with $\vec{F}_{net} = 0$ N. Note that there are three action/reaction pairs. For Block 1 and Block 2, $\vec{F}_{net} = 0$ N and we have

$$T'_4 = (F_G)_1 = m_1 g \quad T'_5 = (F_G)_2 = m_2 g$$

Then, by Newton's third law:

$$T_4 = T'_4 = m_1 g \quad T_5 = T'_5 = m_2 g$$

The knots are also in equilibrium. Newton's law applied to the left knot is

$$(F_{net})_x = T_2 - T_1 \cos\theta_1 = 0 \text{ N} \quad (F_{net})_y = T_1 \sin\theta_1 - T_4 = T_1 \sin\theta_1 - m_1 g = 0 \text{ N}$$

The y-equation gives $T_1 = m_1 g / \sin\theta_1$. Substitute this into the x-equation to find

$$T_2 = \frac{m_1 g \cos\theta_1}{\sin\theta_1} = \frac{m_1 g}{\tan\theta_1}$$

Newton's law applied to the right knot is

$$(F_{net})_x = T_3 \cos\theta_3 - T'_2 = 0 \text{ N} \quad (F_{net})_y = T_3 \sin\theta_3 - T_5 = T_3 \sin\theta_3 - m_2 g = 0 \text{ N}$$

These can be combined just like the equations for the left knot to give

$$T'_2 = \frac{m_2 g \cos\theta_3}{\sin\theta_3} = \frac{m_2 g}{\tan\theta_3}$$

But the forces $\vec{T}_2$ and $\vec{T}'_2$ are an action/reaction pair, so $T_2 = T'_2$. Therefore,

$$\frac{m_1 g}{\tan\theta_1} = \frac{m_2 g}{\tan\theta_3} \Rightarrow \tan\theta_3 = \frac{m_2}{m_1}\tan\theta_1 \Rightarrow \theta_3 = \tan^{-1}\left(2\tan 20°\right) = 36°$$

We can now use the *y*-equation for the right knot to find $T_3 = m_2 g / \sin\theta_3 = 67$ N.