11.8 **IDENTIFY:** Apply the first and second conditions of equilibrium to the shelf.

SET UP: The free-body diagram for the shelf is given in Figure 11.8. Take the axis at the left-hand end of the shelf and let counterclockwise torque be positive. The center of gravity of the uniform shelf is at its center.

EXECUTE: **(a)** $\sum\tau_z = 0$ gives $-w_\text{t}(0.200\text{ m}) - w_\text{s}(0.300\text{ m}) + T(0.400\text{ m}) = 0$.

$$T = \frac{(25.0\text{ N})(0.200\text{ m}) + (50.0\text{ N})(0.300\text{ m})}{0.400\text{ m}} = 50.0\text{ N}$$

$\sum F_y = 0$ gives $T_1 + T_2 - w_\text{t} - w_\text{s} = 0$ and $T_1 = 25.0\text{ N}$. The tension in the left-hand wire is 25.0 N and the tension in the right-hand wire is 50.0 N.

EVALUATE: We can verify that $\sum\tau_z = 0$ is zero for any axis, for example for an axis at the right-hand end of the shelf.

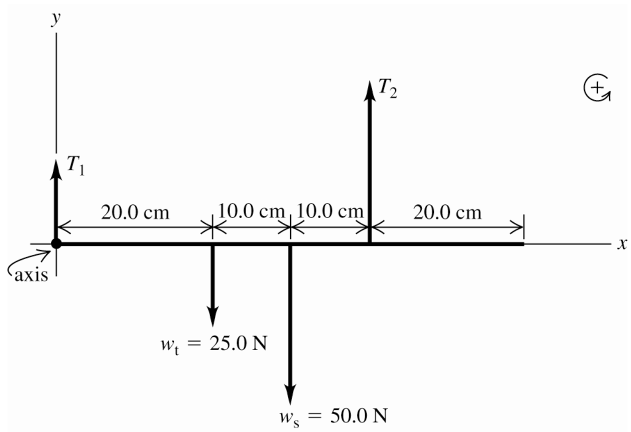

Figure 11.8

11.13. **IDENTIFY:** Apply the first and second conditions of equilibrium to the strut.

(a) SET UP: The free-body diagram for the strut is given in Figure 11.13a. Take the origin of coordinates at the hinge (point A) and $+y$ upward. Let F_h and F_v be the horizontal and vertical components of the force $\vec{F}$ exerted on the strut by the pivot. The tension in the vertical cable is the weight w of the suspended object. The weight w of the strut can be taken to act at the center of the strut. Let L be the length of the strut.

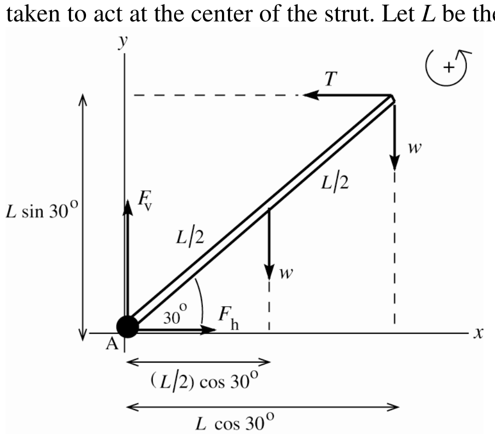

Figure 11.13a

EXECUTE:

$\sum F_y = ma_y$

$F_\text{v} - w - w = 0$

$F_\text{v} = 2w$

Sum torques about point A. The pivot force has zero moment arm for this axis and so doesn't enter into the torque equation.

$\tau_A = 0$

$TL\sin 30.0° - w\big((L/2)\cos 30.0°\big) - w(L\cos 30.0°) = 0$

$T\sin 30.0° - (3w/2)\cos 30.0° = 0$

$$T = \frac{3w\cos 30.0°}{2\sin 30.0°} = 2.60w$$

Then $\sum F_x = ma_x$ implies $T - F_\text{h} = 0$ and $F_\text{h} = 2.60w$.

We now have the components of $\vec{F}$ so can find its magnitude and direction (Figure 11.13b)

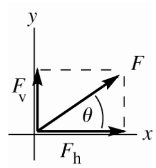

Figure 11.13b

$$F = \sqrt{F_h^2 + F_v^2}$$
$$F = \sqrt{(2.60w)^2 + (2.00w)^2}$$
$$F = 3.28w$$
$$\tan\theta = \frac{F_v}{F_h} = \frac{2.00w}{2.60w}$$
$$\theta = 37.6°$$

(b) SET UP: The free-body diagram for the strut is given in Figure 11.13c.

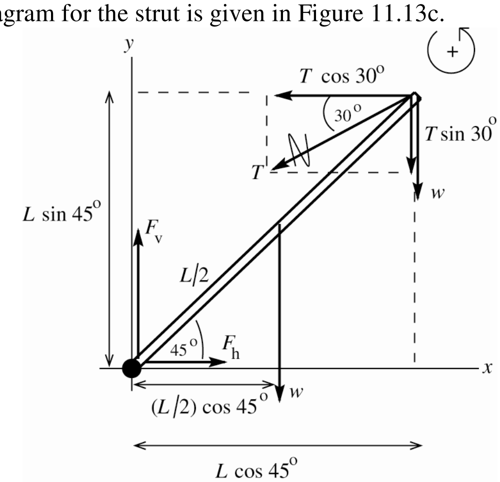

Figure 11.13c

The tension *T* has been replaced by its *x* and *y* components. The torque due to *T* equals the sum of the torques of its components, and the latter are easier to calculate.

EXECUTE: $\sum\tau_A = 0 + (T\cos 30.0°)(L\sin 45.0°) - (T\sin 30.0°)(L\cos 45.0°) -$
$w((L/2)\cos 45.0°) - w(L\cos 45.0°) = 0$

The length *L* divides out of the equation. The equation can also be simplified by noting that $\sin 45.0° = \cos 45.0°$. Then $T(\cos 30.0° - \sin 30.0°) = 3w/2$.

$$T = \frac{3w}{2(\cos 30.0° - \sin 30.0°)} = 4.10w$$
$$\sum F_x = ma_x$$
$$F_h - T\cos 30.0° = 0$$
$$F_h = T\cos 30.0° = (4.10w)(\cos 30.0°) = 3.55w$$
$$\sum F_y = ma_y$$
$$F_v - w - w - T\sin 30.0° = 0$$
$$F_v = 2w + (4.10w)\sin 30.0° = 4.05w$$

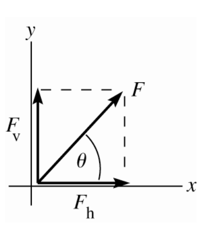

Figure 11.13d

From Figure 11.13d,

$$F = \sqrt{F_h^2 + F_v^2}$$
$$F = \sqrt{(3.55w)^2 + (4.05w)^2} = 5.39w$$
$$\tan\theta = \frac{F_v}{F_h} = \frac{4.05w}{3.55w}$$
$$\theta = 48.8°$$

EVALUATE: In each case the force exerted by the pivot does not act along the strut. Consider the net torque about the upper end of the strut. If the pivot force acted along the strut, it would have zero torque about this point. The two forces acting at this point also have zero torque and there would be one nonzero torque, due to the weight of the strut. The net torque about this point would then not be zero, violating the second condition of equilibrium.

11.19. **IDENTIFY:** Apply the first and second conditions of equilibrium to the rod.
SET UP: The force diagram for the rod is given in Figure 11.19.

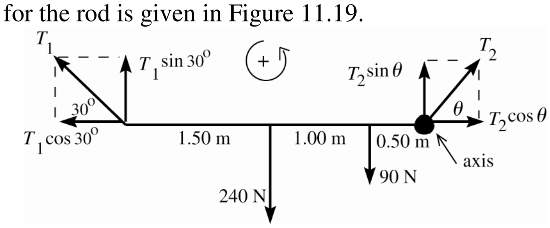

Figure 11.19

EXECUTE: $\sum \tau_z = 0$, axis at right end of rod, counterclockwise torque is positive

$(240\text{ N})(1.50\text{ m}) + (90\text{ N})(0.50\text{ m}) - (T_1 \sin 30.0°)(3.00\text{ m}) = 0$

$T_1 = \dfrac{360\text{ N}\cdot\text{m} + 45\text{ N}\cdot\text{m}}{1.50\text{ m}} = 270\text{ N}$

$\sum F_x = ma_x$

$T_2 \cos\theta - T_1 \cos 30° = 0$ and $T_2 \cos\theta = 234\text{ N}$

$\sum F_y = ma_y$

$T_1 \sin 30° + T_2 \sin\theta - 240\text{ N} - 90\text{ N} = 0$

$T_2 \sin\theta = 330\text{ N} - (270\text{ N})\sin 30° = 195\text{ N}$

Then $\dfrac{T_2 \sin\theta}{T_2 \cos\theta} = \dfrac{195\text{ N}}{234\text{ N}}$ gives $\tan\theta = 0.8333$ and $\theta = 40°$

And $T_2 = \dfrac{195\text{ N}}{\sin 40°} = 303\text{ N}.$

EVALUATE: The monkey is closer to the right rope than to the left one, so the tension is larger in the right rope. The horizontal components of the tensions must be equal in magnitude and opposite in direction. Since $T_2 > T_1$, the rope on the right must be at a greater angle above the horizontal to have the same horizontal component as the tension in the other rope.

11.20. **IDENTIFY:** Apply the first and second conditions for equilibrium to the beam.
SET UP: The free-body diagram for the beam is given in Figure 11.20.
EXECUTE: The cable is given as perpendicular to the beam, so the tension is found by taking torques about the pivot point; $T(3.00\text{ m}) = (1.00\text{ kN})(2.00\text{ m})\cos 25.0° + (5.00\text{ kN})(4.50\text{ m})\cos 25.0°$, and $T = 7.40\text{ kN}$. The vertical component of the force exerted on the beam by the pivot is the net weight minus the upward component of T, $6.00\text{ kN} - T\cos 25.0° = 0.17\text{ kN}$. The horizontal force is $T\sin 25.0° = 3.13\text{ kN}$.

EVALUATE: The vertical component of the tension is nearly the same magnitude as the total weight of the object and the vertical component of the force exerted by the pivot is much less than its horizontal component.

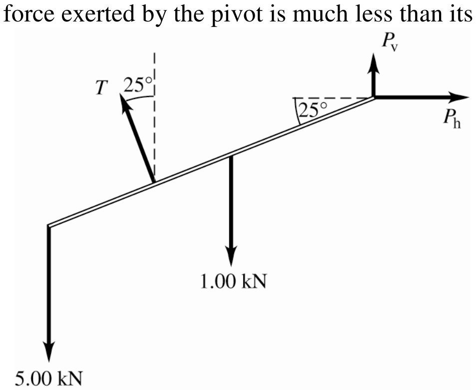

Figure 11.20