Solutions to Practice Problems Chapter 11

Responses to Questions

Q11.2 (a) Yes. The net force can be zero while the net torque is not zero. For example, there can be two forces acting on the object that are equal in magnitude and opposite in direction. If these forces act at different points on the object they can produce a net torque even though the net force is zero. A simple example of an object in translational equilibrium but not in rotational equilibrium is the cylinder in Fig. 10.9a. (b) Yes. There can be a net force but no net torque. A simple example is a baseball falling without air resistance. There is a net downward force due to gravity but that force acts at the center of gravity of the baseball and produces no torque.

Q11.14 With your arm extended there is a large torque about your shoulder due to the weight of the dumbbell and your muscles must exert an equal opposing torque.

Q11.16 They add more weight in their abdomen region, extending away from their spine. They have to lean backward a bit to keep their center of gravity from extending horizontally past their feet.

Solutions to Problem

P11.3. **IDENTIFY:** Treat the rod and clamp as point masses. The center of gravity of the rod is at its midpoint, and we know the location of the center of gravity of the rod-clamp system.

SET UP: $x_{\text{cm}} = \dfrac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$.

EXECUTE: $1.20 \text{ m} = \dfrac{(1.80 \text{ kg})(1.00 \text{ m}) + (2.40 \text{ kg})x_2}{1.80 \text{ kg} + 2.40 \text{ kg}}$.

$$x_2 = \frac{(1.20 \text{ m})(1.80 \text{ kg} + 2.40 \text{ kg}) - (1.80 \text{ kg})(1.00 \text{ m})}{2.40 \text{ kg}} = 1.35 \text{ m}$$

EVALUATE: The clamp is to the right of the center of gravity of the system, so the center of gravity of the system lies between that of the rod and the clamp, which is reasonable.

P11.5. **IDENTIFY:** Apply $\sum \tau_z = 0$ to the ladder.

SET UP: Take the axis to be at point *A*. The free-body diagram for the ladder is given in Figure 11.5. The torque due to *F* must balance the torque due to the weight of the ladder.

EXECUTE: $F(8.0 \text{ m})\sin 40° = (2800 \text{ N})(10.0 \text{ m})$, so $F = 5.45 \text{ kN}$.

EVALUATE: The force required is greater than the weight of the ladder, because the moment arm for F is less than the moment arm for w.

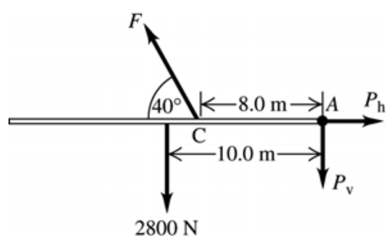

Figure 11.5

P11.12. IDENTIFY: Apply the first and second conditions of equilibrium to the beam.

SET UP: The boy exerts a downward force on the beam that is equal to his weight.

EXECUTE: **(a)** The graphs are given in Figure 11.12.

(b) $x = 6.25\text{ m}$ when $F_A = 0,$ which is 1.25 m beyond point B.

(c) Take torques about the right end. When the beam is just balanced, $F_A = 0$, so $F_B = 900\text{ N}$.

The distance that point B must be from the right end is then $\dfrac{(300\text{ N})(4.50\text{ m})}{(900\text{ N})} = 1.50\text{ m}.$

EVALUATE: When the beam is on the verge of tipping it starts to lift off the support A and the normal force F_A exerted by the support goes to zero.

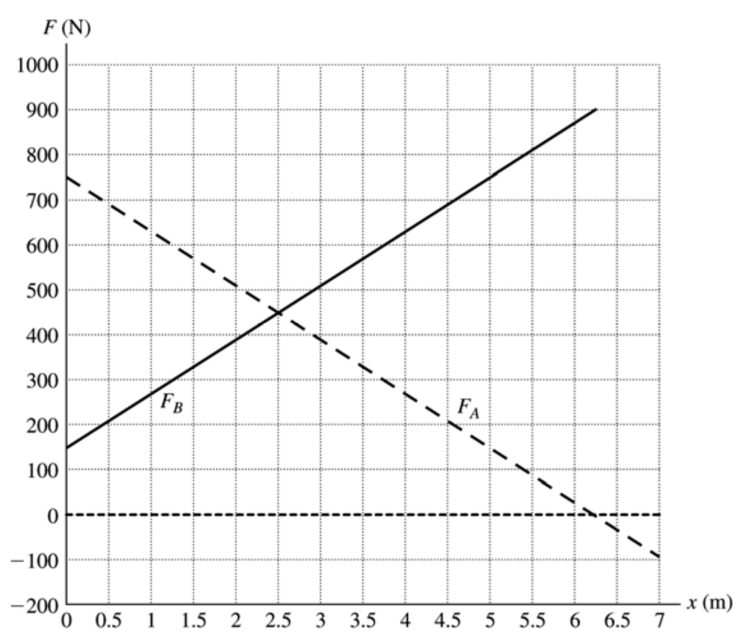

Figure 11.12

P11.14. IDENTIFY: Apply the first and second conditions of equilibrium to the beam.

SET UP: The free-body diagram for the beam is given in Figure 11.14. H_v and H_h are the vertical and horizontal components of the force exerted on the beam at the wall (by the hinge). Since the beam is uniform, its center of gravity is 2.00 m from each end. The angle θ has $\cos\theta = 0.800$ and $\sin\theta = 0.600$. The tension T has been replaced by its x and y components.

EXECUTE: (a) H_v, H_h and $T_x = T\cos\theta$ all produce zero torque. $\sum\tau_z = 0$ gives $-w(2.00\text{ m}) - w_{\text{load}}(4.00\text{ m}) + T\sin\theta(4.00\text{ m}) = 0$ and $T = \dfrac{(150\text{ N})(2.00\text{ m}) + (300\text{ N})(4.00\text{ m})}{(4.00\text{ m})(0.600)} = 625\text{ N}.$

(b) $\sum F_x = 0$ gives $H_h - T\cos\theta = 0$ and $H_h = (625\text{ N})(0.800) = 500\text{ N}.$ $\sum F_y = 0$ gives $H_v - w - w_{\text{load}} + T\sin\theta = 0$ and $H_v = w + w_{\text{load}} - T\sin\theta = 150\text{ N} + 300\text{ N} - (625\text{ N})(0.600) = 75\text{ N}.$

EVALUATE: For an axis at the right-hand end of the beam, only w and H_v produce torque. The torque due to w is counterclockwise so the torque due to H_v must be clockwise. To produce a clockwise torque, H_v must be upward, in agreement with our result from $\sum F_y = 0$.

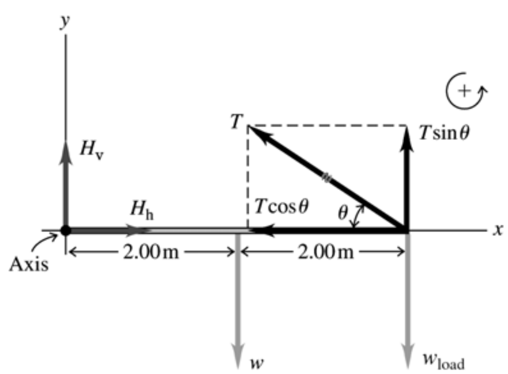

Figure 11.14

P11.29. IDENTIFY: Use the first condition of equilibrium to calculate the tensions T_1 and T_2 in the wires (Figure 11.29a). Then use Eq. (11.10) to calculate the strain and elongation of each wire.

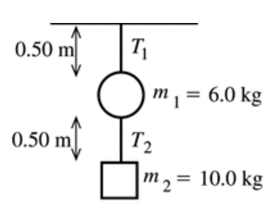

Figure 11.29a

SET UP: The free-body diagram for m_2 is given in Figure 11.27b.

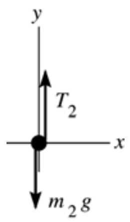

Figure 11.29b

EXECUTE:
$\sum F_y = ma_y$
$T_2 - m_2 g = 0$
$T_2 = 98.0\ \text{N}$

SET UP: The free-body-diagram for m_1 is given in Figure 11.29c.

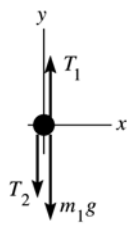

Figure 11.29c

EXECUTE:
$\sum F_y = ma_y$
$T_1 - T_2 - m_1 g = 0$
$T_1 = T_2 + m_1 g$
$T_1 = 98.0\ \text{N} + 58.8\ \text{N} = 157\ \text{N}$

(a) $Y = \dfrac{\text{stress}}{\text{strain}}$ so $\text{strain} = \dfrac{\text{stress}}{Y} = \dfrac{F_\perp}{AY}$

upper wire: $\text{strain} = \dfrac{T_1}{AY} = \dfrac{157\ \text{N}}{(2.5\times10^{-7}\ \text{m}^2)(2.0\times10^{11}\ \text{Pa})} = 3.1\times10^{-3}$

lower wire: $\text{strain} = \dfrac{T_2}{AY} = \dfrac{98\ \text{N}}{(2.5\times10^{-7}\ \text{m}^2)(2.0\times10^{11}\ \text{Pa})} = 2.0\times10^{-3}$

(b) $\text{strain} = \Delta l/l_0$ so $\Delta l = l_0(\text{strain})$

upper wire: $\Delta l = (0.50\ \text{m})(3.1\times10^{-3}) = 1.6\times10^{-3}\ \text{m} = 1.6\ \text{mm}$

lower wire: $\Delta l = (0.50\ \text{m})(2.0\times10^{-3}) = 1.0\times10^{-3}\ \text{m} = 1.0\ \text{mm}$

EVALUATE: The tension is greater in the upper wire because it must support both objects. The wires have the same length and diameter, so the one with the greater tension has the greater strain and elongation.

P11.40. IDENTIFY: The proportional limit and breaking stress are values of the stress, $F_\perp/A$. Use Eq. (11.10) to calculate Δl.

SET UP: For steel, $Y = 20\times10^{10}\ \text{Pa}$. $F_\perp = w$.

EXECUTE: **(a)** $w = (1.6\times10^{-3})(20\times10^{10}\ \text{Pa})(5\times10^{-6}\ \text{m}^2) = 1.60\times10^{3}\ \text{N}$.

(b) $\Delta l = \left(\dfrac{F_\perp}{A}\right)\dfrac{l_0}{Y} = (1.6\times10^{-3})(4.0\ \text{m}) = 6.4\ \text{mm}$

(c) $(6.5\times10^{-3})(20\times10^{10}\ \text{Pa})(5\times10^{-6}\ \text{m}^2) = 6.5\times10^{3}\ \text{N}$.

EVALUATE: At the proportional limit, the fractional change in the length of the wire is 0.16%.

P11.50. IDENTIFY: The beam is at rest, so the forces and torques on it must balance.

SET UP: The weight of the beam acts 4.0 m from each end. Take the pivot at the hinge and let counterclockwise torques be positive. Represent the force exerted by the hinge by its horizontal and vertical components, H_h and H_v. $\sum F_x = 0$, $\sum F_y = 0$ and $\sum \tau_z = 0$.

EXECUTE: **(a)** The free-body diagram for the beam is given in Figure 11.50a.

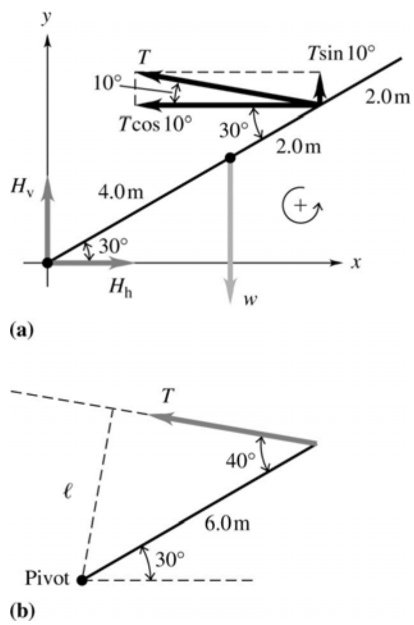

Figure 11.50

(b) The moment arm for T is sketched in Figure 11.50b and is equal to $(6.0\text{ m})\sin 40.0°$. $\sum \tau_z = 0$ gives $T(6.0\text{ m})(\sin 40.0°) - w(4.0\text{ m})(\cos 30.0°) = 0$.

$$T = \frac{(1500\text{ kg})(9.80\text{ m/s}^2)(4.0\text{ m})(\cos 30.0°)}{(6.0\text{ m})(\sin 40.0°)} = 1.32 \times 10^4\text{ N}.$$

(c) $\sum F_x = 0$ gives $H_h - T\cos 10.0° = 0$ and $H_h = T\cos 10.0° = 1.30 \times 10^4\text{ N}$. $\sum F_y = 0$ gives $H_v + T\sin 10.0° - w = 0$ and $H_v = w - T\sin 10.0° = (1500\text{ kg})(9.80\text{ m/s}^2) - 2.29 \times 10^3\text{ N} = 1.24 \times 10^4\text{ N}$. $H = \sqrt{H_h^2 + H_v^2} = 1.80 \times 10^4\text{ N}$. This is the force the hinge exerts on the beam. By Newton's third law, the force the beam exerts on the wall has the same magnitude, so is $1.80 \times 10^4\text{ N}$.

EVALUATE: The tension is less than the weight of the beam because it has a larger moment arm than the weight force has.