43. **THINK** The weight of the object hung on the end provides the source of shear stress.

EXPRESS The shear stress is given by F/A, where F is the magnitude of the force applied parallel to one face of the aluminum rod and A is the cross–sectional area of the rod. In this case $F = mg$, where m is the mass of the object. The cross-sectional area is $A = \pi r^2$ where r is the radius of the rod.

ANALYZE (a) Substituting the values given, we find the shear stress to be

$$\frac{F}{A} = \frac{mg}{\pi r^2} = \frac{(1200\,\text{kg})(9.8\,\text{m/s}^2)}{\pi(0.024\,\text{m})^2} = 6.5\times10^6\ \text{N/m}^2.$$

(b) The shear modulus G is given by

$$G = \frac{F/A}{\Delta x/L},$$

where L is the protrusion of the rod and Δx is its vertical deflection at its end. Thus,

$$\Delta x = \frac{(F/A)L}{G} = \frac{(6.5\times10^6\ \text{N/m}^2)(0.053\,\text{m})}{3.0\times10^{10}\ \text{N/m}^2} = 1.1\times10^{-5}\ \text{m}.$$

LEARN As expected, the extent of vertical deflection Δx is proportional to F, the weight of the object hung from the end. On the other hand, it is inversely proportional to the shear modulus G.

49. (a) Let F_A and F_B be the forces exerted by the wires on the log and let m be the mass of the log. Since the log is in equilibrium, $F_A + F_B - mg = 0$. Information given about the stretching of the wires allows us to find a relationship between F_A and F_B. If wire A originally had a length L_A and stretches by ΔL_A, then $\Delta L_A = F_A L_A / AE$, where A is the cross-sectional area of the wire and E is Young's modulus for steel (200×10^9 N/m^2). Similarly, $\Delta L_B = F_B L_B / AE$. If ℓ is the amount by which B was originally longer than A then, since they have the same length after the log is attached, $\Delta L_A = \Delta L_B + \ell$. This means

$$\frac{F_A L_A}{AE} = \frac{F_B L_B}{AE} + \ell.$$

We solve for F_B:

$$F_B = \frac{F_A L_A}{L_B} - \frac{AE\ell}{L_B}.$$

We substitute into $F_A + F_B - mg = 0$ and obtain

$$F_A = \frac{mgL_B + AE\ell}{L_A + L_B}.$$

The cross-sectional area of a wire is

$$A = \pi r^2 = \pi\left(1.20 \times 10^{-3}\,\text{m}\right)^2 = 4.52 \times 10^{-6}\,\text{m}^2 .$$

Both L_A and L_B may be taken to be 2.50 m without loss of significance. Thus

$$F_A = \frac{(103\,\text{kg})(9.8\,\text{m/s}^2)(2.50\,\text{m}) + (4.52\times10^{-6}\,\text{m}^2)(200\times10^9\,\text{N/m}^2)(2.0\times10^{-3}\,\text{m})}{2.50\,\text{m} + 2.50\,\text{m}}$$
$$= 866\,\text{N}.$$

(b) From the condition $F_A + F_B - mg = 0$, we obtain

$$F_B = mg - F_A = (103\,\text{kg})(9.8\,\text{m/s}^2) - 866\,\text{N} = 143\,\text{N}.$$

(c) The net torque must also vanish. We place the origin on the surface of the log at a point directly above the center of mass. The force of gravity does not exert a torque about this point. Then, the torque equation becomes $F_A d_A - F_B d_B = 0$, which leads to

$$\frac{d_A}{d_B} = \frac{F_B}{F_A} = \frac{143\,\text{N}}{866\,\text{N}} = 0.165.$$

62. To support a load of $W = mg = (670\ \text{kg})(9.8\ \text{m/s}^2) = 6566$ N, the steel cable must stretch an amount proportional to its “free” length:

$$\Delta L = \left(\frac{W}{AY}\right)L \quad \text{where } A = \pi r^2$$

and $r = 0.0125$ m.

(a) If $L = 12$ m, then $\Delta L = \left(\dfrac{6566\ \text{N}}{\pi(0.0125\ \text{m})^2\,(2.0\times10^{11}\ \text{N/m}^2)}\right)(12\ \text{m}) = 8.0\times10^{-4}\,\text{m}.$

(b) Similarly, when $L = 350$ m, we find $\Delta L = 0.023\,\text{m}$.

77. (a) Let $d = 0.00600$ m. In order to achieve the same final lengths, wires 1 and 3 must stretch an amount d more than wire 2 stretches:

$$\Delta L_1 = \Delta L_3 = \Delta L_2 + d\ .$$

Combining this with Eq. 12-23 we obtain

$$F_1 = F_3 = F_2 + \frac{dAE}{L}\ .$$

Now, Eq. 12-8 produces $F_1 + F_3 + F_2 - mg = 0$. Combining this with the previous relation (and using Table 12-1) leads to $F_1 = 1380 \text{ N} \approx 1.38\times10^3 \text{ N}$.

(b) Similarly, $F_2 = 180$ N.