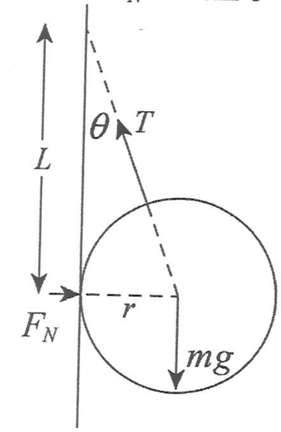
3. Three forces act on the sphere: the tension force $\vec{T}$ of the rope (acting along the rope), the force of the wall $\vec{F}_N$ (acting horizontally away from the wall), and the force of gravity $m\vec{g}$ (acting downward). Since the sphere is in equilibrium they sum to zero. Let θ be the angle between the rope and the vertical. Then Newton's second law gives

vertical component : $T\cos\theta - mg = 0$

horizontal component: $F_N - T\sin\theta = 0$.



(a) We solve the first equation for the tension and obtain $T = mg/\cos\theta$. We then substitute $\cos\theta = L/\sqrt{L^2+r^2}$:

$$T = \frac{mg\sqrt{L^2+r^2}}{L} = \frac{(0.85\ \text{kg})(9.8\ \text{m/s}^2)\sqrt{(0.080\ \text{m})^2+(0.042\ \text{m})^2}}{0.080\ \text{m}} = 9.4\ \text{N}.$$

(b) We solve the second equation for the normal force and obtain $F_N = T\sin\theta$. Using $\sin\theta = r/\sqrt{L^2+r^2}$, we have

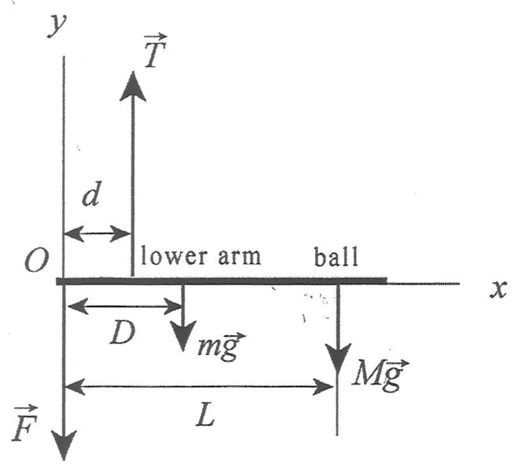
$$F_N = \frac{Tr}{\sqrt{L^2+r^2}} = \frac{mg\sqrt{L^2+r^2}}{L}\frac{r}{\sqrt{L^2+r^2}} = \frac{mgr}{L}$$
$$= \frac{(0.85\ \text{kg})(9.8\ \text{m/s}^2)(0.042\ \text{m})}{(0.080\ \text{m})} = 4.4\ \text{N}.$$

20. Our system consists of the lower arm holding a bowling ball. As shown in the free-body diagram, the forces on the lower arm consist of $\vec{T}$ from the biceps muscle, $\vec{F}$ from the bone of the upper arm, and the gravitational forces, $m\vec{g}$ and $M\vec{g}$. Since the system is in static equilibrium, the net force acting on the system is zero:

$$0 = \sum F_{\text{net},y} = T - F - (m+M)g .$$

In addition, the net torque about O must also vanish:

$$0 = \sum_{O} \tau_{\text{net}} = (d)(T) + (0)F - (D)(mg) - L(Mg) .$$



(a) From the torque equation, we find the force on the lower arms by the biceps muscle to be

$$T = \frac{(mD + ML)g}{d} = \frac{[(1.8\text{ kg})(0.15\text{ m}) + (7.2\text{ kg})(0.33\text{ m})](9.8\text{ m/s}^2)}{0.040\text{ m}}$$
$$= 648\text{ N} \approx 6.5 \times 10^2\text{ N}.$$

(b) Substituting the above result into the force equation, we find F to be

$$F = T - (M+m)g = 648\text{ N} - (7.2\text{ kg} + 1.8\text{ kg})(9.8\text{ m/s}^2) = 560\text{ N} = 5.6 \times 10^2\text{ N}.$$

43. (a) 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 is the weight of the object hung on the end: $F = mg$, where m is the mass of the object. If r is the radius of the rod then $A = \pi r^2$. Thus, the shear stress is

$$\frac{F}{A} = \frac{mg}{\pi r^2} = \frac{(1200\text{ kg})(9.8\text{ m/s}^2)}{\pi(0.024\text{ m})^2} = 6.5 \times 10^6\text{ N/m}^2.$$

(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,

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

52. (a) If L (= 1500 cm) is the unstretched length of the rope and $\Delta L = 2.8\,\text{cm}$ is the amount it stretches, then the strain is

$$\Delta L / L = (2.8\,\text{cm})/(1500\,\text{cm}) = 1.9 \times 10^{-3}.$$

(b) The stress is given by F/A where F is the stretching force applied to one end of the rope and A is the cross-sectional area of the rope. Here F is the force of gravity on the rock climber. If m is the mass of the rock climber then $F = mg$. If r is the radius of the rope then $A = \pi r^2$. Thus the stress is

$$\frac{F}{A} = \frac{mg}{\pi r^2} = \frac{(95\,\text{kg})(9.8\,\text{m/s}^2)}{\pi(4.8\times10^{-3}\,\text{m})^2} = 1.3\times10^7\ \text{N/m}^2.$$

(c) Young's modulus is the stress divided by the strain:

$$E = (1.3 \times 10^7\ \text{N/m}^2) / (1.9 \times 10^{-3}) = 6.9 \times 10^9\ \text{N/m}^2.$$