3. (a) The forces are balanced when they sum to zero: $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$. This means

$$\vec{F}_3 = -\vec{F}_1 - \vec{F}_2 = -(10\,\mathrm{N})\,\hat{\imath} + (4\,\mathrm{N})\,\hat{\jmath} - (17\,\mathrm{N})\,\hat{\imath} - (2\,\mathrm{N})\,\hat{\jmath} = (-27\,\mathrm{N})\,\hat{\imath} + (2\,\mathrm{N})\,\hat{\jmath} \; .$$

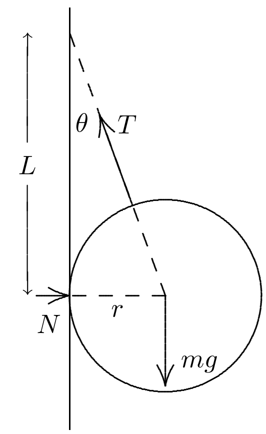
(b) If θ is the angle the vector makes with the x axis then

$$\tan\theta = \frac{F_{3y}}{F_{3x}} = \frac{2\,\mathrm{N}}{-27\,\mathrm{N}} = -0.741 \; .$$

The angle is either -4.2° or 176°. The second solution yields a negative x component and a positive y component and is therefore the correct solution.

7.

Three forces act on the sphere: the tension force $\vec{T}$ of the rope (acting along the rope), the force of the wall $\vec{N}$ (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, the vertical component of Newton's second law is $T\cos\theta - mg = 0$. The horizontal component is $N - T\sin\theta = 0$.



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

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

$$N = \frac{Tr}{\sqrt{L^2+r^2}} = \frac{mg\sqrt{L^2+r^2}}{L}\,\frac{r}{\sqrt{L^2+r^2}} = \frac{mgr}{L}\ .$$

16. (a) Analyzing vertical forces where string 1 and string 2 meet, we find

$$T_1 = \frac{40\,\text{N}}{\cos 35^\circ} = 49 \text{ N} .$$

(b) Looking at the horizontal forces at that point leads to

$$T_2 = T_1 \sin 35^\circ = (49\,\text{N}) \sin 35^\circ = 28 \text{ N} .$$

(c) We denote the components of T_3 as T_x (rightward) and T_y (upward). Analyzing horizontal forces where string 2 and string 3 meet, we find $T_x = T_2 = 28\,\text{N}$. From the vertical forces there, we conclude $T_y = 50\,\text{N}$. Therefore,

$$T_3 = \sqrt{T_x^2 + T_y^2} = 57 \text{ N} .$$

(d) The angle of string 3 (measured from vertical) is

$$\theta = \tan^{-1}\left(\frac{T_x}{T_y}\right) = \tan^{-1}\left(\frac{28}{50}\right) = 29^\circ .$$

28. (a) Computing torques about the hinge, we find the tension in the wire:

$$TL\sin\theta - Wx = 0 \implies T = \frac{Wx}{L\sin\theta} .$$

(b) The horizontal component of the tension is $T\cos\theta$, so equilibrium of horizontal forces requires that the horizontal component of the hinge force is

$$F_x = \left(\frac{Wx}{L\sin\theta}\right)\cos\theta = \frac{Wx}{L\tan\theta} .$$

(c) The vertical component of the tension is $T\sin\theta$, so equilibrium of vertical forces requires that the vertical component of the hinge force is

$$F_y = W - \left(\frac{Wx}{L\sin\theta}\right)\sin\theta = W\left(1 - \frac{x}{L}\right) .$$

37. (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,

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