40.

(a) The force along the slope is given by

$$F_g = mg\sin\theta - \mu F_N = mg\sin\theta - \mu mg\cos\theta = mg(\sin\theta - \mu\cos\theta)$$
$$= (85.0\ \text{kg})(9.80\ \text{m/s}^2)\left[\sin 40.0° - (0.04000)\cos 40.0°\right]$$
$$= 510\ \text{N}.$$

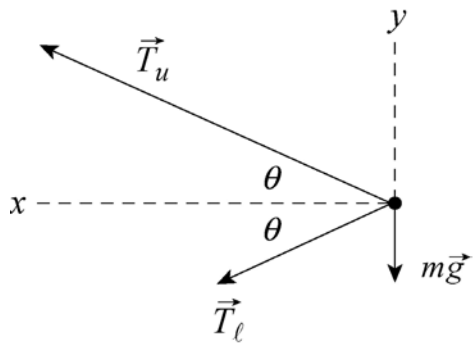
Thus, the terminal speed of the skier is

$$v_t = \sqrt{\frac{2F_g}{C\rho A}} = \sqrt{\frac{2(510\ \text{N})}{(0.150)(1.20\ \text{kg/m}^3)(1.30\ \text{m}^2)}} = 66.0\ \text{m/s}.$$

(b) Differentiating v_t with respect to C, we obtain

$$dv_t = -\frac{1}{2}\sqrt{\frac{2F_g}{\rho A}}\,C^{-3/2}dC = -\frac{1}{2}\sqrt{\frac{2(510\ \text{N})}{(1.20\ \text{kg/m}^3)(1.30\ \text{m}^2)}}(0.150)^{-3/2}\,dC$$
$$= -(2.20\times 10^2\ \text{m/s})dC.$$

59. The free-body diagram for the ball is shown below. $\vec{T}_u$ is the tension exerted by the upper string on the ball, $\vec{T}_\ell$ is the tension force of the lower string, and m is the mass of the ball. Note that the tension in the upper string is greater than the tension in the lower string. It must balance the downward pull of gravity and the force of the lower string.



(a) We take the $+x$ direction to be leftward (toward the center of the circular orbit) and $+y$ upward. Since the magnitude of the acceleration is $a = v^2/R$, the x component of Newton's second law is

$$T_u \cos\theta + T_\ell \cos\theta = \frac{mv^2}{R},$$

where v is the speed of the ball and R is the radius of its orbit. The y component is

$$T_u \sin\theta - T_\ell \sin\theta - mg = 0.$$

The second equation gives the tension in the lower string: $T_\ell = T_u - mg/\sin\theta$. Since the triangle is equilateral $\theta = 30.0°$. Thus,

$$T_\ell = 35.0\ \text{N} - \frac{(1.34\ \text{kg})(9.80\ \text{m/s}^2)}{\sin 30.0°} = 8.74\ \text{N}.$$

(b) The net force has magnitude

$$F_{\text{net,str}} = (T_u + T_\ell)\cos\theta = (35.0\ \text{N} + 8.74\ \text{N})\cos 30.0° = 37.9\ \text{N}.$$

(c) The radius of the path is

$$R = ((1.70\ \text{m})/2)\tan 30.0° = 1.47\ \text{m}.$$

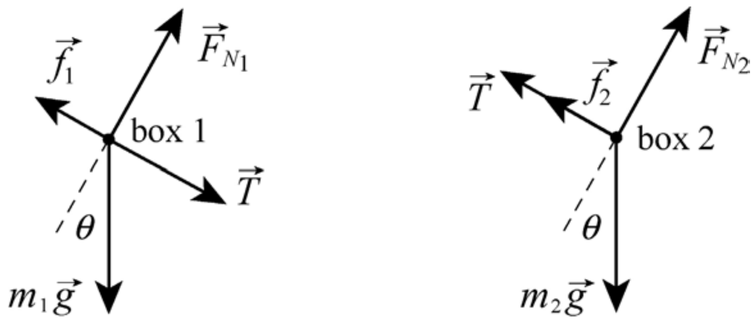
Using $F_{\text{net,str}} = mv^2/R$, we find that the speed of the ball is

$$v = \sqrt{\frac{RF_{\text{net,str}}}{m}} = \sqrt{\frac{(1.47\ \text{m})(37.9\ \text{N})}{1.34\ \text{kg}}} = 6.45\ \text{m/s}.$$

(d) The direction of $\vec{F}_{\text{net,str}}$ is leftward ("radially inward").

60. The free-body diagrams for the two boxes are shown below. T is the magnitude of the force in the rod (when $T > 0$ the rod is said to be in tension and when $T < 0$ the rod is under compression), $\vec{F}_{N2}$ is the normal force on box 2 (the uncle box), $\vec{F}_{N1}$ is the the normal force on the aunt box (box 1), $\vec{f}_1$ is kinetic friction force on the aunt box, and $\vec{f}_2$

is kinetic friction force on the uncle box. Also, m_1 = 1.65 kg is the mass of the aunt box and m_2 = 3.30 kg is the mass of the uncle box (which is a lot of ants!).



For each block we take +x downhill (which is toward the lower-right in these diagrams) and +y in the direction of the normal force. Applying Newton's second law to the x and y directions of first box 2 and next box 1, we arrive at four equations:

$$m_2 g \sin\theta - f_2 - T = m_2\, a$$
$$F_{N2} - m_2 g \cos\theta = 0$$
$$m_1 g \sin\theta - f_1 + T = m_1 a$$
$$F_{N1} - m_1 g \cos\theta = 0$$

which, when combined with Eq. 6-2 ($f_1 = \mu_1 F_{N1}$ where μ_1 = 0.226 and $f_2 = \mu_2 F_{N2}$ where μ_2 = 0.113), fully describe the dynamics of the system.

(a) We solve the above equations for the tension and obtain

$$T = \left(\frac{m_2 m_1 g}{m_2 + m_1}\right)(\mu_1 - \mu_2)\cos\theta = 1.05\ \text{N}.$$

(b) These equations lead to an acceleration equal to

$$a = g\left(\sin\theta - \left(\frac{\mu_2 m_2 + \mu_1 m_1}{m_2 + m_1}\right)\cos\theta\right) = 3.62\ \text{m/s}^2.$$

(c) Reversing the blocks is equivalent to switching the labels. We see from our algebraic result in part (a) that this gives a negative value for T (equal in magnitude to the result we got before). Thus, the situation is as it was before except that the rod is now in a state of compression.

70. (a) We note that R (the horizontal distance from the bob to the axis of rotation) is the circumference of the circular path divided by 2π; therefore, $R = 0.94/2\pi = 0.15$ m. The angle that the cord makes with the horizontal is now easily found:

$$\theta = \cos^{-1}(R/L) = \cos^{-1}(0.15 \text{ m}/0.90 \text{ m}) = 80^\circ.$$

The vertical component of the force of tension in the string is $T\sin\theta$ and must equal the downward pull of gravity (mg). Thus,

$$T = \frac{mg}{\sin\theta} = 0.40\ \text{N}\ .$$

Note that we are using T for tension (not for the period).

(b) The horizontal component of that tension must supply the centripetal force (Eq. 6-18), so we have $T\cos\theta = mv^2/R$. This gives speed $v = 0.49$ m/s. This divided into the circumference gives the time for one revolution: 0.94/0.49 = 1.9 s.