Problem 5.104

104. The 4.00-kg block in Fig. 1 is attached to a vertical rod by means of two strings. When the system rotates around the axis of the rod, the strings are extended as shown in the diagram and the tension in the upper string is 80.0 N.
a) What is the tension in the lower cord?

\[ \Sigma F_y = 0 \]
\[ F_{\text{g}} + T_d \sin(53.13^\circ) - T_u \sin(53.13^\circ) = 0 \]
\[ 40^* + T_d \sin(53.13^\circ) - 80 \sin(53.13^\circ) = 0 \]
\[ T_d = [80 \sin(53.13^\circ) - 40]/\sin(53.13^\circ) \]
\[ T_d = 30.00 \text{N} \]

b) How many revolutions per minute does the system make?

\[ \Sigma F_x = ma \]
\[ T_u \cos(53.13^\circ) + T_d \cos(53.13^\circ) = 4 \left( \frac{V^2}{R} \right) \]
\[ 80 \cos(53.13^\circ) + 30 \cos(53.13^\circ) = 4 \left( \frac{V^2}{.75} \right) \]
\[ V^2 = \left[ 80 \cos(53.13^\circ) + 30 \cos(53.13^\circ) \right]/4 \cdot .75 \]
\[ V = \frac{3.52 \text{ m/s}}{1 \text{ sec}} \left( \frac{60 \text{ sec}}{1 \text{ min}} \right) \left( \frac{1 \text{ rev}}{2\pi(0.75) \text{ m}} \right) = 44.82 \text{ rev/min} \]
c) Find the number of revolutions per minute at which the lower chord just goes slack.

\[ \cos^{-1}(1/1.25) = 36.87^\circ \]
\[ 180 - 90 - 36.87 = 53.13 \]
\[ 1.25^2 - 1^2 = .75^2 \]

\[ ^* - \text{At the point when the bottom chord } \text{"goes slack," there is no tension in the chord. The angles and radius in the situation remain consistent with those in part a. The tension in the top chord will be greater than } T_u \text{ in part A.} \]

\[ \Sigma F_y = 0 \]
\[ T_u \sin(53.13^\circ) - F_g = 0 \]
\[ T_u \sin(53.13^\circ) - 40^* = 0 \]
\[ T_u = 40 / \sin(53.13^\circ) \]
\[ T_u = 50 \text{N} \]

\[ F_g = mg = 4 \text{kg} \cdot 10 \text{m/s}^2 = 40 \text{N} \]

\[ \Sigma F_x = ma \]
\[ T_u \cos(53.13^\circ) = 4 \left( \frac{V^2}{R} \right) \]
\[ 50 \cos(53.13^\circ) = 4 \left( \frac{V^2}{.75} \right) \]
\[ V^2 = [50 \cos(53.13^\circ)] \left( \frac{1 \text{ rev}}{2\pi(.75) \text{ m}} \right) = 30.18 \text{ rev/min} \]
d) Explain what happens if the number of revolutions per minute is less than in part (c).

When the number of revolutions per minute is less than 30.18, the distance between the block and the pole decreases, and the bottom chord begins to bend. The angle between the pole and top chord decreases, and the block moves down in the Y direction.