11.79 A garage door is mounted on an overhead rail (Fig. 11.49). The wheels at A and B have rusted so that they do not roll, but rather slide along the track. The coefficient of kinetic friction is 0.52. The distance between the wheels is 2.00 m, and each is 0.50 m from the vertical sides of the door. The door is uniform and weighs 950 N. It is pushed to the left at constant speed by a horizontal force \( F \). a) If the distance \( h \) is 1.60 m, what is the vertical component of the force exerted on each wheel by the track? b) Find the maximum value \( h \) can have without causing one wheel to leave the track.

**Note:** The \( y \) distance \( l \) between the CM and the wheel force points A and B is not provided.

The unknowns are: \( F_{Ax}, F_{Ay}, F_{Bx}, F_{By}, \) and \( F \). The door is moving at a constant velocity, so it is in equilibrium. Thus: \( \Sigma F_x = 0, \Sigma F_y = 0, \Sigma I = 0 \).

In addition, kinematic friction applies for the forces at A and B with \( \mu_k = 0.52 \). \( F_{Ay} \) and \( F_{By} \) are normal forces, so:

\[
F_{Ax} = \mu_k F_{Ay} \quad \text{and} \quad F_{Bx} = \mu_k F_{By}
\]

Thus there are five equations and five unknowns.

\[
\Sigma F_y = 0 \quad \Rightarrow \quad F_{Ay} + F_{By} - W = 0 \quad F_{Ay} + F_{By} = W = 950 \text{N}
\]

\[
\Sigma F_x = 0 \quad \Rightarrow \quad F_{Ax} + F_{Bx} - F = 0
\]

\[
F = F_{Ax} + F_{Bx} = 0.52(F_{Ay} + F_{By})
\]

\[
F = 0.52(950 \text{N}) = 494 \text{ N}
\]
Part A: What is $F_{Ay}$ and $F_{By}$ if $h = 1.60\text{m}$?

To isolate and calculate $F_{Ay}$ alone, calculate the torque about point B.

Forces $F_{By}$, $F_{Bx}$, and $F_{Ax}$ have lever arms of length zero and thus produce no torque about point B. $F$ has a lever arm of length $h = 1.60\text{m}$. $F_{Ay}$ has a lever arm of length $2.00\text{m}$. $W$ has a lever arm of length $1.00\text{m}$.

Thus $\Sigma T = 0 \Rightarrow W(1.00\text{m}) - F_{Ay} (2.00\text{m}) - F(h) = 0$

\[
F_{Ay} = \frac{W(1.00\text{m}) - F(h)}{2.00\text{m}}
\]

\[
F_{Ay} = \frac{950\text{N}(1.00\text{m}) - 494\text{N}(1.60\text{m})}{2.00\text{m}}
\]

\[
F_{Ay} = 79.8\text{N}
\]

\[
F_{By} = W - F_{Ay} = 950\text{N} - 79.8\text{N} = 870\text{N}
\]

Part B: What is $h_{\text{max}}$ when one wheel lifts?

Solve the torque equation for the value of $h$ when $F_{Ay}$ has a value of zero:

\[
F(h) = W(1.00\text{m})
\]

\[
h = \frac{W(1.00\text{m})}{F}
\]

\[
h_{\text{max}} = \frac{950\text{N}(1.00\text{m})}{494\text{N}} = 1.92\text{m}
\]