Example

What is the static friction coefficient needed between a ladder and a floor to ensure a \( L = 3 \text{m} \) long ladder leaned against a wall with \( \theta = 60^\circ \) does not slip?

1. Drawing (big!) and coordinate system

\[ n_1 = n_1 \cdot \sin \theta \]

2. Force diagram - add forces to drawing

3. Decompose forces into I and II components for rotation around pivot (see triangles above) and into \( x, y \) components (not necessary here)

4. Setup 3 equations

\[
\begin{align*}
\text{I} & : F_{x \text{net}} = 0 \quad \Rightarrow \quad -F_s + n = 0 \quad \Rightarrow \quad F_s = n \\
\text{II} & : F_{y \text{net}} = 0 \quad \Rightarrow \quad n_2 - Mg = 0 \quad \Rightarrow \quad n_2 = Mg \\
\text{III} & : \tau_{\text{net}} = 0 \quad \Rightarrow \quad F_1 \cdot \frac{L}{2} - n_1 \cdot L = 0 \\
& \quad \Rightarrow \quad Mg \cos \theta \cdot \frac{L}{2} - n_1 \cdot \sin \theta \cdot L = 0
\end{align*}
\]
5. Solve, and use \( f_s = n_2 \cdot \mu_s \) for maximum \( f_s \) (to get minimum \( \mu_s \))

with that we have

(i) \( n_2 \mu_s = n_1 \)

(ii) \( n_2 = Mg \)

(iii) \( \frac{1}{n_1} \sin \theta = Mg \cos \theta \cdot \frac{1}{2} \)

Combine I and II: \( Mg \mu_s = n_1 \)

Insert to III

\[ Mg \mu_s \sin \theta = Mg \cos \theta \cdot \frac{1}{2} \]

\[ \Rightarrow \mu_s = \frac{\cos \theta \cdot \frac{1}{2}}{\sin \theta} \]

\[ \Rightarrow \mu_s = \frac{1}{2 \tan \theta} \]

So minimum \( \mu_s = 0.29 \) or \( \mu_s \geq 0.29 \)