

# Physics Problem: Forces on a Ladder

## Solution Guide

July 17, 2025

### Problem Statement

To get up on the roof, a person (mass 70.0 kg) places a 6.00 m aluminum ladder (mass 10.0 kg) against the house on a concrete pad with the base of the ladder 2.00 m from the house. The ladder rests against a plastic rain gutter, which we can assume to be frictionless. The center of mass of the ladder is 2 m from the bottom. The person is standing 3 m from the bottom. What are the magnitudes of the forces on the ladder at the top and bottom?

### Solution

The forces involved are:

- The weight of the man ( $w$ )
- The weight of the ladder ( $W$ )
- The normal force of the ground on the ladder bottom ( $N$ )
- The normal force of the gutter on the ladder top ( $N'$ )
- Friction between the ground and ladder bottom ( $f$ )

The condition of no net force horizontally leads to  $f = N' \sin \theta$ , where  $\theta$  is the angle between the ladder and the ground:

$$\theta = \arccos\left(\frac{2}{6}\right) = 70.5^\circ \quad (1)$$

The condition of no net force vertically leads to  $w + W = N + N' \cos \theta$ , which combines with the previous condition to give  $f = (w + W - N) \tan \theta$ .

The condition of no torque about the ladder bottom leads to  $3w \cos \theta + 2W \cos \theta = 6N'$ , which combines with the first condition to give:

$$f = \left(\frac{1}{2}w + \frac{1}{3}W\right) \sin \theta \cos \theta \quad (2)$$

Combining these last two conditions, we can solve for  $N$ :

$$\begin{aligned} f &= \left(\frac{1}{2}w + \frac{1}{3}W\right) \sin \theta \cos \theta = (w + W - N) \tan \theta \\ N &= \left(1 - \frac{\cos^2 \theta}{2}\right) w + \left(1 - \frac{\cos^2 \theta}{3}\right) W \\ &= (0.944)(9.80 \text{ m s}^{-2})(70.0 \text{ kg}) + (0.963)(9.80 \text{ m s}^{-2})(10.0 \text{ kg}) \\ &= 742 \text{ N} \end{aligned}$$

We can use this value to solve for  $f$  and  $N'$ :

$$f = (w + W - N) \tan \theta = 119 \text{ N}$$
$$N' = \frac{f}{\sin \theta} = 126 \text{ N}$$

## Final Answer

The magnitude of the force at the top is  $N' = \boxed{126 \text{ N}}$

The force at the bottom is the sum of friction and the normal force, with a magnitude of:

$$\sqrt{f^2 + N^2} = \boxed{751 \text{ N}}$$