

# Ladder Problem Analysis Assignment

## Student Workbook

July 17, 2025

### Problem Analysis Guide

Given the ladder problem solution, complete the following analysis steps to deepen your understanding of the problem-solving process.

### Part 1: System Visualization (20 points)

1. Draw a detailed system diagram showing:

- The ladder's position relative to the house
- The person's position on the ladder
- All relevant dimensions
- The center of mass of the ladder
- System boundaries clearly defined

2. Create a Free Body Diagram (FBD) showing:

- All forces acting on the ladder
- Proper force vectors with labels
- The angle  $\theta$  between the ladder and the ground
- The coordinate system you're using

3. Identify and list all known quantities with their units:

- Mass of person = \_\_\_\_\_ kg
- Mass of ladder = \_\_\_\_\_ kg
- Length of ladder = \_\_\_\_\_ m
- Distance from wall = \_\_\_\_\_ m
- Height of person on ladder = \_\_\_\_\_ m
- Center of mass location = \_\_\_\_\_ m

### Part 2: Mathematical Analysis (40 points)

4. Show the step-by-step calculation of the angle  $\theta$ :

$$\theta = \arccos\left(\frac{2}{6}\right) = \text{_____}^\circ$$

5. Write out the three equilibrium equations with proper units:

- Sum of forces in x-direction: \_\_\_\_\_
- Sum of forces in y-direction: \_\_\_\_\_
- Sum of torques about the bottom of the ladder: \_\_\_\_\_

6. Show the complete algebraic steps to find  $N$  starting from:

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

Include units in each step.

7. Calculate the weights  $w$  and  $W$  with proper units:

$$w = \underline{\hspace{10cm}}$$

$$W = \underline{\hspace{10cm}}$$

### Part 3: Final Calculations (40 points)

8. Show the detailed calculation of  $N$  with units:

$$N = \left( 1 - \frac{\cos^2 \theta}{2} \right) w + \left( 1 - \frac{\cos^2 \theta}{3} \right) W$$

$$= \underline{\hspace{10cm}}$$

$$= \underline{\hspace{10cm}} \text{ N}$$

9. Calculate  $f$  showing all steps and units:

$$f = (w + W - N) \tan \theta$$

$$= \underline{\hspace{10cm}}$$

$$= \underline{\hspace{10cm}} \text{ N}$$

10. Calculate  $N'$  showing all steps and units:

$$N' = \frac{f}{\sin \theta}$$

$$= \underline{\hspace{10cm}}$$

$$= \underline{\hspace{10cm}} \text{ N}$$

11. Calculate the magnitude of the total force at the bottom:

$$F_{\text{bottom}} = \sqrt{f^2 + N^2}$$

$$= \underline{\hspace{10cm}}$$

$$= \underline{\hspace{10cm}} \text{ N}$$

### Analysis Questions (Bonus: 10 points)

- Why is the force at the top ( $N'$ ) much smaller than the force at the bottom?
- How would the forces change if the angle  $\theta$  were smaller?
- Why is it important that the rain gutter is assumed to be frictionless?
- What assumptions are we making about the ladder's structure in this problem?