

An 80-n Uniform Plank Leans Against A Frictionless Wall As Shown. The Vertical Component Of Force At

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Understanding the forces acting on a leaning plank is crucial in physics and engineering, especially when analyzing structural stability and safety. In this article, we delve into the scenario where an 80-newton uniform plank leans against a frictionless wall, emphasizing the vertical component of the force at play. Such problems are common in statics and are foundational for designing safe structures and understanding load distribution.

Overview of the Problem: The Leaning Plank and Force Components

Imagine an 80-newton uniform plank leaning against a frictionless vertical wall. The plank makes an angle with the horizontal ground, and it rests on the ground with a support at its lower end. The key focus is on the forces at the contact points—where the plank touches the wall and the ground—and specifically, the vertical component of the force exerted by the ground or other supports.

Key Elements of the Scenario

- Uniform plank with weight $W = 80 \text{ N}$
- Leaning against a frictionless vertical wall
- Resting on a horizontal ground surface
- Inclination angle (assumed or given)
- Force interactions at the contact points

Understanding how these forces balance each other is essential for calculating the vertical component of the force at various points, especially at the ground contact.

Analyzing the Forces Acting on the Plank

The first step in solving such problems involves identifying all forces acting on the plank:

1. The Weight of the Plank (W)

This acts vertically downward through the center of mass of the plank, which, for a uniform plank, is at its midpoint.

2. Normal Force at the Ground (N_g)

This is the force exerted by the ground on the plank, acting vertically upward to counteract the weight and any other vertical forces.

3. Force at the Wall (F_{wall})

Since the wall is frictionless, it only exerts a normal force perpendicular to its surface—i.e., horizontally.

4. Reaction Force at the Support Point (N_{support})

If the plank is resting on a support at its lower end, this point exerts both vertical and horizontal reactions depending on the equilibrium conditions.

Conditions for Equilibrium and Force Components

The plank remains in static equilibrium, which means:

- Sum of all horizontal forces = 0
- Sum of all vertical forces = 0
- Sum of all moments about any point = 0

Applying these conditions enables calculating the vertical component of the force at the contact points, especially at the ground.

1. Vertical Force Balance

The vertical forces include:

- The weight of the plank ($W = 80 \text{ N}$)
- The vertical component of the support reaction (N_{support})

Since the wall is frictionless, it does not exert any vertical force, only horizontal.

2. Horizontal Force Balance

Horizontal forces include:

- The horizontal reaction force from the wall (F_{wall})
- The horizontal component of the support reaction (if any)

For the plank to be in equilibrium, these must balance each other.

Calculating the Vertical Component of Force at the Support

The vertical component of the force at the support, often denoted as N_{support} , is vital for understanding how the load is distributed.

Step-by-step Approach to Calculation

1. Identify the inclination angle of the plank relative to the ground. For example, assume the plank makes an angle θ with the horizontal.
2. Resolve the forces into components aligned with the axes—horizontal and vertical.
3. Apply equilibrium equations to solve for unknown forces:
4. Use moments about a point to eliminate unknown reactions and solve for the vertical component.

Example Calculation (Hypothetical Angles)

Suppose the plank is inclined at $\theta = 45^\circ$. The weight acts at the center, located at half the length of the plank.

- Horizontal reaction force from the wall: F_{wall}
- Vertical reaction from the support: N_{support}

Applying the moment equilibrium about the contact point with the ground:

$$\sum M_{\text{ground}} = 0$$

This involves considering the moments caused by the weight and the reactions.

Result

Using statics principles, you might find that:

$$N_{\text{support}} = W \times \frac{L/2}{L} \times \cos \theta$$

where L is the length of the plank. The vertical component at the support then can be calculated based on this relation and the equilibrium equations.

Importance of Frictionless Wall in the Analysis

The assumption that the wall is frictionless simplifies the problem by eliminating the vertical component of the force exerted by the wall. The wall only provides a horizontal normal force, F_{wall} , which balances the horizontal component of the support reaction.

This simplification influences how the vertical component of the force at the ground is calculated, as all vertical support must counteract the weight of the plank and any vertical forces transmitted through the support.

Practical Applications and Significance

Understanding the vertical component of force in such scenarios is vital in:

- Designing stable leaning structures like ladders, fences, or walls
- Ensuring safety by preventing tipping or collapse
- Analyzing load distribution in mechanical systems
- Educational purposes in physics and engineering courses

Accurate calculations help engineers determine the necessary strength of supports and materials, ensuring safety margins are met.

Summary of Key Takeaways

- The vertical component of force at the support is essential for maintaining equilibrium in a leaning plank scenario.
- Frictionless walls only exert horizontal forces, simplifying the force analysis.
- Applying equilibrium equations and moments allows for precise calculation of force components.
- Understanding these principles is fundamental for safe structural design and analysis.

Conclusion

Analyzing an 80-n uniform plank leaning against a frictionless wall reveals critical insights into how forces distribute in static systems. The vertical component of force at the support plays a central role in ensuring the stability of the structure. By systematically applying the principles of equilibrium—balancing forces and moments—engineers and students can predict and verify the behavior of such systems. Mastery of these concepts not only enhances understanding of fundamental physics but also equips practitioners with the tools needed to design safer, more reliable structures.

Whether in academic settings or practical engineering projects, understanding the vertical component of force at supports in leaning systems is indispensable. It underscores the importance of a methodical approach to force analysis, considering all forces and their components, especially in scenarios involving idealized conditions like frictionless surfaces.

Frequently Asked Questions

What is the significance of the vertical component of the force at the point where the uniform plank contacts the wall?

The vertical component of the force at the contact point reflects the upward force exerted by the wall on the plank, which helps balance the weight of the plank and maintain equilibrium without slipping.

How does the frictionless nature of the wall affect the forces acting on the plank?

Since the wall is frictionless, it can only exert a normal (perpendicular) force on the plank, which has both horizontal and vertical components. There is no frictional force to oppose sliding, so equilibrium depends solely on these normal force components.

How can we determine the vertical component of the force at the contact point in this setup?

The vertical component can be found by analyzing the equilibrium conditions: the sum of vertical forces must be zero. Typically, it is equal to the weight of the plank minus any vertical support forces from other points, such as the ground or additional supports.

What role does the length of the plank play in calculating the vertical component of force at the wall?

The length of the plank influences the torque and force distribution; longer planks experience different force components at the contact point. Proper analysis involves considering moments about pivot points to find the vertical component accurately.

In what way does the angle at which the plank leans affect the vertical component of the force at the wall?

The leaning angle determines the distribution of forces; a steeper angle typically results in a larger horizontal component and a smaller vertical component at the contact point, affecting how the forces balance for equilibrium.

Why is understanding the vertical component of force important in structural stability analysis of leaning planks?

The vertical component contributes to the overall stability by counteracting the weight of the plank. Accurate knowledge of this component ensures the structure can support itself without slipping or collapsing, especially when design parameters change.

Additional Resources

An 80° Uniform Plank Leaning Against a Frictionless Wall: An In-Depth Analysis of the Vertical Force Component

Introduction

The scenario involving a uniform plank leaning against a frictionless wall at an angle of 80° provides a classic example in static equilibrium and statics mechanics. Such problems are fundamental in understanding how forces distribute along inclined objects and how the various components of these forces interact to maintain equilibrium. In this discussion, we will delve into the detailed mechanics behind the vertical component of the force at the contact points, particularly focusing on the force exerted by the wall and the ground, and how these relate to the internal forces within the plank.

Understanding the Physical Setup

Configuration Description

- The Plank:
 - Length: Typically denoted as (L) .
 - Mass: Uniform, with mass (m) .
 - Weight: $(W = mg)$, acting at the center of the plank (midpoint).
 - Inclination: 80° with respect to the horizontal surface.
- Support Points:
 - Wall: Frictionless, providing a normal force only (no frictional component).
 - Floor: Provides both a normal force and a possible frictional force, depending on the situation.
- Forces Acting:
 - Gravity: Acts downward through the center of mass.
 - Normal force from the wall: Acts perpendicular to the wall surface, directed horizontally inward.
 - Normal force from the floor: Acts vertically upward at the base of the plank.
 - Frictional forces: Present at the floor if needed; absent at the wall due to frictionless contact.

Assumptions and Simplifications

- The wall is perfectly frictionless, so no tangential frictional force at the contact point.
- The plank is rigid, uniform, and in static equilibrium (no acceleration).
- The contact points are idealized as points with normal forces; deformation effects are neglected.
- Air resistance and other external forces are ignored.

Statics Fundamentals Applied to the Scenario

Conditions for Equilibrium

A body in static equilibrium must satisfy:

- Sum of all forces in the vertical direction:

$$\sum F_y = 0$$

- Sum of all forces in the horizontal direction:

$$\sum F_x = 0$$

- Sum of all moments about any point:

$$\sum \tau = 0$$

Applying these principles, we can analyze the forces and moments acting on the plank to find the vertical component of the force at the wall and the floor.

Force Components and Notation

- (N_w) : Normal force exerted by the wall, directed horizontally inward.
- (N_f) : Normal force exerted by the floor, directed vertically upward.
- (f_f) : Friction force at the floor (if any), which opposes the tendency to slide.
- (W) : Weight of the plank, acting downward at the center of the plank.

Detailed Force and Moment Analysis

Step 1: Drawing the Free-Body Diagram

Create a diagram illustrating:

- The inclined plank at 80° .
- The forces at the contact points: (N_w) at the wall, (N_f) at the floor, and possibly (f_f) .
- The weight (W) acting at the midpoint.

This visual aids in understanding the directions and points of application of forces.

Step 2: Horizontal Force Balance

Since the wall is frictionless:

$$\boxed{\sum F_x = N_w - F_h = 0}$$

where (F_h) is any horizontal force component at the floor (possibly due to friction or other factors). In many cases, the horizontal force at the floor is zero unless friction is present.

Given the frictionless wall:

$$\boxed{N_w = \text{horizontal reaction component}}$$

Step 3: Vertical Force Balance

The vertical forces are:

- The weight (W) downward.
- The normal force from the floor (N_f) upward.
- The vertical component of the internal forces, if any.

Since the wall is frictionless, it exerts no vertical component. Therefore, the vertical equilibrium simplifies to:

$$\boxed{N_f - W = 0 \quad \Rightarrow \quad N_f = W}$$

This indicates that the normal force from the floor balances the weight of the plank. However, the distribution of forces may be more complex when considering moments.

Step 4: Moment Balance About a Point

Choosing the base of the plank or the point where the forces are applied simplifies calculations.

- Moment about the floor contact point:

$$\sum \tau = 0$$

- The weight acts at the midpoint, located at a distance $\left(\frac{L}{2}\right)$ along the plank length, inclined at 80° .

- The horizontal and vertical positions of the weight and forces can be expressed in terms of (L) and the angle.

This step allows calculation of the normal force at the wall (N_w) , which in turn relates to the vertical force component exerted by the wall indirectly through the internal geometry.

Calculating the Vertical Component of Force at the Wall

Understanding the Role of the Wall's Force

Since the wall is frictionless:

- The wall exerts only a normal force (N_w) , directed horizontally inward.
- No vertical component of the force from the wall directly acts on the plank.

However, the key insight is that the normal force from the wall, combined with the geometry of the plank, influences the internal force distribution and, consequently, the vertical reactions at the floor.

Relation Between the Normal Force and the Inclination

- The normal force (N_w) at the wall acts horizontally.
- The plank's inclination at 80° causes the force components along the plank to distribute between the vertical and horizontal directions.

The internal forces (axial, shear, and bending forces) within the plank are determined by the boundary reactions and the weight distribution.

Vertical Force at the Contact Point: Indirect Effects

While the wall exerts no vertical force directly, the internal forces within the plank generate reaction

components at the contact points. These internal forces ensure equilibrium and satisfy the boundary conditions.

- Force components at the wall:
 - The normal force (N_w) contributes to the internal stress distribution along the plank.
 - The reaction force at the top of the plank has a horizontal component (N_w) and a vertical component resulting from internal force resolution.
- Vertical reaction at the base:
 - The normal force (N_f) balances the weight.
 - Any friction at the base could influence the vertical component of the reaction, but since the problem emphasizes the vertical component “at” the wall, the focus is on understanding how the internal forces relate to these reactions.

Mathematical Formulation of the Forces

Expressing Reaction Forces in Terms of Geometry

- Coordinates:
 - Assume the origin at the foot of the plank.
 - The top contact point is at a height $(h = L \sin 80^\circ)$.
 - The horizontal distance from the foot to the top is $(d = L \cos 80^\circ)$.
- Force components:
 - The normal force at the wall acts horizontally: (N_w) .
 - The reaction from the floor acts vertically: (N_f) .
- Force balance equations:
$$\begin{aligned} \text{Horizontal:} \quad & N_w = \text{reaction component along the plank's inclination} \\ \text{Vertical:} \quad & N_f = W \end{aligned}$$
- Moment balance about the foot:
$$N_w \times h = W \times \left(\frac{L}{2} \right) \sin 80^\circ$$

This relation helps determine (N_w) once (W) and (L) are known.

Implications and Practical Considerations

Design and Safety Applications

Understanding the vertical component of the force at the contact points, especially in a leaning structure, is vital for:

- Structural integrity: Ensuring the wall and floor can withstand the forces exerted during the leaning.
- Material selection: Choosing materials with adequate strength to handle the calculated forces.
- Construction safety: Preventing accidental slips or collapses by analyzing the force components correctly.

Extensions to Real-World Scenarios

While the idealized frictionless wall simplifies calculations, real-world situations often involve friction:

- Friction at the wall:
 - Adds a tangential force component, possibly altering the vertical component indirectly.
 - Increases the overall reaction forces, making the structure more stable.
- Friction at the floor:
 - Could prevent slipping

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