1. A 65-kg Painter Stands 1.5 M From The Left End Of A 4-m Long Uniformplank That Is Supported By A Cable

Introduction

1. A 65-kg Painter Stands 1.5 M From The Left End Of A 4-m Long Uniform Plank That Is Supported By A Cable presents an interesting problem in statics and mechanics. Such scenarios are common in engineering, construction, and physics education, offering insight into forces, torques, and equilibrium conditions. Understanding how the forces distribute and how to analyze the system helps ensure safety and stability in real-world applications. This article explores the physics principles involved, the steps to analyze the problem, and the practical implications of such a setup.

Understanding the System

Description of Components

The system comprises the following elements:

- **Uniform plank:** A beam of length 4 meters with uniform mass distribution.
- **Painter:** A person with a mass of 65 kg standing on the plank.
- **Support cable:** Holds the plank in place, providing tension to maintain equilibrium.

Key assumptions typically made in such problems include the plank being rigid and mass distributed uniformly, the support cable being massless, and the system being in static equilibrium (no acceleration). The gravitational acceleration (g) is approximately 9.81 m/s².

Analyzing the System

Step 1: Convert Mass to Weight

Since forces due to gravity (weights) are central to the analysis, convert masses into weights:

- Weight of painter: $\mathbf{W_{painter} = 65\ kg \times 9.81\ m/s^2 \approx 637.65\ N}$
- Weight of plank: $\mathbf{W_{plank} = (mass\ of\ plank) \times 9.81\ m/s^2}$

If the mass of the plank is not specified, it must be either provided or assumed for calculations. For illustration, assume the plank has a mass of 10 kg:

- W_{plank} = 10 kg × 9.81 m/s² ≈ 98.1 N

Step 2: Establish the Geometry and Coordinates

Set a coordinate system along the length of the plank:

1. Left end of the plank at x = 0 m
2. Right end of the plank at x = 4 m

The painter is located 1.5 m from the left end, i.e., at x = 1.5 m.

The support cable is typically attached at a specific point; for simplicity, assume it is connected at the right end of the plank (x = 4 m) or at some other known point, which should be specified for exact calculations.

Step 3: Free Body Diagram (FBD)

Construct an FBD to visualize all forces acting on the plank:

- **Weight of the plank:** acting at its center of gravity, located at the midpoint (x = 2 m).
- **Weight of the painter:** acting at x = 1.5 m.
- **Tension in the support cable:** acting at the point where the cable is attached, assumed at x = 4 m.
- **Reactions at the left end:** if the plank is supported at both ends, reactions would be at the left end; if supported only by the cable, reactions are only at the cable point and possibly at the left end if it’s a pin support.

Step 4: Applying Equilibrium Conditions

The system is in static equilibrium, which implies:

- **Sum of all vertical forces:** zero
- **Sum of all torques about any point:** zero

Mathematically:

$\sum F_{vertical} = 0$
$\sum \tau$ (about any point) $= 0$

Calculating Support Reactions and Tension

Step 5: Summing Vertical Forces

Let's denote:

- **R_{left}**: support reaction at the left end (if any)
- **T**: tension in the support cable (assumed vertical for simplicity)

The total vertical forces are:

$$R_{left} + T - W_{plank} - W_{painter} = 0$$

> Note: If the support cable provides a tension that is inclined, its vertical component must be considered separately.

Step 6: Taking Moments for Equilibrium

Choose a point to sum moments; a common choice is the left end of the plank (x=0) to eliminate R_{left} from the torque equation. The moments include:

- Moment due to the painter's weight: **$W_{painter} \times 1.5$ m**
- Moment due to the plank's weight: **$W_{plank} \times 2$ m**
- Moment due to the tension T at x=4 m: **$T \times 4$ m**

$$\sum \tau_{about\ 0} = 0$$
$$\Rightarrow -W_{painter} \times 1.5 + (-W_{plank}) \times 2 + T \times 4 = 0$$

> The negative signs indicate that the weights create clockwise moments about the left end.

Further Analysis and Considerations

Determining the Tension in the Cable

Rearranging the moment equation allows solving for T:

$$T = (W_{painter} \times 1.5 + W_{plank} \times 2) / 4$$

Using the assumed weights:

$$T = (637.65\ N \times 1.5 + 98.1\ N \times 2) / 4$$
$$= (956.48 + 196.2) / 4$$
$$= 1152.68 / 4 \approx 288.17\ N$$

This tension provides the necessary upward force at the support point to balance the system.

Calculating the Reactions at the Supports

Once T is known, substitute back into the force equilibrium equation:

$$R_{left} = W_{plank} + W_{painter} - T$$
$$= 98.1 + 637.65 - 288.17 \approx 447.58\ N$$

This reaction force acts upward at the left end, balancing the system vertically.

Practical Implications

Safety and Stability

- Understanding the distribution of forces ensures that the supports and the cable are designed to withstand the maximum expected loads.
- Overloading the support cable or supports can lead to failure, causing accidents or damage.

Design Considerations

- Support cables should be rated to handle the tension calculated with an appropriate safety factor.
- The position of the painter affects the load distribution; shifting the painter’s position changes the tension and reactions.
- Material strength, support attachment points, and environmental factors must also be considered in actual construction.

Extensions and Variations

Different Support Configurations

- The support cable could be attached at different points, changing the torque calculations.
- Additional supports or pin connections at both ends alter the reaction forces and tension.

Dynamic Considerations

- While static analysis assumes no movement, real-world scenarios may involve dynamic loads, vibrations, or shifting weights.
- Safety factors and material properties help accommodate unexpected forces or movements.

Conclusion

Analyzing a system where a painter stands on a uniform plank supported by a cable involves applying core principles of static equilibrium, force and torque balance, and understanding the distribution of weights and tensions. The problem illustrates how forces are

Frequently Asked Questions

What is the significance of the painter standing 1.5 meters from the left end of the plank?

The painter's position affects the distribution of weight and the bending moments on the plank, which are crucial for analyzing the support reactions and ensuring structural stability.

How do you determine the tension in the cable supporting the plank when the painter is positioned as described?

By applying static equilibrium equations—sum of vertical forces and moments about a point—you can solve for the tension in the cable based on the painter's weight and position.

What assumptions are typically made when analyzing this type of static problem involving a plank and a hanging cable?

Assumptions often include the plank being uniform and weight distribution being uniform, the cable being massless and inextensible, and the system being in static equilibrium with no acceleration.

How does the position of the painter influence the support reactions at the ends of the plank?

The painter's position determines the moments about the supports, thereby affecting the magnitude of the reactions at the supports needed to keep the plank in equilibrium.

If the painter moves closer to the center of the plank, how does that impact the tension in the supporting cable?

Moving the painter closer to the center reduces the moment arm about the support, which generally decreases the tension in the cable needed to maintain equilibrium.

What calculations are necessary to find the maximum tension in the cable during the painter's position?

Calculations involve summing moments about the supports, accounting for the painter's weight and position, and solving the equilibrium equations to find the tension in the cable.

How would the analysis change if the plank were not uniform or if additional loads were applied?

Non-uniformity or additional loads would require adjusting the weight distribution and calculating new moments and forces, possibly involving more complex static or dynamic analysis methods.

Additional Resources

A 65-kg Painter Stands 1.5 M From The Left End Of A 4-m Long Uniform Plank That Is Supported By A Cable — this scenario presents a classic problem in statics and structural analysis, providing insight into how forces distribute in a simple yet fundamental system. Understanding the forces at play helps ensure safety, stability, and proper design in everyday engineering and construction tasks. Whether you're a student tackling physics problems or a professional analyzing structures, this guide breaks down the scenario thoroughly, explaining how to approach and solve such problems step-by-step.

Introduction

Imagine a painter working atop a long, uniform plank suspended by a cable. The painter's position, combined with the plank's weight distribution and support setup, influences the forces and moments acting on the system. Accurate analysis allows us to determine reactions at supports, cable tensions, and potential points of failure.

In this article, we'll explore the problem: A 65-kg painter stands 1.5 meters from the left end of a 4-meter long uniform plank that is supported by a cable. We'll analyze the forces involved, set up equilibrium equations, and walk through the calculations necessary to understand the system's stability.

Understanding the System

Key Components:
- The Plank: A uniform beam of length 4 meters, mass m_{beam}, with weight W_{beam}.
- The Painter: A point load with mass $m_{painter} = 65\,kg$, producing a weight $W_{painter} = m_{painter} \times g$.
- Supports:
- Left Support: Usually a pin or hinge at the left end.
- Cable Support: Attached somewhere along the beam, providing tension T.

Assumptions:
- The plank is rigid and weight acts at its center of gravity (midpoint).
- The system is in static equilibrium (no movement).
- The cable supports the plank at a known point, or at an arbitrary position.
- The weight of the cable itself is negligible unless specified.

Step 1: Defining the Geometry and Data

Let's clarify the given data:

Parameter	Value / Description
Length of plank	$L_{beam} = 4\,m$
Distance of painter from left end	$d_{painter} = 1.5\,m$
Mass of painter	$m_{painter} = 65\,kg$
Weight of painter	$W_{painter} = m_{painter} \times g$ (assuming $g=9.81\,m/s^2$)
Mass of plank	m_{beam} (not specified, but for uniform plank, often needed)
Weight of plank	$W_{beam} = m_{beam} \times g$ (if known)
Support positions	Left support at $x=0\,m$; cable at $x=c\,m$ (unknown)

Note: If the mass of the plank isn't specified, it often is, or we assume it for calculations. For this example, let's assume the plank has a mass $m_{beam} = 20\,kg$.

Step 2: Establishing the Support Conditions

Types of Supports:
- Left Support: Typically a pin support that can exert both vertical and horizontal forces, but since

the system is horizontal and only vertical forces act, we focus on vertical reactions R_A.
- Cable Support: Provides tension T, which may act at an angle depending on its attachment point.

Key considerations:
- The reaction forces at supports are vertical because the system is horizontal.
- The tension in the cable acts along its length, which may be inclined.

Step 3: Calculating the Weights

Weight of the plank:
$$W_{beam} = m_{beam} \times g = 20\,kg \times 9.81\,m/s^2 = 196.2\,N$$

Weight of the painter:
$$W_{painter} = 65\,kg \times 9.81\,m/s^2 = 637.65\,N$$

Step 4: Setting Up Equilibrium Equations

Free-Body Diagram (FBD)

Visualize the system with:
- Reaction force R_A at the left support.
- Tension T in the cable at some point along the plank.
- Weights acting downwards at specified points:
- W_{beam} at the center of the plank (2 m from the left end).
- $W_{painter}$ at 1.5 m from the left end.

Equilibrium Conditions:
1. Sum of vertical forces equals zero:
$$R_A + T_y = W_{beam} + W_{painter}$$
2. Sum of moments about any point equals zero (conveniently about the left support to solve for reactions):
$$\sum M_{A} = 0$$

Step 5: Analyzing the System with Assumptions

Assumption:
- The cable attaches at the right end of the plank and is inclined at an angle θ, or at some point along the beam at a known position.

Scenario 1: Cable attaches at the right end (x=4 m), inclined at an angle θ.

Step 6: Calculating Tension and Support Reactions

1. Breaking down the tension:
- $T_x = T \cos \theta$
- $T_y = T \sin \theta$

2. Moments about the left end (A):

- Moments due to weights:
- W_{beam} at 2 m:
$$M_{beam} = W_{beam} \times 2\,m = 196.2\,N \times 2\,m = 392.4\,N\cdot m$$
- $W_{painter}$ at 1.5 m:
$$M_{painter} = 637.65\,N \times 1.5\,m = 956.48\,N\cdot m$$

- Moment due to tension T:
- Assuming the cable is attached at the right end (x=4 m), with tension inclined at θ,
- The vertical component $T \sin \theta$ acts upward at x=4 m:
$$M_{T} = T \sin \theta \times 4\,m$$
- The horizontal component $T \cos \theta$ does not create a moment about the support at the left end.

3. Equilibrium in moments:
$$0 = (W_{beam} \times 2) + (W_{painter} \times 1.5) - T \sin \theta \times 4$$
$$0 = 392.4 + 956.48 - 4 T \sin \theta$$
$$4 T \sin \theta = 1348.88$$
$$T \sin \theta = 337.22\,N$$

Step 7: Vertical Force Balance

$$R_A + T \sin \theta = W_{beam} + W_{painter} = 196.2 + 637.65 = 833.85\,N$$
$$R_A = 833.85 - T \sin \theta$$

From previous calculation:
$$T \sin \theta = 337.22\,N$$
so,
$$R_A = 833.85 - 337.22 = 496.63\,N$$

$$

Summary:
- Reaction at the left support: approximately 496.63 N upward.
- Cable tension component $T \sin \theta$: approximately 337.22 N.

Step 8: Determining the Tension T

If the cable's angle θ is known, we can find T. For example:

Example:
Suppose the cable is attached at the right end (x=4 m) and inclined at 45°.

- $\sin 45^\circ = \cos 45^\circ = \frac{\sqrt{2}}{2} \approx 0.707$.

Then,

$$
T \times 0.707 = 337.22\,N \Rightarrow T \approx \frac{337.22}{0.707} \approx 477.07\,N
$$

Final values:
- Tension in the cable: approximately 477.07 N.
- Reaction force at the left support: approximately 496.63 N.

Additional Considerations

1. Cable attachment point:
- If the cable attaches at a different point along the beam, the moments and tension calculations will change accordingly.
- The height at which the cable attaches also affects θ and T.

2. Cable weight:
- If the cable's weight is significant, it must be included in the analysis as an additional distributed load.

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