A Meter Stick Is Supported At The 50 Cm Mark. A 0.40 Kg Mass Is Hanging At The 20 Cm Mark And A 0.60

A Meter Stick Is Supported At The 50 Cm Mark. A 0.40 Kg Mass Is Hanging At The 20 Cm Mark And A 0.60 is a classic physics problem that involves understanding concepts of static equilibrium, torque, and forces. Such problems are fundamental in mechanics, providing insight into how objects respond to various loads and supports. This scenario involves analyzing the forces acting on the meter stick, calculating the torques to ensure equilibrium, and determining the reactions at the support point. In this comprehensive guide, we will explore the principles behind this problem, step-by-step calculations, and the key physics concepts involved.

Understanding the Setup of the Problem

Before delving into the calculations, it is essential to grasp the physical setup:

- Meter Stick: A uniform, rigid object 1 meter (100 cm) long.
- Support Point: Located at the 50 cm mark, which acts as a fulcrum or pivot point.
- Masses:
- A 0.40 kg mass hanging at the 20 cm mark.
- A 0.60 kg mass (assuming at the 70 cm mark, though the problem statement appears incomplete, but we will proceed with typical assumptions).

Assuming the second mass is hanging at the 70 cm mark, as the problem seems to be truncated, but the concept remains the same.

Note: When analyzing such problems, it's crucial to know the exact positions of all masses and supports. For this example, we'll assume the second mass is at the 70 cm mark, allowing us to demonstrate the principles effectively.

Key Data Summary:
- Length of meter stick: 100 cm
- Support at: 50 cm
- First mass: 0.40 kg at 20 cm
- Second mass: 0.60 kg at 70 cm

Fundamental Concepts Involved

Understanding this problem requires familiarity with several physics principles:

1. Static Equilibrium

An object in static equilibrium has no net force and no net torque acting upon it. For the meter stick:

- The sum of vertical forces must be zero.
- The sum of torques about any point must be zero.

2. Torque (Moment of Force)

Torque is a measure of the tendency of a force to rotate an object about a pivot point. It is calculated as:

$$
\tau = r \times F
$$

where:
- r = perpendicular distance from the pivot to the point of force application
- F = force applied (weight in this case)

Calculating the Forces and Torques

Let's proceed step-by-step.

Step 1: Determine the weights of the masses

The weights are given by:

$$
W = m \times g
$$

where $g \approx 9.8\, \text{m/s}^2$.

- For the 0.40 kg mass:

$$
W_1 = 0.40\, \text{kg} \times 9.8\, \text{m/s}^2 = 3.92\, \text{N}
$$

- For the 0.60 kg mass:

$$
W_2 = 0.60\, \text{kg} \times 9.8\, \text{m/s}^2 = 5.88\, \text{N}
$$

\]

Step 2: Establish the coordinate system

Let's set the origin at the 0 cm mark of the meter stick for clarity.

- The stick extends from 0 cm to 100 cm.
- Support point at 50 cm.
- Mass 1 at 20 cm.
- Mass 2 at 70 cm.

Step 3: Calculate torques about the support point

Choosing the support point (at 50 cm) as the pivot simplifies calculations because the reaction force at this point does not produce torque about itself.

- Distance from support to mass 1 (at 20 cm):

\[
r_1 = 20\, \text{cm} - 50\, \text{cm} = -30\, \text{cm} = -0.3\, \text{m}
\]

- Distance from support to mass 2 (at 70 cm):

\[
r_2 = 70\, \text{cm} - 50\, \text{cm} = 20\, \text{cm} = 0.2\, \text{m}
\]

Negative value indicates the direction of torque (clockwise or counterclockwise).

Step 4: Write the equilibrium equation for torques

Sum of torques about the support point must be zero:

\[
\sum \tau = 0
\]

Considering clockwise torques as positive and counterclockwise as negative (or vice versa), the sum becomes:

$$
W_1 \times r_1 + W_2 \times r_2 + R \times 0 = 0
$$

However, since the reaction force R acts vertically at the support point, it produces no torque about that point.

So, the sum of torques due to weights:

$$
- W_1 \times 0.3\, \text{m} + W_2 \times 0.2\, \text{m} = 0
$$

Plugging in the weights:

$$
- 3.92\, \text{N} \times 0.3\, \text{m} + 5.88\, \text{N} \times 0.2\, \text{m} = 0
$$

Calculating:

$$
- 1.176\, \text{Nm} + 1.176\, \text{Nm} = 0
$$

This confirms the torques balance, assuming the system is in equilibrium.

Calculating the Support Reaction Force

Since the sum of vertical forces must be zero:

$$
\text{Reaction force } R + W_1 + W_2 = \text{Total downward forces}
$$

But note that the reaction force at the support must balance the combined weight of the hanging masses plus the weight of the meter stick itself.

Step 1: Find the weight of the meter stick

Assuming the meter stick has a uniform mass distribution. Let's denote its mass as m_{stick}:

- If the problem states the mass of the meter stick, include it. If not, assume negligible mass.

Suppose the meter stick has a mass of 0.2 kg:

$$
W_{stick} = 0.2\, \text{kg} \times 9.8\, \text{m/s}^2 = 1.96\, \text{N}
$$

Step 2: Sum of downward forces

Total downward force:

$$
W_{total} = W_{stick} + W_1 + W_2 = 1.96\, \text{N} + 3.92\, \text{N} + 5.88\, \text{N} = 11.76\, \text{N}
$$

Step 3: Find the reaction force at the support

Since the system is in equilibrium:

$$
R = W_{total} = 11.76\, \text{N}
$$

The support provides an upward force of approximately 11.76 N to keep the system balanced.

Key Takeaways and Practical Applications

This problem illustrates fundamental principles of static equilibrium:

- How to analyze forces and torques to determine reactions.
- The importance of choosing the correct pivot point.
- How weights and distances influence the balance of forces.

Practical Applications:
- Design of bridges and structures to ensure stability.
- Mechanical lever systems and their efficiency.
- Physics experiments involving torque and equilibrium.

Common Mistakes to Avoid

- Ignoring the weight of the meter stick: Always include the mass of the object being analyzed.
- Incorrect sign conventions: Be consistent with the direction of torques.
- Incorrect distances: Make sure to measure the perpendicular distance from the pivot accurately.
- Assuming masses without given data: Confirm the mass of the meter stick or any other object.

Conclusion

Analyzing a meter stick supported at the 50 cm mark with hanging masses involves understanding static equilibrium, calculating forces, and applying torque principles. By carefully identifying forces, choosing the appropriate pivot point, and ensuring the sum of torques and forces are balanced, we can determine the reactions at the support and understand how different masses influence the stability of the system. Such problems are foundational in physics and engineering, providing essential insights into the mechanics of structures and systems. Whether for academic purposes or practical engineering design, mastering these concepts is crucial for analyzing and ensuring the stability of physical systems.

Frequently Asked Questions

What is the purpose of supporting a meter stick at the 50 cm mark in this setup?

Supporting the meter stick at the 50 cm mark provides a pivot point or fulcrum, allowing the system to balance and analyze the forces and torques acting on the hanging masses.

How do you calculate the torque exerted by the 0.40 kg mass hanging at the 20 cm mark?

The torque is calculated using $\tau = r \times F$, where r is the distance from the pivot (50 cm - 20 cm = 30 cm = 0.30 m), and F is the weight of the mass (0.40 kg × 9.8 m/s² = 3.92 N). So, $\tau = 0.30 \text{ m} \times 3.92 \text{ N} = 1.176 \text{ Nm}$.

What is the significance of the 0.60 kg mass in this scenario?

The 0.60 kg mass, hanging at a certain point (not fully specified in the prompt), is likely used to balance or create a torque to analyze equilibrium conditions or to determine the position of the mass for balancing purposes.

How do you determine whether the system is in rotational equilibrium?

The system is in rotational equilibrium when the sum of all torques about the pivot point is zero, meaning the clockwise torques equal the counterclockwise torques, ensuring no net rotation.

If the 0.60 kg mass is hanging at the 70 cm mark, what is the torque it exerts about the support point?

First, find the distance from the support: 70 cm - 50 cm = 20 cm = 0.20 m. Then, calculate the weight: 0.60 kg × 9.8 m/s^2 = 5.88 N. The torque is τ = 0.20 m × 5.88 N = 1.176 Nm.

How can this setup be used to find unknown masses or distances in physics problems?

By applying the principles of torque and equilibrium, you can set up equations balancing torques on either side of the support to solve for unknown masses or distances, making it a practical way to analyze static systems.

What assumptions are typically made when analyzing this type of static equilibrium problem?

Assumptions include that the meter stick is massless or its weight is negligible, the forces are applied at single points, and the system is in perfect equilibrium without external influences like friction or air resistance.

Additional Resources

A meter stick is supported at the 50 cm mark. This seemingly simple setup provides a fascinating opportunity to explore the principles of static equilibrium, torque, and the distribution of forces. Whether you are a physics student conducting a basic experiment or an educator illustrating fundamental concepts, understanding the intricacies of this system is both engaging and educational. In this article, we will analyze the problem comprehensively, breaking down the forces involved, calculating torques, and examining the implications of various parameters on the system's stability.

Understanding the System Setup

The described system involves a meter stick supported at its 50 cm mark, with a mass hanging at the 20 cm mark. Although the problem statement cuts off, it likely involves additional masses or forces, so for clarity, we will assume the second mass mentioned is hanging at a certain point, perhaps at another specific mark, and analyze the system accordingly.

Key components:

- Meter stick (length = 100 cm)
- Support point at 50 cm
- Hanging mass at 20 cm
- Additional mass (possibly at another point)

Assumptions for analysis:
- The meter stick is uniform, with its weight acting at its center of mass (at 50 cm)
- The masses are point masses
- The system is in static equilibrium (no movement)
- The support exerts an upward force to balance the downward forces

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Analyzing Forces and Torques

Identifying Forces Acting on the System

The forces involved include:
- The weight of the meter stick (W_s)
- The weight of the hanging mass (W_m)
- The reaction force at the support (R)

Calculations:

- Weight of the meter stick:

$$
W_s = m_s \times g = (1.0 \text{ kg}) \times 9.8\, \text{m/s}^2 = 9.8\, \text{N}
$$

(assuming the meter stick's mass is 1 kg; if not specified, this is a typical value)

- Weight of the hanging mass:

$$
W_m = 0.40\, \text{kg} \times 9.8\, \text{m/s}^2 = 3.92\, \text{N}
$$

- Additional mass (if the second mass is specified, e.g., 0.60 kg):

$$
W_{additional} = 0.60\, \text{kg} \times 9.8\, \text{m/s}^2 = 5.88\, \text{N}
$$

Note: Since the description is incomplete, these are typical assumptions.

Calculating Torques for Equilibrium

To ensure the system is in equilibrium, the sum of torques about the support point must be zero:

$$
\sum \tau = 0
$$

Choosing the support at 50 cm (or 0.50 m) as the pivot point:

- Torque due to the meter stick's weight:

$$
\tau_{stick} = W_s \times (distance\, from\, support) = 9.8\, \text{N} \times (0.50\, \text{m}) = 4.9\, \text{Nm}
$$

Since the center of mass of the stick is at the 50 cm mark, it acts downward at that point, producing a specific torque depending on its position relative to the support.

- Torque due to the hanging mass at 20 cm:

$$
\tau_{mass} = W_m \times (distance\, from\, support) = 3.92\, \text{N} \times (0.30\, \text{m}) = 1.176\, \text{Nm}
$$

This torque acts in a direction tending to rotate the stick in one direction (say clockwise).

- If there's an additional mass at a different position (say at 80 cm):

$$
\tau_{additional} = 5.88\, \text{N} \times (0.30\, \text{m}) \quad \text{(assuming at 80 cm, 0.30 m from 50 cm)}
$$

Or, more precisely, at 80 cm (0.30 m to the right of 50 cm):

$$
\tau_{additional} = 5.88\, \text{N} \times 0.30\, \text{m} = 1.764\, \text{Nm}
$$

The signs of the torques depend on the direction of rotation they tend to cause.

Balancing the torques:

$$
R \times 0 = \sum \tau \Rightarrow \text{Reactions at support} = \text{sum of downward torques}
$$

which implies:

$$
R = \frac{\text{sum of all torques}}{\text{lever arm}}
$$

But since the support is at 50 cm, the upward force (reaction) must balance the total weight:

$$
R = W_s + W_m + W_{additional}
$$

Calculating the Support Force and System Stability

Vertical Force Balance

The sum of vertical forces must be zero:

$$
R = W_s + W_m + W_{additional}
$$

Using earlier calculations:

$$
R = 9.8\, \text{N} + 3.92\, \text{N} + 5.88\, \text{N} = 19.6\, \text{N}
$$

The support must exert an upward force of approximately 19.6 N to keep the system in equilibrium.

Torque Balance Check

Calculating the net torque:

$$
\text{Net torque} = (W_s \times 0.50\, \text{m}) + (W_m \times 0.30\, \text{m}) + (W_{additional} \times 0.30\, \text{m})
$$

$$
= 4.9\, \text{Nm} + 1.176\, \text{Nm} + 1.764\, \text{Nm} = 7.64\, \text{Nm}
$$

Since this torque is balanced by the reaction force at the support, the system remains stable if the reaction force can produce an equal and opposite torque.

Note: The actual calculation involves summing torques and ensuring they sum to zero, considering signs for clockwise and counterclockwise rotations.

Implications of the System Parameters

Effect of Changing Mass Positions

- Moving the hanging mass closer to the support reduces the torque exerted by that mass, making the system easier to balance.
- Placing the mass farther from the support increases torque, potentially causing the system to become unstable if the support cannot counteract the torque.

Effect of Varying Masses

- Increasing the hanging mass increases the downward force and torque, demanding a greater reaction force at the support.
- Conversely, lighter masses exert less torque, easing stability.

Support Location and Stability

- Supporting the meter stick at its center (50 cm) generally provides the most balanced configuration.
- Supporting at a different point shifts the torque distribution, potentially creating a tipping moment if the torques are unbalanced.

Practical Features and Educational Value

Features:

- Demonstrates principles of static equilibrium
- Illustrates torque and force balance
- Offers hands-on experience with real-world physics

Pros:

- Simple setup, accessible for classroom experiments
- Visualizes abstract concepts concretely
- Encourages understanding of how forces and torques interact

Cons:

- Simplifies real-world factors like friction and air resistance
- Assumes point masses and uniform rods, which may not reflect real objects perfectly
- Limited to static analysis; dynamic effects are ignored

Conclusion

The setup where a meter stick is supported at the 50 cm mark with hanging masses at various points provides a rich context for exploring fundamental physics concepts. By analyzing forces, calculating torques, and understanding the conditions for equilibrium, students and educators can deepen their grasp of mechanics. Adjusting parameters such as mass values and positions offers insights into system stability and the principles governing static equilibrium. While simplified, this model forms a foundational basis for more complex investigations into rotational dynamics and structural analysis.

In essence, this system exemplifies how forces and torques work together to maintain balance, reinforcing core physics principles through practical experimentation and critical thinking.

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