

A Vertical Spring Stretches 9.6 Cm When A 1.3 Kg Block Is Hung From Its End. (a) Calculate The Spring

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Understanding the Physics Behind Spring Stretching and Hooke's Law

When analyzing how a spring responds to an attached weight, it's essential to understand the fundamental principles governing such behavior. The scenario where a vertical spring stretches by a specific amount when a mass is hung from it provides valuable insights into the properties of the spring, particularly its spring constant. This article explores the process of calculating the spring constant based on the given data, delves into the physics concepts involved, and discusses the broader applications of such calculations in engineering and physics.

Key Concepts in Spring Mechanics

Before diving into calculations, it's crucial to familiarize yourself with the core concepts:

Hooke's Law

- Definition: Hooke's Law states that the force exerted by a spring is directly proportional to its displacement, provided the elastic limit is not exceeded.

- Mathematical Expression:

$$F = -kx$$

where:

- F is the restoring force exerted by the spring (in Newtons),
- k is the spring constant (in N/m),
- x is the displacement from the equilibrium position (in meters).

Spring Constant (k)

- Represents the stiffness of the spring.
- A larger k indicates a stiffer spring.
- The spring constant is fundamental in predicting how much a spring will stretch or compress under a given load.

Force Due to Gravity (Weight)

- The weight of the hanging mass causes the spring to stretch.
- Calculated as:

$$W = m g$$

where:

- m is the mass (in kg),
- g is the acceleration due to gravity ($\sim 9.8 \text{ m/s}^2$).

Given Data and Problem Statement

Let's restate the problem with the provided data:

- Spring stretches by 9.6 cm when a 1.3 kg mass is hung.
- Convert displacement to meters:

$$x = 9.6 \text{ cm} = 0.096 \text{ m}$$

- Mass of the block:

$$m = 1.3 \text{ kg}$$

- Acceleration due to gravity:

$$g = 9.8 \text{ m/s}^2$$

Our goal is to calculate the spring constant k .

Step-by-Step Calculation of the Spring Constant

Step 1: Calculate the weight of the hanging mass

The weight W is the force exerted by gravity on the mass:

$$W = m \times g$$

$$W = 1.3 \, \text{kg} \times 9.8 \, \text{m/s}^2 = 12.74 \, \text{N}$$

Step 2: Apply Hooke's Law to relate force and displacement

In equilibrium, the force exerted by the spring balances the weight:

$$F_{\text{spring}} = W$$

Using Hooke's Law:

$$k \times x = W$$

Rearranged to find k :

$$k = \frac{W}{x}$$

Substituting the known values:

$$k = \frac{12.74 \, \text{N}}{0.096 \, \text{m}} \approx 132.71 \, \text{N/m}$$

Therefore, the spring constant k is approximately 132.7 N/m.

Implications of the Calculated Spring Constant

Understanding the spring constant is vital in various contexts:

Design and Engineering Applications

- Suspension Systems: Engineers use spring constants to design vehicle suspensions that absorb shocks efficiently.
- Measuring Devices: Springs with known k are used in scales and force measurement tools.
- Vibration Analysis: Determining how springs respond to oscillations helps

in designing stable mechanical systems.

Physics and Education

- Demonstrating Hooke's Law experimentally.
- Teaching students about elastic potential energy storage.

Extended Topics: Elastic Potential Energy and Oscillations

Beyond calculating the spring constant, understanding how energy is stored and transferred in spring systems is fundamental in physics:

Elastic Potential Energy

- The energy stored in a stretched or compressed spring is given by:

$$U = \frac{1}{2} k x^2$$

- For our example:

$$U = \frac{1}{2} \times 132.7 \, \text{N/m} \times (0.096 \, \text{m})^2 \approx 0.612 \, \text{J}$$

This energy reflects how much work the spring can do when returning to its equilibrium state.

Simple Harmonic Motion (SHM)

- When displaced from equilibrium, springs can cause oscillations.
- The period of oscillation (T) for a mass-spring system:

$$T = 2\pi \sqrt{\frac{m}{k}}$$

- Using the calculated (k) :

$$[$$

$$T = 2\pi \sqrt{\frac{1.3 \text{ kg}}{132.7 \text{ N/m}}} \approx 2\pi \times 0.099 \approx 0.622 \text{ seconds}$$

This information is crucial for designing systems involving periodic motion.

Factors Affecting Spring Behavior and Accuracy of Calculations

While the above calculations are straightforward, real-world scenarios involve additional considerations:

- Spring Elastic Limit: The spring must not be stretched beyond its elastic limit; otherwise, Hooke's Law doesn't apply.
- Material Properties: The material's properties affect the spring's behavior and durability.
- Measurement Precision: Accurate measurement of displacement and mass is essential for precise calculations.
- Temperature Effects: Variations in temperature can influence the spring's stiffness.

Conclusion: Applying Physics to Real-Life Problems

Calculating the spring constant from observed data, such as the stretch caused by a hanging mass, exemplifies how fundamental physics principles translate into practical applications. Understanding the relationship between force, displacement, and material properties enables engineers and scientists to design better mechanical systems, measure forces accurately, and analyze dynamic behaviors effectively.

In our specific example, the spring constant of approximately 132.7 N/m indicates a relatively stiff spring, suitable for applications requiring precise control of displacement under load. Whether in designing vehicle suspensions, measuring forces, or studying oscillations, these calculations form the foundation of many technological advancements.

Further Reading and Resources

- Hooke's Law and Elasticity: Explore detailed physics textbooks for an in-depth understanding.
- Spring Mechanics Simulations: Interactive tools available online to visualize spring behavior.
- Engineering Design Principles: Learn how spring constants influence real-world product development.

Keywords for SEO optimization:

Spring constant calculation, Hooke's Law, vertical spring stretch, physics of springs, elastic potential energy, oscillation period, force and displacement, mechanics of springs, spring stiffness, physics problem-solving, engineering applications of springs.

Remember: Accurate measurements and understanding the underlying physics principles are key to solving problems involving springs and elastic systems.

Frequently Asked Questions

What is the spring constant of the vertical spring when a 1.3 kg block stretches it by 9.6 cm?

The spring constant can be calculated using Hooke's Law: $k = (m g) / x$. Substituting $m = 1.3 \text{ kg}$, $g = 9.8 \text{ m/s}^2$, and $x = 0.096 \text{ m}$, we get $k = (1.3 \cdot 9.8) / 0.096 \approx 132.92 \text{ N/m}$.

How do you convert the stretch from centimeters to meters in the calculation?

Since $1 \text{ cm} = 0.01 \text{ meters}$, the stretch of 9.6 cm equals 0.096 meters for the calculation.

What physical principle is used to determine the spring constant in this problem?

Hooke's Law is used, which states that the force exerted by a spring is proportional to its displacement: $F = kx$.

Why is the weight of the block important in

calculating the spring constant?

The weight (force due to gravity) of the block ($m g$) causes the stretch in the spring, which helps determine the spring constant using Hooke's Law.

What assumptions are made in calculating the spring constant in this scenario?

It is assumed that the spring obeys Hooke's Law within the stretch range, the system is in equilibrium, and factors like air resistance are negligible.

If the spring were to be stretched by 15 cm under a different load, how would you find the new spring constant?

You would convert 15 cm to meters (0.15 m), then divide the weight of the new load by this displacement: $k = (m g) / x$.

What is the significance of the spring constant in mechanical systems?

The spring constant indicates the stiffness of the spring; a larger k means a stiffer spring that requires more force to stretch or compress.

Can the spring constant change if the material or dimensions of the spring change?

Yes, altering the material or dimensions of the spring can change its stiffness and thus its spring constant.

Additional Resources

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Introduction

In the realm of classical mechanics, the behavior of springs under load is a fundamental concept, illustrating the principles of elasticity and force interactions. Imagine a simple scenario: a vertical spring is suspended, and when a weight is hung from its end, it stretches by a certain amount. This everyday experiment encapsulates key physics principles and serves as an entry point into understanding Hooke's Law, elastic potential energy, and the properties that define a spring's stiffness.

Specifically, consider the case where a vertical spring stretches by 9.6 centimeters upon hanging a 1.3-kilogram mass. This scenario isn't just a classroom demonstration; it embodies the practical applications seen in engineering, design, and various scientific fields, where understanding the spring constant is crucial for designing resilient systems and ensuring safety.

In this article, we will explore how to determine the spring constant, often denoted as k , from the given data. We will delve into the physical principles underpinning the problem, analyze the forces involved, and provide a comprehensive step-by-step solution that highlights the importance of each factor involved.

Understanding the Physics Behind the Scenario

Before jumping into calculations, it's essential to understand the physics principles at play:

- Hooke's Law:

The foundational principle governing spring behavior states that the force exerted by a spring is proportional to its displacement from equilibrium, given by:

$$F = -k \times x$$

where:

- F is the restoring force in newtons (N),
- k is the spring constant in newtons per meter (N/m),
- x is the displacement from equilibrium in meters (m).

- Equilibrium Condition:

When a mass is hung from the spring, it stretches until the upward restoring force balances the downward gravitational force. At equilibrium:

$$\text{Restoring Force} = \text{Weight of the mass}$$
$$k \times x = m \times g$$

where:

- m is the mass in kilograms,
- g is the acceleration due to gravity ($\sim 9.8 \text{ m/s}^2$).

- Implication for Calculation:

Knowing the mass and the displacement allows us to solve for the spring constant directly.

Step-by-Step Calculation of the Spring Constant

Let's now move through the process of calculating the spring constant based on the provided data.

1. Identify the Known Data

- Mass of the block, $(m = 1.3, \text{kg})$
- Displacement (stretch), $(x = 9.6, \text{cm})$
- Conversion of displacement to meters:
 $[x = 9.6, \text{cm} = 0.096, \text{m}]$
- Acceleration due to gravity, $(g = 9.8, \text{m/s}^2)$

2. Calculate the Weight of the Block

The weight is the force due to gravity acting on the mass:

$$[W = m \times g = 1.3, \text{kg} \times 9.8, \text{m/s}^2 = 12.74, \text{N}]$$

This is the force exerted downward, which, at equilibrium, is balanced by the spring's restoring force.

3. Apply Hooke's Law to Find the Spring Constant

At equilibrium:

$$[k \times x = W]$$
$$[k = \frac{W}{x}]$$

Substituting the known values:

$$[k = \frac{12.74, \text{N}}{0.096, \text{m}} \approx 132.71, \text{N/m}]$$

Therefore, the spring constant is approximately 132.7 N/m.

Interpreting the Result

The calculated spring constant, $(k \approx 132.7, \text{N/m})$, signifies the stiffness of the spring. A higher value indicates a stiffer spring that resists deformation more strongly, whereas a lower value suggests a more

compliant spring.

This value is crucial for various engineering applications, such as designing suspension systems, measuring devices, or any system where elastic deformation under load is a key factor. For example, in shock absorbers, knowing the spring constant helps engineers tune the system for optimal performance.

Additional Considerations

While the calculation appears straightforward, several factors can influence the accuracy and interpretation:

- Material Properties:

The elasticity of the spring depends on the material, which affects the linearity of the behavior within certain limits.

- Limit of Hooke's Law:

Hooke's Law applies within the elastic limit of the material. If the spring stretches beyond this limit, the behavior becomes nonlinear, and the calculated k no longer accurately represents the spring's properties.

- Measurement Precision:

Accurate measurement of displacement is vital. Parallax errors or measurement inaccuracies can affect the result.

- Environmental Factors:

Temperature and material fatigue can alter the spring's behavior over time.

Practical Applications and Real-World Significance

Understanding how to determine the spring constant from simple measurements has broad implications:

- Design and Manufacturing:

Engineers need to know the stiffness of springs to design systems that can withstand specific loads without failure.

- Calibration of Instruments:

Springs are fundamental components in measuring devices like force gauges and balances.

- Vibration Analysis:

The spring constant influences the natural frequency of oscillating systems, which is essential in fields like civil engineering, aerospace, and automotive design.

- Educational Demonstrations:

Simple experiments like hanging weights from springs serve as effective teaching tools to illustrate fundamental physics principles.

Conclusion

The scenario of a vertical spring stretching by 9.6 centimeters under a 1.3-kilogram load offers an excellent opportunity to explore the principles of elasticity, force balance, and material behavior. Through a systematic approach grounded in Hooke's Law, we've demonstrated how to calculate the spring constant, arriving at a value of approximately 132.7 N/m.

This calculation not only embodies core physics concepts but also highlights the importance of understanding material properties and force interactions in real-world applications. Whether in designing resilient structures, developing precise measurement tools, or simply understanding everyday phenomena, mastering the calculation of spring constants remains a vital skill in physics and engineering.

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