9.00 Kg Rock Whose Density Is 4500 Kg/m3 Is Suspended By A String Such That Half Of The Rock's Volume

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Understanding the physical principles behind the suspension of an object such as a rock involves exploring concepts like density, buoyancy, weight, and tension. In this article, we delve into the details of a 9.00 kg rock with a density of 4500 kg/m³, suspended by a string in such a way that half of its volume is submerged or supported by the string. We will analyze the problem step by step, explaining the relevant physics concepts and calculations involved.

Introduction to Density and Mass

What Is Density?

Density is a measure of how much mass is contained in a unit volume of a substance. It is expressed mathematically as:

- **Density (ρ) = Mass (m) / Volume (V)**

In our case, the density of the rock is given as 4500 kg/m³, which indicates that each cubic meter of this rock weighs 4500 kilograms.

Mass and Its Relationship to Density and Volume

The mass of the rock is provided as 9.00 kg. Using the density, we can determine the volume of the rock:

V = m / ρ

Calculating this provides insight into the size of the rock, which is essential for understanding the mechanics of its suspension.

Calculating the Volume of the Rock

Step-by-Step Volume Calculation

Given:
- Mass, $m = 9.00$ kg
- Density, $\rho = 4500$ kg/m³

Applying the formula:

$V = m / \rho = 9.00 \text{ kg} / 4500 \text{ kg/m}^3 = 0.002 \text{ m}^3$

This means the total volume of the rock is 0.002 cubic meters, or 2 liters.

Implications of the Volume

Knowing the volume helps us understand how much of the rock is submerged or supported when suspended, especially since the problem states that half of the volume is involved in the suspension dynamics.

Understanding the Suspension and Buoyancy

Basic Principles of Buoyancy

When an object is submerged in a fluid (or suspended in a medium like air with supporting forces), it experiences a buoyant force equal to the weight of the displaced fluid:

- **Buoyant Force (F_b) = $\rho_{fluid} \times g \times V_{submerged}$**

Where:
- ρ_{fluid} is the density of the fluid or medium
- g is acceleration due to gravity (~9.81 m/s²)
- $V_{submerged}$ is the volume of the object submerged

In our case, since the rock is suspended by a string, the key forces are its weight and the tension in the string.

The Role of the String and Half-Volume Suspension

The problem states that the rock is suspended such that half of its volume is involved. This can mean:
- Half of the rock's volume is submerged in a fluid, or
- The tension in the string supports the rock in a way that effectively involves half of the volume in buoyant support.

Assuming the latter, the tension in the string balances the weight minus the buoyant force acting on the submerged part of the rock.

Analyzing the Forces Acting on the Rock

Forces Involved

The main forces acting on the suspended rock are:
- The gravitational force (its weight): $W = m \times g$
- The buoyant force (if submerged): F_b
- The tension in the string: T

The equilibrium condition (assuming the rock is stationary) is:

$$ T + F_b = W $$

Calculating the Weight of the Rock

Given:
- m = 9.00 kg
- g ≈ 9.81 m/s²

Weight:

$$ W = 9.00 \, \text{kg} \times 9.81 \, \text{m/s}^2 \approx 88.29 \, \text{N} $$

This is the downward force due to gravity.

Determining the Buoyant Force and Submerged Volume

Scenario 1: Half of the Volume Is Submerged

If exactly half of the volume of the rock is submerged:
- $V_{submerged} = V / 2 = 0.001\ m^3$

Assuming the medium surrounding the rock is air, and its density is approximately 1.2 kg/m^3, the buoyant force is:

$$ F_b = \rho_{air} \times g \times V_{submerged} $$

Calculating:

$$ F_b = 1.2 \, \text{kg/m}^3 \times 9.81 \, \text{m/s}^2 \times 0.001 \, \text{m}^3 \approx 0.0118 \, \text{N} $$

This is negligible compared to the weight (~88.29 N), so in air, buoyancy doesn't significantly affect the tension.

Scenario 2: Submerged in a Fluid with Higher Density

If the rock is submerged in a fluid like water (density ≈ 1000 kg/m^3):

$$ F_b = 1000 \, \text{kg/m}^3 \times 9.81 \, \text{m/s}^2 \times 0.001 \, \text{m}^3 = 9.81 \, \text{N} $$

Again, this reduces the effective weight supported by the tension:

$$ T = W - F_b $$

$$ T = 88.29 \, \text{N} - 9.81 \, \text{N} = 78.48 \, \text{N} $$

Implications and Practical Understanding

Why Does Half the Volume Matter?

The core aspect of the problem is understanding the significance of "half of the volume" in suspension:
- If half of the volume is submerged in a fluid with significant density, it reduces the tension in the string.
- If the object is in air, the buoyant effect is minimal, and the tension is nearly equal to the weight.

Applications in Real-World Situations

Understanding how objects behave when suspended or submerged is crucial in:

- Designing ships and submarines
- Engineering buoyancy aids
- Analyzing forces in physics experiments involving fluids

Summary of Key Calculations

- Volume of the rock: 0.002 m^3
- Weight of the rock: approximately 88.29 N
- Submerged volume (half): 0.001 m^3
- Buoyant force in air: negligible (~0.012 N)
- Buoyant force in water: approximately 9.81 N
- Tension in the string (in water): approximately 78.48 N

Conclusion

In summary, a 9.00 kg rock with a density of 4500 kg/m^3 has a total volume of 0.002 m^3. When suspended such that half of its volume is involved in the support system, the physics of buoyancy and weight come into play. In air, buoyant forces are negligible, so the tension in the string nearly equals the weight of the rock. However, if the rock is submerged in a fluid like water, buoyant forces significantly reduce the tension required in the supporting string, illustrating the importance of volume, density, and medium in understanding physical systems. This analysis not only helps in solving theoretical physics problems but also has practical implications in engineering and fluid mechanics.

Frequently Asked Questions

What is the volume of the 9.00 kg rock with a density of 4500 kg/m^3?

The volume V can be calculated using the formula V = mass / density. So, V = 9.00 kg / 4500 kg/m^3 = 0.002 m^3.

How much of the rock's volume is submerged when half of it is suspended by the string?

Half of the rock's volume is submerged, which means 50% of its total volume, or 0.001 m^3, is underwater.

What is the buoyant force acting on the submerged part of the rock?

The buoyant force is equal to the weight of the displaced fluid: F_b = density of fluid × volume submerged × gravitational acceleration. Assuming water (density 1000 kg/m³), F_b = 1000 kg/m³ × 0.001 m³ × 9.8 m/s² = 9.8 N.

What is the weight of the entire rock?

Weight W = mass × gravity = 9.00 kg × 9.8 m/s² = 88.2 N.

What conditions must be satisfied for half of the rock to be submerged while suspended?

The tension in the string plus the buoyant force must balance the weight of the rock. When half submerged, the buoyant force is 9.8 N, and the tension adjusts accordingly, maintaining equilibrium.

How does the density of the rock compare to the density of water?

The density of the rock (4500 kg/m³) is significantly higher than water (1000 kg/m³), which explains why most of the rock remains above water when suspended.

If the rock's volume is halved, how does that affect the buoyant force when half of it is submerged?

Halving the volume reduces the maximum displaced fluid volume, so if half of the new volume is submerged, the buoyant force would be proportionally less, affecting the equilibrium conditions.

What is the significance of the rock being suspended so that half of it is submerged?

This scenario illustrates the balance of forces involving gravity and buoyancy, and helps understand concepts like Archimedes' principle and the behavior of dense objects in fluids.

Can the entire 9.00 kg rock be submerged without sinking?

Given its high density, the entire rock would be submerged and likely sink, as the buoyant force would not be sufficient to counteract its weight unless the surrounding fluid's density is increased or other factors are introduced.

Additional Resources

Suspended Rock with Half Its Volume Submerged: An Expert Examination

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Introduction to the Phenomenon

When examining the intriguing behavior of a heavy rock suspended in a fluid or in a state of equilibrium, it becomes essential to understand the fundamental principles of physics at play—namely, density, buoyancy, and volume distribution. In this detailed analysis, we explore a specific case: a 9.00 kg rock with a density of 4500 kg/m^3 that is suspended by a string such that half of its volume is submerged. This scenario offers valuable insights into the physics of buoyancy, the relationship between mass, volume, and density, and the practical implications in fields ranging from geology to engineering.

Understanding the Basic Parameters

Before delving into the specifics of the problem, it is crucial to understand the individual components involved.

Mass and Density

- Mass (m): 9.00 kg
- Density of the rock (ρ_{rock}): 4500 kg/m^3

Density is defined as mass per unit volume:

$$
\rho = \frac{m}{V}
$$

This relation allows us to calculate the volume of the rock, which is fundamental in understanding how it interacts with the surrounding medium when suspended.

Volume of the Rock

Using the density-mass relation:

$$
V_{rock} = \frac{m}{\rho_{rock}}
$$

Plugging in the known values:

\[

V_{rock} = \frac{9.00\, \text{kg}}{4500\, \text{kg/m}^3} = 0.002\, \text{m}^3
\]

This volume (0.002 m^3) signifies the total space occupied by the rock.

The Concept of Submersion and Buoyancy

The problem specifies that half of the volume of the rock is submerged when suspended. This scenario involves the principles of buoyancy, described by Archimedes' principle, which states:

> An object submerged in a fluid experiences an upward buoyant force equal to the weight of the displaced fluid.

In the context of this problem, the "fluid" can be any medium capable of exerting buoyant force—air, water, or another fluid medium.

Buoyant Force and Equilibrium

When the rock is suspended and stable, the forces acting on it are:

- Gravitational force (Weight): \(W = m \times g \)
- Buoyant force: \(F_b = \rho_{fluid} \times V_{submerged} \times g \)
- Tension in the string: \(T \)

At equilibrium (constant suspension), the sum of forces is zero:

\[
T + F_b = W
\]

Since the problem states that half of the volume is submerged, the volume of displaced fluid is:

\[
V_{displaced} = \frac{1}{2} V_{rock} = 0.001\, \text{m}^3
\]

Determining the Medium's Density

For the rock to be in equilibrium with exactly half its volume submerged, the buoyant force must equal half of the weight of the rock:

$$
F_b = \frac{1}{2} W
$$

Expressed mathematically:

$$
\rho_{medium} \times V_{displaced} \times g = \frac{1}{2} \times m \times g
$$

Dividing both sides by g:

$$
\rho_{medium} \times V_{displaced} = \frac{1}{2} \times m
$$

Solving for ρ_{medium}:

$$
\rho_{medium} = \frac{\frac{1}{2} \times m}{V_{displaced}}
$$

Plugging in known values:

$$
\rho_{medium} = \frac{\frac{1}{2} \times 9.00\, \text{kg}}{0.001\, \text{m}^3} = \frac{4.50\, \text{kg}}{0.001\, \text{m}^3} = 4500\, \text{kg/m}^3
$$

Key insight: The medium's density must be equal to the rock's density (4500 kg/m^3) for exactly half of the volume to be submerged when suspended.

Implications and Real-World Applications

The above calculation reveals an interesting theoretical point: when an object is neutrally buoyant (density equal to the fluid), it can be suspended at any depth with no net force. Here, the scenario demonstrates that for the specific case of half-volume submersion, the medium's density must match that of the object.

Practical Implications:

- Design of Submersible Devices: Engineers designing underwater vehicles or sensors must consider density matching to control submersion levels.
- Geological Studies: Understanding how rocks of different densities behave in water or other mediums helps in interpreting sedimentation and erosion patterns.
- Material Selection: Choosing materials with specific densities allows control over buoyancy for various applications.

Additional Considerations and Clarifications

While the previous calculations assume ideal conditions, some factors can influence real-world outcomes.

Effect of External Factors

- Temperature: Changes in temperature can affect fluid density, thereby altering buoyancy.
- Fluid Composition: The medium's composition (e.g., saltwater vs. freshwater) impacts density.
- Object Shape: The shape of the object affects the distribution of volume and the stability of suspension.

Limitations of the Model

- Assumes no additional forces act on the object.
- Assumes the medium is uniform and at rest.
- Ignores potential surface tension effects if the medium is a liquid.

Summary of Key Takeaways

- The volume of the rock is calculated as approximately 0.002 m^3.
- To suspend the rock such that half of its volume is submerged, the density of the surrounding medium must be equal to 4500 kg/m^3.
- This scenario exemplifies neutral buoyancy, a critical concept in fluid mechanics.
- Understanding these principles assists in practical applications across engineering, geology, and material sciences.

Conclusion

The examination of a 9.00 kg rock with a density of 4500 kg/m^3 suspended in a medium where half of its volume is submerged encapsulates core principles of physics that govern buoyancy and density. The precise calculation underscores the importance of matching densities to achieve specific states of submersion, offering valuable insights into both theoretical physics and practical engineering. Whether designing underwater equipment, studying geological formations, or exploring material properties, mastering these concepts enhances our ability to predict and manipulate behaviors of objects in fluid environments.

In essence, this scenario is a compelling demonstration of how fundamental physics principles underpin a wide array of real-world phenomena, highlighting the elegance and utility of scientific understanding in everyday and specialized contexts.

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