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Understanding the principles of buoyancy is essential in physics, especially when dealing with objects submerged in fluids. The scenario where a metal block weighs 40 N in air and 30 N in water provides an excellent opportunity to explore the concept of buoyant force, its calculation, and related physical principles. This article delves into the details of how to determine the buoyant force acting on the metal block, the implications of the weight differences, and the broader significance of buoyancy in physics.

Understanding the Basics: Weight and Buoyant Force

Before analyzing the specific problem, it is crucial to understand some fundamental concepts:

Weight of an Object

- The force exerted by gravity on an object.
- Calculated as: $\text{Weight (W)} = \text{mass (m)} \times \text{acceleration due to gravity (g)}$.
- Measured in Newtons (N).

Buoyant Force

- An upward force exerted by a fluid on an object immersed in it.
- Governed by Archimedes' Principle, which states:

"The buoyant force on an object submerged in a fluid is equal to the weight of the fluid displaced by the object."

- The magnitude of the buoyant force depends on:
 - The volume of fluid displaced.
 - The density of the fluid.
 - The acceleration due to gravity.

Understanding the difference in weights in air and water helps us analyze the forces acting on the object.

Analyzing the Problem: Weight Measurements and What They Signify

In our scenario, the key measurements are:

- The weight of the metal block in air: 40 N.
- The weight of the same block in water: 30 N.

This data indicates that:

- When weighed in air, the normal weight is 40 N.
- When submerged in water, the apparent weight reduces to 30 N.

The reduction in weight when submerged is due to the upward buoyant force exerted by the water.

What Does the Difference in Weights Tell Us?

- Apparent weight in water reflects the actual weight minus the buoyant force.
- Therefore, the buoyant force (F_b) can be calculated as:

$$F_b = \text{Weight in air} - \text{Weight in water}$$

- Using the given data:

$$F_b = 40\text{ N} - 30\text{ N} = 10\text{ N}$$

Hence, the buoyant force acting on the metal block due to water is 10 N.

Key Point Summary:

- The buoyant force equals 10 N.
- This force results from water displaced by the metal block.
- The difference in apparent weight directly provides the magnitude of the buoyant force.

Calculating the Volume of the Metal Block

Given the buoyant force, we can determine the volume of the metal block, which is essential for understanding the physical properties of the object.

Using Archimedes' Principle

Archimedes' principle states:

$$F_b = \rho_{\text{fluid}} \times g \times V$$

Where:

- F_b = Buoyant force (10 N)
- ρ_{fluid} = Density of water ($\sim 1000 \text{ kg/m}^3$)
- g = Acceleration due to gravity ($\sim 9.8 \text{ m/s}^2$)
- V = Volume of the displaced fluid (m^3)

Rearranged to solve for V :

$$V = \frac{F_b}{\rho_{\text{fluid}} \times g}$$

Plugging in the values:

$$V = \frac{10 \text{ N}}{1000 \text{ kg/m}^3 \times 9.8 \text{ m/s}^2} = \frac{10}{9800} \approx 0.00102 \text{ m}^3$$

The volume of the metal block is approximately 0.00102 cubic meters (or 1020 cubic centimeters).

Understanding Density and Material Properties

Knowing the volume and weight in air, we can find the density of the metal, which helps identify or classify the material.

Calculating the Mass of the Metal Block

- The weight in air relates to mass:

$$m = \frac{W}{g} = \frac{40\text{ N}}{9.8\text{ m/s}^2} \approx 4.08\text{ kg}$$

Calculating Density of the Metal

$$\rho_{\text{metal}} = \frac{\text{Mass}}{\text{Volume}} = \frac{4.08\text{ kg}}{0.00102\text{ m}^3} \approx 4000\text{ kg/m}^3$$

This density suggests the metal could be similar to materials like aluminum or certain alloys.

Summary of Key Calculations:

- Volume of the block: approximately 0.00102 m^3 .
- Mass of the block: approximately 4.08 kg .
- Density of the metal: approximately 4000 kg/m^3 .

Broader Implications and Applications of Buoyancy

Understanding buoyant forces has numerous applications in science and engineering:

Applications in Engineering and Design

- Designing ships and submarines.
- Creating buoyant devices and floats.
- Measuring fluid densities and object densities.

Importance in Scientific Research

- Studying fluid mechanics.
- Conducting experiments involving submerged objects.
- Developing materials with specific buoyant properties.

Environmental and Practical Considerations

- Calculating the buoyant force helps in understanding sedimentation.
- Assisting in the design of underwater robots and vehicles.
- Enhancing safety protocols for submerged structures.

Summary and Final Thoughts

The problem of a metal block weighing 40 N in air and 30 N in water illustrates fundamental principles of buoyancy and fluid mechanics. By analyzing the weight difference, we determine that:

- The buoyant force acting on the block due to water is 10 N.
- The volume of the block is approximately 0.00102 cubic meters.
- The metal's density is around 4000 kg/m³, indicating the material's nature.

Understanding these principles is vital for various scientific and engineering applications, from designing ships to developing underwater exploration devices. The concept of buoyancy not only explains why objects float or sink but also provides critical insights into the physical properties of materials and the behavior of objects submerged in fluids.

Whether you're a student learning physics fundamentals or an engineer designing underwater equipment, grasping the relationship between weight, buoyant force, and fluid properties is essential for success.

Frequently Asked Questions

What is the weight of the block in air?

The weight of the block in air is 40 N.

What is the weight of the block when submerged in water?

The weight of the block in water is 30 N.

How do you calculate the buoyant force acting on the block?

The buoyant force is equal to the loss of weight of the object in water, so it is $40\text{ N} - 30\text{ N} = 10\text{ N}$.

What is the value of the buoyant force acting on the block?

The buoyant force acting on the block is 10 N.

Why does the weight of the block decrease in water?

The weight decreases due to the upward buoyant force exerted by the water on the block.

What does the buoyant force depend on?

The buoyant force depends on the volume of water displaced by the block and the density of water.

Can we determine the density of the water from this data?

Yes, using the buoyant force and the volume of the block, we can calculate the density of water.

Is the buoyant force equal to the weight of displaced water?

Yes, the buoyant force is equal to the weight of the displaced water according to Archimedes' principle.

What physical principle explains the buoyant force experienced by the block?

Archimedes' principle explains the buoyant force, stating it is equal to the weight of the displaced fluid.

What information do we need to find the volume of the block?

We can find the volume if we know the density of water and the buoyant force, using the relation $\text{volume} = \text{buoyant force} / (\text{density of water} \times \text{gravitational acceleration})$.

Additional Resources

A Block Of Metal Weighs 40 N In Air And 30 N In Water. What Is The Buoyant Force On The Block Due To?

Understanding the forces acting on objects submerged in fluids is fundamental

in physics, especially in fluid mechanics. The simple scenario of a metal block weighing less in water than in air offers an insightful window into the concepts of weight, apparent weight, and buoyancy. In this article, we will explore the principles behind these phenomena, calculate the buoyant force acting on the metal block, and discuss the broader implications of these forces in real-world applications.

Introduction to Forces on a Submerged Object

When an object is weighed in air, the force measured—its weight—is due to gravity acting on its mass. However, when the same object is immersed in a fluid such as water, the measured weight decreases. This difference arises because the fluid exerts an upward force on the object, known as the buoyant force, which counteracts some of the object's weight.

Key Concepts:

- True Weight: The actual weight of the object in air, caused by gravity.
- Apparent Weight: The weight measured when the object is submerged in a fluid; it is less than the true weight due to buoyancy.
- Buoyant Force: The upward force exerted by a fluid on an immersed object, following Archimedes' principle.

Understanding these concepts is essential to solving the problem at hand, where a metal block's weight in air and water is given, and the goal is to determine the buoyant force acting upon it.

Analyzing the Given Data

Let's restate the given data:

- Weight of the metal block in air (W_{air}): 40 N
- Apparent weight of the metal block in water (W_{water}): 30 N

These measurements provide a basis to analyze the forces involved.

Interpreting the Data:

- The true weight of the block (in air) is $W_{\text{air}} = 40 \text{ N}$.
- When submerged in water, the weight appears to decrease to $W_{\text{water}} = 30 \text{ N}$.
- The reduction in weight ($W_{\text{air}} - W_{\text{water}}$): $40 \text{ N} - 30 \text{ N} = 10 \text{ N}$.

This difference directly indicates the buoyant force acting on the block, as it is the force that opposes gravity when the object is submerged.

Calculating the Buoyant Force

Using the principle of apparent weight, the buoyant force (F_b) can be calculated as:

$$F_b = W_{\text{air}} - W_{\text{water}}$$

Substituting the known values:

$$F_b = 40 \text{ N} - 30 \text{ N} = 10 \text{ N}$$

This means that the buoyant force acting on the metal block due to water is 10 N.

What does this mean?

- The buoyant force is the upward force exerted by water on the block.
- It is responsible for reducing the apparent weight of the block in water by 10 N.

Understanding Archimedes' Principle

This scenario perfectly exemplifies Archimedes' principle, which states:

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

Mathematically:

$$F_b = \rho_{\text{fluid}} \times g \times V_{\text{displaced}}$$

Where:

- F_b is the buoyant force
- ρ_{fluid} is the density of the fluid
- g is acceleration due to gravity
- $V_{\text{displaced}}$ is the volume of fluid displaced

By knowing the buoyant force, we can deduce properties like the volume of the block and the density of the fluid if needed.

Determining the Volume of the Metal Block

From the buoyant force equation, and knowing the fluid's density, we can find the volume of the block.

Assuming standard gravity ($g = 9.8 \text{ m/s}^2$):

The buoyant force is:

$$F_b = \rho_{\text{water}} \times g \times V$$

Rearranged to find volume:

$$V = F_b / (\rho_{\text{water}} \times g)$$

Given:

- $F_b = 10 \text{ N}$
- $\rho_{\text{water}} \approx 1000 \text{ kg/m}^3$

Calculations:

$$V = 10 \text{ N} / (1000 \text{ kg/m}^3 \times 9.8 \text{ m/s}^2) = 10 / 9800 \approx 0.00102 \text{ m}^3$$

This indicates the volume of the metal block is approximately 0.00102 cubic meters.

Implication:

The volume of the block is directly related to its displacement of water and is a key parameter in assessing its density and material properties.

Understanding the Material Density

Knowing the weight in air and the volume, we can estimate the density of the metal:

$$\text{Density } (\rho_{\text{metal}}) = \text{Mass} / \text{Volume}$$

Since weight (W) relates to mass (m) via:

$$W = m \times g \rightarrow m = W / g$$

Calculating mass:

$$m = 40 \text{ N} / 9.8 \text{ m/s}^2 \approx 4.08 \text{ kg}$$

Thus,

$$\rho_{\text{metal}} = 4.08 \text{ kg} / 0.00102 \text{ m}^3 \approx 4000 \text{ kg/m}^3$$

This density suggests the metal could be iron or a similar dense material.

Broader Implications and Real-World Applications

Understanding buoyant forces is not just an academic exercise—it has numerous practical applications:

- Ship Design: Ensuring ships displace enough water to stay afloat.
- Hydrometers: Instruments used to measure fluid densities based on buoyancy.
- Submarine Engineering: Calculating ballast to control submersion depth.
- Material Testing: Determining the density and purity of materials via displacement methods.
- Medical Imaging: Using principles of buoyancy and density in techniques like ultrasound.

In engineering and science, calculating buoyant forces helps optimize designs, improve safety, and understand natural phenomena.

Conclusion: Summarizing the Key Findings

In summary, a metal block weighing 40 N in air and 30 N in water experiences a buoyant force of 10 N due to water displacement. This force not only explains the difference in apparent weight but also allows us to infer the volume and density of the metal. Archimedes' principle provides the theoretical foundation for these calculations, illustrating how fluid forces influence objects immersed in liquids.

This example underscores the importance of understanding buoyancy in both scientific inquiry and engineering applications. Whether designing ships, developing measurement instruments, or studying natural phenomena, recognizing and calculating buoyant forces is essential for accurate analysis and effective design.

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