A Board That Is 20.0 Cm Wide, 5.00 Cm Thick, And 3.00 M Long Has A Density 650 Kg/m3. The Board Is Floating

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Understanding the physics behind floating objects is essential in fields such as engineering, marine biology, and environmental science. Consider a board measuring 20.0 centimeters in width, 5.00 centimeters in thickness, and 3.00 meters in length, with a density of 650 kg/m^3. When this board floats on water, it demonstrates fundamental principles of buoyancy, density, and displacement. This article explores these concepts in detail, offering insights into how such a board floats, the forces involved, and the practical applications of this knowledge.

Dimensions and Density of the Floating Board

Physical Dimensions

The board's dimensions are critical in determining its volume and, consequently, its buoyant force. The given measurements are:

- Width: 20.0 cm (0.20 meters)
- Thickness: 5.00 cm (0.05 meters)
- Length: 3.00 meters

Using these, the volume (V) of the board can be calculated as:

$$
V = \text{width} \times \text{thickness} \times \text{length} = 0.20\, m \times 0.05\, m \times 3.00\, m = 0.03\, m^3
$$

Density and Mass

The density (ρ) of the board is 650 kg/m^3. The mass (m) can be derived from:

$$
m = \rho \times V = 650\, kg/m^3 \times 0.03\, m^3 = 19.5\, kg
$$

This mass influences how much water the board displaces and whether it floats or sinks.

Principles of Buoyancy and Floating

Archimedes' Principle

The foundational principle explaining floating objects is Archimedes' principle, which states:
> An object submerged in a fluid experiences an upward buoyant force equal to the weight of the fluid displaced.

This implies that for the board to float, the weight of the displaced water must be equal to the weight of the board:

$$
\text{Buoyant Force} = \text{Weight of the Board}
$$

or

$$
\rho_{water} \times V_{displaced} \times g = m \times g
$$

where:
- ρ_{water} is the density of water (~1000 kg/m^3),
- $V_{displaced}$ is the volume of water displaced,
- g is acceleration due to gravity (~9.81 m/s^2),
- m is the mass of the board.

Since gravity cancels out on both sides, the condition simplifies to:

$$
\rho_{water} \times V_{displaced} = m
$$

Calculating the Displaced Volume

The volume of water displaced when the board floats partially submerged is:

$$
V_{displaced} = \frac{m}{\rho_{water}} = \frac{19.5\, kg}{1000\, kg/m^3} = 0.0195\, m^3
$$

This means the board displaces approximately 0.0195 cubic meters of water when floating.

Submersion Depth and Stability

Fraction of the Board Submerged

The fraction of the board submerged (f) can be determined by comparing the displaced volume to the total volume:

$$
f = \frac{V_{displaced}}{V} = \frac{0.0195\, m^3}{0.03\, m^3} \approx 0.65
$$

Thus, about 65% of the board's volume is submerged when floating.

Calculating the Submersion Depth

The submersion depth (d) along the length of the board is:

$$
d = f \times \text{length} = 0.65 \times 3.00\, m = 1.95\, m
$$

Therefore, approximately 1.95 meters of the board's length is underwater when floating in equilibrium.

Implications for Stability

The stability of the floating board depends on factors such as the center of gravity, center of buoyancy, and the shape of the board. A wider and thicker board offers a broader base, enhancing stability, especially if weight distribution is uniform.

Practical Applications and Real-World Implications

Designing Floating Structures

Understanding how dimensions and density influence buoyancy is crucial when designing floating platforms, boats, or rafts. Engineers can optimize these parameters to ensure stability and safety.

Environmental Impact and Buoyancy Control

In environmental science, calculating the buoyancy of various materials helps assess their impact when introduced into aquatic ecosystems, such as floating debris or pollutant containment devices.

Material Selection and Cost Efficiency

Choosing materials with appropriate densities can reduce weight while maintaining buoyancy. For instance, lighter materials may require less volume to float but could be less durable, so a balance must be struck based on application.

Additional Factors Affecting Floating Behavior

Water Conditions

The above calculations assume calm water at standard conditions. Variations in water density due to temperature, salinity, or pollution can alter buoyancy.

Load Distribution

Adding weight or uneven load distribution can cause the board to sink deeper or become unstable, emphasizing the importance of balanced loading.

External Forces

Waves, currents, and wind can influence the stability and position of floating objects, necessitating further design considerations for real-world applications.

Summary

A board measuring 20.0 cm wide, 5.00 cm thick, and 3.00 m long with a density of 650 kg/m^3 will float on water due to the principles of buoyancy. Its mass of approximately 19.5 kg means it displaces about 0.0195 m^3 of water when floating, with roughly 65% of its volume submerged. These calculations are fundamental in designing floating devices, understanding natural phenomena, and ensuring safety and efficiency in various applications.

By mastering the relationship between dimensions, density, and buoyant forces, scientists and engineers can innovate better solutions for floating structures, environmental management, and aquatic resource utilization. Whether constructing a simple raft or designing complex floating platforms, understanding these principles is essential for success.

Frequently Asked Questions

What is the volume of the board?

The volume of the board is calculated by multiplying its length, width, and thickness: 3.00 m × 0.20 m × 0.05 m = 0.03 m^3.

What is the mass of the board?

Using density (650 kg/m^3) and volume (0.03 m^3), the mass is 650 kg/m^3 × 0.03 m^3 = 19.5 kg.

What is the weight of the board?

Weight is mass times gravity: 19.5 kg × 9.8 m/s^2 ≈ 190.9 N.

What is the buoyant force acting on the floating board?

The buoyant force equals the weight of the displaced water, which, for a floating object, is equal to the weight of the board: approximately 190.9 N.

What is the density of the water in which the board floats?

The density of the water is approximately 1000 kg/m^3, assuming fresh water.

How much of the board is submerged when floating?

The fraction submerged (volume submerged / total volume) is equal to the ratio of the density of the board to the density of water: 650/1000 = 0.65. So, approximately 65% of the board is submerged.

What is the weight of the water displaced when the board floats?

The weight of displaced water is equal to the buoyant force, approximately 190.9 N, which corresponds to a displaced water mass of about 0.0194 m^3 × 1000 kg/m^3 ≈ 19.4 kg.

How does the density of the board relate to its floating condition?

Since the density of the board (650 kg/m^3) is less than that of water (1000 kg/m^3), the board floats because it displaces a volume of water weighing as much as itself.

If the board were denser than water, what would happen?

If the board's density exceeded that of water, it would sink because it would not displace enough water to support its weight.

Additional Resources

Floating Board with Dimensions 20.0 Cm Wide, 5.00 Cm Thick, and 3.00 M Long: An In-Depth Analysis

Floating objects often captivate our curiosity, especially when their physical properties interplay with the principles of buoyancy. In this review, we explore a specific scenario involving a board measuring 20.0 cm in width, 5.00 cm in thickness, and 3.00 meters in length, with a density of 650 kg/m^3, which is floating in a fluid. We will dissect the physical characteristics, analyze the buoyant forces at play, and delve into the scientific principles that explain its floating behavior.

Understanding the Dimensions and Material Properties

Physical Dimensions

The board's physical dimensions are fundamental to understanding its volume, surface area, and the volume of fluid it displaces:

- Width: 20.0 cm (0.20 m)
- Thickness: 5.00 cm (0.05 m)
- Length: 3.00 m

From these, the volume of the board can be calculated as:

$$
V_{board} = \text{length} \times \text{width} \times \text{thickness} = 3.00\, \text{m} \times 0.20\, \text{m} \times 0.05\, \text{m} = 0.03\, \text{m}^3
$$

This volume is crucial for understanding the mass and the buoyant forces involved.

Material Density and Mass

The density of the board material is given as 650 kg/m^3, which suggests a relatively lightweight material—possibly a type of foam, light wood, or composite material.

The mass of the board is:

\[

$$
m_{board} = \rho_{board} \times V_{board} = 650\, \text{kg/m}^3 \times 0.03\, \text{m}^3 = 19.5\, \text{kg}
$$

This mass, combined with the volume, determines the weight force acting downward due to gravity, which is:

$$
W_{board} = m_{board} \times g = 19.5\, \text{kg} \times 9.81\, \text{m/s}^2 \approx 191.2\, \text{N}
$$

Buoyancy and Floating Conditions

The Principle of Buoyancy

Archimedes' principle states that an object submerged in a fluid experiences an upward buoyant force equal to the weight of the displaced fluid:

$$
F_{buoyant} = \rho_{fluid} \times V_{displaced} \times g
$$

Where:
- ρ_{fluid} is the density of the fluid,
- $V_{displaced}$ is the volume of fluid displaced,
- g is acceleration due to gravity.

When an object floats, the buoyant force balances the weight of the object:

$$
F_{buoyant} = W_{board}
$$

This equilibrium condition determines how much of the board is submerged.

Determining the Submerged Volume

Since the board is floating, the volume of fluid displaced is directly related to the board's weight:

$$
\rho_{fluid} \times V_{displaced} \times g = W_{board}
$$

Rearranged to find $V_{displaced}$:

$$
V_{displaced} = \frac{W_{board}}{\rho_{fluid} \times g}
$$

Suppose the board is floating in freshwater with a density $\rho_{water} \approx 1000\, \text{kg/m}^3$. Then:

$$
V_{displaced} = \frac{191.2\, \text{N}}{1000\, \text{kg/m}^3 \times 9.81\, \text{m/s}^2} \approx 0.0195\, \text{m}^3
$$

This volume is approximately 65% of the total volume of the board, indicating that roughly two-thirds of the board is submerged when floating in freshwater.

Implications of Density and Material Composition

Density Relative to Water

The density of the board (650 kg/m^3) is less than that of water (1000 kg/m^3). This difference is critical because:

- The lower the density relative to water, the less of the object needs to be submerged to displace enough fluid to support its weight.
- The floatation is stable because the center of buoyancy and center of mass are aligned or balanced.

Comparison with Water and Other Fluids

If the fluid's density changes (e.g., saltwater with $\sim 1025\, \text{kg/m}^3$), the volume displaced for the same weight decreases, resulting in less of the board being submerged.

Analysis of the Floating State

Fraction of the Board Submerged

To find the fraction submerged:

$$
\text{Fraction submerged} = \frac{V_{displaced}}{V_{board}} = \frac{0.0195\, \text{m}^3}{0.03\, \text{m}^3} \approx 0.65
$$

This indicates that approximately 65% of the board's volume is submerged, with the remaining 35% above water. This proportion determines the stability and buoyancy characteristics.

Stability Considerations

The stability of the floating board depends on several factors:

- Center of gravity (CG): The point where weight acts downward.
- Center of buoyancy (CB): The centroid of the displaced fluid volume.
- When the CB is beneath the CG, the object tends to return to equilibrium after tilting, indicating stability.
- The shape and distribution of mass influence stability; a broad base (wide width) enhances stability.

Additional Factors Impacting Floatation

Surface Area and Wetted Surface

The wetted surface area influences drag and stability:

$$
A_{wetted} = \text{length} \times \text{width} = 3.00\, \text{m} \times 0.20\, \text{m} = 0.6\, \text{m}^2
$$

A larger wetted surface area can help stabilize the board against tipping.

Effect of Thickness and Material Strength

While the thickness (5 cm) is relatively small, it provides rigidity:

- Ensures the board maintains its shape under the load.
- Prevents bending or warping that could affect buoyancy.

The material's strength and flexibility influence how the board responds to dynamic forces, such as waves or shifting weight.

Practical Applications and Real-World Relevance

Use in Marine and Recreational Contexts

Understanding the floating behavior of such a board is essential for:

- Designing lightweight floating platforms.
- Crafting surfboards or paddleboards with similar dimensions.
- Engineering floating walkways or docks.

Environmental and Material Considerations

Choosing the right material density and dimensions influences:

- Buoyancy and stability.
- Durability in water.
- Environmental impact and sustainability.

Summary and Key Takeaways

- The dimensions of the board (20 cm wide, 5 cm thick, 3 m long) result in a total volume of 0.03 m^3.
- Its mass, based on a density of 650 kg/m^3, is approximately 19.5 kg, with a weight of about 191.2 N.
- When floating in freshwater, approximately 65% of the board's volume is submerged, providing the necessary buoyant force to support its weight.
- The density being less than water's density ensures buoyancy; the difference determines the submerged volume.
- Stability is influenced by the shape, the distribution of mass, and the relative positions of the center of mass and buoyancy.
- The physical properties make the board suitable for various applications, from recreational use to engineering designs involving buoyant structures.

Conclusion

The detailed examination of this floating board underscores the fundamental principles of buoyancy, material science, and structural stability. Such a comprehensive understanding is vital for designing objects that float reliably in water, whether for recreational, industrial, or scientific purposes. Recognizing the interplay between dimensions, density, and buoyant forces allows engineers and designers to optimize floating structures for safety, stability, and efficiency.

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