

Buoyancy

Why does an object seem to lose weight when submerged in water?

Introduction

Forces due to water pressure act on any side of a submerged object. Pressure is greater at the bottom of the object than at the top. So upward forces against the bottom are greater than downward forces against the top. As a result the object is pushed upward by the liquid. This net upward force is called *buoyancy*.

Note: Regardless of whether an object is submerged in a liquid or not, the (downward) gravitational force is acting upon it at all times.

When submerged in a liquid, the liquid exerts the (upward) buoyant force upon the object *in addition* to the gravitational force. This is why it seems to become lighter.

Numerical example for calculating the net force exerted by the water on the cube

Here's an iron cube (sides 0.10 m) submerged in water. Let's calculate the net force on the cube from the difference in pressure at the bottom and at the top.

Formulae: $p = \frac{F}{A}$ $p = \rho_{\text{fluid}} \cdot g \cdot h$, use: $g = 10 \frac{\text{m}}{\text{s}^2}$, $\rho_{\text{water}} = 1'000 \frac{\text{kg}}{\text{m}^3}$

1. What is the size of the top surface area?

$$A_{\text{top}} =$$

2. What is the pressure against the top surface area (at 0.20 m depth)?

$$p_{\text{top}} =$$

3. What is the force acting on the top surface area? What is the direction of this force? Depict this force as an arrow (10 N corresponds to 1.0 cm)

$$F_{\text{top}} =$$

4. What is the size of the bottom surface area?

$$A_{\text{bottom}} =$$

5. What is the pressure against the bottom surface area (at 0.30 m depth)?

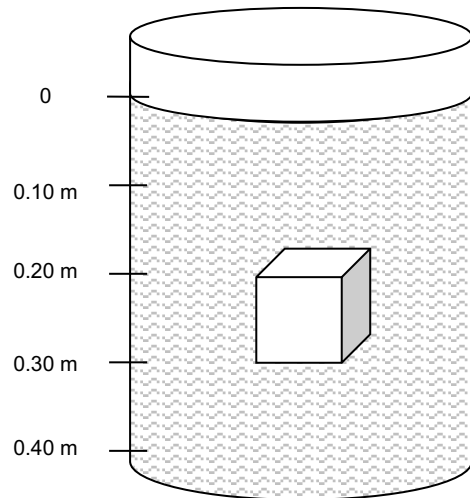
$$p_{\text{bottom}} =$$

6. What is the force acting on the bottom surface area? What is the direction of this force? Depict this force as an arrow (10 N corresponds to 1.0 cm)

$$F_{\text{bottom}} =$$

7. The buoyant force F_B is the resultant force of F_{bottom} and F_{top} . Determine the value and the direction of the resultant force.

$$F_B =$$



Algebraic deduction of the formula for buoyancy

Consider a cube of Volume V_{object} submerged in a fluid of density ρ_{fluid} . Use the following symbols and formulae:

Symbols: A : the cube's surface area (top and bottom)

h : the cube's height

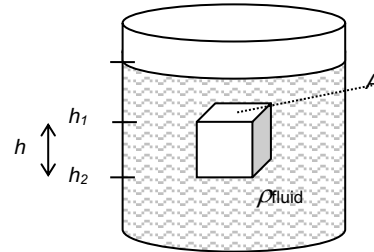
V_{object} : the cube's volume

h_1 : depth underneath the surface (top)

h_2 : depth underneath the surface (bottom)

ρ_{fluid} : the fluid's density

g : acceleration of free fall



Formulae: $V_{\text{object}} = A \cdot h$ $p = \frac{F}{A}$ $p = \rho_{\text{fluid}} \cdot g \cdot h$

- Write the formula for calculating the pressure against the cube's top surface (at depth h_1):

$$p_{\text{top}} =$$

- Write the formula for calculating the force acting upon the top surface area from the pressure p_{top} and the surface area A . Substitute p_{top} using the equation for p_{top} in 1.

$$F_{\text{top}} = \quad =$$

- Write the formula for calculating the pressure against the cube's bottom surface (at depth h_2):

$$p_{\text{bottom}} =$$

- Write the formula for calculating the force acting upon the bottom surface area from the pressure p_{bottom} and the surface area A . Substitute p_{bottom} using the equation for p_{top} in 3.

$$F_{\text{bottom}} = \quad =$$

- The buoyant force is the difference between the upward force F_{bottom} and the downward force F_{top} . Substitute F_{bottom} and F_{top} using the equations in 2. and 4.

$$F_B = F_{\text{bottom}} - F_{\text{top}} =$$

- Simplify 5: a) Bracket b) Substitute: $h_2 - h_1 = h$. c) Substitute: $A \cdot h = V_{\text{object}}$

$$F_B = \quad = \quad =$$

- Write the formula in the box

$$F_B =$$

Archimedes' principle: An immersed object is buoyed up by a force equal to the weight of the fluid it displaces.