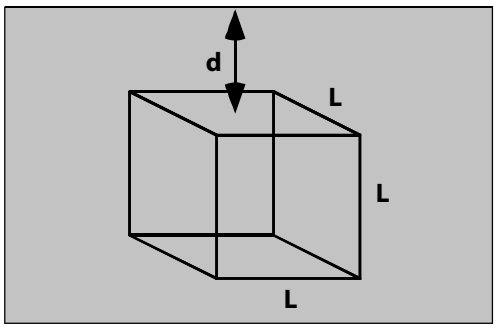
PhyzSpringboard: Buoyancy Basics

BOX OF WATER

Consider a cube of water with each side length L. The water is housed in a container that has the same density (ρ) as water. Suppose the cube were submerged to some depth in a container of water and released.



1. The cube would be in a state of _____neutral equilibrium_____.

2. The downward force on the cube of water is its own _____weight_____.

3. The upward force on the cube of water is the _____buoyant_____ force.

4. Which force is greater and why? equal since the box is in equilibrium ...no acceleration

5. What is the pressure (gauge pressure) at some point *d* below the surface of the water?

$P = \rho g d$

Suppose the top of the submerged cube of water is at a depth *d*.

6. Determine the fluid force pushing the downward on the top of the cube.

$F_T = P_T A_T = \rho g d \cdot L^2$

7. Determine the fluid force pushing upward on the bottom of the cube.

$F_B = P_B A_B = \rho g(d+L) \cdot L^2 = \rho g d \cdot L^2 + \rho g L \cdot L^2$

8. What is the net fluid force acting on the cube?

$F_{NET} = F_B - F_T = \rho g d L^2 + \rho g L^3 - \rho g d L^2 = \rho g L^3$

9. Simplify if possible. (Eliminate L and generalize to any shape with volume V.) The net fluid force is the **buoyant force,** B.

$F_{NET} = \rho g L^3$

$B = \rho g V$

10. What is the mass of an object in terms of its density and volume?

$m = \rho V$

11. Express the weight of the cube in terms of ρ, V, and constants.

$W = mg = \rho Vg$

12. How does the weight of the water cube compare to the buoyant force on the water cube?

They are equal

METAL CUBE

Suppose the cube of water were replaced with a cube having the same dimensions but made of a metal having 3 times the density of water.

13. What would the weight of the metal cube be?

$W = 3\rho Vg$

14. If submerged in water, what would the buoyant force on the metal cube be?

$B = \rho Vg$

15. What would the net force (magnitude and direction) on the immersed metal cube be?

$F_{NET} = W - B = 3\rho Vg - \rho Vg = 2\rho Vg$ downward

FOAM CUBE

Suppose the cube of water were replaced with a cube having the same dimensions but made of a plastic foam having 0.3 times the density of water.

17. What would the weight of the plastic cube be?

$W = 0.3\rho Vg$

18. If submerged in water, what would the buoyant force on the plastic cube be?

$B = \rho Vg$

19. What would the net force (magnitude and direction) on the immersed plastic cube be?

$F_{NET} = B - W = \rho Vg - 0.3\rho Vg = 0.7\rho Vg$ upward

FLOATING

20. Under what condition will an object float?

Buoyancy and weight are equal: $B = W$

21. Why can the metal cube NOT float?

The weight is greater than the buoyant force when the cube is fully submerged

22. How deep will the plastic cube float (how much of the cube will be submerged?

$B = W = \rho V_W g = \rho_P V_P g = \rho V_W = 0.3\rho V_P = V_W = 0.3V_P \Rightarrow L_W = 0.3L_P$

The plastic will float submerged to 0.3L. (The depth of water displaced is 0.3 one side of the plastic cube.)