Archimedes Principle

When you're playing in a swimming pool, you feel a lot lighter than you do on land. The reason you feel this way is because of the buoyant force. This force was first quantified by Archimedes. So the underlying principle of the buoyant force is called the Archimedes' principle. It states that the buoyant force acting on an object in a liquid is equal to the weight of the liquid it displaces.

This principle applies to objects that are either completely or partially submerged in a fluid. If we express the Archimedes principle mathematically, we can say that the buoyant force F sub B is equal to the density of the fluid, rho sub f, times the volume of the fluid that is displaced, V, times the acceleration of gravity, g. Density has units of kilograms per meter cubed, volume has units of meters cubed, and gravity has units of meters per second squared.

We can simplify this expression. The density times volume of the displaced fluid gives us the mass of the displaced fluid. We further know that mass times gravity is equal to weight. So we can express this equation as the buoyant force is equal to the weight of the displaced fluid, which is exactly what Archimedes posited.

We can include the buoyant force in the free body diagram for any object that experiences it, for example, a soccer ball floating in the water. It experiences the force of gravity, mg, pulling it downward, but it also experiences the equal buoyant force, rho Vg, which pulls it upward. Let's see how this plays out in a more complex scenario.

This example reads a 1.45 kilogram rock has a volume of 5.27 times 10 to the negative fourth cubic meters. If the rock is placed on a scale at the bottom of a pool of water, what reading will the scale give for the rock's weight? The density of water is 1,000 kilograms per cubic meter. Well, let's begin by creating a free body diagram.

We have the force of gravity pulling down and the buoyant force and normal force pushing up. Since the rock is at rest at the bottom of the pool, the sum of these forces is equal to 0 newtons. Let's begin solving by finding the weight of displaced fluid, rho Vg.

The density of water is given as 1,000 kilograms per cubic meter times the volume of water displaced, 5.27 times 10 to the negative fourth cubic meters, times the acceleration of gravity, 9.81 meters per second squared. Multiply all that out, and you'll find that the weight of the displaced water is 5.17 newtons. Let's put that into our equation and move on.

Next, we need to solve for the force of gravity acting on the rock. That is equal to the rock's mass times the acceleration of gravity, which is approximately 14.22 newtons. Let's put that into our equation. And now we can solve for the normal force, which is the apparent weight of this rock, 9.05 newtons.

Notice that with these values, the buoyant force is equal to the difference between the weight of the rock and the apparent weight of the rock. There are three possible scenarios you might encounter when dealing with buoyant forces. First, if the buoyant force is greater than the force of gravity, then the object will float upwards. Think about pulling a basketball to the bottom of a pool. As soon as you let go, it will immediately accelerate upwards.

Next, if the buoyant force is less than the force of gravity, then the force of gravity will pull the object downward, and it will sink. It might sink slowly, but it will sink. And lastly, if the buoyant force is equal in magnitude to the force of gravity, then the object will float in place. Think about a ball floating on the surface of a pool, not moving up or down.