Archimedes' Principle

Last week we finished by concluding that when a mass is immersed in water, it exerts less downward force on a spring scale than when it is immersed in air. This led to the question: How *much* less force does the mass exert?

The answer is contained in ***Archimedes' Principle*:**

> A body ***completely or partially*** immersed in a ***fluid*** is ***buoyed up*** by a force equal to the weight of the fluid it displaces.

Let's think about two important words in this statement of Archimedes' Principle, ***fluid*** and ***buoyed***. A ***fluid*** is "something that flows," so gases and liquids are fluids. Water is a fluid. Air is a fluid. To say that a body or object is ***buoyed up*** means that the fluid exerts an upward push or force on the body or object.

BUOYANT FORCE of WATER

According to ***Archimedes' Principle,*** a mass immersed in water is ***buoyed up*** by a force equal to the weight of the water it displaces. Using a spring balance we can show that when a 200g mass is immersed in air, it exerts a downward force of 2N on the spring scale. When it is immersed in water it exerts a downward force on the spring scale of 1.75N. According to Archimedes Principle, the buoyant force of the water, 0.25N (2N-1.75N), should be equal to the weight of the water it displaces.

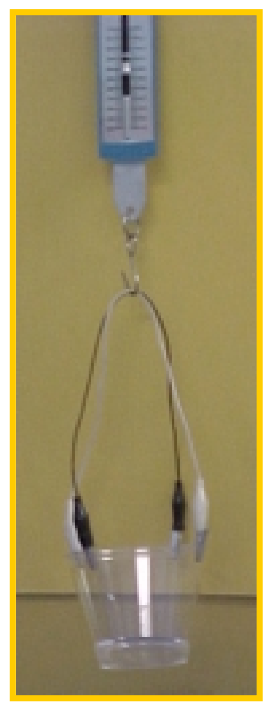
We can check if this is true by measuring the weight of the water a ***200g*** mass displaces when immersed in water.

The volume of water displaced is **25ml.**

Initial water level in the cylinder = 425ml
Water level after the mass is added = 450ml
Volume of water displaced = 25ml

The weight of water displaced is .25N.

Weight of cup + water = .45N
Weight of empty cup = .20N
Weight of water = .25N



Stated in Terms of Archimedes' Principle:

> A ***200g*** mass immersed in water is buoyed up by a force equal to the weight of the water it displaces. In this case .25 Newtons.

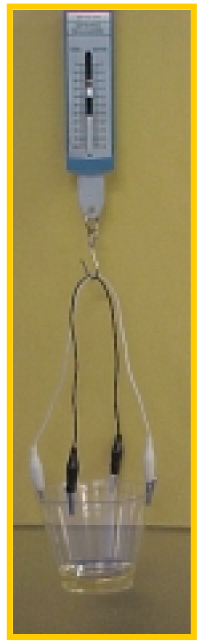
BUOYANT FORCE of SALAD OIL

OK, what do you predict will happen if we immerse the ***200g*** mass in 425 ml of salad oil?

We know that because we are using the same 200g mass, the same *volume* of salad oil will be displaced as the *volume* of water displaced.

What We Have Measured

The volume of salad oil displaced is **25 ml.**



The weight of oil displaced is .22N

Weight of cup + oil = .42N
Weight of empty cup = .20N
Weight of oil = .22N

When the 200g mass is immersed in oil, the downward force of the mass on the spring scale is **1.78 N**

What We Have Shown

When the 200g mass is immersed in oil, it exerts a downward force of 1.78N on the spring scale. This is .22N less force than it exerts on the spring scale when it is immersed in air. The weight of oil the mass displaces, .22N, is equal to the buoyant force (2N-1.78N).

BOUYANT FORCE of AIR

Archimedes' Principal is true for all fluids. Air is a fluid. Does it exert a buoyant force?

Yes, it does.

But we can only *calculate* the buoyant force on the 200g mass because the force is so small it cannot be *measured* with our spring scale. We have shown that the 200 gram mass displaces 25 ml of fluid (water or oil). Therefore, in another fluid (air), it will also displace 25 ml. Our calculations show the buoyant (upward force) of the air on the mass is approximately .025 N.

What We Have Measured

The downward force of the mass in air is **2.0 Newtons.**

TYING IT TOGETHER

Our Measurements

We have measured the downward force (F) of the mass on the spring scale when the 200g mass is immersed in air, oil, and water.

- 200g mass immersed in air: $F_A = 2.00$ Newtons
- 200g mass immersed in salad oil: $F_O = 1.78$ Newtons
- 200g mass immersed in water: $F_W = 1.75$ Newtons

We have shown that the downward force in air ($\mathbf{F_A}$) is greater than the downward force in oil ($\mathbf{F_O}$), which in turn is greater than the downward force in water ($\mathbf{F_W}$).

This can be written: $\mathbf{F_A > F_O > F_W}$

We have measured the force exerted by the fluid displaced and have shown that for water and oil, the buoyant force **(B)** is equal to the weight **(W)** of the fluid, water or oil, displaced.

$$\mathbf{B_W = W_W}$$

$$\mathbf{B_O = W_O}$$

We have calculated the buoyant force **(B)** and weight **(W)** of the air displaced by the ***200g*** mass. Based on our calculations:

$$\mathbf{B_A = W_A}$$

Our measurements and calculations have demonstrated that for a 200g mass immersed in water, salad oil, or air the buoyant force is equal to the weight of the water, salad oil, or air displaced.

BUOYANT FORCE and WEIGHT

In an earlier e-mail we said that the downward pull of the mass on the spring was its weight. Because air exerts a buoyant force on the ***200g*** mass, the reading on the spring scale is not an exact measure of the weight. An exact measurement requires a much more accurate tool for measuring force and some correction for the buoyant force of air.

WHERE DO WE GO FROM HERE

In upcoming emails we will look at sinking and floating. To move in that direction, think about what was discussed in this email and consider: we just stated that when measuring the downward force exerted on the spring scale by the 200g mass in air, the buoyant force of the air was too small to detect. But is this always true?

Questions to ponder:

Think about measuring the weight of a balloon filled with helium.!!!!!

- What happens if you tie the string attached to the balloon on the spring scale?
- Is there a force of attraction between the rubber the balloon is made from and the earth?
- Is there a force of attraction between the helium gas contained in the balloon and the earth?
- Does the rubber have weight?
- Does the helium have weight?

On to floating and sinking!