Another Perplexing Pair…

Our last e-mail left you with a question to ponder. The question was about **<u>force</u>**. In one situation, Archimedes was sitting in a bathtub filled with water. In the other situation, he was sitting on a chair.

The question is:

> ***How hard did Archimedes' bottom push down on the bottom of the bathtub filled with water compared with how hard his bottom pushed down on a chair?***

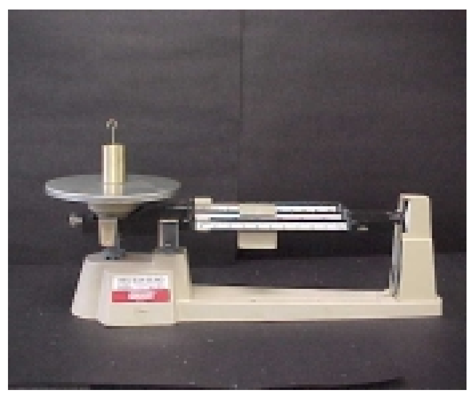
If you have ever thought about the situations we just described, you know that the *push is less* when part of your body is immersed in water than when it is all immersed in air.

BUT- before we talk about *why* there is a difference, we need to talk about ***force***. The downward push that Archimedes exerts on the chair is a *force*. The *force* Archimedes exerts on the chair is related to his weight. Weight is also a *force*. BUT wait a second, we have learned that whenever we mention weight, we are asked, **how are mass and weight related?** Let's take a detour and think about the relationship between mass and weight. Understanding that relationship will help us better understand Archimedes' Principle.

Mass is the <u>quantity of matter</u> of which an object is composed.

Archimedes was composed of hair, bones, skin, flesh, internal organs and body fluids. At any time, his mass was the same whether he was sitting in a bath tub filled with water, sitting on a chair surrounded by air, or even in a space suit on the moon. As long as **nothing has been added or taken away from an object, its mass remains the same.**

We measure mass, by comparing the mass of an object with a standard mass. Grams and kilograms are standard masses. To make the comparison, typically we use a double pan balance or a triple beam balance.

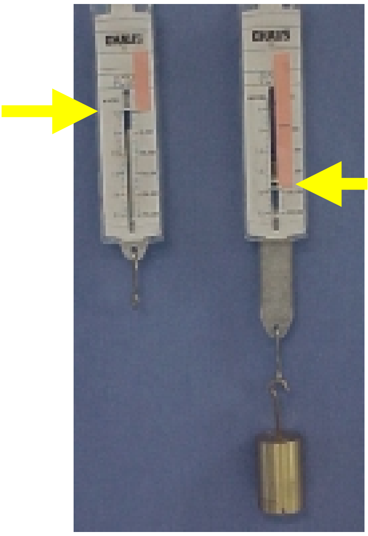


Whether the balance is sitting on a lab table or on the moon, the measure of mass will be the same. If a bar of gold balances a 1000 kilogram mass on the earth, it will balance a 1000 kg mass on the moon.

Weight is the <u>force of attraction</u> between an object and the Earth..

Typically we use a spring scale to measure weight. Think about what happens when a mass is hung on the end of a spring.

When a 200g mass is hung on the end of a spring, the spring extends. The 200g mass exerts a downward force on the spring. This downward force is equal to the weight of the 200g mass. The weight of an object, in this case the 200g mass, is a measure of the force of attraction between the mass and the Earth.

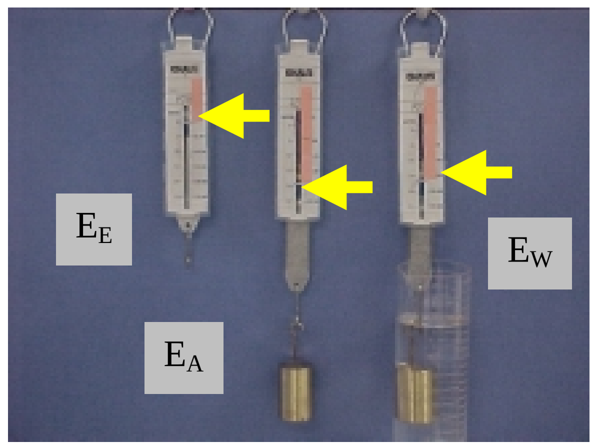


- Pulls are forces.
- Pushes are forces.
- Weight is a force.

The Newton N, is the unit force. A one kilogram mass exerts a downward force on the spring scale of one Newton, 1N.

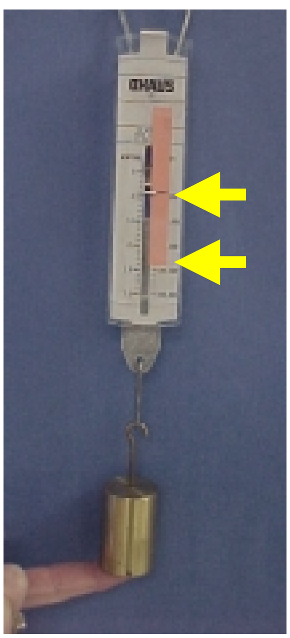
Now let us think about weight in the same way as we thought about mass. If we take the spring scale and the 200g mass to the moon, will the spring extend as far as it extends on Earth? The answer is no. On the moon the spring will extend less because the force of attraction between the 200g mass and the moon is less.

Let us think about the question. Is Archimedes' weight in air different than his weight in water? We can't weigh Archimedes so we will use a 200 gram mass as a model for Archimedes. We compare the extension of the spring when the 200 gram mass is in air and water.



What do you observe?
The spring extends less when the 200 gram mass is immersed in water than when it is immersed in air. This can be written

$$E_W < E_A$$



Does this mean that the weight of the 200 gram mass has changed?

No, the weight is defined as the force of attraction between the 200 gram mass and the Earth. Then why is the spring extended less when the mass is in the water? The picture to the left gives a clue to the answer.

When the mass is in the water, the water pushes up on the mass, so the mass exerts less force on the spring scale and the spring scale is extended less. How much less force does the mass exert?

The answer is contained in Archimedes' Principle.

Next week: We'll go back to Archimedes' bathtub and think about the answer to the question.