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Overflow Can with Spout
#4-15002

Warning:

- **California Proposition 65 Warning: This product can expose you to chemicals including lead, which are known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.**

When a body is placed in a fluid, it is buoyed up by a force equal to the weight of the fluid it displaces. This is known as Archimedes' Principle.

The Overflow Can is primarily used for the demonstration of Archimedes' Principle. It can also be used to measure the volume of an irregular object and determine the density of an object or a liquid.

Introduction

Archimedes was challenged to discover a way to identify whether or not a king's crown was made of solid gold or whether or not the metal smith had induced other materials into the crown and thereby keeping some of the gold for himself. The story that has been handed down over centuries was that Archimedes stepped into a bath tub which then overflowed. This was the inspiration that was responsible for his jumping from the tub and running through the streets nude. From this action he surmised that if an object were completely submersed in water it would displace an amount of water that is equal to the amount of weight loss. This principle now known as buoyancy and it is the foundation of shipbuilding, body fat measurement and many other uses. It states that if an object is completely immersed in a liquid, there will be an upward force equal to the weight of an equivalent volume of the fluid.

Calculating Pressure

If an object is submerged within a fluid, this fluid will exert an equal amount of pressure in every direction upon and within the object. This fluid can be water but can also be air. The magnitude of this force is given by the formula $F=PA$ where P is the pressure of the fluid and A is the surface of the object. The SI unit of measurement to determine pressure N/m^2 also known as *pascal* (pa). Atmospheric pressure at sea level is about 10^5 pa. Atmospheric pressure comes from the force exerted by the ocean of air above us. The weight of force of this air is its mass m multiplied by the acceleration of gravity $g=10m/s^2$ pulling down on the mass of air. The mass of a column of air that has an area of $1cm^2$ is approximately 1kg.

Experimenting with the Overflow Can

You will need the can as well as something to catch the water that overflows. This can be another can, beaker or even a tray that the overflow can sets in. You will need a 250-gram spring scale, a hook weight of 100 to 250-grams, and a metric liquid cylinder and some water.

Begin by filling the overflow can with water until water begins to run out. Now weigh the hook weight by hooking the spring scale to the hook. Record this as the total weight. Next submerge the weight in the water of the overflow can and notice the new weight as measured on the spring scale. Record floating weight from the total weight to arrive at the weight loss. Record this amount as weight loss.

You now have found that a mass manufactured in this particular shape will lose a certain amount of weight when submerged in water. The final step is to pour the water that overflowed from the overflow can into the cylinder to measure its volume. Record this volume.

You may wonder where the loss weight of the mass went. With a little more calculating you will discover that there is a direct relationship to the amount of weight that was lost from the mass to the amount of water that was displaced. Furthermore, you will find that the weight of the water that overflowed from the can is equivalent to the weight loss by the mass when it was submerged into the can.

Taking it a Step Further

You can take your findings a couple of steps beyond this simple experiment. First by noting that the amount of water displacement is directly related to the configuration of the mass or any other object that is placed in a liquid. If the material of mass were to be melted and formed into a sheet, its surface area would increase and thus displace more water. As a matter of fact, the material may now float. If that were the case, then the weight as measured by a spring scale would be zero. That would mean that the weight of the water displaced would have to equal the amount of the weight loss of the sheet. In this case, that would be all of the weight because the sheet would register as weighing zero in water. Naturally, in order for the water weight to equal the weight of the entire sheet there will have to be more water displaced.

One Last Step

There is one last calculation that we can determine from our simple experiment. It is possible to tell the exact volume of liquid that will be displaced without actually measuring it. We can also calculate the weight loss of an object submerged in water without actually weighing it but by measuring the amount of water displaced. This is because there is a direct relationship between all of these variables.

If you could accurately weigh 10 millimeters of water, you should find that 10ml of water will weigh 10 grams. That means that one mL of water weighs one gram and this is the foundation for the metric system of weights and volume. From knowing this rule, it is easy to determine that if you were to measure the amount of water in millimeters that is displaced by an object submerged into a vessel of water you will have an equivalent amount of weight loss. In other words, if the object submerged displaces 50ml of water, there will be a 50 gram weight loss in the object. Furthermore, if there were a 50 gram weight loss of an object submerged in water there will be 50ml of water displaced. This is one of the great advantages of using the metric system.

Theory

When a body is placed in a fluid, it is buoyed up by a force equal to the weight of the fluid it displaces.

The weight of an object is: $w_o = m_o g = d_o v_o g$ (1)

Where do is the density of the object, v_o is the volume, and g the acceleration due to gravity.

The buoyant force, according to Archimedes' Principle, is: $F_b = m_f g = d_f v_f g$ (2)
where d is the density of the fluid.

If the object is completely submerged in the liquid, the $v_f=v_o$. Dividing equation (2) by equation (1) – $F_b/W_o=d_f/d_o$ (3)

This shows that the ratio of the buoyant force to the weight of the object is equal to the ratio of the density of the fluid to the density of the object. So, an object will float in a fluid if its density is less than that of the fluid, and sink if its density is greater than that of the fluid.

Equation (3) can be used to determine the density of the object if the weight of the object and the density of the fluid are known. The density of a fluid can be determined in a similar way.

A. Demonstration of Archimedes' Principle
   1. Measure the weight of the object, "w_o" in air with a spring balance.
   2. Fill the overflow can with water.
   3. Measure the apparent weight of the object in water. "w_a", with the spring balance.
   4. Calculate the difference between "w_o" and "w_a", which will be the buoyant force of the object "F_b".
   5. Measure the weight of the water "w_f" collected by the beaker (or catch bucket) on the scale.
   6. Compare "F_b" with "w_f".

B. Demonstration of the Density of an Object
   1. Do steps 1 through 4 in part A.
   2. Use the following formula from equation (3) to calculate the density of the object:

      $$D_o=w_o\, d_f / F_b$$

      Where d_f = 1 g/cm^3 (or 1000 kg/m^3) for water.

C. Demonstration of the Density of a Fluid
   1. Do steps 1 through 4 in part A, using the fluid in place of water.
   2. Use the following formula from equation (3) to calculate the density of the fluid:

      $$D_f=F_b\, d_o/w_o$$

      Where d_o is the density of the known object.

D. Measurement of the Volume of an Irregular Object.
   1. Fill the overflow can with water.
   2. Immerge the object into water and collect the water flowing out of the overflow can.
   3. Measure the volume of the water with a graduated cylinder, which is also the volume of the object.

Included in the Kit

- Overflow Can
- Instructions

Accessories

Spring Scale (Balance)
Weight
Beaker or Catch Bucket Cylinder