What is Buoyancy?
Lab

Objective

In this laboratory activity, you will investigate what makes objects, such as ships and submarines, float or sink. You will learn how buoyancy affects objects in water.

Introduction

Have you ever wondered why massive boats and ships weighing hundreds of tons float while small objects like rocks sink? Have you ever wondered why when you inhale in a pool you float and when you exhale you sink to the bottom even though you weigh the same? This phenomenon can be explained by the scientific principle called **buoyancy**.

Buoyancy is the upward force that an object feels from the water and when compared to the weight of the object, it is what makes an object float, sink, or remain **neutrally buoyant** in the water.

When an object floats, the upward buoyant force exerted by the water is greater than the downward force of the weight of the object. You can also understand this concept with numbers. If an object's density is less than water's density (1 g/cm³), it will float.

When an object sinks, the weight of the object is greater than the upward buoyant force exerted by the water and its density is greater than 1 g/cm³.

When an object is neutrally buoyant, meaning it neither sinks nor floats, then the weight of the object is equal to the upward buoyant force exerted by the water. When neutrally buoyant in water, the object also has the same density as water. Neutral buoyancy is a very important principle in the sea perch competition. Just like a real submarine, you will want your sea perch to be able to submerge below the surface of the water without just sinking to the floor.

When you start to build your sea perch, you will want to consider this principle. We can calculate just how much buoyancy your sea perch will need in order to be neutrally buoyant if we understand **Archimedes' Principle.**

Archimedes' said that the upward buoyant force is equal to the weight of the displaced volume of liquid. What this means is, by calculating the volume of water that must be pushed aside or displaced by your sea perch when you place it in the water as well as measuring the mass of your perch, we can use the equation Density = Mass/Volume to determine how much flotation is needed in order for it to equal the upward buoyant force exerted by the water. To calculate this, we will need to conduct an experiment!

Experiment: In this experiment, you will need to submerge your sea perch in water and then find the difference in the volume of water displaced by the sea perch. You will then calculate how much buoyancy is needed in order to create a neutrally buoyant sea perch in the water. By applying what

we know, we can find how much flotation is needed. We know that the density of water is 1 g/cm³. We also know that if an object's density is less than 1 g/cm³, it will float and if it is more than 1 g/cm³, it will sink. In order to remain neutrally buoyant, we will attempt to make our sea perch's density as close to 1 g/cm³ as possible.

Before you begin your experiment with your sea perch, you will need to know a few definitions and equations. First, you must understand the difference between an object's weight and its mass. Take your body, for example. Your mass is a measurement of how much matter there is in you. Your weight is a measurement of how hard gravity pulls on the matter that makes up your body. Mass is dependent on the amount of matter, but weight is dependent upon the pull of gravity on matter. The pull of gravity changes, depending on where you are in the universe. For example, gravity on the earth is greater than on the moon. And gravity on the moon is greater than gravity out in space. So, even if your mass remained the same, your weight could change depending on where in the universe you are standing.

On Earth, your weight is your mass (in kilograms) multiplied by the force of gravity felt here on earth (9.81 meters/second²). On the moon, you would weigh less because the force of gravity on the moon is about 1/6 of what it is on the Earth. Because in space there is no gravity, your weight would be equal to zero.

Your weight on the Earth, the moon, and in Space.
Weight = mass * gravity
Because gravity is a constant here on earth, mass can be measured using scales made to give mass values such as Grams and Kilograms without having to do the math yourself.

Materials

- A small storage bucket (a trash bin will work too!)
- Your completed SeaPerch
- Water
- Ruler
- Permanent marker
- Scale
- Calculator

<u>Procedure</u>

1. Fill your bucket about 2/3 of its total volume.
2. With your permanent marker, mark the location of the top of the water on the bucket.
3. Find the area of the bucket at the surface of the water, where you made the mark with your marker using the formula, Area=πr^2 where r is the radius of the bucket at the water level. If you used a storage bin, use the equation Area=length*width where you will measure what the length and the width of the bucket are at the surface of the water. You will need this in order to later calculate the volume of the water inside of the bucket.
4. Completely submerge your sea perch without the flotation devices under the water.
5. Roll it around a few times under the water so that all of the bubbles come out of the PVC pipes.
6. Now, mark the new location of the top of the water on the bucket. Remove the sea perch from the bucket.
7. With your ruler, measure the change in height of the water that you have marked.
8. Calculate this change in volume of the water by subtracting the initial height from the final height using the equation V=(A)(h) where V is the change in volume of the water, A is the area of the base of the bucket and h is the change in height of the water.

Change in Volume = Area of the base of the bucket * change in height of the water

For example, if your initial height was 20 cm of water and after you rolled your sea perch around under water, the height was 20.5 cm, you would subtract the first height from the second. Your equation would look like this: V = (Area)(20.5-20). If the area of your bucket was 1400 cm², your final change in volume would be equal to 700 cm³=(1400)(.5) .

9. Next, you will have to measure the mass of the sea perch without the flotation devices, and take another measurement of the mass of the flotation devices. Make sure your units are still in grams!

10. Using the equation Density = Mass/Volume, you can now calculate the density of your sea perch!

Using the same example as above, if the mass of your perch is 900 g and the volume is 700 cm³, your density will be 1.28 g/cm³. Because this number is larger than 1 g/cm³ (the density of water), this means that your perch will sink, or will have negative buoyancy. In order to increase the buoyancy of your perch, you will need to increase the density by adding floatation. Since we know the mass of the perch and know the mass of the water displaced because of the equivalent relationship between the volume of water in cm³ and the mass of water in g, we can solve for the mass needed of the float.

Mass of Perch – Mass of Water Displaced = Buoyancy needed from Floatation Material

Ex: 900 g – 700 g = 200 g of buoyancy needed

We can measure the buoyancy provided by the floatation devices just by determining the density of the float material and comparing it to the density of water.

The difference between the density of water and the density of the float*the volume of the float is the buoyant force.

First, we must find the density of the float. To do this, we must find its volume and mass. Once these values are found, we can calculate the density of the floats and use any mass and volume and the density will remain the same!

You can measure the volume of the flotation devices by using the equation Volume = $\pi R^2 h - \pi r^2 h$ where π is 3.14, R is the radius of the outer circle of the flotation device, h is the height, and r is the radius of the inner circle.

Once you have found the density by dividing the mass of the float by its volume, you should have found it to be a very small number. For our density equation, we will use a volume of 775 cm³ and a mass of 5 g. By dividing the mass by the volume, we will get a density of 0.006 g/cm³. Because this number is less than 1.0 g/cm³ (the density of water), the float will have positive buoyancy and will float.

Now that you know the buoyancy per cm³ of the floats as well as how much upward buoyant force you will need, you're finally ready to find out how much volume of the float material you will need to make your perch neutrally buoyant! Using the equation below, you will find out the volume you will need:

(Density of Water-Density of Float)*Volume Needed=Buoyant Force needed

Ex: (1.0 g/cm³ - 0.006 g/cm³)*Volume Needed = 200g

Volume needed = 201.21 cm³

Using the numbers we have been using in our example, you should obtain a needed volume of about 201.21 cm³ of floatation.

Knowing that Volume = $\pi R^2 h - \pi r^2 h$, and the outer and inner radii do not change, you can now solve for h. Divide this number by two and you now know how long each floatation device needs to be in order for your perch to maintain neutral buoyancy in the water.