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LAB: BUOYANT FORCE (ARCHIMEDES' PRINCIPLE)

AP PHYSICS II

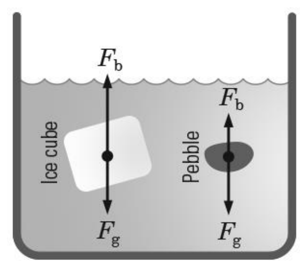
Driving Question | Objective

What are the relationships between the buoyant force on an object submerged in a fluid and a) the volume of the submerged object, and b) the weight of the fluid displaced by the submerged object? Perform an experiment whose data will help determine both relationships.

Materials and Equipment

- PASCO Force Sensor
- Overflow Can
- Support Rod
- Balance
- Table clamp or large base
- Support rod, 45-cm (2)
- Thread and paper clip hanger
- Various graduated cylinders
- Balance
- Right Angle Clamp
- Water
- Meter stick

Background



Fluids are generally thought of as liquids; however, this is a common misconception. A fluid is anything that can flow, which includes gasses as well as liquids. When an object is submerged in a fluid, it experiences an upward buoyant force F_b that opposes gravitational force F_g. This is the reason ice floats on the top of water, and a balloon filled with helium rises in air. If we define F_g in the negative direction, a submerged object will rise in the fluid if the net force is positive (the condition of ice rising in water, or a helium balloon rising in air), and sink if it is negative (the condition of a rock sinking in a pond).

The magnitude of the gravitational force acting on an object is proportional to its mass, but it is easily observable that the buoyant force acting on a submerged object is not proportional to the object's mass: a small rock may have the same mass as a tennis ball, but a tennis ball floats in water and the rock does not. So, what is different between these two objects? Their masses may be the same but their volumes are different, and so is the volume of water displaced by each once submerged.

In this activity you will explore the relationship between the buoyant force acting on an object and the volume of fluid displaced by the object, and draw conclusions that help establish the mathematical relationship between buoyant force and a) the volume of the submerged object, and b) the weight of the fluid displaced by the submerged object.

Safety

Follow this important safety precaution in addition to your regular classroom procedures:

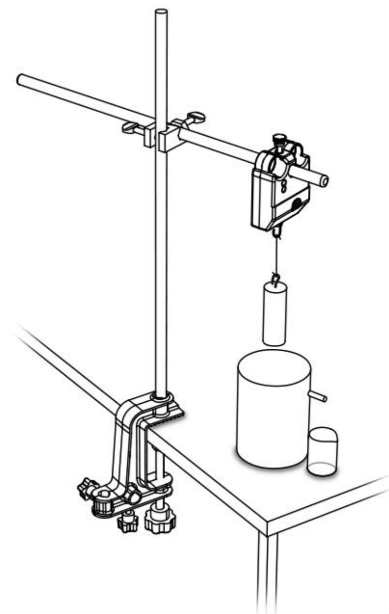
- Make necessary arrangements to your workstation to avoid getting water on any electronic equipment.

Procedure

SET UP

1. Fill the large beaker with soapy water. You will only be using this soapy water during the experiment and not water directly from the sink. This is to reduce surface tension and to allow the water to flow out of the overflow can more easily. Please be sure to recycle all water used back into the water basin.

2. Assemble your equipment like the diagram at right:
   - Use the thread and paper clip hanger to hang a cylinder from the force sensor hook so that it hangs vertically with its top surface approximately 5 cm to 10 cm from the sensor.
   - Place the small beaker or graduated cylinder under the spout of the overflow can so it will catch water as it pours out.



3. Open the Capstone File called "Force Sensor".

4. Remove the brass cylinder from the force sensor hook, and then press the Zero button on the force sensor. Rehang the cylinder after the sensor is zeroed.

5. Fill the overflow can with soapy water from the basin until it begins to pour out the overflow spout. The water will continue to drip into the beaker until it reaches the exact level of the spout inside the can.

6. Once the overflow can has finished dripping, empty the small beaker back into the water basin. Be sure to dry the small beaker before proceeding.

7. Measure the mass of the dry small beaker or graduated cylinder and keep this value for record.

COLLECT DATA

8. With the force sensor, you will be measuring the tensions in the string supporting the masses.
   a. **The difference between the force reading of tension with the mass outside of the water vs the mass inside the water is the buoyant force**

9. As you dip the masses into the overflow can, water will begin to flow out of the spout. Be sure to catch this water into the small beaker so you can measure it's weight and volume.

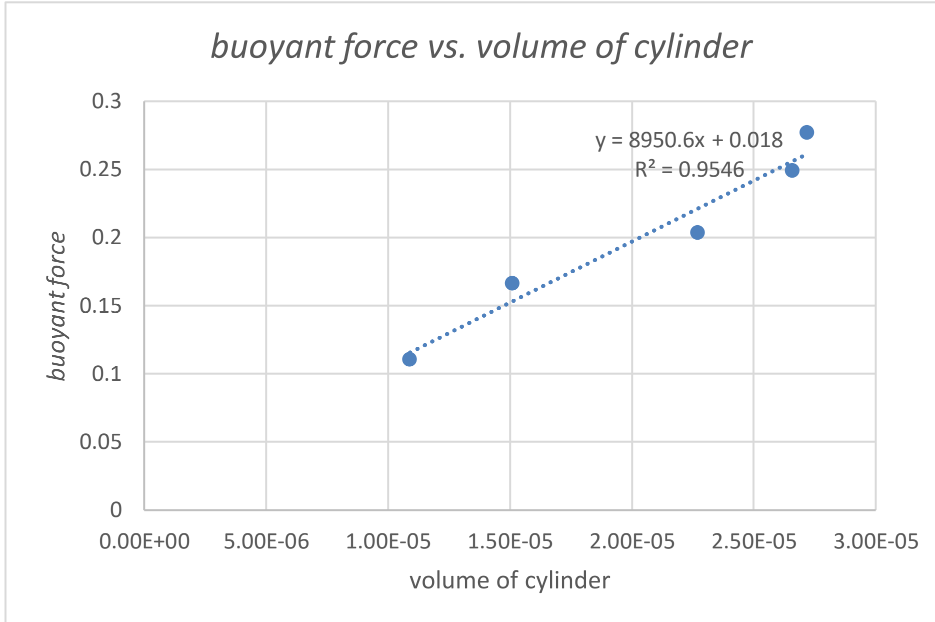
10. Use the equipment to record enough data to answer the following questions:
    a. What is the relationship between the Buoyant Force and the volume of the cylinder submerged?
    b. What is the relationship between the Buoyant Force and the weight of the fluid that flows out of the overflow can?

Cylinder	Weight of Object (N)	Tension in Water (N)	Buoyant Force (N)	Volume of Water Displaced(m^3)	Weight of Water Displaced (N)
Cylinder 1	0.9701	0.8592	0.1109	1.09e-5	0.09898
Cylinder 2	1.1918	1.0255	0.1663	1.51e-5	0.13622
Cylinder 3	1.9678	1.7641	0.2037	2.27e-5	0.20972
Cylinder 4	2.0787	1.8293	0.2494	2.66e-5	0.24794
Cylinder 5	2.1896	1.9124	0.2772	2.72e-5	0.24991

Data Analysis

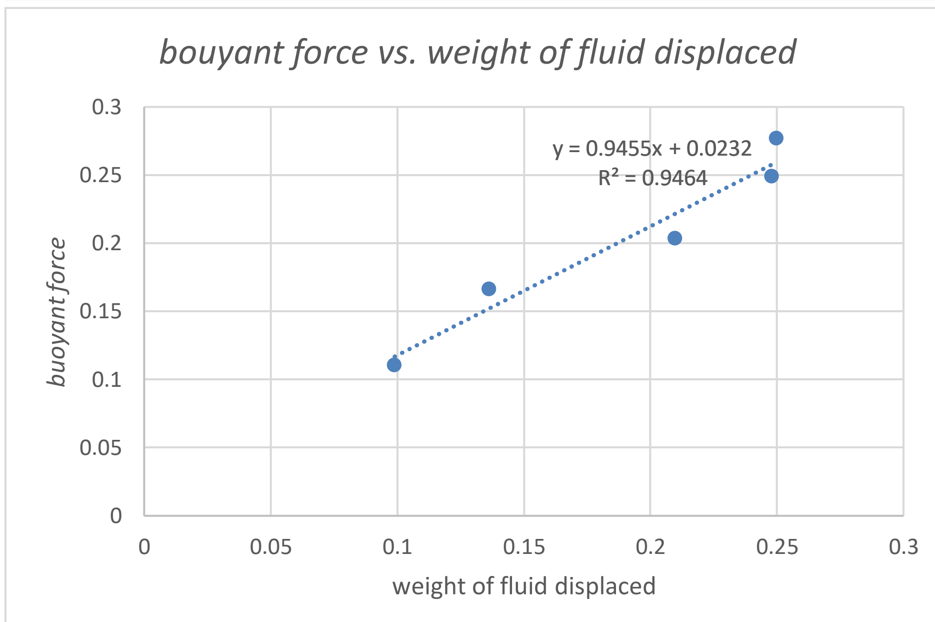
Graph 1: Buoyant force on a cylinder versus volume of cylinder submerged

Volume of Cylinder (m^3)	Buoyant Force (N)
1.09e-5	0.1109
1.51e-5	0.1663
2.27e-5	0.2037
2.66e-5	0.2494
2.72e-5	0.2772



Graph 2: Buoyant force on a cylinder versus weight (in newtons) of fluid displaced by the cylinder

Weight of Fluid Displaced (N)	Buoyant Force (N)
0.09898	0.1109
0.13622	0.1663
0.20972	0.2037
0.24794	0.2494
0.24991	0.2772



Questions

1. Suppose one of the cylinders is 100% submerged with the top of the cylinder just below the water's surface. If the same cylinder were submerged deeper into the fluid, how would this affect the buoyant force? Feel free to try this out with your lab materials.

The buoyant force would not be affected. The only factors affecting buoyancy are density of fluid, volume of the fluid displaced, and the gravitational field. It would not matter if the cylinder was at the top or bottom of the water.

2. What do the slopes of each of your graphs represent?

The slope of graph 1 (buoyant force vs. volume of cylinder) represents the quantity buoyant force/volume of the cylinder. This is equal to density of the fluid times the gravitational field. The slope of graph 2 (buoyant force vs weight) represents buoyant force/weight. Buoyant force is equal to density of the fluid*volume of the fluid*gravity. Density is equal to mass/volume, which means that density*volume is equal to mass, so we can replace density*volume*gravity with mass*gravity. mass*gravity is weight, dividing both sides of the equation by weight will just equal 1. Another way to think about this is that fluid in static equilibrium has a balanced force of gravity and buoyant force. Therefore, the buoyant force must equal the weight of the fluid, and thus the slope on a buoyant force vs. weight graph equals 1.

3. What other quantity measured is the buoyant force equal to? How can you use this to express the equation for buoyant force?

Buoyant force is equal to the weight of the fluid displaced. The equation for buoyant force can be expressed as buoyant force = weight of the fluid. This can also be expressed as buoyant force = (mass of fluid)*gravitational field.

4. If two objects of identical volume, but different densities were 100% submerged into a container of water, which object, if either, would have the larger buoyant force? Why?

The objects would experience the same buoyant force. The density of the object dropped in water does not matter; only the density of the fluid does. Since the volume of both objects is equal, that means the volume of water displaced is equal, and therefore the weight of the water displaced is equal.

5. Suppose a block of wood and a block of lead of identical volume were placed in a pool of water. The wood block floats to the surface while the lead block sinks to the bottom. Which of the two objects, if either, would experience the larger buoyant force? Why?

The lead block experiences a larger buoyant force because it displaces a larger volume of fluid. This means that the weight of the fluid displaced (which is equal to the buoyant force) is larger for the lead block. Even though they have the same volume, the wood block floats, which means it displaces a smaller volume of fluid.