Archimedes' Principle

Saddleback College Physics Department

Purpose

To calculate the average density of (**Part I**) an egg in salt water and (**Part II**) a metal object suspended from a scale (in air and then in water) by applying Archimedes' Principle then comparing these densities to their theoretical values.

Theory

Archimedes' Principle:

The buoyant force on an object equals the weight of the fluid displaced by the object and is directed vertically upward. Written mathematically, the buoyant force is

$$\boxed{F_B = w_f = m_f g = \rho_f g V_f} \quad \text{Recall} \quad \boxed{\rho = \frac{m}{V}}$$

where w_f = weight of fluid displaced
m_f = mass of fluid displaced
g = gravity
ρ_f = density of fluid displaced
V_f = volume of fluid displaced

Specific gravity is measured with a hydrometer. To determine the density of a liquid using a hydrometer, place the hydrometer in enough fluid for the hydrometer to float. Read the number off the hydrometer scale where the fluid's meniscus intersects the scale. This is called the specific gravity of the fluid. Use the following relation to calculate the density of the fluid:

$$\boxed{\rho_{fluid} = specific\ gravity \cdot \rho_{water}} \quad \text{where } \rho_{water} = 1.0\ {}^{g}\!/_{cm^3} \text{ at STP}$$

Equipment

PART I
Graduated cylinder
Salt
Room Temperature Water
600 ml Beaker
Stirrer
Egg
Digital Balance
Hydrometer
Pipette

PART II
Digital Balance
String
Metal Object (Cu, Al, Pb, Sn or Zn)
Beaker
Room Temperature Water
Lab Jack
Ring Stand
Right Angle Clamp

* Write directly on pages 4 & 5 then staple them to the informal lab report.

Sketch

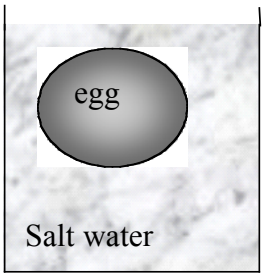

Figure I

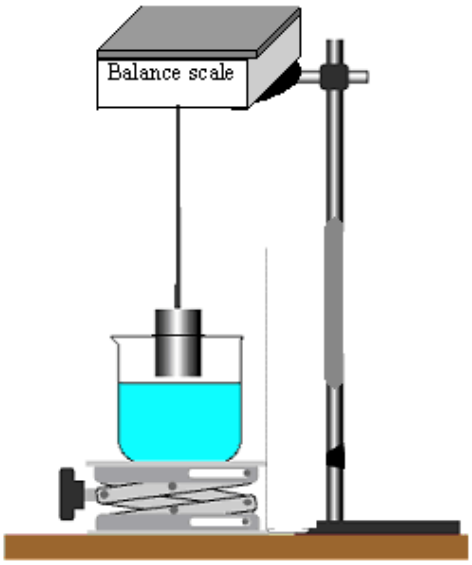

Figure II

Procedure

Warning: **DO NOT USE YOUR BOOK** ***as you perform Step 1 of PARTs I and II as they are "discoveries" which will likely tax your patience, but should result in significant learning. You are to work through each step 1 (Part I & II) below with ONLY YOUR LAB TEAM and if you are stuck more than ~5 minutes, approach your instructor for a hint/guidance. You and your lab partner(s) are obligated to discuss and explain any progress/reasoning to one another.***

Part I:

1. Using Archimedes' Principle and Newton's Law(s) derive an expression to calculate the average density of an egg submerged in salt water, assuming you can adjust the salinity of the water and that you can determine the specific gravity (i.e. density) of the salt water at any particular salinity. Show this derivation in the "calculations" section of your lab report and ***you must bring your entire derivation to your professor for approval before beginning Part I of the experiment***. HINT: It may help to answer the questions for Part I first. Part I must be completed before you begin Part II of the experiment.
Write the result in this box. [ ] eqn (1)

2. Fill a 600 ml beaker about ¾ full with room temperature water. Gently place your egg in the water.

3. Gradually add a small amount of salt to the water and stir the mixture until the salt dissolves. When you have nearly achieved the situation describable by your derived equation in step #1 above, you will have to add the salt in very small increments and in the end you will most likely need to add a bit of water to the solution using a water filled pipette to slightly decrease the salinity and achieve the desired results.

4. Once you have achieved the desired situation, remove egg and pour saltwater into a dry graduated cylinder then use the hydrometer to measure the specific gravity of your salt water solution inside the graduated cylinder. Record this value and call it the **experimental density** of the **salt water** mixture.

5. Measure and record the mass and volume (using the graduated cylinder) of your egg. Calculate the approximate density of the egg and call this the theoretical value. Which density do you think is more precise, the one obtained from step 4 above or from this step?

Part II:

1. Apply Newton's Law(s) and Archimedes' Principle to determine an equation for the experimental density of the metal object, ρ_o. The equation for ρ_o must be only in terms of the density of the fluid displaced, ρ_f, the mass of the object in air, *m*, and the mass of the object in water, *m'*. Show this derivation in the "calculations" section of your lab report, including any relevant F.B.D.'s. ***Bring your derivation to your professor for approval before beginning Part II of the experiment***.
   Write the result in this box. [ ] eqn (2)

2. Tie string to the hook on the underneath side of the digital balance scale and suspend the metal object from the other end of the string.

3. Set up the ring stand and place the digital balance scale on top of the ring, threading the string through the ring.

4. Measure and record the weight of the object when it hangs in air. Be sure to zero the digital balance scale **while holding up the metal object**.

5. Fill the beaker with enough water that the object can be submerged and place it on a lab jack, underneath the suspended mass. The bottom of the object should be almost touching the water. See picture above.

6. Slowly raise the water until the object is submerged completely. Measure and record the weight of the object when submerged in water.

Data

	Item	Value
Part I	Experimental Density of Saltwater (Hydrometer)	
	Experimental Density of Egg (eqn 1)	
	Mass of Egg	
	Volume of Egg	
	Theoretical Density of Egg (mass/volume)	
Part II	Type of Metal (for object)	
	Mass of Object in Air, *m*	
	Mass of Object in Water, *m'*	
	Experimental Density of Object (eqn 2)	
	Theoretical Density of Object	

Analysis

Part I

1. Calculate the **theoretical density** of your egg by using mass per unit volume of the egg. Determine the **percent difference** between the measured and "theoretical" density of your egg.

Part II

1. Calculate the experimental density of your object using equation (2) and the density of water at STP, 1.0 g/cm^3.

2. Look-up the handbook value (see Appendix F in textbook) for the density of your metal cylinder and compare it to your measured density.

Questions (Answer these before you leave lab today!)

Part I

Answer the three questions below in terms of <u>forces</u> and in terms of <u>densities</u>.

1. An object sinks when

_____

_____.

2. An object floats but is submerged when

_____

_____.

3. An object floats, partially submerged when

_____

_____.

Part II

1. Does a ship float higher or lower in saltwater versus in freshwater? Why?

2. A pure ice cube is floating (partially submerged) in a glass of pure water and the water level is noted. When the ice cube melts, does the water level go up, down or remain unchanged? Why? Try proving it.

3. EXTRA CREDIT (if proven): An ice cube that contains pure water but also has grains of sand frozen in it is floating in a glass of pure water and the water level is noted. When the ice cube melts, does the water level go up, down or remain unchanged? Why?