PHYS 103 LAB 10 ARCHIMEDES' PRINCIPLE AND ETC.

(THIS WEEK YOU JUST FILL IN THE BLANKS FOR YOUR REPORT)

Group name:.......................................

Partners' names:.......................................

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INTRODUCTION

In this lab you will investigate the concept of *density* and *Archimedes' principle*. You will use the **electronic scale** and the **Force Sensor** in **Data Studio**.

THEORY

Density

The *density, ρ,* of an object is defined as the ratio of the *mass, m,* of the object and its *volume, V*:

$$\rho = \frac{m}{V} \tag{1}$$

The metric units for *density* are kg/m^3. Another commonly used unit for *density* is g/cm^3 (grams per cubic centimeter). The *density* of water is 1 g/cm^3.

Archimedes' principle

Archimedes' principle states that an object placed in a fluid experiences an upward *buoyant force, $\boldsymbol{F_B}$*, acting on it equal to the *weight* of fluid displaced by that object.

$$\boldsymbol{F_B} = m_f\, g \tag{2}$$

where m_f is the *mass* of the displaced fluid. The *mass* of displaced fluid is given by

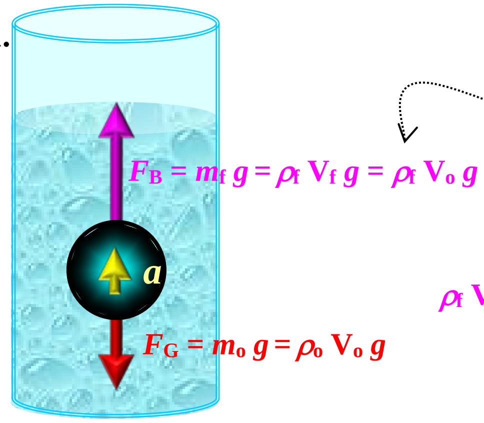
$$m_f = \rho_f\, V_f \tag{3}$$

where ρ_f is the *density* and V_f is the *volume* of the displaced fluid.

When an object is placed in a fluid, such as water, it may either sink or float to its surface. *Archimedes' principle* explains why. If the *density* of an object is less than the *density* of the fluid it is placed in, then the object **floats** to the surface (see figure 1). Once on the surface it will remain submerged in the fluid to a *depth* that is sufficient to displace the *weight* of the fluid equal to the objects *weight*. If the *buoyant force* is less than the *weight* of the object, the object **sinks** (see figure 2) until it hits the bottom at which point the *normal force* balances the remainder of its *weight*.

Objects whose *density* is greater than the *density* of a fluid, and which, thus, would sink in it, can remain stationary in the fluid if they are otherwise supported e.g. if we hang them on a string. Those submerged objects appear to weigh less when suspended from a scale – or as we'll do in our experiment: a **Force Sensor**. This occurs because the *buoyant force* has already balanced part of their actual *weight* and so the string needs to support it less (see figure 3). We call the *weight* measured while the object is submerged in a fluid its *apparent weight*.

Figure 1.

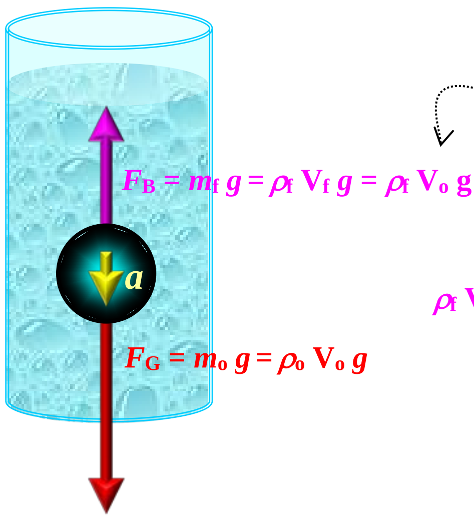


Fully submerged object displaces a volume of fluid V_f equal to its own volume V_o.

$F_B > F_G$ **so that F_{net} is upward and thus:**

$\rho_f\, V_o\, g > \rho_o\, V_o\, g$ **or** $\boxed{\rho_f > \rho_o}$

Figure 2.



Fully submerged object displaces a volume of fluid V_f equal to its own volume V_o.

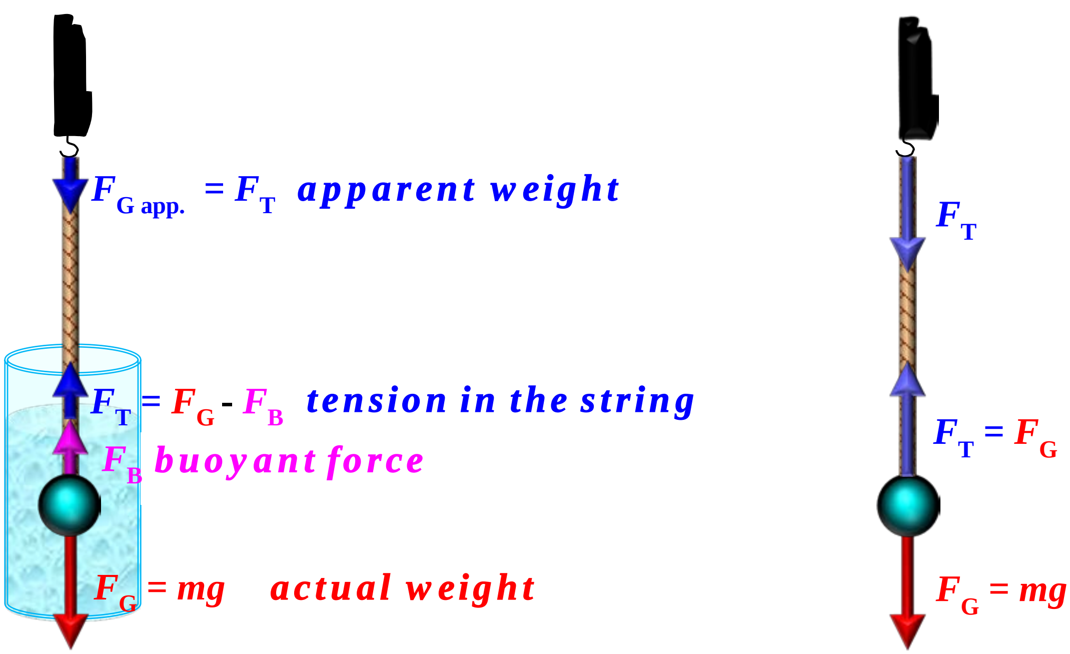
$F_B < F_G$ **so that F_{net} is downward and thus:**

$\rho_f\, V_o\, g < \rho_o\, V_o\, g$ **or** $\boxed{\rho_f < \rho_o}$

Figure 3.

In a fluid

In the air



PROCEDURE

PART 1 DENSITY OF WATER

Place an empty calibrated cylinder on the electronic scale. Record its mass. Then pour 100 milliliters (ml) of water into the calibrated cylinder and measure the mass. Determine the mass and the density of water in the cylinder.

Mass of an empty calibrated cylinder……………………………..____________

Mass of a calibrated cylinder containing 100 ml of water ………..____________

Mass of 100 ml of water ...…………...……………………………..____ _______

Volume of 100 ml water in cm^3………...…………………………..____________

Density of water in g/cm^3 is ………...…………………………..____________

Is your calculated value for the density of water close to the accepted value of 1 g/cm^3?

PART 2 DENSITY OF SOLIDS

1. Examine the cubes in the density kit. Each cube has the same volume. In Excel make list of these materials in column A of a table similar to table 1 below (you'll need twelve rows for the twelve different materials in the kit). Also, enter the cube's volumes into your table and the equations for calculating their densities.

2. Use the electronic scale to determine the mass of each of the cubes. Record these masses (in grams) in Excel.

3. Use formula (1) to calculate the density of each object in grams per cubic centimeter (g/cm^3).

Table 1.

Material	**Mass (g)**	**Volume (cm^3)**	**Density (g/cm^3)**	**Floats or sinks?**	**For floating objects: fraction of volume under water**

4. Place the objects in a container half filled with water and observe whether they sink or float. Record your observations in Excel.

5. For objects that float, estimate what fraction of their volume is under water. Record in Excel column F.

6. Take the objects out of water and dry them up.

7. <u>How do the densities of the objects that sunk compare with the density of water?</u>

8. <u>How do the densities of the objects that floated compare with the density of water? Discuss.</u>

9. <u>How do the estimated fractions of the objects volume under water compare with their densities? Discuss.</u>

<u>PART 3 ARCHIMEDES' PRINCIPLE: APPARENT WEIGHT OF A STEEL BALL</u>

1. Start **Data Studio** and enable the **Force Sensor**. Create a graph of *force* vs. *time*. Check and make sure that your **Force Sensor** is correctly calibrated.

2. Tie a light string loop to the metal ball's hook.

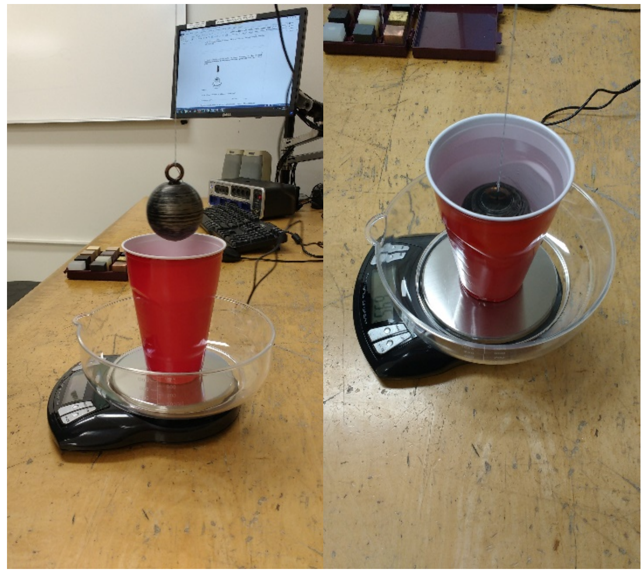
3. Suspend the metal ball on the string from the metal hook on the bottom of the **Force Sensor** and measure its *weight*.

The measured value for the *weight*, F_G, of the ball is ……………………… F_G = ____________

4. Fill the red cup with water and place it in the clear plastic dish on the scale (figure 4 on the next page). Make sure you have enough water to fully submerge the ball but not so much as to spill it all over the place, though the plastic tray mitigates that. **Once the cup is placed on the scale, tare the scale.**

5. Carefully insert the ball into the water until it is fully submerged (including the hook). **Make sure the ball is not touching the bottom or the sides of the cup and that it is supported solely by the Force Sensor** (see figure 5 a and b on the next page).

Figure 4.



(a) (b)

Figure 5.

6. What is the *apparent weight* of the ball fully submerged in water?

The *apparent weight* is……………………………………….. $\boldsymbol{F_G}$ apparent = ____________

Is the *apparent weight* of the ball the same as the *weight* found in step 3? Should it be? Explain why or why not.

7. Find the magnitude of the *buoyant force* acting on the ball when it is fully submerged in water.

The *buoyant force is*………………………..………………………………$\boldsymbol{F_B}$ = ____________

8. What does the scale read? Multiply by *g* to convert to force/weight. How does it compare with the buoyant force, $\boldsymbol{F_B}$? Does this make sense? Why or why not?

9. Dispose of the water. Dry up the ball, the cup, and the bowl.

PART 4 BUOYANCY OF HELIUM BALLOONS

1. Measure the *force* required to hold a helium balloon stationary by tying the string to the balloon. The balloon should not be inflated too much. Tie one end of the string to the balloon, place the ball of string on the desk and let enough of the string unwind so that the balloon floats without rising or falling. Cut the string at the spool and verify that the balloon remains stationary. If not adjust the length of the string by cutting some off or tying on more, so the balloon neither falls nor rises.

2. Untie the string from the balloon and using the **electronic scale,** measure its *mass*.

The mass attached to the balloon needed to keep it stationary is………………....…..____________

The *force* required to hold the balloon stationary is…….…...………………..…..____________

3. What makes the balloons float in air? Draw free body diagrams for the balloon without and with the added weight. Discuss *forces* involved.

No conclusion today; hand in the entire manual and attach Excel spreadsheet for part 2.

Clean and dry your hardware and the table.

REMINDERS: Include units.
Disconnect all equipment, close all applications, and log off your PC.
Make sure you leave the classroom as you found it.