Name:______________________________
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# 4 Lab 4: Density

## 4.1 Introduction

In this lab we will consider how to determine the average **density** of irregular shapes and what that density can tell us about the internal composition and structure of the material within the object of interest.

The average density is defined as the *mass* of the object divided by the *volume*. We will use grams (g) for mass and cubic centimeters ($cm^3$) for volume. What will the units of density be?

The *mass* of an object is a measure of how many protons and neutrons (atomic nuclei particles) the object contains. Denser materials (such as lead) possess many more protons and neutrons within a cubic centimeter than do less dense materials (such as water).

The *weight* of an object is a measure of the *force* exerted upon that object by the gravitational attraction (gravitational 'pull') of the Earth or some other large, massive body. An object here on Earth's surface with a *mass* of 454 grams (grams and kilograms are a measure of the mass of an object) has a weight of one pound. If we do not remove or add any protons or neutrons to this object, its mass and density will not change if we move the object around. However, if we move this object to a location in the Solar System where the gravitational attraction is different than what it is at the Earth's surface, than the *weight* of this object will be different. It is these concepts that we will address with this lab.

## 4.2 Exercise

You will determine the densities of five different objects and compare these values with each object's appearance to convince yourself of the uses and limitations of determining average density in an effort to understand the internal structure and composition of objects. We use a similar technique to make first-guess estimates of the composition of various solar system bodies.

- The volume of an object may be determined by measuring how much water it displaces. Apply this technique, realized long ago by Archimedes, to determine the volumes of the irregularly shaped objects. Enter these values in Table 4.1. (**5 points**)
- The masses of the various objects can be determined using the balance. Measure the masses and record the numbers in Table 4.1. (**5 points**)
- When you have completed these measurements, calculate the density of each of the objects. Use units of cubic centimeters and grams. You may recall from your past

scientific experience that a volume of one cubic centimeter is the same as one milliliter (one-thousandth of a liter); see Figure 4.1. Record the density values you calculate in Table 4.1. (**5 points**)

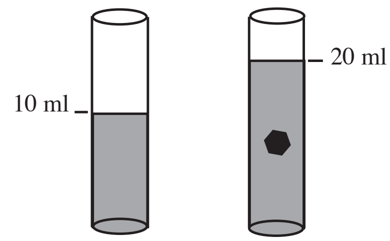


Figure 4.1: The black object displaces 10 ml of water. Therefore, it has a volume of 10 ml = 10 $cm^3$.

| Object | Volume ($cm^3$) | Mass (g) | Density ($g/cm^3$) |
|---|---|---|---|
| 1. golf ball | | | |
| 2. Sierra Blanca rock | | | |
| 3. vesicular lava | | | |
| 4. shiny weight | | | |
| 5. Piñon meteorite | | | |

Table 4.1: Density calculations based on masses and volumes of different objects.

To answer the following questions, you will need to refer to Table 4.2, which contains density values for different materials.

1. Consider the average densities of objects 1, 2, and 3. Do the values indicate whether the metal content of any one of the three could be greater than for the others? Explain your answer. (**10 points**)

| Material | Density (g/cm$^3$) |
|---|---|
| Gold | 19.3 |
| Lead | 11.4 |
| Iron | 7.9 |
| Aluminum | 2.7 |
| Rock (typical) | 2.5 |
| Liquid Water | 1.0 |
| Wood (typical) | 0.8 |
| Insulating foam | 0.1 |
| Silica Gel | 0.02 |
| Air (dry, at sea level) | 0.0012 |
| Helium | 0.0001785 |

Table 4.2: Densities of different materials.

2. Compare the density of the shiny weight with the densities listed in Table 4.2. What do you suspect this object is made of? Why do you think this? (**10 points**)

3. Compare the densities of 3, 4, and 5 and consider Table 4.2. Do you agree that the Piñon meteorite could be rich in iron? Why? (**10 points**)

4. Referring only to Table 4.2, what material (or combination of materials) would you guess the golf ball to be composed of? Is this a reasonable composition for a golf ball? What does this suggest about the use of *average density information* **only** when we make 'guestimates' about what materials solar system bodies might be composed of? (**10 points**)

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## 4.3 Take-Home Questions

1. Some scientists have measured the density of a substance to be 3.1 g/cm$^3$. Based on what you have learned so far, is the substance more likely to be a solid, a liquid, or a gas? (**5 points**)

2. A solid cylinder of plastic has a density of 1.6 g/cm$^3$. It is then cut exactly in half. What is the density of each of the pieces now? Explain your answer. (**5 points**)

3. Liquid A has a density of 0.90 g/cm$^3$, liquid B has a density of 1.15 g/cm$^3$, and liquid C has a density of 0.65 g/cm$^3$. They are poured into a graduated cylinder and allowed to sit overnight. Assuming that the liquids do not mix into one another, which liquid will be on the bottom, in the middle, and at the top of the graduated cylinder? *Draw a picture to illustrate this scenario.* (**5 points**)

4. Use your textbook (Appendix E) or information on-line to fill in the following table (**12 points**):

| Object | Mass (kg) | Average Density (g/cm$^3$) |
|---|---|---|
| Sun | | |
| Mercury | | |
| Venus | | |
| Earth | | |
| Moon | | |
| Mars | | |
| Ceres (largest asteroid) | $8.7 \times 10^{20}$ | 1.98 |
| Jupiter | | |
| Saturn | | |
| Titan (Saturn's largest moon) | | |
| Uranus | | |
| Neptune | | |
| Pluto | | |
| Comet Halley (nucleus) | $4 \times 10^{15}$ | 0.1 |

Table 4.3: Densities of different solar system objects.

5. Based on the density information in Table 4.3, can you group the objects in our solar system into different classes or categories? How would you divide them up? (**5 points**)

6. How does the density of the Sun compare to the densities of other objects in our solar system? Can you say anything about the chemical composition of the Sun as compared to the composition of the planets based on Table 4.3 alone?(**5 points**)

7. Which planet is the most massive? (**2 points**)

   Which planet is the most dense? (**2 points**)

Comment on the difference between *mass* and *density*. Does the most massive planet also need to be the densest? (**4 points**)