<u>Timothy Ryan</u>, Jake Vlahakis
Honors Physics
Lab Experiment #1
Measurement of Density

<u>Purpose</u>: To practice measurement skills and calculations with significant figures, to observe if materials have ferromagnetic properties, and to investigate the relationship between the buoyancy of a fluid and the density of a solid placed in it.

<u>Materials</u>: Materials A, B, C, and D, tap water, and paper towel.

<u>Equipment</u>: Mass balance, graduated cylinder, beaker, metric ruler, and a magnet.

<u>Introduction:</u>

The study of science requires that we make observations about physical objects, using both our senses and logical reasoning. Observations can be either *qualitative* in nature, describing the actual composition of an object, which is important for discovering all possible information about what was observed, or *quantitative* in nature, which requires measurement against a dimension using a measuring instrument and defining these dimensions using a *unit of measurement.* It is important to record such observations accurately and completely to ensure that the results of the experiment are correct.

Quantitative measurements in science are defined using the SI (Metric) system of measurement, which defines several dimensional quantities. The basic, or fundamental, quantities defined by SI are for *length*, *mass*, and *time*, the base units of which are the *meter*, *kilogram*, and *second*, respectively. SI also defines several derived units which are defined by multiplying or diving base quantities.

Prefixes can be placed in from of SI base units to signify multiplication by a power of ten. Each metric prefix is associated with a power of ten, and there exists both *positive exponents* (powers of ten greater than or equal to 10) and *negative exponents* (powers of ten less than one, or decimal fractions).

10^0 is, by definition, equal to one. A knowledge of these prefixes and powers of ten is important to be able to utilize the SI system fully.

One derived unit of the SI system is *volume*, the amount of space occupied by an object. Volume can normally be determined using a mathematical formula for regular solids. For example, the volume of a *rectangular solid* can be calculated by multiplying the length, width, and height of the solid (represented by the formula **V = lwh**). Volume is normally expressed in *cubic meters* (written as m^3), though other metric volume units are used, such as the *liter* (now defined as a *cubic decimeter*, written as dm^3.)

Density is another derived unit, and is defined as the mass of an object divided by its volume (resulting in how *dense* an object is per unit of space). This can be calculated by the formula **D = M/V**. Density can be used to identify different kinds of matter, a fact discovered by the Greek mathematician and “natural philosopher” *Archimedes*. He also discovered that the buoyancy of a fluid (its ability to sustain floating objects) is related to the density of the object placed in it, a relationship called **Archimedes’ Principle**.

This experiment will require the student to measure several different dimensions, including masses, length,s and volumes, in order to calculate the densities of several materials. These materials will also be tested for *ferromagnetic* properties, and tested for their buoyancy in tap water. Once these measurements have been performed, using the qualitative and quantitative observations, the student will attempt to identify these materials using ***The CRC Handbook of Chemistry and Physics***, to test the calculated density of each material against its “true value” density.

Procedure:

1. The specified materials and equipment were obtained for each group. Samples of materials A, B, C, and D were placed on a paper towel on the lab table, and the letter of each sample was labeled on the paper towel.
2. Qualitative observations of each of the four samples were made and recorded, using all senses except for taste. Each sample was tested for ferromagnetic properties by using the magnet.
3. Each of the four samples, as well as the graduated cylinder, were individually weighed on the mass balance to the nearest tenth of a gram (± 0.1 g) and recorded.
4. Using the metric ruler, the length, width, and height dimensions of each of the four samples were measured to the nearest tenth of a centimeter (± 0.1 cm) and recorded.
5. An amount of tap water between 10.0 mL and 50.0 mL was obtained in the graduated cylinder. The volume of tap water was recorded to the nearest half-milliliter (± 0.5 mL) by reading the water level to the bottom of the meniscus. The cylinder with water was weighed to the nearest tenth of a gram (± 0.1 g) and recorded.
6. The beaker was filled approximately halfway with tap water. Materials B, C, and D, were tested individually in the beaker, and it was recorded which of the samples, if any, floated in the water in the beaker. After testing each sample, the water was changed and the wet sample was placed back to its original position on the labeled paper towel.

7. The materials were returned to the designated areas where they were obtained, and the area around the lab table was cleaned, wiping up any spilled water with paper towels and disposing of excess towels in the nearest trash bin.

Observations:

Qualitative Observations:

A) Material A was a brick-like rectangular prism, relatively large and heavy compared to the other materials. It felt rough to the touch and was colored a dull mixture of grey and brown, as well as being speckled with black dots. It had a metallic, but otherwise odorless scent. Material A was not magnetic, and was not tested for buoyancy in water.

B) Material B was a tiny, flat rectangular solid, which bore many similarities to soap. It had an off-white color, a smooth texture, and was rather fragrant and pleasant-smelling. Material B was not magnetic, but it was able to float in tap water.

C) Material C was similar to Material B, a tiny, flat rectangular solid. It had a slightly darker off-white color, a smooth texture, and a rather stronger, yet still pleasant-smelling, fragrance. Material C was not magnetic, and was not able to float in tap water.

D) Material D was a very small metallic cube. It had a primarily silver color to it, with rusted spots around its exterior. It had a primarily metallic, but otherwise odorless smell. Material D does have ferromagnetic properties, but was not able to float in tap water.

Weight:

The weight of each material was determined using the mass balance.

Material Weights (g ± 0.1 g)	
Material A	1124.8
Material B	10.7
Material C	17.8
Material D	15.5
Graduated Cylinder	27.4
Graduated Cylinder w/Tap Water	71.3

Dimensions:

The dimensions of each material was determined using the metric ruler, and the length, width, and height of each were recorded.

Material Dimensions (cm ± 0.1 cm)			
	Length	**Width**	**Height**
Material A	9.3	9.5	5.3
Material B	2.4	2.6	2.1
Material C	4.0	2.2	1.7
Material D	1.2	1.2	1.2

Volume of tap water in graduated cylinder:

The volume of tap water that was used in the graduated cylinder was measured.

Volume of Tap Water in Graduated Cylinder (mL ± 0.1 mL)	
Tap Water	44.5

Results:

1. The mass of water in the graduated cylinder was determined by subtracting the mass of the empty cylinder from the mass of the cylinder and water combined.

   Mass of tap water = 71.3 – 27.4 = 43.9

Mass of Water in Graduated Cylinder (g ± 0.1 g)	
Tap Water	43.9

2. The volume of each of the materials was calculated using the formula **V = lwh**.

   Volume of Material A = (9.3 cm) × (9.5 cm) × (5.3 cm) = 470 cm^3

Volume of Materials (cm^3 ± 0.1 cm^3)	
Material A	470
Material B	13
Material C	15
Material D	1.7

3. Density calculations:

   a) The densities of each of the materials was calculated using the formula **D = M/V**, using the measured weight of the materials and the volumes calculated in step 2.

      Density of Material A = 1124.8 g / 470 cm^3 = 2.4 g/cm^3

Observed Density of Materials (g/cm^3 ± 0.1 g/cm^3)	
Material A	2.4
Material B	0.82
Material C	1.2
Material D	9.1

b) The density of *tap water* was calculated from its calculated mass and its observed volume, using the formula **D = M/V**

Density of tap water = 43.9 g / 44.5 mL = 0.98 g/mL

Density of Tap Water (g/mL ± 0.1 g/mL)	
Tap Water	0.98

4. Material D was the only material to exhibit ferromagnetic properties.

Discussion:

1. Identification of materials:

A) Material A had a rock-like texture and color to it, and it was observed that it was in the form of a molded brick. Based on these observations, and the approximate accuracy of their densities, Material A can be identified as **concrete**.

B) Material B was in the form of a bar of soap, and had a distinct soap-like fragrance. Due to its ability to float in water, it can be correctly identified as **Ivory-brand soap**, the only kind which has a density light enough to do so.

C) Material C was also in the form of a bar of soap, and had a distinct soap-like fragrance. It can be correctly identified as some form of **bar soap**, other than Ivory.

D) Material D was a small, ferromagnetic, metallic cube. While there are several ferromagnetic materials which have a density close to the observed density, the metal **nickel** has the closest true value density to what was observed.

A “true value”, or accurate, density can be found for each of the above materials, to which our observed densities can be compared.

True Value Density of Materials (g/cm^3)	
Material A (Concrete)	2.403
Material B (Ivory soap)	0.9
Material C (soap)	1.04
Material D (nickel)	8.908

2. Error Analysis:

A) A percent error can be calculated of the *observed value* of the materials to their *true value*, using the fomula **[(‘observed value’ – ‘true value’)/’true value’] × 100**. We can calculate the percent error for our observed density of tap water, also, as tap water’s density at room temperature and normal atmospheric pressure is exactly 1.00 g/cm^3.

Percent error for Material A = $((2.4\ g/cm^3 - 2.403\ g/cm^3) / 2.403\ g/cm^3) \times 100$ = -0.1%

Percent Error (± 0.1%)	
Material A	-0.1%
Material B	-9%
Material C	15%
Material D	2%
Tap Water	-2%

B) **Qualitative**: Even while attempting to make the most accurate observations, there were many situations in the experiment where sources of error could exist. Analysis using the mass balance could be affected by point of view (observation error), or if the mass balance itself did not balance correctly (instrument error). Observation error could affect the measurements of the dimensions of the materials, as well as the volume of the tap water. If the measurements of the dimensions or weight were off, they would affect the remainder of the calculations.

3. **Theory and Ramifications:**

The results of this experiment show how measurements made using the SI System can be interpreted and calculated to yield unobservable results, such as the density of an object. The results also allow us to be able to identify a material based on both its qualitative and quantitative properties, including its density and its ferromagnetic properties. It was expected that, using the data observed from this experiment, we would be able to correctly identify the type of each of the materials we were provided, in addition to being able to calculate its density close to its actual, true density.

Applications of the measurement of density has been a crucial part of analytical science, in fields such as astronomy, geology, chemical manufacturing, and more. Not only would density allow the scientist to find a constant with which to identify a type of material, density is also a component of how objects interact, how gas expands, and the buoyancy of objects. This experiment has been an instruction on the use of the SI system in practical science, to identify materials and measure a property of an object that cannot be identified using only a tool, but rather, which requires calculation.

<u>Conclusion:</u> The experiment has been a demonstration on usage of the SI System, the accurate measurement of dimensions, and the calculation of derived units such as density.