2. Density

Driving Questions

In 250 B.C., Archimedes, a famous Greek philosopher, was given the task of determining if the king's crown was solid gold. The crown could not be damaged in any of the tests. Archimedes found a solution using one of gold's intensive physical properties. What procedure did Archimedes use to test if the crown was gold and why did this procedure work?

Background

You can make a number of different observations when given a sample of a substance. Some properties of a substance, such as weight and volume, depend on the amount of material present. These properties are called extensive properties. Other properties, such as the substance's color, remain constant no matter how much material you have. These properties are called intensive properties.

Density is an intensive property of a substance that relates the substance's mass to the amount of space (volume) the substance occupies. Lead is a very dense material. It is very heavy compared to its size. Aluminum, however, is not dense. It feels light for the amount of material present. If the density of an object is less than the density of water (ρ_{water} = 1.0 g/mL), then the object floats. If the density of the object is greater than the density of water, the object sinks.

The density of a substance can be found using the formula, $\text{density} = \frac{\text{mass}}{\text{volume}}$.

You can use a balance to find an object's mass. The volume of the object can be found using two different methods. If the object is a regular geometric shape, such as a cylinder, a cube, or a sphere, a mathematical formula can be used to determine the volume. If the object is of an irregular shape, then volume can be determined by water displacement. By comparing a sample's density to a list of known densities, the identity of the substance can be found.

Materials and Equipment

For each student or group:

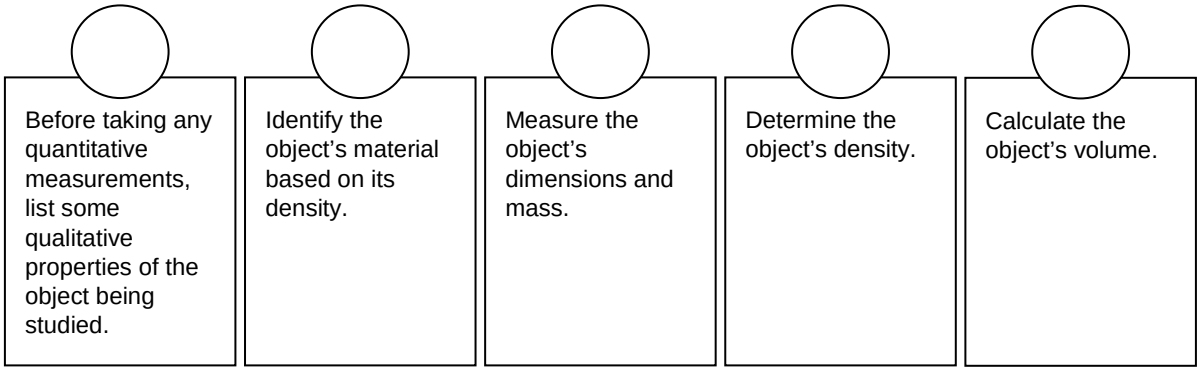
- PASCO density set
- Beaker, 150-mL
- Graduated cylinder, 50- or 100-mL
- Balance (2 to 3 per class)
- Overflow can
- Metric ruler (or calipers)
- Water, 500 mL
- String

Safety

Follow all standard laboratory practices.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.



Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Collect Data

Part 1 – Brass Objects

1. ☐ List at least two qualitative observations about the brass objects.

_____

2. ☐ Predict how the density of the brass block compares to the density of the brass cylinder.

_____

_____

3. ☐ Measure the length, width, height, and mass of the brass block and the height, diameter, and mass of the brass cylinder. Record your results in Table 1 below.

Table 1: Dimensions and mass of brass objects

Object	Length (cm)	Width (cm)	Height (cm)	Diameter (cm)	Mass (g)
Brass block					
Brass cylinder					

Part 2 – Aluminum Objects

4. ☐ List at least two qualitative observations about the aluminum objects.

_____

5. ☐ Predict how the densities of the three aluminum objects will compare to each other.

_____

_____

6. ☐ Measure the length, width, height and mass of the aluminum block and the height, diameter, and mass of the aluminum cylinder and record your results in Table 2 below.

Table 2: Dimensions and mass of aluminum objects

Object	Length (cm)	Width (cm)	Height (cm)	Diameter (cm)	Mass (g)
Aluminum block					
Aluminum cylinder					

7. ☐ Measure the mass of the irregular-shaped aluminum object.

Mass of irregular-shaped aluminum object (g): _____

8. ☐ Complete the following steps to measure the volume of the irregular-shaped aluminum object using water displacement.

   a. Put the beaker under the overflow can spout.

   b. Pour water into the overflow can until it overflows into the beaker.

   c. Allow the water to stop overflowing on its own and empty the beaker into the sink.

   d. Place the beaker back in its position under the overflow can spout without touching the overflow can.

   e. Tie a string to the irregular-shaped object and gently lower the object into the overflow can until it is completely submerged.

   f. Allow the water to stop overflowing and then pour the water from the beaker into the graduated cylinder.

   g. Measure the volume that was displaced by reading the water level in the graduated cylinder.

   h. Record the volume of water that was displaced in units of cm^3 (1 mL = 1 cm^3).

   Volume of water displaced (mL): _____

9. ☐ Why do you need to use the water displacement method for the irregular-shaped object?

_____

_____

Part 3 – Unknown Plastic Objects

10. ☐ List at least two qualitative observations about the plastic cylinder.

_____

11. ☐ Table 3 lists three common plastics and their densities. How might you determine the material that the plastic cylinder is made?

Table 3: Density of plastics

Types of Plastic	Density
Polypropylene	0.95 g/cm^3
Nylon	1.15 g/cm^3
Polyvinyl chloride	1.39 g/cm^3

_____

_____

_____

12. ☐ Measure the height, diameter, and mass of the plastic cylinder and record your results in Table 4 below.

Table 4: Dimensions and mass of a plastic cylinder

Object	Height (cm)	Diameter (cm)	Mass (g)
Plastic cylinder			

13. ☐ Clean up your lab station according to the teacher's instructions.

Data Analysis

Part 1 – Brass Objects

1. ☐ Use the following equations to calculate the volumes of the brass block and brass cylinder. Show your work and record your results in Table 5 below.

Volume (block) = length × width × height Volume (cylinder) = height × πr^2

Table 5: Volume of brass objects

Object	Show Your Work Here	Volume
Brass block		
Brass cylinder		

2. ☐ Use the following equation to calculate the densities of the brass block and brass cylinder. Show your work and record your results in Table 6 below.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Table 6: Density of brass objects

Object	Show Your Work Here	Density
Brass block		
Brass cylinder		

3. ☐ Did the shape of the brass object have an effect on the resulting density?

_____

Part 2 – Aluminum Objects

4. ☐ Calculate the volumes of the aluminum block and the aluminum cylinder. Show your work and record your results in Table 7 below.

Table 7: Volume of aluminum objects

Object	Show Your Work Here	Volume
Aluminum block		
Aluminum cylinder		

5. ☐ Calculate the density of the aluminum block, aluminum cylinder, and the irregular-shaped aluminum object. Show your work and record your results in Table 8 below.

Table 8: Density of aluminum objects

Object	Show Your Work Here	Density
Aluminum block		
Aluminum cylinder		
Irregular-shaped aluminum object		

6. ☐ Did the shapes of the aluminum objects have an effect on the resulting densities?

_____

Part 3 – Unknown Plastic

7. ☐ Calculate the volume of the plastic cylinder. Show your work and record your results in Table 9 below.

Table 9: Volume of plastic cylinder

Object	Show your work here	Volume
Plastic cylinder		

8. ☐ Calculate the density of the plastic cylinder. Show your work and record your results in Table 10 below.

Table 10: Density of plastic cylinder

Object	Show your work here	Density
Aluminum block		

9. ☐ From which plastic is the cylinder made?

_____

_____

Analysis Questions

1. **Does the shape of an object affect its density?**

_____

_____

2. **Is it possible for two objects to have the same volume and different densities? Explain your answer and provide evidence from this experiment to support it.**

_____

_____

_____

3. **Which material, brass, aluminum, or plastic, was the most dense?**

4. **Research the accepted values for the densities of aluminum and brass. How do the accepted answers compare to the values you calculated in this experiment?**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Will the brass, aluminum, or plastic cylinder float in water? Explain.**

2. **If a company buys 200 cm^3 of aluminum, how much would you expect the aluminum to weigh?**

3. **A 260-kg tree that is 10 m tall and 25 cm in diameter falls into a river. Explain mathematically why the tree floats, given that the density of water is 1000 kg/m^3.**

4. **Can a very large object have the same density as a very small object? Explain.**

5. **A student has three silver cubes. Although the cubes look the same, one is made of zinc, another is made of lead, and third is made of aluminum. How can the student determine the material that was used to make each cube?**

6. **A rectangular object weighs 2445 g and its density is 12.9 g/cm^3. When measured, its height is 7.43 cm and its width is 3.45 cm. How long is the object?**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **Diamond has a density of 3.26 g/cm^3. What is the mass of a diamond that has a volume of 0.350 cm^3?**

   A. 0.107 g
   B. 1.14 g
   C. 9.31 g
   D. None of the above

2. **What is the volume of a sample of liquid mercury that has a mass of 76.2 g, given that the density of mercury is 13.6 g/mL?**

   A. 0.178 mL
   B. 5.60 mL
   C. 1040 mL
   D. None of the above

3. **Which statement about density is true?**

A. Two samples of nickel may have different densities
B. Density is constant for all types of metals
C. The density of a sample depends on its location on Earth
D. Density is a constant value for all objects made of the same material

4. **A zinc block has a mass of 20 g and a zinc cylinder has a mass of 40 g. How will the density of the two objects compare?**

A. The zinc block will be less dense than the zinc cylinder
B. The zinc block will be more dense than the zinc cylinder
C. The zinc block and the zinc cylinder will have the same density
D. There is not enough information to answer the question

5. **Density equals:**

A. Mass / volume
B. Volume / mass
C. Mass × volume
D. Length × width × height

Key Term Challenge

Fill in the blanks from the list of words in the Key Term Challenge Word Bank.

1. Properties that depend on the amount of material present are called _____ properties, and include _____ and _____. Those properties that are independent of the amount of substance being studied are called _____ properties, and include color, _____, and _____.

2. _____ is the amount of matter in a particular amount of space. Density is the ratio of _____ to _____. Substances with large densities feel _____ for their size. Substances with densities less than 1.0 g/mL _____ in water. To find an object's density, a _____ is used to determine its mass. Volume is found either by using a _____ or by _____. Density can be used to _____ a substance.

Key Term Challenge Word Bank

Paragraph 1

boiling point
chemical
density
extensive
intensive
mass
physical
volume

Paragraph 2

balance
change
cold
density
dissolve
float
gravity
heavy
hot
identify
light
mass
mathematical formula
react
sink
temperature
thermometer
volume
water displacement