Lab: A Penny For Your Thoughts

Background Information:

Density is defined as the ratio of mass to volume, and its formula is density = mass ÷ volume. The units for mass are **grams (g)**. The units for volume are either **cubic centimeters (cm^3)** or **milliliters (mL)**, so the units for **density** can either be **g/cm^3** or **g/mL**.

Density is a physical property that can be used to identify an unknown substance. It is also considered an **intensive property**; that is, the density of an object does not depend on how much of the substance is present. For example the density of water is 1.00 g/ml. Whether you have a drop, a glass, or a bucket of water, its density is always 1.00 g/ml.

Over 2000 years ago King Hieron of Syracuse suspected that the jeweler who made his gold crown had mixed the gold with another cheaper metal. Although the king could measure the mass of the crown, its intricate design prevented measurement of its volume.

King Hieron hired Archimedes, a Greek mathematician, physicist, and engineer to solve his dilemma. Archimedes knew that in order to solve the problem, he had to calculate the density of the crown and match it to the density of pure gold.

While taking a bath, Archimedes noticed the water level rise as he lowered himself into the tub and knew he had the solution. He could find the volume of the crown by measuring how much water it moved, or displaced. (This method is now known as **water displacement**). He was so excited about his great discovery that he ran through the streets of Syracuse naked shouting "Eureka!" which is Greek for "I have found it."

Using the mass and volume of the crown, he calculated the density of the crown. The crown was indeed a fake. Archimedes was a hero!

In this lab, you will measure the mass and volume of two sets of pennies: pre-1982 pennies and 1982 and later pennies. You will then graph the data, calculate the slope of the lines, and determine the density of the pennies.

Materials:

electronic balance
25 pre-1982 pennies
25 1982 and older pennies
50 mL plastic graduated cylinder
tap water

Procedure:

1) Mass five pre-1982 pennies. Record this value to the hundredths place in your data table.

2) Determine the volume of the five pennies by water displacement.
   things to keep in mind when measuring the volume of the pennies:
   - ✓ read the graduated cylinder to the tenths place
   - ✓ read the graduated cylinder at eye-level
   - ✓ slide the pennies into the graduated cylinder gently; avoid splashing any water onto the sides of the graduated cylinder
   - ✓ tap the graduated cylinder on the lab table to eliminate any air bubbles have formed between pennies
   - ✓ keep the pennies in the graduated cylinder until you finish collecting data for all 25 pennies

3) Repeat steps 1 and 2 until you have collected data for at least 25 pennies.

4) Repeat steps 1 – 3 for 1982 and older pennies.

Data: Copy the provided data tables (twice!) into your lab notebook before coming to class. Use a ruler/straight edge and make sure to make a data table for each penny.

Penny Category: Pre-1982 or Post-1982?

Trial Number	Mass	Initial level of water	Final level of water	Volume of pennies
	g	mL	mL	mL
1				
2				
3				
4				
5				

Number of Pennies	Mass	Volume of pennies
	g	mL
5		
10		
15		
20		
25		

Graph:

1. Make a graph of mass vs. volume for each data set. Mass should be on the y-axis, and volume should be on the x-axis. You will plot two lines on this single graph (one line for each data set).

2. Plot points for each set of data (use a different color for each data set and include a legend on the graph). Draw a small circle around each data point.

3. Draw best-fit lines for each data set on your graph (again, use different colors).

4. Find 2 "nice" new points on each best fit line, and make a square around them in yet **another** color.

5. Label the “nice” points (x_1, y_1) and (x_2, y_2) for each line.

Calculations:

1. Calculate the slope of each best-fit line. Include units and significant figures in your answer. Remember the equation of slope is:

$$\text{Slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)}$$

2. According to the US Mint (www.usmint.gov), pennies minted before 1982 are made of copper (density = 8.96 g/ml). Compare your experimental density value with the accepted value by calculating your percent error for the density of a pre-1982 penny:

$$\textbf{Percent Error} = \frac{\textbf{(Experimental Value – Accepted Value)}}{\textbf{Accepted Value}} \times 100\%$$

3. Since 1982, pennies have been comprised of an inexpensive "unknown" metal surrounded by copper plating. The US Mint states that new pennies still contain about 2.5% copper in the plating. Using your experimental density value for post-1982 pennies, and the information provided by the mint, calculate the density of the unknown metal.

4. Determine the identity of the unknown metal using the chart below. Include an explanation of your logic.

Metal	Density (g/cm^3)
Gold	19.32
Iron	7.86
Lead	11.34
Zinc	7.13
Mercury	13.55
Tin	7.3
Titanium	4.5
Silver	10.5
Platinum	21.45
Nickel	8.9

Questions:

1. Explain what the slope of the line on a mass vs. volume graph represents in one sentence.

2. Use your density value to calculate the volume of a 1986 penny that has a mass of 5.0 g. Show your math.

3. Based on your previous experiences, list the following substances in order from the lowest density to the highest. Explain your reasoning.
   lead pipe, water, pine 2" X 4" board, styrofoam peanuts.

4. Identify one area of engineering (applied research) where the density of a material might be important. Be specific and explain your answer.

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