Occasionally the US Department of Treasury changes the composition of pennies, which changes the overall mass and density of each coin. In this experiment, you will determine the average density of two groups of pennies made at different times. Then you will compare the average densities of the pennies in the two groups. In the process, you will apply your knowledge of scientific measurements and significant figures.

Density is a physical property. It can be used in conjunction with other properties to help identify a substance or check on its purity. Conceptually, it is a measure of how closely the particles in the sample are packed together. Density is calculated by dividing the mass by the volume.

$$D = \frac{mass}{volume}$$

Density values for pure substances are tabulated and can be used for comparison to an unknown sample. Density of many substances changes with temperature since many objects expand as they are heated. The table shown below is for metals at 20°C—roughly room temperature.

Metal	Density (g/ml)
Aluminum	2.70
Copper	8.89
Gold	19.33
Iron	7.86
Lead	11.35
Magnesium	1.74
Mercury	13.60
Nickel	8.85
Potassium	0.87
Silver	10.60
Zinc	7.19

Problem
How did changing the composition of pennies in 1982 change the density of pennies?

Objectives
- Determine the average densities of pennies by using mass and volume.
- Compare the average densities of pennies made before and after 1982.
- Infer the change made in the composition of pennies in 1982.
- Using lab equipment for precise measurements
- Applying rules of significant figures in measurements
- Applying rules of significant figures in calculations

Materials
Pre-1982 and post-1982 pennies   Plastic cups
Quad beam balance   cm ruler

Roles Record the names of your group members—make sure this information is included in your lab report.

- Project Manager   _____
  Reads directions; keeps track of time; keeps group on task
- Quality Control Manager   _____
  Approves data table; checks data quality; checks calculations
- Materials Manager   _____
  Gets and returns materials; supervises sharing of materials

Procedure

1. Sort your pennies into two piles. One pile should contain 20 pennies coined prior to 1982, and one pile should contain 20 pennies coined after 1982. You do not want any pennies coined in 1982.
2. Carefully read through the data tables. Use the materials listed above and write out a step-by-step plan in your lab notebook.
3. Have your instructor approve your plan.
4. Collect your data.
5. Answer the analysis questions.

Data and Calculations

Table 1

Volume: Height and Diameter Method	Pre-1982 pennies	Post-1982 pennies
Height of 5 pennies (cm)		
Height of 10 pennies (cm)		
Height of 15 pennies (cm)		
Height of 20 pennies (cm)		
Diameter of 1st penny (cm)		
Diameter of 2nd penny (cm)		
Diameter of 3rd penny (cm)		
Diameter of 4th penny (cm)		
Diameter of 5th penny (cm)		

Table 2

Mass Data	Pre-1982 pennies	Post-1982 pennies
Mass of empty cup (g)		
Mass of cup and 5 pennies (g)		
Mass of cup and 10 pennies (g)		
Mass of cup and 15 pennies (g)		
Mass of cup and 20 pennies (g)		

Calculations: (include the formula and show one sample calculation for each type; report answers with the correct number of significant figures and an appropriate unit)

        The average height of one penny: pre-1982 and post-1982
        The average diameter of one penny: pre-1982 and post-1982
        The average volume of one penny: pre-1982 and post-1982
        The experimental density of pre-1982 pennies and post-1982 pennies

Graph:

        Using the volume of the pennies and the actual mass of the pennies, create a graph of your data. Use volume of the pre-1982 pennies as the independent variable and mass as the dependent variable. On the same graph, but using a different color, plot the data for the post-1982 pennies. For both plots, draw the line of best fit (a different color for each). Calculate the slope of each best-fit line (remember to show your work) and report it with appropriate units and significant figures. You are encouraged to create your graph electronically.

Analyze and Apply

Answer these questions in complete sentences!

1. You calculated the volume of the pennies assuming that the stack was a cylinder.
   a. List three plausible drawbacks of this method.
   b. Suggest an alternative procedure you could use to determine the volume of a penny.

2. Compare your slopes from the graphs with the densities you calculated. Which data set do you think is more accurate? Justify your answer based on the quality of your measurements.

3. According to your data, which group of pennies has the greater average density, pre-1982 or post-1982?

4. Based on the densities of copper and zinc and your calculated densities, do you think the ratio of copper to zinc in the pennies made after 1982 is higher or lower than the ratio of copper to zinc in the pennies made before 1982? Why? Be clear and specific, and use complete sentences.

5. Compare your experimental densities for the pre and post 1982 pennies to the actual densities for pennies pre and post 1982. To determine the actual densities of pre and post 1982 pennies, use your density values for copper and zinc and plug them into the formula below where x and y represent the % composition of copper and zinc.

       $(x)(7.13 \text{ g/mL}) + (y)(8.96 \text{ g/mL}) = \text{density (g/ml)}$

   You will find the following website helpful:

   http://www.usmint.gov/about_the_mint/fun_facts/index.cfm?action=fun_facts2

   Then, to calculate percent error, use the equation below:

   $$\% \ error = 100 * \left| \frac{Accepted \ value - Experimental \ value}{Accepted \ value} \right|$$

6. Why is it important to use the correct number of significant figures when expressing measurements and calculated values based on those measurements?

Remember to write an appropriate conclusion for this lab!
Restate your results—be quantitative. *Based on your data, explain how the composition of the penny was changed in 1982.* Discuss experimental or procedural sources of error, and specifically describe how these errors affected your results.

In your introduction:

- Use picture (particle level) models to compare densities of substances (create your own illustrations!)
- Compare precision and accuracy—explain in your own words
- Compare dependent and independent variables
- Compare intensive and extensive variables—use examples from the lab in your explanation
- Describe types of error: random, systematic—explain in your own words and give examples
- State the overall purpose of the lab

Your introduction needs to demonstrate that you understand and can explain the key concepts explored in this lab. You need to go further than simply providing definitions. This will be submitted via Google Drive as a group formal lab report. Make sure that the editing history reflects the equally shared work. Consider using a different color font for each group member.