Experiment 2
Statistical Analysis of Pennies

Are all pennies created equal?

The scientific method is a process that works in the following sequence; posing a question, hypothesizing about a likely answer, devising an experimental plan to test the hypothesis, performing an experiment, modifying the hypothesis to account for the results, and often performing follow-up experiments to test the new or revised hypothesis, and so on. The question that is posed in this experiment is what happens to the mass of a penny as it circulates. You will initially form a hypothesis (best educated guess) that answers this question. Then we will plan and execute an experiment to test your hypothesis.

Experimental Procedure
Part A

Each student will obtain 15 pennies from the instructor. You must weigh each penny on an analytical balance. *Do not wash the pennies prior to weighing! They must be weighed as is and certainly can not be wet!!!* Record the mass to the fourth decimal place (±0.0001 g). Record the mass and *year* of each penny in your lab notebook. When you are finished, enter the mass and year data set into the Excel spreadsheet on the laptop computer in lab. We will plot the class data, constantly updating the plot as it is added. Toward the end of lab we will save the class data. This data will be used to complete a lab report for this experiment.

for lab report:

1. **Provide a graph of mass vs. year minted.** Use a scatter plot to make the graph. Plot the pre-1983 data and post-1982 data as *two separate series*. Label the axis well and make it look pretty. Add a regression lines to each series in the plot.
2. **Does the mass of a penny increase or decrease as it circulates? Is the change statistically meaningful to the 95 % CL?**
   You can answer this question by using the "Regression" tool that you can find under "Tools" and "Data Analysis". If there is no "data analysis" under your "tool" tab you must add it through the "Add-Ins" function. The regression tool will calculate all kinds of useful things about the linear regression analysis of your data set. For example, it gives you R^2, standard error of regression, the slope (x-variable), intercept, and the standard deviations and 95 % confidence limits for the slope and intercept. For the purposes of this question we want to calculate the 95 % CL for the true mean of the slope; ie. slope $\pm$ (ts)/$n^{1/2}$. The two extreme values of the 95 % CL are calculated for you and listed as upper and lower 95 % CL to the right of the "x-variable". Perform the regression analysis on each of the data sets (pre and post) plotted above using the regression tool to answer these questions.

3. **What do you suppose is causing the mass to decrease (or increase) as a function of mint year?** What could be the possibilities? Can you devise an experiment(s) to test your hypothesis?

4. ***Hypothesize about what is causing the break in the data a 1983***. *Do this in class!*

Experimental Procedure
Part B
Testing your hypothesis

Step1: Determine the density of water based on the laboratory temperature using the data table below.

Step 2: Calibrate the volume of a 25 mL glass graduated cylinder using the mass of water needed to fill it exactly to the 25 mL mark.

Step 3: Determine the density of a set of 15 pennies that pre-date 1983 by using the method of water displacement.
Empty the graduated cylinder. Dry it. Weigh it (be sure the readout on the scale is constant). Record the mass of the dry cylinder. Carefully add 15 pennies to the graduated cylinder. Reweigh the cylinder with the 15 pennies. Record the mass of the dry cylinder plus the 15 pennies. Carefully add water to the cylinder containing the pennies to exactly the 25 mL mark. Be sure no water is splashed on to the sides of the cylinder above the 25 mL mark. Re-weigh the cylinder. Record the mass of the cylinder plus the 15 pennies plus the water. Calculate the average mass and volume of the pennies. *Use the mass of water needed to fill the 25 mL graduated cylinder (step 2) to calculate the volume of the pennies.* Add this data to spreadsheet 2 on the laptop.

Step 4: Repeat step 3 using 15 pennies that are dated post 1983.

Step 5: Toward the end of lab each student will save the class data. This data will be used to complete a lab report for this experiment.

Questions for lab report:

5. **Using all of the class data on the spreadsheet, determine if the volumes of the post-1983 and pre-1983 pennies statistically different to the 95 % CL?** Use the comparison of means, Case 2 discussed on page 70 of your Harris text.
6. **Using all of the class data on the spreadsheet, determine if the densities of the post-1983 and pre-1983 pennies statistically different to the 95 % CL?** Again, use the comparison of means, Case 2 discussed on page 70 of your Harris text.
7. **How is the above difference(s) reflected in the plot from Part A?**
8. **From what pure metal were pennies made prior to 1983?** Do your density measurements support your assertion?

Note to instructor: The change between 1982 and 1983 is dramatic. However, late in 1982 they started to make the new pennies, so that a few 1982 pennies align with the later 1983-present set. You should exclude these couple of points from the class data because they could potential skew the results of the regression analysis.

Temperature (°C)	Density of H_2O (g/mL)
18.50	0.998531
18.75	0.998483
19.00	0.998435
19.25	0.998385
19.50	0.998335
19.75	0.998285
20.00	0.998234
20.25	0.998182
20.50	0.998129
20.75	0.998076
21.00	0.998022
21.25	0.997968
21.50	0.997913
21.75	0.997857
22.00	0.997800
22.25	0.997743
22.50	0.997686
22.75	0.997627
23.00	0.997568
23.25	0.997509
23.50	0.997449
23.75	0.997388
24.00	0.997327
24.25	0.997265
24.50	0.997202
24.75	0.997139
25.00	0.997075
25.25	0.997011
25.50	0.996946