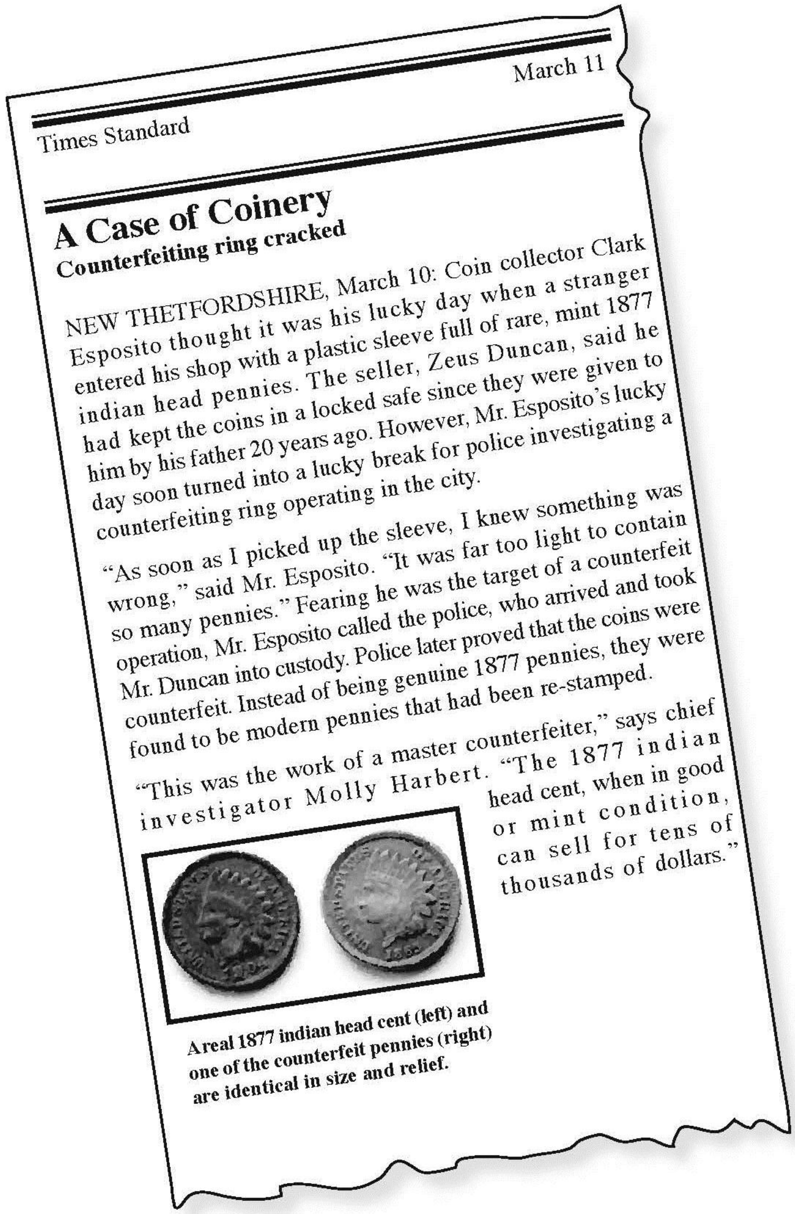
Case File 4

Flipping Coins: Density as a characteristic property

Expose a counterfeiter by proving his "old" coins have a "new" density.



March 11

Times Standard

A Case of Coinery

Counterfeiting ring cracked

NEW THETFORDSHIRE, March 10: Coin collector Clark Esposito thought it was his lucky day when a stranger entered his shop with a plastic sleeve full of rare, mint 1877 indian head pennies. The seller, Zeus Duncan, said he had kept the coins in a locked safe since they were given to him by his father 20 years ago. However, Mr. Esposito's lucky day soon turned into a lucky break for police investigating a counterfeiting ring operating in the city.

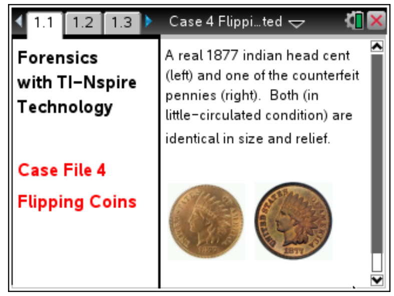
"As soon as I picked up the sleeve, I knew something was wrong," said Mr. Esposito. "It was far too light to contain so many pennies." Fearing he was the target of a counterfeit operation, Mr. Esposito called the police, who arrived and took Mr. Duncan into custody. Police later proved that the coins were counterfeit. Instead of being genuine 1877 pennies, they were found to be modern pennies that had been re-stamped.

"This was the work of a master counterfeiter," says chief investigator Molly Harbert. "The 1877 indian head cent, when in good or mint condition, can sell for tens of thousands of dollars."

A real 1877 indian head cent (left) and one of the counterfeit pennies (right) are identical in size and relief.

About the Lesson

- This lab introduces the concept of density and uses it to distinguish between pennies minted in different years.
- Teaching time: one 45 minute class period



Science Objectives

- Identify counterfeit coins based on the characteristic property of density.
- Model data using a linear equation.
- Interpret the slope and intercept values from a linear model.
- Identify a characteristic property of a substance.

Activity Materials

- TI-Nspire™ technology
- *Case 4 Flipping Coins.tns* file
- *Case_4_Flipping_Coins_Student.doc student activity sheet*
- Vernier EasyLink™ or TI-Nspire Lab Cradle
- Vernier Dual-Range Force Sensor
- clamp or heavy tape
- small plastic cup
- string
- 20 pennies dated 1963–1981
- 20 pennies dated 1982
- 20 pennies dated after 1982

TI-Nspire™ Navigator™

- Send out *Case 4 Flipping Coins.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Teacher Notes and Teaching Tips

- The student activity sheet and .tns file contain the complete instructions for data collection. All assessment questions are also included in both places giving you the flexibility to either collect the .tns files with student data/answers (using TI-Nspire Navigator) or the student activity sheet.
- Before assigning this activity, you may want to review the concept of density, the formula for density (mass divided by volume), and the equation of a line ($y = ax + b$).
- If pennies are scarce, have groups share batches. This is a great place for data capture if you have a Navigator system.
- It is important that the Force Sensor be firmly attached to a stationary object. Simply holding the sensor in place will not be sufficient. You may need to experiment a bit to devise a mechanism to hold the Force Sensor in place on the tables available in your classroom; the image given in the procedure is just a suggestion.

Background Information

As shown in the table, the U.S. Department of the Treasury has changed the composition, and thus the density, of the penny several times.

Date	Penny Composition
1793	Pure copper
1837	95 % copper, 5% tin and 5% zinc
1857	88 % copper, 12% nickel
1864	95% copper, 5% tin and zinc
1943	Zinc coated steel; pure copper in a few
1944	95% copper, 5% tin and zinc
1962	95% copper, 5% zinc
1982	97.5% zinc, 2.5% copper; (copper-coated zinc)

Source: http://www.usmint.gov/about_the_mint/fun_facts/index.cfm?flash=yes&action=fun_facts2

Metal	Density
Copper	8.92
Nickel	8.91
Tin	7.31
Zinc	7.14

The general equation for the density of a coin is the following:

Density =

[(percentage of metal A) × (density of metal A)] + [(percentage of metal B) × (density of metal B)]

Density of pennies from 1963 to 1981 =

$(0.95)\ (8.92\ g/cm^3) + (0.05)\ (7.14\ g/cm^3) = 8.83\ g/cm^3$

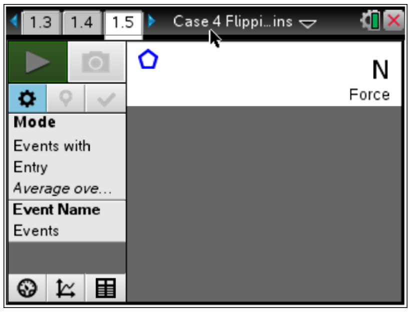
Density of pennies since 1983 =

$(0.975)\ (7.14\ g/cm^3) + (0.025)\ (8.92\ g/cm^3) = 7.18\ g/cm^3$

The composition was changed in 1982 because the cost of making the penny was more than the penny was worth!

Modifications

If you have trouble finding enough 1982 pennies, students can skip that part of the activity.



If students are having trouble understanding how to interpret the equations the data-collection program generates, you may want to have them sketch and label the graphs.

Advanced students can use the chemical composition and density data in the Background Information to calculate and compare the densities of pennies minted in different years and then compare those densities to their experimental data. Depending on how advanced the students are, you may have them research the penny compositions and metal density information themselves. It is important that they understand that the slope of the weight–number-of-pennies line is not actually density (see Case Analysis questions 7 and 8).

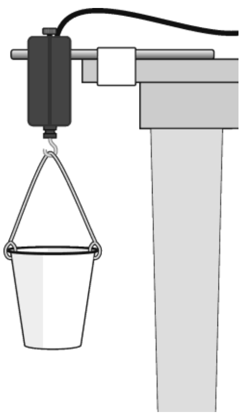
Allow students to read the forensics scenario on the first page of their student activity sheet.

Procedure

Part 1 – Preparing for Analysis

Move to pages 1.2 – 1.6.

Students will need to follow the directions on their student activity sheet or pages 1.2-1.6 to set-up the apparatus as shown here.



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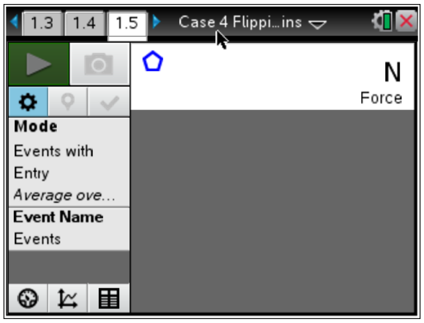
Part 2 – Collecting Data
Move to page 1.4-1.8



Remind students because they want to measure the weight of the pennies only (not the pennies, cup, and string), they will need to zero the Force Sensor. Wait until the reading is stable. Select **MENU > Experiment >Set Up Sensors > Zero**

Part 3 – Analyzing the Data

Move to page 1.9-1.10

Students will now determine the equation that describes the relationship between weight and number of pennies, by adding a linear fit to their data. Select **MENU > Analyze > Curve Fit.**

Evidence Record

SAMPLE DATA

Penny Date	Equation of the Line of Best Fit ***y* = *mx* + *b***
1963–1981	m = 0.030 b = –0.009 R = 0.998 Equation for the line $y = 0.030x - 0.009$
1982	m = 0.023 b = –0.011 R = 0.996 Equation for the line $y = 0.023x - 0.011$
After 1982	m = 0.019 b = 0.033 R = 0.003 Equation for the line $y = 0.019x - 0.033$

Case Analysis

Have students answer the following questions on the handheld, on their activity sheet, or both.

Q1. The equation for a straight line is $y = ax + b$, where x and y are coordinates on the line, a is the slope of the line, and b is the y-intercept (the value of y when $x = 0$).

In this case, y is the weight of the pennies in Newtons, x is the number of pennies, and a is the "density" of the pennies. What are the units of "density" in this equation?

<u>Answer</u>: The units of "density" in this equation are Newtons per penny.

Q2. Explain why the y-intercept, b, should be 0.

<u>Answer</u>: When $x = 0$, there are no pennies being measured. The weight of no pennies should be 0 N.

Q3. Was the value of *b* that you recorded for each group of pennies equal to 0? If not, explain why not.

Answer: Answers will vary. Possible reasons for non-zero *b* values include air currents in the room or movement of the Force Sensor. It is difficult to collect the first point exactly when the Force Sensor measures 0.

Q4. How do the "densities" of the three sets of pennies compare? Based on your measurements, what do you think probably happened to the composition of the penny in 1982?

Answer: The pennies minted before 1982 are denser than the pennies minted after 1982. The density of pennies minted in 1982 falls between the other two groups. The composition of the penny was probably changed in 1982 in a way that made it less dense.

Q5. Use the appropriate equation to determine the weight of 5000 pennies from 1980. Show the equation you used and how you rearranged and/or substituted into the equation. Underline your answer.

Answer: $y = 0.0297\,x - 0.0096$
$y = 0.0297\,(5000) - 0.0096 = \underline{148\text{ N}}$

Q6. Use the appropriate equation to determine the weight of 5000 pennies from 2005. Show the equation you used and how you rearranged and/or substituted into the equation. Underline your answer.

Answer: $y = 0.0186\,x - 0.0332$
$y = 0.0186\,(5000) - 0.0332 = \underline{93\text{ N}}$

Q7. In this activity, "density" is in quotation marks because the slope of the line, *a*, is not actually density; *a* is just a measure of density. Explain why the value of *a* is not really density.

Answer: Density is mass divided by volume. The *a* here equals weight (force, in Newtons) divided by number of pennies. Although a penny is essentially a unit of volume, weight is not the same thing as mass.

Q8. Why can you still use slope, *a*, as a measure of density?

Answer: You can use weight divided by number because you can assume that the ratio of weight to mass does not change and that every penny has the same volume, regardless of the year it was minted. (The ratio of weight to mass does not change because weight is a measure of the force of gravity on a mass. Because every penny is in the same place, the force of gravity is the same on each, so only the mass affects the measured weight.)

Q9. What could have made the penny "densities" you calculated inaccurate?

Answer: If the Force Sensor is not kept stable, the readings can be inaccurate.

Q10. From 1864 to 1962, pennies were made of 95% copper and 5% zinc-tin alloy. From 1962 to 1981, pennies were made of 95% copper and 5% zinc. Since 1983, pennies have been made of 97.5% zinc and 2.5% copper. Zinc is significantly less dense than copper. Tin is slightly more dense than zinc but still much less dense than copper.

If the suspect's coins are genuine 1877 pennies, how should their density compare with the densities of the pennies you measured in this activity?

Answer: They should be denser than any of the pennies in the activity.

Q11. Police measured the weight of five of the suspect's coins and found them to be 0.09 N each. Based on the data you collected, explain how the police knew that the suspect's coins were fakes. Hint: What is the weight of five pennies made after 1982?

Answer: Five pennies from 1877 should weigh significantly more than 0.09 N, which is the approximate weight of five pennies from 2005. Therefore, the suspect's pennies were fakes.

Q12. Correlation is a measure of how well the line fits the data points. A Correlation value near 1.0 indicates that the line is a good fit to the data points. Which group of pennies showed the best fit to a straight line? How do you know?

Answer: Answers will vary. In the case of the sample data, the 1963–1981 pennies showed the best fit (the Correlation value closest to 1.0).