About the Lesson

In this activity, students will model data using a linear equation, interpret the slope and intercept values from a linear model and identify a characteristic property of a substance. As a result, students will:

- Find the equations of the lines that best fit the density data of three different groups of pennies.

Vocabulary

- Linear equation
- Slope
- Y-Intercept
- Mass
- Volume
- Density
- Newton

Teacher Preparation and Notes

- Students should know how to collect data with a probe and the EasyData App.
- Students should be familiar with modeling data with a line.
- Students will be using the EasyData App in this activity.

Activity Materials

- Compatible TI Technologies:

    TI-84 Plus*
    TI-84 Plus Silver Edition*
    🌐TI-84 Plus C Silver Edition
    🌐TI-84 Plus CE

* with the latest operating system (2.55MP) featuring MathPrint™ functionality.

Tech Tips:

- Watch for Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials
- Any required calculator files can be distributed to students via handheld-to-handheld transfer.

Lesson Files:

- I_Am_Your_Density_Student.pdf
- I_Am_Your_Density_Student.doc

Collecting the Data

1. First, you will need to set up your materials:

   a) Use a pencil to poke two small holes on opposite sides of the paper cup, near the top rim. Thread a piece of string through the holes, and then tie the ends of the string together to form a loop to hang the cup from.

   b) Separate each group of 20 pennies into four stacks of 5 pennies each. As you do this, confirm that you have 20 pre-1982 pennies, 20 pennies from 1982, and 20 post-1982 pennies.

   c) Set the range switch on the **Dual-Range Force Sensor** to **±10 N**.

   d) Secure the force sensor to the edge of a table. The sensor must be positioned with the hook closest to the ground and should remain level at all times.

2. Plug the **Dual-Range Force Sensor** into **EasyLink**^TM, and plug **EasyLink** into the USB port on the calculator. The calculator should automatically turn on and take you to the force sensor's main screen.
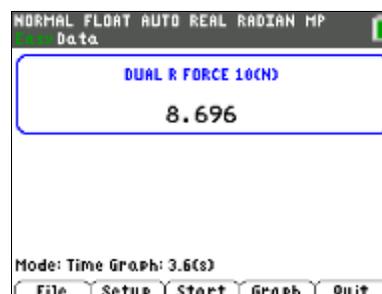
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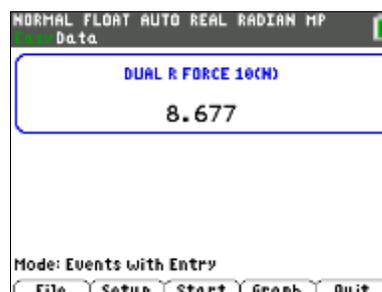
4. Notice that the bottom of your screen says **Time Graph**. You need to change this to **Events With Entry** so that you can tell the calculator when to record the force. Press window to select **Setup** from the main screen. Select option **3: Events with Entry**. Your main screen should now say **Events with Entry** on the bottom.

5. In this experiment, you are to measure only the weight of the pennies, not including the cup and string. To tell the calculator to ignore the weight of the cup and string, you need to first "zero" the force sensor:

a. Hang the empty cup from the hook on the force sensor.

b. Press p to select Setup, and select option 7:Zero.

c. Wait until the reading is stable and the cup is not moving. Select Zero (not 0) to zero the force sensor. This will set the current weight reading to 0 N, so the sensor will ignore the weight of the cup and the string.

6. You are now ready to record the weights of different numbers of pennies:

    a) The empty cup should be hanging from the hook on the force sensor. Press ⌜zoom⌝ to select **Start** and begin data collection.

    b) When the weight reading of the empty cup is stable (very close to 0), select **Keep**.

    c) The calculator will then ask you to enter a value. Type ⌜0⌝ for the number of pennies now in the cup. Select **OK** to store this weight-number data pair.

    d) Place five of the pre-1982 pennies in the cup, and wait until the reading is stable. Select **Keep**.

    e) Type ⌜5⌝ as the value for the number of pennies in the cup. Select **OK** to store this weight-number data pair.

    f) Continue with this procedure, using increasing numbers of pennies from before 1982. Each time you keep a data pair, enter the *total* number of pennies in the cup as the number value.

    g) Select **Stop** when you have finished collecting data for the pre-1982 pennies.

7. The calculator screen will now show a graph with number of pennies on the x-axis and weight in newtons on the y-axis. The graph should appear linear (a straight line). If it does not, press ⌜trace⌝ to select **Main** to return to the main screen, and then repeat steps 4 and 5.
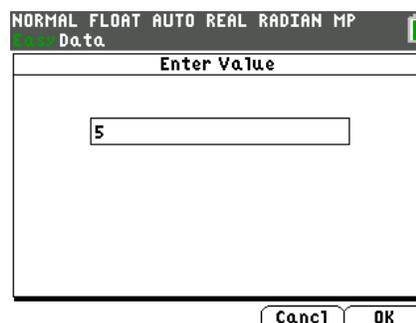
8. Determine the equation that describes the relationship between weight and number of pennies:

   a) Press ⌷zoom⌷ to select **Analyz**.

   b) Select option **2:Linear Fit**. This will tell the calculator to compute the equation of the straight line that best fits your data.

   c) The calculator will display values for **a, b**, and **R**. **Record these values in the data table below.**

   d) The equation of a straight line is y = ax + b. Using the values shown on the screen, write the equation that best fits your data for pre-1982 pennies into the data table. (For example, if a = 3 and b = 5, the equation for the line is y = 3x + 5.)

   e) Select **OK** to plot a line through the data points. Make a quick sketch of this graph next to the information you gathered in the data table.

   f) Select **Main** to return to the main screen.

9. Repeat steps 4-7 for the pennies <u>dated 1982</u>.

10. Repeat steps 4-7 for the pennies <u>dated after 1982</u>.

Data Table: *Student answers will vary.*

Penny date	Equation of the best-fit line	Sketch of graph
1963–1981	a: 0.029 b: 0.018 R: 0.998 Equation (y = ax + b): y = 0.029x + 0.02	
1982	a: 0.029 b: 0.007 R: 0.999 Equation (y = ax + b): y = 0.029x + 0.007	
post-1982	a: 0.025 b: -0.001 R: 0.9998 Equation (y = ax + b): y = 0.025x + 0	

Data Analysis

1. 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?

   Answer: Weight (in newtons) divided by number is "density," so the units are N/penny.

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

   Answer: The value of b is the weight of zero pennies*.*

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

   Answer: The value of b was about 0 for each group (-0.001 – 0.018).

4. 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 pre-1982 and 1982 pennies have "densities" of about 0.029, and the post-1982 pennies have lower "densities," of about 0.025. This indicates that pennies have been made of lighter materials since 1982.

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

   Answer: Density is really mass per volume, not weight per penny.

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

    Answer: You can use a as a measure of density because weight depends on mass and you can assume that most pennies have the same volume.

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

    Answer: In reality, pennies gain mass, when dirt and other substances adhere to them, and lose mass, when they are worn down. The "density" of a very worn, very clean penny will be lower than when it was new.

8. **R** is a measure of how well the line fits the data points. A large value of **R** 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?

    Student answers will vary*.*

    Sample response*:* For R values of 0.996, 0.997, and 0.998, the pennies with the 0.998 R value show the best fit to a straight line