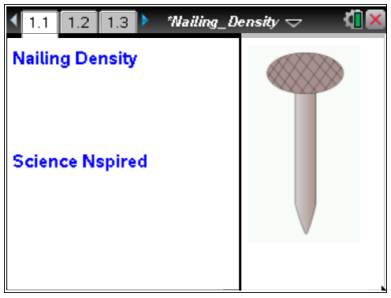
Science Objectives

- Students will determine the relationship between mass and volume.
- Students will mathematically describe the relationship between mass and volume.
- Students will relate the slope of a line to a physical property (density).



Math Objectives

- Students will generate a linear least-squares line from mass and volume data.
- Students will analyze a linear mathematical relationship.

Materials Needed

- Five (5) different-sized nails of the same material (7, 8, 9, 10, or 12 penny nails)
- 0.01g balance
- 10 or 50-mL graduated cylinder (depending on the size of the nails)

Vocabulary

- mass
- volume
- density

About the Lesson

- This lesson involves determining the mass and volume of five nails.
- As a result, students will:
  - Determine the relationship between mass and volume.
  - Graph the mass and volume of each nail.
  - Mathematically describe the relationship between mass and volume.
  - Generate a linear least-squares line from mass and volume data.
  - Relate the slope of a line to a physical property (density).

TI-Nspire™ Navigator™ System

- Screen Capture to monitor student progress.
- Live presenter allows students to show their graphs to the class.

TI-Nspire™ Technology Skills:

- Download a TI-Nspire™ document
- Open a document
- Move between pages
- Entering and graphing data
- Tracing and interpolating

Lesson Materials:

Student Activity

- Nailing_Density_Student.pdf
- Nailing_Density_Student.doc

TI-Nspire document

- Nailing_Density.tns

Discussion Points and Possible Answers

Mass can be measured using a balance.
Volume can be calculated from the dimensions of a regularly-shaped object. For irregularly- shaped solids, water displacement can be used to determine the volume. The volume of water is measured before and after the irregular solid is added to the measuring device. The difference in volume is the volume of the object.
Another property of matter is **density**. Density is defined as the mass per unit volume of a substance. The formula for density is $D = \frac{m}{V}$ where *D* is density, *m* is mass, and *V* is volume. If the mass and the volume are known, the density can be calculated using the density formula.
The units of density are commonly g/mL or g/cm^3 for liquids and solids. For gases, the density is often expressed in g/L since gases are much less dense than solids or liquids. Density is an intensive property that is NOT dependent on the amount of the substance that is measured.

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1. The volume of an irregular object is most easily determined by_____.

   Answer: Water displacement.

2. Which is heavier-a pound of feathers or a pound of lead?

   Answer: Neither.

3. Explain your answer to the previous question.

   Answer: Neither a pound of feathers nor a pound of lead is heavier—their mass is both equal to one pound. However, the lead has a much greater density since the volume of one pound of lead would be much less than the volume of pound of feathers.

4. Density is defined as_____.

   Answer: mass per unit volume

5. Which one of the following is not a unit of density?

   a. g/mL
   b. g/cm3
   c. g/L
   d. L/g

   Answer: d. L/g

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Nails will be provided by your teacher.

6. Add enough water to the graduated cylinder to cover the tallest nail (do NOT add the nails to the water yet).
7. Read the initial volume to the nearest 0.1 mL, and record it in the spreadsheet on Page 2.1 under **volw** for 0 nails.
8. Measure the mass of the first nail to 0.01 g, and record it under **massn** for 1 nail.
9. Gently let one nail slide head first into the tilted cylinder, and measure the new volume under **volw** for 1 nail.
10. Repeat this procedure for the four remaining nails, accumulating all of the nails in the graduated cylinder.
11. Calculate the **total mass** of nails in the spreadsheet by adding each to the previous total using cell notation (in cell C2 enter =C1+B2). Repeat for the four remaining nails.
12. Calculate the **volume** of each nail by subtracting the previous water volume from the current (in cell E2 enter =D2-D1). Repeat for the remaining four nails.
13. Calculate the **density** of the nails by dividing the mass of the nail by its volume (enter = **massn/voln** in the formula bar under **dens**).

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14. On the Data & Statistics page (Page 2.2), explore some graphs by clicking an axis and choosing the variable you want to plot.
15. Plot **massn** vs. **voln**, and determine the best fit line for the nails' volume and mass relationship by selecting **MENU > Analyze > Regression > Show Linear(mx + b)**.
17. Plot **masst** vs. **volw** and again find the best line.
    - Cycle between the last two graphs to see the similarities and differences.

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18. a. What is the regression equation for your graph?

Answer: ~ y = 7.85x + 0

Sample Data: (steel nails)

Mass of nail (**massn**) g	Water volume (**volw**) mL
0	27.0
4.3	27.5
7.06	28.5
7.73	29.5
9.64	30.8
15.13	32.8

b. What is the slope of the line?

Answer: ~7.85 g/mL

c. What would the units of the slope be?

Answer: g/mL

19. The formula for Density is $D = \frac{m}{V}$, where *D* is density, *m* is mass, and *V* is volume. Rearrange the formula for density by isolating mass instead of density.

Answer: *m* = *DV*

20. Rewrite the regression equation from the *Data & Statistics* page, replacing the "*x*" variable with *V* for volume and the "*y*" variable with m for mass.

Answer: *m* = 7.85*V* + 0

21. How does the rearranged $D = \frac{m}{V}$ equation from question 19 compare with the equation that you wrote for question 20? Explain.

Answer: The equations are the same.

22. a. What does the slope of the graph on the *Data & Statistics* page represent?

    Answer: The density.

    b. What unit(s) would be assigned to the slope of this graph?

    Answer: g/mL

23. Why are the densities calculated for each nail not exactly the same and not exactly equal to the slope of the line?

    Sample Answers: Because of experimental errors.

24. Use the Internet to visit http://www.engineeringtoolbox.com/metal-alloys-densities-d_50.html. Use this page to identify the element or metal alloy whose properties would match the density that you calculated for the nail. Remember that 1 kg/m^3 = 0.001 g/cm^3 and that 1 cm^3 = 1mL.

    Answer: Iron and steel.

25. Refer to the data that was collected. What effect does increasing the mass of the nail have on the volume of the nail?

    Answer: The volume increases.

26. Refer to the data that was collected. What effect does increasing the mass of the nail have on the density of the nail?

    Answer: The density is unchanged.

26. Which of the following is NOT true of the density of a substance?
    a. intensive property
    b. extensive property
    c. characteristic or identifying property
    d. temperature dependent

    Answer: b. Extensive property.

27. Summarize what you have learned about density from this experiment.

Sample Answers: Answers will vary. The density of a substance is a constant, independent of mass and volume and only changes with temperature. Density is an intensive property that is characteristic of a substance. Density can be used to identify a substance.

TI-Nspire Navigator Opportunity: *Screen Capture*
See Note 1 at the end of this lesson.

Wrap Up

Upon completion of this discussion, the teacher should ensure that students understand:

- The relationship between mass and volume.
- The relationship between the slope of a line and density.

Assessment

Formative and summative assessment questions are embedded in the TI-Nspire™ document. The questions will be graded when the TI-Nspire™ documents are retrieved. The Slide Show can be utilized to give students immediate feedback on their assessment.

TI-Nspire Navigator Notes

Note 1: Screen Capture

Screen Capture can be used to monitor student progress.