Canister Conundrum

Determining Mass Indirectly

MATERIALS AND RESOURCES

EACH GROUP

balance

5 known film canisters

unknown film canister

TEACHER

1 box paper clips, jumbo

ABOUT THIS LESSON

In this inquiry lesson, students are given a real-world scenario and the task of finding the mass of one paper clip and the mass of an empty film canister using an indirect method of measurement. This activity relies on students' prior knowledge of graphing, slope, and linear regression. This activity should be performed in conjunction with "Barbie® Doll Bungee Jumping," where students learn a protocol that will allow them to solve the puzzle presented here.

OBJECTIVES

Students will:

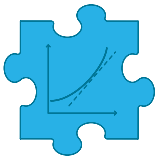
- Create a procedure to determine the mass of an object without directly measuring the mass of the object
- Construct a data table and determine what data to collect
- Generate a graph of that data and decide what the resulting linear regression represents

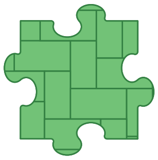
LEVEL

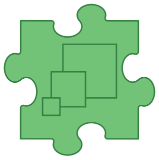
Middle Grades: General

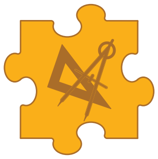
NEXT GENERATION SCIENCE STANDARDS


PLANNING/CARRYING OUT INVESTIGATIONS


ANALYZING AND INTERPRETING DATA


PATTERNS


SCALE, PROPORTION, AND QUANTITY


ETS1: ENGINEERING DESIGN

ASSESSMENTS

The following types of formative assessments are embedded in this lesson:

- Visual assessment of student-generated data tables and graphs

COMMON CORE STATE STANDARDS

(LITERACY) RST.6-8.1

Cite specific textual evidence to support analysis of science and technical texts.

(LITERACY) RST.6-8.3

Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

(LITERACY) RST.6-8.7

Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

(LITERACY) WHST.6-8.1

Write arguments focused on discipline-specific content.

(LITERACY) WHST.6-8.2

Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

(MATH) 6.EE.C

Represent and analyze quantitative relationships between dependent and independent variables.

(MATH) 7.EE.B

Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

(MATH) 7.RP.A

Analyze proportional relationships and use them to solve real-world and mathematical problems.

(MATH) 8.EE.B

Understand the connections between proportional relationships, lines, and linear equations.

(MATH) 8.EE.C

Analyze and solve linear equations and pairs of simultaneous linear equations.

(MATH) 8.F.A

Define, evaluate, and compare functions.

(MATH) 8.F.B

Use functions to model relationships between quantities.

(MATH) 8.SP.A

Investigate patterns of association in bivariate data.

TEACHING SUGGESTIONS

This activity is an inquiry lab that draws on students' prior knowledge of graphing, slope, and linear regression. Students will know the formula for a line ($y = mx + b$) and what the slope and y-intercept of a line represent prior to completing this activity if they have completed the lesson, "Barbie® Doll Bungee Jumping."

This activity will allow students to apply these concepts to solve a problem and give the teacher insight into their true understanding of these relationships. This activity has many implications for various scientific endeavors, for example, utilizing graphing skills to indirectly find atomic mass.

Students are provided with five sealed film canisters containing a known number of paper clips and asked to determine both the mass of a single paper clip and the number of paper clips in the unknown opaque canister. They will measure the masses of each of the known paper clip containers and use a graph to determine the mass of a single paper clip (slope), the mass of the empty container (y-intercept), and the number of paper clips in an "unknown" canister (interpolation).

If film canisters are not available, condiment cups with lids, baby food containers, padded envelopes, and other packaging containers could be used. The criteria are that the container remains sealed and has a similar mass in all cases. If the container is not naturally opaque, you could cover the outside with paint, tape, or paper so long as all containers maintain the same approximate mass.

The paper clips could be replaced with pennies (all dated post-1982), nickels, or anything with a mass that is consistent.

SAMPLE PROCEDURE, DATA, AND ANALYSIS

1. Determine the mass of the canisters with the known number of paper clips.
2. Graph mass vs. number of paper clips, including the line of manual fit.
3. Determine the slope $\left(\frac{\Delta y}{\Delta x}\right)$ and y-intercept of the line of manual fit.
4. The slope represents the mass of one paper clip, and the y-intercept represents the mass of the film canister.

Table A. Sample Data

Number of Paper Clips	Mass of Container with Paper Clips (g)
5	10.73
7	12.76
9	15.04
11	17.38
13	18.88
Unknown	Varies

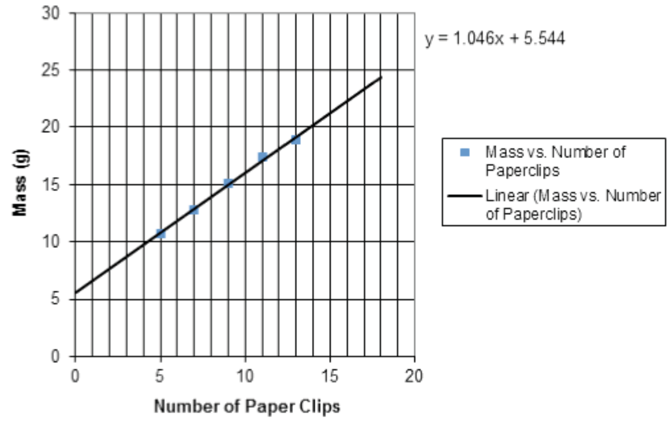


Figure A. Mass vs. number of paper clips

TEACHER PAGES

PROCEDURE

SAMPLE PROCEDURE

1. Mass the canisters with the known number of paper clips.
2. Graph mass vs. number of paper clips, including the line of manual fit.
3. Determine the slope $\left(\frac{\Delta y}{\Delta x}\right)$ and y-intercept of the line of manual fit.
4. The slope equals the mass of one paper clip and the y-intercept equals the mass of the canister.

DATA AND OBSERVATIONS

SAMPLE DATA

Table B. Sample Data

Number of Paper Clips	Mass of Container with Paper Clips (g)
5	10.73
7	12.76
9	15.04
11	17.38
13	18.88
Unknown	Varies

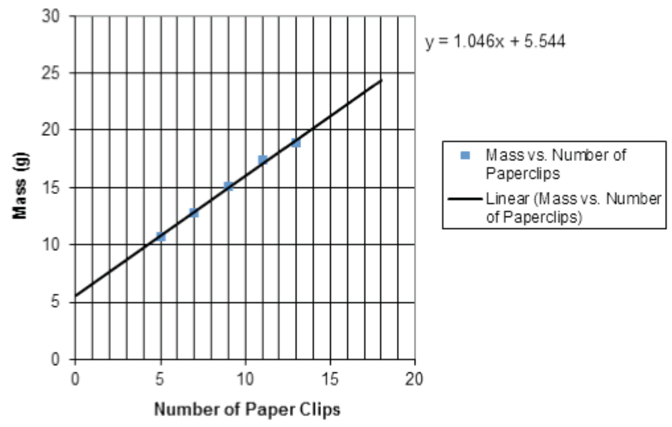


Figure B. Mass vs. number of paper clips

ANSWER KEY

ANALYSIS

1. Determine the number of paper clips in your unknown canister using two methods:
   a. Place an "X" on your graph at the point that represents the mass and number of paper clips in your unknown sample. Record the number of paper clips in the space provided.

   The number varies depending on the number of paper clips. However, students should use interpolation to determine the even number of paper clips in their canister

   b. Using the formula for the line of best fit from your graph, determine the number of paper clips in your unknown sample. Show your work and record your answer in the space provided.

   Final answers will vary based on the unknown canister.

$$y = 1.046x + 5.544$$

$$\text{mass}_{\text{unknown}} = 1.046(\text{number}_{\text{paper clips}}) + 5.544$$

$$\text{number}_{\text{paper clips}} = \frac{\text{mass}_{\text{unknown}} - 5.544}{1.046}$$

2. Use your graph to determine the mass of your canister containing 15 paper clips. Place a small circle on your graph at the point that represents the mass, and record this value in the space provided.

   Students should inspect the graph for the intersection of the plotted line and $x = 15$ (paper clips). The y-value of the intersection of these two lines will represent the mass of 15 paper clips. For the sample data, the mass of 15 paper clips is most nearly 21 g.

3. What would be the mass of a canister with 100 paper clips? Show your work and record your answer in the space provided.

$$\text{mass}_{\text{canister}} = 1.046(\text{number}_{\text{paper clips}}) + 5.544$$

$$\text{mass}_{\text{canister}} = 1.046(100) + 5.544 = 110.1 \text{ g}$$

CONCLUSION QUESTIONS

1. Did the two methods for determining the number of paper clips in your unknown canister yield the same result? Justify your answer by citing evidence from your data.

   Student answers will vary, but the two methods should yield similar results.

2. Would your graph allow you to determine the mass of 10 nickels? Why or why not?

   No, this graph only applies to the size of paper clips used. No other objects could be determined using this graph.

3. Would this type of graph allow you to determine the mass of 10 seashells? Why or why not?

   No, seashells vary in mass and thus this method would not work.

4. Chemists use a similar concept to count atoms. Explain how the mass of a sample of atoms can provide an accurate count of the number of atoms based on what you have experienced in this activity.

   Once the mass of an individual atom is known (from the periodic table) the number of grams of sample can be divided by the mass of the individual atom to yield the number of atoms present.

   In chemistry, because atoms are so small we use a unit called the *mole* to represent a group of 6.02×10^{23} atoms. The atomic mass on the table represents the mass in grams that has to be measured to contain exactly 6.02×10^{23} atoms of that element.

   For example, if you have a sample of gold that weighs 196.97 g, there will be almost exactly 6.02×10^{23} atoms of gold in that sample.

NATIONAL MATH + SCIENCE INITIATIVE

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MATERIALS

balance

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unknown film canister

A paper clip packaging company has had a major malfunction with its counting machine. The company cannot get the machine fixed or replaced for five days. Not wanting to shut down the company for this time period, they are looking into alternative ways of counting paper clips.

Counting 100 paper clips is a tedious task when done by hand. Instead of counting the paper clips individually, the company would like to package the paper clips by mass. If they do not get the correct mass, the number of paper clips in the package will not be correct and this could affect profits.

They have asked you to determine the mass of one paper clip using indirect methods of measurement. The task given to you is to find the mass of one paper clip and the mass of the empty packaging canister.

PURPOSE

In this activity, you will determine the mass of a single object without directly measuring the mass of that object.

PROCEDURE

Record the procedures you developed to determine the mass of one paper clip and the mass of the empty canister.

DATA AND OBSERVATIONS

Create your data table here.

Mass of one paper clip = ________________________

Mass of the empty canister = _____________________

ANALYSIS

1. Determine the number of paper clips in your unknown canister using two methods:
   a. Place an "X" on your graph at the point that represents the mass and number of paper clips in your unknown sample. Record the number of paper clips in the space provided.

   b. Using the formula for the line of best fit from your graph, determine the number of paper clips in your unknown sample. Show your work and record your answer in the space provided.

2. Use your graph to determine the mass of your canister containing 15 paper clips. Place a small circle on your graph at the point that represents the mass, and record this value in the space provided.

3. What would be the mass of a canister with 100 paper clips? Show your work and record your answer in the space provided.

CONCLUSION QUESTIONS

1. Did the two methods for determining the number of paper clips in your unknown canister yield the same result? Justify your answer by citing evidence from your data.

2. Would your graph allow you to determine the mass of 10 nickels? Why or why not?

3. Would this type of graph allow you to determine the mass of 10 seashells? Why or why not?

4. Chemists use a similar concept to count atoms. Explain how the mass of a sample of atoms can provide an accurate count of the number of atoms based on what you have experienced in this activity.