Half-Life Pennies

Subject Area(s) Math, Science
Associated Unit: N/A
Associated Lesson: N/A
Activity Title: Half-Life Pennies

Grade Level 7 (6-8)
Activity Dependency Knowledge of addition, subtraction
Time Required 60 minutes
Group Size 2
Expendable Cost per Group: $2

Summary: The goal of this activity is to familiarize students with exponential decrease through a demonstration of how radioactive elements decay over time. Additionally this activity serves to improve the student’s ability to create data tables and to create graphs from those data tables.

Engineering Connection: Radioactive materials are used in nuclear power plants to provide clean, efficient, cheap power. These materials all have a unique half-life, or speed at which they decay which must be known in order to use the materials in nuclear power plants, nuclear submarines or other devices powered with these materials.

Keywords: math, exponential decrease, decay, radioactive
Educational Standards
• Math: 2.8B, 2.8C, 2.8D, 2.8E, 2.1D, 2.3A, 2.9F, 2.9K

Pre-Requisite Knowledge:
• Ability to add and subtract.
• Basic understanding of setting up and filling in data tables
• Ability to graph data from data tables.

Learning Objectives
After this lesson, students should be able to:
• Discuss how radioactive materials decay
• Create data tables from experimental data
• Create graphs from experimental data

Materials List
Each group needs:
• One Shoebox
• 100 pennies
• Graph paper
• Data table

Introduction / Motivation
Exponential decrease is a surprisingly relevant topic that comes from mathematics. It turns out to be a very important idea to grasp in order to understand radioactive half-life. If we look at a radioactive material over time it turns out that within a fixed amount of time half of the atoms decay or give off energy. This means that if we know how long it takes for that to happen (half-life) and how much of the material we start with we can create an exponential curve describing the entire life of our radioactive sample.

Engineers and scientists uses this type of information to calculate how much material will be needed for a certain period of time or how long a sample will last in a nuclear submarine or nuclear power plant. These types of calculations are important so that too much of the material or not enough of the material is purchased and used in these devices. This context also provides an interesting way to reinforce the concept of exponential decrease and to show with graphs how it is different from a simple linear decrease that students are often much more comfortable graphing and studying.
### Vocabulary / Definitions

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Radioactivity</td>
<td>Emission of radiation from the nucleus (center) of an atom</td>
</tr>
<tr>
<td>Plutonium</td>
<td>Radioactive material often used in nuclear power plants</td>
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<tr>
<td>Half-life</td>
<td>Time it takes for half of the atoms in a radioactive material to decay</td>
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<tr>
<td>Exponential</td>
<td>Decreasing at a ratio proportional to its value. As an example half of the material is gone every second.</td>
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## Procedure

### Background

Radioactive materials have become an important part of our everyday lives. Nuclear power plants use radioactive elements, such as plutonium, to produce very clean and safe power. Plutonium is a very unstable element and the nucleus, or center, of these atoms loses energy by emitting particles and radiation at a particular rate. When these reactions occur and energy is lost it is referred to as radioactive decay. This decay happens at a particular rate for each radioactive material and the rate at which it happens is called the material’s half-life. Half-life is simply a measure of how long it takes for half of the atoms in a sample of material to go through the process of radioactive decay. This time is different for each material. Let’s do an example. Plutonium 239 (a particular type of plutonium) has a half-life of 24,100 years. This means half of the atoms will decay every 24,100 years. If we start with 100 atoms, how many years would it take for us to only have 25 atoms left?

We start with 100 atoms. After the first, half life we only have 50 atoms left. After one more half-life we have the 25 atoms left. This means we went through two half-lives to get to 25 atoms.

One half-life=24,100 years  
24,100 X 2 half-lives = 48,200 years

Engineers often do half-life calculations to figure out how many years a particular sample of radioactive material will last in a nuclear power plant or in a nuclear submarine.

The really interesting thing about half-life is that when you graph it for a particular example the graph looks like the exponential decrease you learn about in math class! Let’s do an experiment to show those curves and give us an idea of how radioactive decay works.

### Before the Activity

- Have the students explain what half-life is in their own words and write down that explanation in their notebooks.
With the Students

Have the students perform the following steps:
1. Place 100 pennies in the box so that all of them are tails side up
2. Shake the box (remember exactly how many times you shook the box so you can do the same thing next time).
3. Remove all the pennies that are now heads side facing up from the box
4. Count the number of pennies removed
5. Record the number of pennies removed and the number of pennies still in the box in your data table.
6. Repeat the process until all of your pennies have been removed
7. Create a graph showing each iteration of shaking the box vs. how many pennies remained

Safety Issues
• None

Troubleshooting Tips
• Sometimes the last penny will take a lot of iterations to finally flip. This is ok and expected. Simply have the students continually record in their data table that 1 penny remains in the box for each iteration.

Investigating Questions
1. What do the pennies represent?
2. Describe the shape of your graph.
3. How is the penny experiment connected to the idea of radioactive materials?
4. What would happen if the heads side of the pennies was weighted (meaning heavier than the tails side)?
5. Predict how your data would change if you did not remove the heads side up pennies.

Assessment

Pre-Activity Assessment
Students should write a short paragraph in their notebooks describing half-life in their own words and relating that to the mathematical concept of exponential decrease.

Activity Embedded Assessment
Graphs and data tables should be used as an activity embedded assessment. Check that all tables and graphs are properly labeled and data is represented correctly.

Post-Activity Assessment
Students should answer the investigation questions and turn in their responses in full sentence form.

Activity Extensions
There is a very simply to do extension of this activity that demonstrates how one radioactive material will decay into another material and then that material would decay into an unusable product. To perform this start with nickels in the box instead of pennies and perform the box
shaking as described before. Instead of simply removing the nickles and recording how many are left, record the number of nickels left in the box and then replace the nickels you removed with pennies (tails side up). Perform the same iterations and when the pennies are heads side up remove them from the box. Record both the nickels and the pennies in your data table.

Activity Scaling
• 6th graders can perform the activity as is and it will provide a nice advanced discussion of exponential decrease so that when they see it again in 7th grade it will simply be a review.
• Higher grades can perform the base activity described as well as the extension described in the above activity extensions section.

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