Earthquake Energy

Grades
9-12

Overview:

In this lesson, students calculate the amount of energy released in an earthquake. This lesson assumes students have some understanding of logarithms and scientific notation.

Targeted Alaska Grade Level Expectations:

Science

[9] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[10-11] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

Math

[10] E&C-2 The student accurately solves problems (including real-world situations) by applying basic operations with real numbers using powers [and scientific notation L] (M3.4.2 & M3.4.3)

[9-10] F&R-1 The student demonstrates conceptual understanding of functions, patterns, or sequences including those represented in real-world situations by describing or extending patterns (families of functions: linear, quadratic, absolute value) up to the nth term, represented in tables, sequences, graphs, or in problem situations (M4.4.1)

[9] F&R-4 The student demonstrates conceptual understanding of functions, patterns, or sequences including those represented in real-world situation by using a calculator as a tool when describing, extending, representing, or graphing patterns or linear equations (L) (M4.4.2)

[10] F&R-4 The student demonstrates conceptual understanding of functions, patterns, or sequences including those represented in real-world situations by using a calculator as a tool when describing, extending, representing, or graphing patterns, linear, equations, or quadratic equations (L) (M4.4.2)

[9] PS-5 The student demonstrates the ability to apply mathematical skills and processes across the content strands by using real-world contexts such as science, humanities, peers, community, careers, and national issues (M10.4.1 & M10.4.2)

Objectives:

The student will:

- calculate the amount of energy released by earthquakes of various magnitudes;
- graph the relationship between energy expended and magnitude.

Materials:

- Scientific Calculator
- STUDENT WORKSHEET: “Earthquake Energy”
- STUDENT WORKSHEET: “Earthquake Energy Excel” (optional)
- VISUAL AID: “Common Magnitude Measurements”
- VISUAL AID: “Earthquake Frequency in Alaska”

Whole Picture:

Magnitude is a quantitative description that is related to the amount of energy released by an earthquake. This is determined by examining the amplitude of seismic waves at known distances from the epicenter using a seismograph. The magnitude scale is logarithmic, meaning that the shaking from a magnitude 5 earthquake will be 10 times larger than from a magnitude 4 earthquake at the same distance. However, the total amount of energy released from a magnitude 5 earthquake will be 32 times larger than from a magnitude 4 earthquake. There are many different ways that seismologists measure magnitude, depending on how large and deep an earthquake is and what type of seismometer is recording the shaking. The most common ways to report magnitudes today are listed on the VISUAL AID: "Common Magnitude Measurements."

The joule is a unit of measure for energy. A joule is equivalent to 1 Newton exerted over a distance of 1 meter.

$$1\ J = 1\ N \bullet m$$

Some points to consider:

- One joule represents the approximate amount of energy it takes to lift an apple one meter from the ground. An apple weighs about one Newton.
- The average amount of energy expended by one person in a year in the United States is 10^{12} joules.
- The energy expended to put the space shuttle into orbit is 10^{13} joules.
- The energy expended by the atomic bomb explosion at Hiroshima, Japan was 10^{14} joules.

The energy released in an earthquake may be expressed as:

$$\log E = 1.44 M_s + 5.24$$

or,

$$E = 10^{1.44M_s + 5.24}$$

where E is the energy released by the earthquake in joules and M_s represents surface wave magnitude.

Activity Procedure:

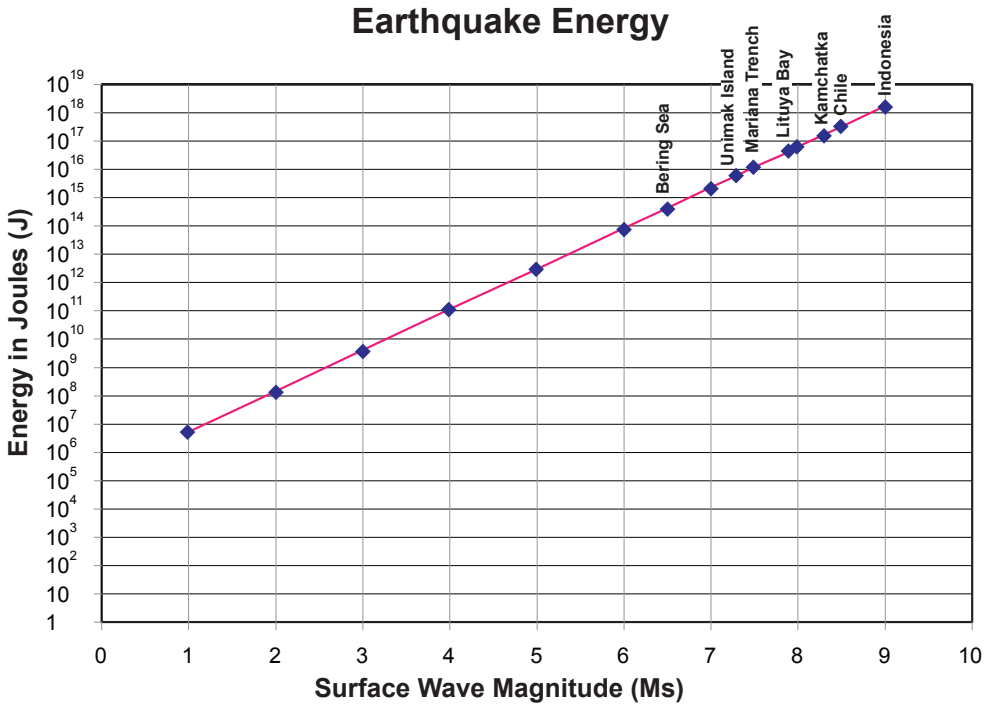
1. Explain that students will explore the energy output related to earthquakes, including tsunami-generating earthquakes affecting Alaska's coastline.
2. Share information about magnitude using information from the Whole Picture section. Display VISUAL AID: "Common Magnitude Measurements" to aid in explaining the various types of magnitudes. Then display VISUAL AID: "Earthquake Frequency in Alaska" to help explain the frequency of various sizes of earthquakes in Alaska.
3. Distribute scientific calculators and the STUDENT WORKSHEET: "Earthquake Energy." If students are to use Excel for calculations, also distribute STUDENT WORKSHEET: "Earthquake Energy Excel." Review information on the sheets and then students complete worksheets.

Extension Ideas:

- Graph the data using Excel.
- Use VISUAL AID: "Earthquake Frequency in Alaska" and calculate the total amount of energy expended by earthquakes in Alaska each year. Compare the energy released in the few large earthquakes to the many small earthquakes.

Answers:

1. 4786300.9 or 4.7863×10^{6}
2. 1.3183×10^{8}
3. 3.6308×10^{9}
4. 1×10^{11}
5. 2.7542×10^{12}
6. 7.5858×10^{13}
7. 2.0893×10^{15}
8. 5.7544×10^{16}
9. 1.5849×10^{18}
10. 5.6494×10^{15}
11. 1.556×10^{17}
12. 4.1305×10^{16}
13. 3.02×10^{17}
14. 1.0965×10^{16}
15. 3.9811×10^{14}
16. 1.5849×10^{18}
17. See table below.



Lesson Information Sources:

Lillie, R. J. (1999). *Whole earth geophysics: An introductory textbook for geologists and geophysicists.* Upper Saddle River, N.J.: Prentice Hall.

Alaska Earthquake Information Center. www.aeic.alaska.edu

National Geophysical Data Center. NOAA/WDC Historical Tsunami Database at NGDC. http://www.ngdc.noaa.gov/hazard/tsu_db.shtml

Name:_____

Earthquake Energy

Student Worksheet (page 1 of 2)

Grades 9-12

What is the relationship between earthquake magnitude and the energy released from an earthquake?

Magnitude is a quantitative description that is related to the amount of energy released by an earthquake. This is determined by examining the amplitude of seismic waves at known distances from the epicenter using a seismograph.

The joule is a unit of measure for energy. A joule is equivalent to 1 Newton exerted over a distance of 1 meter.

$$1\ J = 1\ N \bullet m$$

Some points to consider:

- One joule represents the approximate amount of energy it takes to lift an apple one meter from the ground. An apple weighs about one Newton.
- The average amount of energy expended by one person in a year in the United States is 10^{12} joules.
- The energy expended to put the space shuttle into orbit is 10^{13} joules.
- The energy expended by the atomic bomb explosion at Hiroshima, Japan was 10^{14} joules.

The energy released in an earthquake may be expressed as:

$$\log E = 1.44 M_s + 5.24$$

or

$$E = 10^{1.44 M_s + 5.24}$$

where E is the energy released by the earthquake in Joules and Ms represents surface wave magnitude.

Use a calculator and the equation listed above to determine the amount of energy released in joules. The first one has been completed for you.

	M_s	**Energy expended in joules (J)**
1.	1	*4786300.9 or 4.7863 x 10^6*
2.	2	
3.	3	
4.	4	
5.	5	
6.	6	
7.	7	
8.	8	
9.	9	

Name:_____

Earthquake Energy

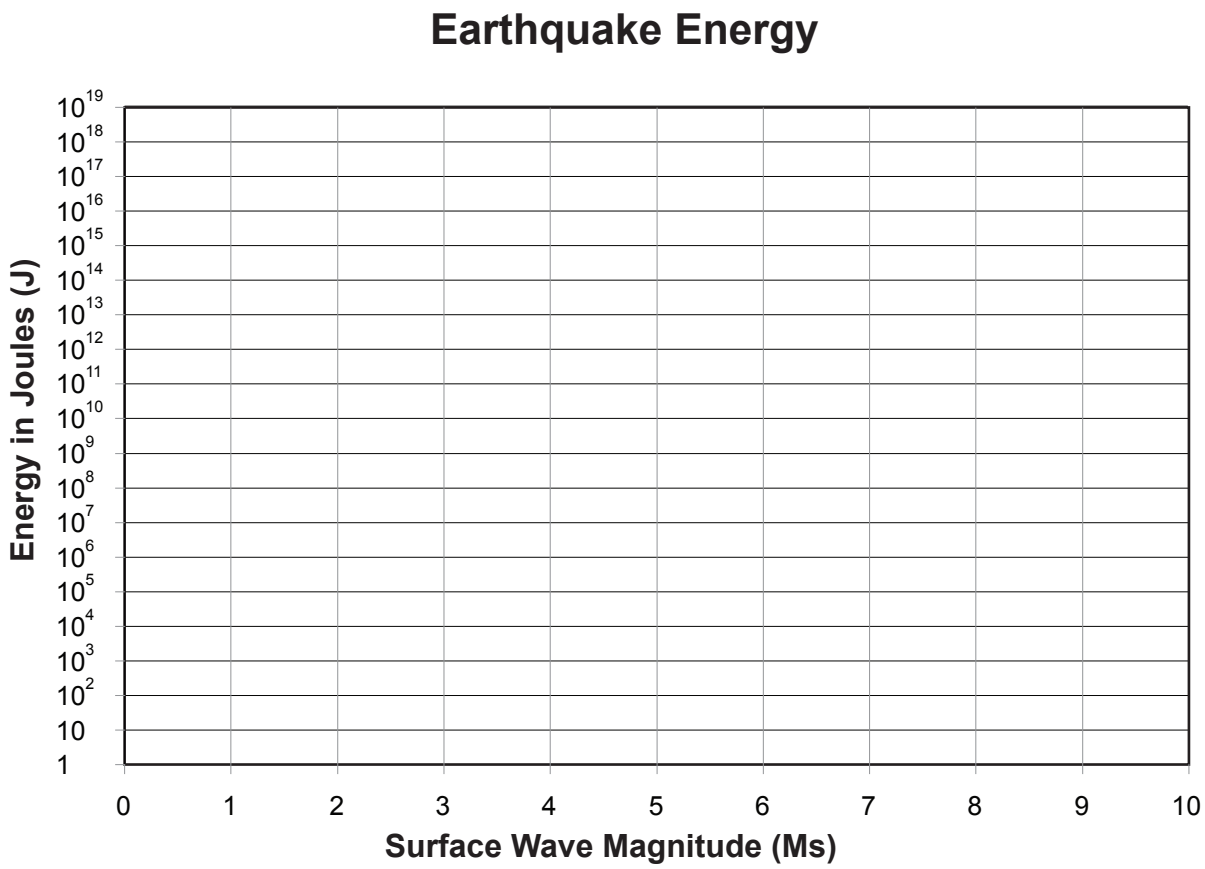
Student Worksheet (page 2 of 2)

Grades 9-12

The table below lists earthquakes that generated tsunamis affecting Alaska's coast. Use a calculator and the equation listed above to determine the amount of energy released in joules. The first one has been completed for you.

	Year	M_s	Source	Energy expended in joules (J)
10.	1946	7.3	Unimak Island	5.6494×10^{15}
11.	1952	8.3	Kamchatka	
12.	1958	7.9	Lituya Bay	
13.	1960	8.5	Chile	
14.	1990	7.5	Mariana Trench	
15.	1991	6.5	Bering Sea	
16.	2004	9.0	Indonesia	

17. Enter the data onto the following graph. Plot the points from questions 1-9. For questions 10-16, plot the point and label the source of the tsunami.



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Earthquake Energy Excel

Student Worksheet

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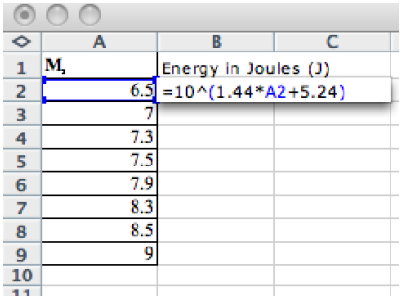
9-12

1. Enter the surface wave magnitudes (M_s) in one column of Excel.

2. To calculate the energy in joules (J) based on the surface wave magnitude (M_s) enter =10^(1.44*A2+5.24) into the cell to the right of the first magnitude. Then press enter.



	A	B	C
1	M_s	Energy in Joules (J)	
2	6.5	=10^(1.44*A2+5.24)	
3	7		
4	7.3		
5	7.5		
6	7.9		
7	8.3		
8	8.5		
9	9		
10			

3. To fill in the energy quantities for the other magnitudes, select cell B2 and the cells below it. Go to “Edit”, then “Fill”, and then “Down.

4. To round off the scientific notation, highlight all the cells of energy in joules, go to “Format,” and select “cells.” Select “Number,” then “Scientific.” Enter “2” for decimal places.