CEETEP

ShakeAlert

Pasta Quake*

Teaching about earthquake magnitude and the logarithmic scale.

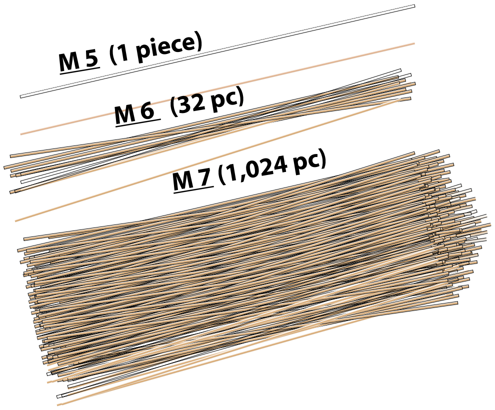


Figure 1: Strands of uncooked pasta model magnitude.

Summary

This engaging demonstration provides an intuitive introduction to earthquake magnitude using a familiar item - spaghetti! The sizes of the pasta bundles dramatically show that the energy released in earthquakes does not go up linearly with steps in the magnitude scale.

Content Objectives

Students will be able to

- distinguish the Richter Magnitude, Moment Magnitude and Intensity scales
- explain the energy difference between the Moment Magnitude steps

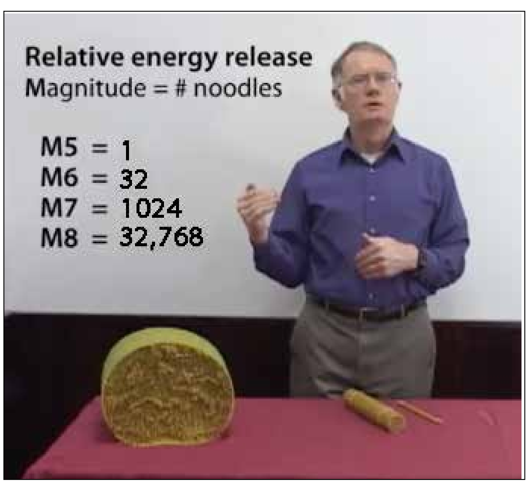


Figure 2: Screen grab from video of Dr. Robert Butler demonstrating this activity: ***www.iris.edu/hq/inclass/video/201***

Time: 15-20 Minutes

Audience: General public

Materials

- 1 lb package of thin spaghetti <u>*or*</u>
- 2 lb package of regular spaghetti
- *Optional*: Student Worksheets Pages SW1-2.

Background—Intensity or Magnitude?

Before demonstrating the magnitude scale, it is important to recognize that the severity of an earthquake can be expressed in terms of two scales: <u>*Magnitude*</u> and <u>*Intensity*</u>. The two terms are quite different, yet are often confused.

<u>***Magnitude***</u> is the amount of seismic energy released at the *hypocenter* (point within the earth where an earthquake rupture starts) of the earthquake. It is based on the amplitude of the earthquake waves recorded on instruments which have a common calibration. The magnitude of an earthquake is thus represented by a single, instrumentally determined value. That is, there is only one magnitude. Magnitude is measured using the Moment Magnitude scale, which has replaced the historic, but outdated, Richter Magnitude scale. Watch: www.iris.edu/hq/inclass/animation/205

<u>***Intensity***</u> is based on the observed effects of ground shaking on people, buildings, and natural features within the disturbed region. What a person experiences can vary from place to place depending on the location of the person with respect to the earthquake *epicenter (*the point on the Earth's surface directly above the hypocenter). Thus, there can be many intensities for a single earthquake. Intensity is measured using the Modified Mercalli Intensity scale. Watch: www.iris.edu/hq/inclass/animation/517

Lesson Development

Step 1: Engage learners by discussing historic earthquakes. The Haiti 2010 7.0M earthquake caused over 200,000 deaths, while similar sized earthquakes in 1989 (6.9M, Loma Prieta, CA) and 2018 (7.1M Anchorage, AK) caused 67 and 0 deaths, respectively. What does earthquake magnitude really mean? How can the impacts of earthquakes be so different?

**Activity, Pasta Quake—The San Francisco Treat is used with permission from Paul Doherty http://www.exo.net/~pauld/index.html. Worksheets were modified after those by Roger Groom, Mount Tabor Middle School, Portland Oregon*

Step 2: Introduce the difference between earthquake energy and intensity. Emphasize that the Pasta Quake exercise focuses on magnitude, which is one of the factors that contributes to the intensity of earthquakes.

Note: bundles of pasta are used as analogies for earthquake magnitude on the Moment Magnitude scale. This scale is not linear. The energy increases 32 times with each step up the scale, which is represented by increasing the number of strands of pasta in each bundle. Rather than counting out thousands of pasta strands, it is easier to create bundles using diameters. The underlying math for this calculation is presented on page 3. Incorporate as much of this background math into your presentation as you see fit to support your learners.

Step 3: Demonstrate the Pasta Magnitude Scale
M5—Distribute single spaghetti noodles to the learners. Have learners hold up the spaghetti noodle, and bend it between their hands until it breaks. Guide learners to notice the work it takes to break the spaghetti. Call this a 5 on the Pasta Magnitude scale, and discuss how learners have now calibrated their fingers to understand this amount of energy.

?? *What would you need to multiply this single piece of spaghetti by to equal a Pasta Magnitude 6? (Answer: 32)*

M6—Hold up the smallest bundle of 32 strands of spaghetti. Bend the bundle until it breaks. Notice the work it takes to break the bundle. If the pasta magnitude scale were like the earthquake magnitude scale, this would be a Pasta Magnitude 6 break. Notice that the bundle is about the diameter of a large/fat drawing pencil (1.2 cm or 0.47 in).

?? *What did you notice? Was it still fairly easy to break? Did it feel like twice as much as the M5? Did the bundle break all at once or a strand at a time?*

M7— We can now find out how large the next bundle of spaghetti representing a Pasta Magnitude 7 would be. Multiplying 32 (M6) by 32 gives 1,024 pieces of spaghetti representing an M7. The cross-sectional area of this bundle is 36.48 cm^2, and the diameter is 6.82 cm or 2.69 in, or approximately the diameter of a tennis ball (refer to the Pasta Quake Math page).
Hold up the small 32 strand bundle and the large bundle of 1,024 strands of spaghetti.

?? *"How much energy do you think it would take to break a bundle of spaghetti this large?"*

Either break or flex the bundle to show that it takes much more effort to make the bundle break.

M8—Holding up the M7 bundle of pasta, ask "What would you need to multiply this bundle by to equal a Pasta Magnitude 8?" (Answer: 32)

Multiplying 1,024 pieces of spaghetti representing Pasta M7 by 32 gives 32,768 pieces of spaghetti representing an M8. The cross-sectional area of the M8 bundle is 1167 cm^2 and the diameter is 38.6 cm or 15.2 in., or approximately the size of a beach ball (Refer to the Pasta Quake Math page). Hold up a tarp circle with the new M8 diameter.

?? How much energy do you think it would take to break a bundle of pasta this large?"

M9—Now let's consider a Pasta Magnitude 9 earthquake. "How big of a spaghetti bundle do you think this will be?" Look around the room for a comparable diameter and make an educated guess based on how the sizes have been progressing. Let's do the math. Multiplying 32,768 pieces of spaghetti representing Pasta M8 by 32 gives 1,048,576 pieces of spaghetti representing an M9. The cross-sectional area of the M9 bundle is 37,355 cm^2 and the diameter is 218.1 cm or 85.9 in, which is 7.16 feet, or the height of a door! (Refer to the Pasta Quake Math page). Hold up a circle of plastic tarp with this new diameter.

?? "How much energy do you think it would take to break a bundle of spaghetti this large?"

Now we can begin to understand the energy involved in a great subduction-zone earthquake!

Step 4: Have students complete the worksheet (optional), and/or discuss the infographic on page 4 about the relative magnitudes and impacts of recent earthquakes. Introduce and discuss the factors that contribute to variations in intensity, such as depth to hypocenter, variations in how seismic waves interact with local soils and rocks, seismic engineering of structures, building codes, etc.

Extensions:

- Compare intensity shake maps of different earthquakes of the same magnitude to analyze differences (for example 2018 M7.1 Anchorage to 2019 M7.1 Ridgecrest)
    - https://earthquake.usgs.gov/earthquakes/eventpage/ak20419010/region-info
    - https://earthquake.usgs.gov/earthquakes/eventpage/ci38457511/executive
- Introduce students to the USGS Did You Feel It?
    - https://earthquake.usgs.gov/data/dyfi/

Pasta Quake Math

The following math shows the calculations used to determine the size of each bundle of spaghetti for magnitudes 6, 7, 8 and 9. Magnitude increases by a factor of 32. Bundle sizes are calculated both in cross-sectional area, and diameter.

Magnitude	Spaghetti Strands	Area of Bundle	Diameter of Bundle
5	1		
6	32	1.14 cm^2	1.2 cm or 0.47 in.
7	1024	36.28 cm^2	6.82 cm or 2.69 in.
8	32,768	1167.36 cm^2	38.56 cm or 15.18 in.
9	1,048,576	37,355.52 cm^2	218.08 cm or 85.86 in.

M6: A 32 strand bundle of spaghetti = an area of 1.14 cm^2. To determine the diameter of the bundle, divide the area by π (3.14159) = 0.36 cm^2. Next, take the square root of the product to determine the radius √ .36 cm^2 = 0.6 cm. And finally multiply by 2 to determine the new diameter 0.6 cm x 2 = 1.2 cm or 0.47 in.

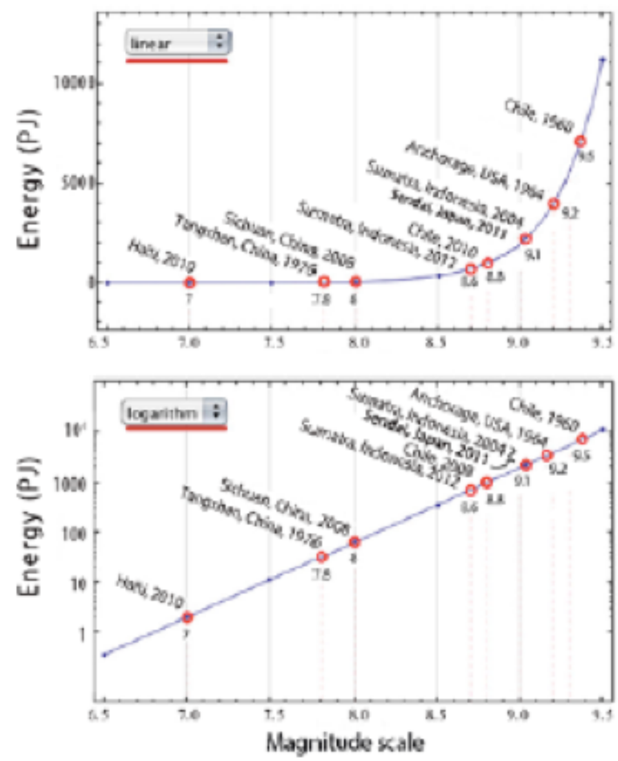


Figure 3: Earthquake magnitude vs. energy released, plotted using a linear scale (top) and a logarithmic scale (bottom)

M7: 32 x 32 strands = 1024 strands. ***Area***: multiply the area of M6 1.14 cm^2 by 32 = 36.48 cm^2

Diameter: divide the area by π (3.14159) = 11.61 cm^2 Next, take the square root of the product to determine the radius √ 11.61 cm^2 = 3.41 cm. And finally multiply by 2 to determine the new diameter 3.41 cm x 2 = 6.82 cm or 2.69 in.

M8: 32 x 1024 = 32,768 strands. ***Area***: multiply the area of M7 36.48 cm^2 by 32 = 1,167.36 cm^2

Diameter: divide the area by π (3.14159) = 371.58 cm^2. Next, take the square root of the product to determine the radius √ 371.58 cm^2 = 19.28 cm. And finally multiply by 2 to determine the new diameter 19.28 cm x 2 = 38.56 cm or 15.18 in.

M9: 32 x 32,768 =1,048,576 *strands* ***Area***: multiply the area of M8 1,167.36 cm^2 by 32 = 37,355.52 cm^2

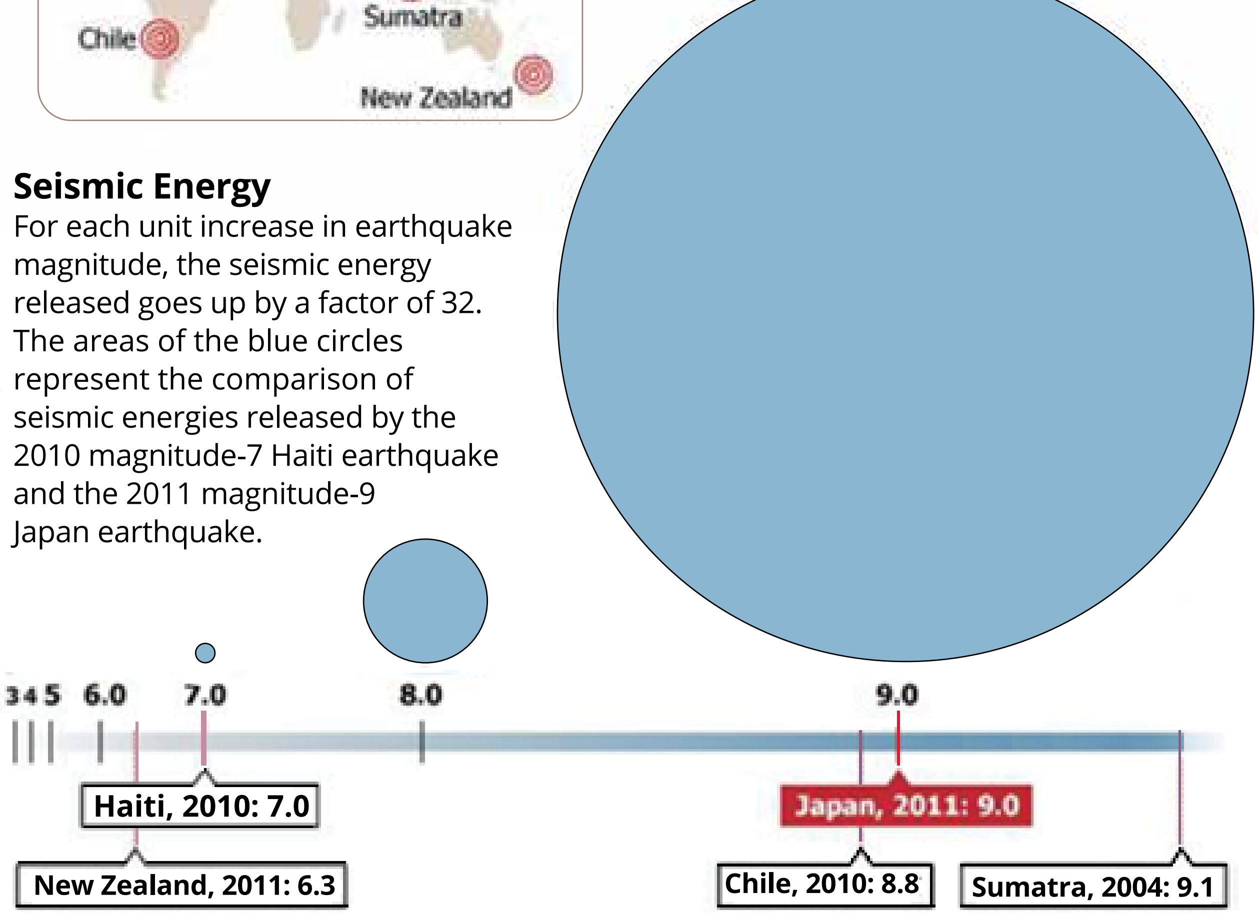
Diameter: divide the area by π (3.14159) = 11,890.64 cm^2. Next, take the square root of the product to determine the radius √ 11,890.64 cm^2 = 109.04 cm. And finally multiply by 2 to determine the new diameter 109.04 cm x 2 = 218.08 cm or 85.86 in, which also equals 7.16 feet

Energy of Recent Earthquakes

According to the US Geological Survey, the 2011 magnitude-9 earthquake off the east coast of Honshu, Japan's largest island, was the fifth largest earthquake recorded worldwide and the largest ever recorded in Japan. Locations of notable recent earthquakes are shown on the map below.

Seismic Energy

For each unit increase in earthquake magnitude, the seismic energy released goes up by a factor of 32. The areas of the blue circles represent the comparison of seismic energies released by the 2010 magnitude-7 Haiti earthquake and the 2011 magnitude-9 Japan earthquake.



Human Impact

The 2011 Japan earthquake and resulting tsunami took ~20,000 lives. The 2010 Haiti earthquake took ~150,000 lives, despite the seismic energy being more than 1000 times less that the seismic energy of the 2011 Japan earthquake. So the human impact of earthquakes is controlled by many factors in addition to earthquake energy. Distance of the earthquake from large cities and the strength of buildings and infrastructure are very important.

SOURCES: USGS, WASHINGTON POST

ROSS TORO, www.OurAmazingPlanet.com

Adapted from *Magnitudes of Recent Earthquakes* graphic by LiveScience: https://www.livescience.com/13773-japan-earthquake-triggered-smaller-quakes.html

APPENDIX A—NGSS SCIENCE STANDARDS & 3 DIMENSIONAL LEARNING

Earth and Human Activity

MS-ESS3-2 Performance Expectation:

Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. MS-ESS3-2

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis

Disciplinary Core Ideas

ESS3.B: Natural Hazardss
Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)

Crosscutting Concepts

Patterns
Graphs, charts, and images can be used to identify patterns in data.(MS-ESS3-2)

Name: _________________________________Date:___________ Per: ____

Pasta Quake!

Background:

The severity of an earthquake can be described using two different scales: magnitude and intensity. The ***magnitude*** is a measure of the amount of energy released in the earthquake, whereas ***intensity*** is a measure of the impact of the earthquake, in terms of shaking and destruction caused. We report energy released in earthquakes using the Moment Magnitude scale. In this lesson, you will learn that there is a BIG difference in energy between each step of the scale. While a larger magnitude earthquake does release more energy, there are other factors that contribute to the intensity of an earthquake experienced at any given location.

Warm-Up Questions

Use your science notebook to answer the questions below:

1. What is the difference between the epicenter and the focus of an earthquake? Include a sketch.
2. What is the difference between the Richter Scale, the Moment Magnitude Scale, and the Modified Mercalli Scale?
3. What do you think determines the amount of damage caused by an earthquake? List 3 factors.

Name: ________________________________Date:__________ Per: ____

Pasta Quake!

On the Moment Magnitude Scale, each number is a measurement of the total energy released by an earthquake, and it's about 32 times greater between numbers on the scale. We can demonstrate this with spaghetti:

Pasta Magnitude Scale	# of Spaghetti Pieces Broken
4	1/30
5	1
6	32
7	1,024
8	32,768
9	1,048,576

You could also look at it this way:

It would take about 1 million 5.0M earthquakes to release the energy of a 9.0M earthquake.

Use the following information about major earthquakes over history to answer the questions.

Year	Earthquake Location	Magnitude	# Deaths
1989	Loma Prieta, California	6.9	67
1995	Kobe, Japan	6.9	6,000
2010	Haiti	7.0	222,570
2018	Anchorage, Alaska	7.1	0
1985	Mexico City, Mexico	8.1	5,000
2011	Tohoku, Japan	9.0	15,900
2004	Indian Ocean	9.1	227,900
1964	Prince William Sound, Alaska	9.2	139
1960	Arauco, Chile	9.5	5,000

1. The 2011 9.0M Tohoku earthquake released about ___________________ times more energy than the 2010 7.0M Haiti earthquake.

2. The 2004 Indian Ocean earthquake released about ________________ times more energy than the 1985 Mexico City earthquake.

3. Which earthquake released about 32 times more energy than the 2018 Anchorage M7.1?

4. Compare the magnitude of the listed earthquakes to the number of deaths.
    a. What do you notice about the relationship between magnitude and number of deaths?
    b. What other factors, besides magnitude, might have determined the amount of death and destruction caused by the above earthquakes?

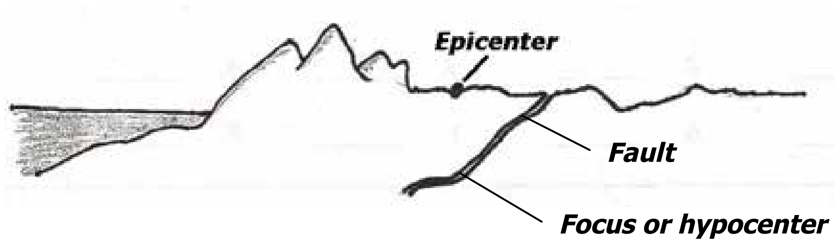
Pasta Quake – KEY

Warm-Up Questions

Use your science notebook to answer the questions below:

1. What is the difference between the epicenter and the focus (hypocenter) of an earthquake? Include a sketch.

The focus (or hypocenter) is the location within the earth where the earthquake rupture begins. The epicenter is the location on the surface of the earth, directly above the focus.



2. What is the difference between the Richter Scale, the Moment Magnitude Scale, and the Modified Mercalli Scale?

Richter Scale - Measures the size of the seismic waves as shown on a seismograph. Somewhat accurate for small or close-by earthquakes, but is not accurate for large earthquakes and has been replaced with the Moment Magnitude Scale.

Modified Mercalli Intensity Scale - Measures the intensity of an earthquake. This is a measure of the strength of ground motion and has a scale of 1 – 12, but in Roman numerals, it's I – XII. One earthquake may have different ratings depending on the damage at different locations.

Moment Magnitude Scale - Measures the total energy released by an earthquake and can be used for all sizes, near or far. This measure is based on a complex calculation rather than a single instrument, and is usually what is reported today.

3. What do you think determines the amount of damage caused by an earthquake? List 3 factors.

A very important factor is the distance the seismic waves have traveled to the location, because energy lessens with distance, just like ripples in a pond. This distance can be measured both by depth to the focus (hypocenter) and distance to the epicenter. Other factors: the way waves interact with the soils and rocks of the area, topographic features that focus seismic waves (like basins or ridges), engineering design of structures, building materials, building codes, etc.

Questions:

1. The 2011 9.0M Tohoku earthquake released about **1024 (32 x 32)** times more energy than the 2010 7.0M Haiti earthquake.
2. The 2004 Indian Ocean earthquake released about **32** times more energy than the 1985 Mexico City earthquake.

3. Which earthquake released about 32 times more energy than the 2018 Anchorage M7.1? The M8.1 Mexico City earthquake in 1985

4. Compare the magnitude of the listed earthquakes to the number of deaths.
   c. What do you notice about the relationship between magnitude and number of deaths? There does not appear to be a relationship. The 2nd largest earthquake, 1964 9.2M only killed 139 people, yet the much smaller Haiti 7.0M killed more than 200,000.
   d. What other factors, besides magnitude, might have determined the amount of death and destruction caused by the above earthquakes? Guide students to notice the relationship between the amount of deaths and the development of the nation. Haiti and the area affected by the 2004 experienced many deaths due to lack of building codes and proper medical facilities. Other factors include depth of the earthquake, and geography such as the types of rocks and soils.