



Drexel-SDP GK-12 ACTIVITY

Activity Template

Subject Area(s): Sound

Associated Unit:

Associated Lesson: None

Activity Title: Where did the earthquake begin?

Grade Level: 8 (7-9)

Activity Dependency: None

Time Required: 90 minutes

Group Size: 3-4 students

Expendable Cost per Group: US \$0.00

Summary:

In this activity, students will explore the different seismic waves of an earthquake, determine the travel times of the seismic waves, and use triangulation to determine the epicenter of an earthquake. As a result, the students will learn how seismic waves travel through Earth and the methods for locating the epicenter of an earthquake. This activity will therefore provide students with an overview of earthquake localization practices and the basics of propagation and measurement of seismic waves.

Engineering Connection:

Engineers working in the field of seismology focus on the scientific study of earthquakes and the propagation of seismic waves through the Earth. In general, engineers who study seismology are also concerned with earthquake effects, such as volcanic, tectonic, and oceanic processes and tsunamis. Specific to this activity, engineers use information gained from seismographs and more modern equipment called seismometers to track and localize earthquakes. Seismometers allow engineers to track vibrations in the ground by analyzing the information extracted from the meters, which display the vibrations on a graph over time. Also, engineers can use seismometers

to track changes in ground vibrations to determine when an earthquake may happen. Therefore, the engineers are basically creating an early warning system that determines when an earthquake could happen before it does. This activity will focus primarily on interpreting the information extracted from the seismometers.

Keywords: earthquakes, seismic waves, P and S waves, seismographs, seismometers

Educational Standards

Science: 3.5 – Earth Sciences

Math: 2.2 – Computation and Estimation

2.3 – Measurement and Estimation

Learning Objectives

After this lesson, students should be able to:

- Explain that an earthquake is composed of several types of waves
- Define and explain P and S waves
- Demonstrate how to triangulate the epicenter of an earthquake
- Use a compass for triangulation

Materials List

Each group needs:

- ruler
- compass
- worksheet
- calculator

Introduction / Motivation

The detection of vibrations in the ground makes it possible to predict future earthquakes and to localize the epicenter of an earthquake once it has occurred. In the first instance, an early detection system would help to protect humans from natural disaster, giving the humans ample time to escape pending danger. In the second instance, seismologists can use data from seismographs to further research in the area of earthquakes. For example, if an area is prone to earthquakes, then the buildings constructed in this region would be required to use specific building materials that are resistant to earthquakes.

Vocabulary / Definitions

Word	Definition
epicenter	the center of an earthquake that is directly above the hypocenter or focus
P wave	the primary wave of an earthquake that is a longitudinal wave
S wave	the secondary wave of an earthquake that is a transverse wave
seismograph	device used to measure and record vibrations in the ground

Procedure

Background

The characteristics of earthquakes are measured by seismographs, which monitor vibrations in the ground. The information obtained by a seismograph can be used to create a graph of amplitude vs. time that represents the current position of the ground relative to a resting position over a period of time. The graph shows the intensity of ground movements and the precise time locations at which vibrations occur. Seismographs within 90 km of the epicenter can record both P and S waves out to about 90 km. The time locations of the P and S waves recorded by several seismographs can be used to triangulate the location of the earthquake's epicenter. The epicenter is the point on the Earth's surface that is directly above the hypocenter, or focus, which is the origin of the earthquake. Generally, the epicenter is the location of greatest destruction. As an earthquake occurs, the seismic waves propagate spherically from the hypocenter.

P waves, or primary waves, are longitudinal waves that cause the ground to repeatedly compress and dilate in the direction of the propagating waves. This motion is similar to the motion of a slinky that is lying on the ground after a section of the slinky is pulled back toward the end and released. It would be beneficial to use this as a demonstration since it is easy to visualize the compressed section of the wave traveling down the slinky. P waves are generally lower in amplitude than S waves, and thus will cause far less destruction or movement of the ground. Although the strength of P waves are less than S waves, the speed of S waves are only approximately 60% as fast as P waves.

S waves, or secondary waves, are transverse or shear waves that cause the ground to move in opposite directions in an up-and-down motion. This motion is similar to the motion of a slinky that is held in the air and shaken up and down. Again, it would be beneficial to demonstrate this motion visually with the slinky. The energy of S waves is far greater than that of P waves, causing far more damage and destruction than P waves. The speed of an S wave, however, is slower than a P wave, with the speeds at approximately 3 km/s and 5 km/s, respectively.

Before the Activity

- Print out a copy of the lab for each student
- Prepare the supplies for each group (ruler, compass, and calculator)

With the Students

1. Ask the students if they have ever experienced an earthquake and, if not, what they think it would feel like.
2. Explain to the students that their job is to determine how long it takes for P and S waves to travel between cities.
3. Explain to the students that once they figure out how to calculate P and S wave travel times they will attempt to determine the location of an earthquake's epicenter.
4. Provide the students with a general background of earthquakes and seismic waves that can be taken directly from the Background section
5. Demonstrate P and S waves using a slinky and explain the difference between the two waves
6. Create an example of the P and S wave travel time calculations and go through the necessary steps to solve the problem as they would on the worksheet

7. Spend quite a bit of time trying to explain triangulation of the epicenter and why this technique is useful
8. Create your own example of triangulation using the provided map
9. Based on the difference in time of the synchronized clocks and the arrival time of the first wave, figure out the distance between the epicenter and the seismograph station
10. Set the compass to the distance and trace a circle on the map that represents the possible locations of the epicenter based on the time information for one station
11. Repeat this process for each station and look for the point where all three circles cross, which is the epicenter
12. Explain to the students that calculations and measurements must be precise when drawing the circles with the compass otherwise the circles will not all cross at one point
13. Provide the students with the handout and have the students work together in small groups of preferably two students, but no more than three students
14. Have the students check with you periodically to see if their answers are correct since the answers are provided below
15. Wrap up by re-explaining how to triangulate the epicenter since this can be a difficult concept to comprehend

Attachments

- [Earthquake Calculations Handout](#)
- [Earthquake Calculations Handout Answers](#)

Safety Issues

- Some compasses have sharp points and could prick the students' skin.

Troubleshooting Tips

Students must be accurate when drawing the circles for triangulation otherwise it will be extremely difficult to determine the location of the epicenter.

Investigating Questions

- What other ways have you heard triangulation used (ex: GPS)?
- How are P and S waves similar to other waves (ex: characterized by amplitude and speed)?

Assessment

Pre-Activity Assessment

Class Discussion:

- Talk with students about waves in general and find out how much they know about wave properties and terminology.
- Talk with the students about earthquakes and what happens during an earthquake.

Activity Embedded Assessment

Lab handout/worksheet: Have the students fill out the lab handout and review their answers as a measure of the concept comprehension.

Post-Activity Assessment

None

Activity Extensions

- Have the students research earthquakes and write a report on the after-effects of earthquakes, such as tsunamis and volcano eruptions, with a focus on one specific after-effect.
- Have the students research other seismic waves beyond P and S waves.

Activity Scaling

- For lower grades, just have the students complete the first part of the worksheet dealing with calculation of travel time for P and S waves.
- For upper grades, the students should be given different variations of P and S wave speeds along with a need for a more complex conversion of the units in the legend.

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Earthquake Calculations Handout

Names: _____

Information

Speed of P waves: 5 km/s

Speed of S waves: 3 km/s

Map Legend: 1 centimeter = 30 km

Determining the travel time of P and S waves

1. Calculate the amount of time it would take for a P wave to travel from Philadelphia to Wilmington. Be sure to fill in each measurement and calculation you perform!

Philadelphia to Wilmington: _____ cm _____ km _____ seconds

2. Calculate the amount of time it would take for an S wave to travel from Philadelphia to Trenton. Be sure to fill in each measurement and calculation you perform!

Philadelphia to Trenton: _____ cm _____ km _____ seconds

3. Calculate the amount of time it would take for an S wave to travel from Reading to Allentown. Be sure to fill in each measurement and calculation you perform!

Reading to Allentown: _____ cm _____ km _____ seconds

4. Calculate the amount of time it would take for a P wave to travel from Trenton to Bethlehem. Be sure to fill in each measurement and calculation you perform!

Trenton to Bethlehem: _____ cm _____ km _____ seconds

5. Calculate the amount of time it would take for P and S waves to travel from Lancaster to Philadelphia. Be sure to fill in each measurement and calculation you perform!

P Wave Values

Lancaster to Philadelphia: _____ cm _____ km _____ seconds

S Wave Values

Lancaster to Philadelphia: _____ cm _____ km _____ seconds

6. Calculate the amount of time it would take for P and S waves to travel from Wilmington to Trenton. Be sure to fill in each measurement and calculation you perform!

P Wave Values

Wilmington to Trenton: _____ cm _____ km _____ seconds

S Wave Values

Wilmington to Trenton: _____ cm _____ km _____ seconds

Determining the epicenter of an earthquake

Each of the problems below will require you to determine the location of the earthquake's epicenter. In each situation, the engineers have previously synchronized their clocks. Shortly afterwards, an earthquake happened! The P and S waves were recorded by all stations, which provide information about how far away the earthquake's epicenter may be. Your job is to determine the exact location of the epicenter. In your calculations, be sure to calculate the number of centimeters on the map, number of kilometers in real life, and the number of seconds in travel time of either the first P or S wave for each site. Use the compass to triangulate the location of the epicenter based on the number of centimeters the epicenter must be from each station.

7. At 12:53:00 PM, engineers at stations in Trenton, Wilmington, and Reading synchronized their clocks. Shortly afterwards, the first P wave of an earthquake was recorded at each station at the times specified below.

Reached Trenton at 12:53:15.6 PM: _____ seconds _____ km _____ cm

Reached Wilmington at 12:53:9.6 PM: _____ seconds _____ km _____ cm

Reached Reading at 12:53:24.6 PM: _____ seconds _____ km _____ cm

8. At 4:12:35 AM, engineers at stations in Lancaster, Philadelphia, and Wilmington synchronized their clocks. Shortly afterwards, the first S wave of an earthquake was recorded at each station at the times specified below.

Reached Lancaster at 4:12:55.0 AM: _____ seconds _____ km _____ cm

Reached Philadelphia at 4:13:22.5 AM: _____ seconds _____ km _____ cm

Reached Wilmington at 4:13:10.0 AM: _____ seconds _____ km _____ cm

9. At 10:05:10 AM, engineers at stations in Allentown, Trenton, and Reading synchronized their clocks. Shortly afterwards, the first P wave of an earthquake was recorded at each station at the times specified below.

Reached Allentown at 10:05:22.0 AM: _____ seconds _____ km _____ cm

Reached Trenton at 10:05:25.0 AM: _____ seconds _____ km _____ cm

Reached Reading at 10:05:31.0 AM: _____ seconds _____ km _____ cm

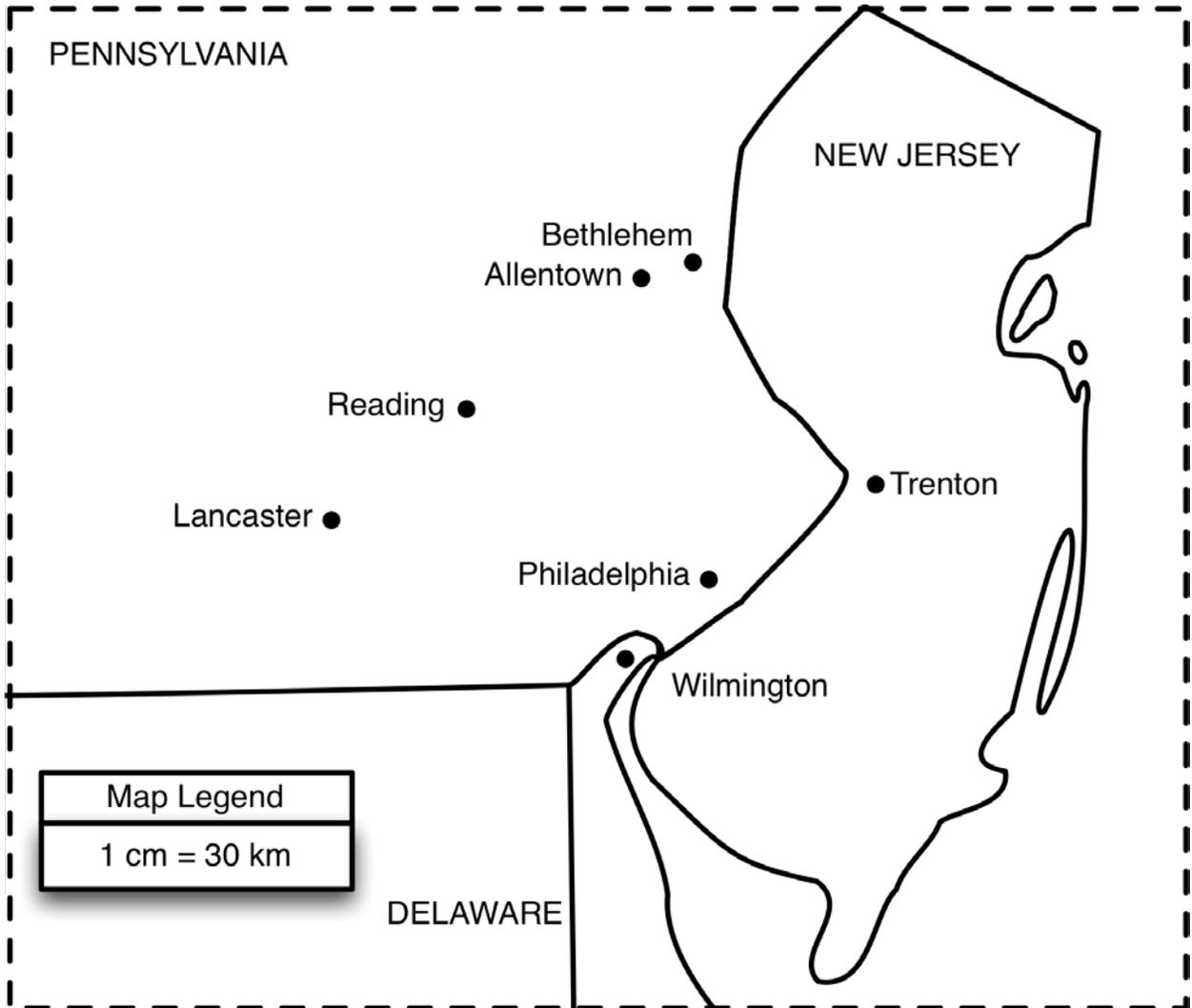
10. At 5:59:45 AM, engineers at stations in Philadelphia, Wilmington, and Trenton synchronized their clocks. Shortly afterwards, the first S wave of an earthquake was recorded at each station at the times specified below.

Reached Philadelphia at 6:00:42.5 AM: _____ seconds _____ km _____ cm

Reached Wilmington at 6:00:50.0 AM: _____ seconds _____ km _____ cm

Reached Trenton at 6:00:35.0 AM: _____ seconds _____ km _____ cm

Earthquake Map



Earthquake Calculations Handout Answers
ALL ANSWERS ARE APPROXIMATES!

Names: _____

Information

Speed of P waves: 5 km/s

Speed of S waves: 3 km/s

Map Legend: 1 centimeter = 30 km

Determining the travel time of P and S waves

1. Calculate the amount of time it would take for a P wave to travel from Philadelphia to Wilmington. Be sure to fill in each measurement and calculation you perform!

Philadelphia to Wilmington: 1.6 cm 48.0 km 9.6 seconds

2. Calculate the amount of time it would take for a S wave to travel from Philadelphia to Trenton. Be sure to fill in each measurement and calculation you perform!

Philadelphia to Trenton: 2.6 cm 78.0 km 26.00 seconds

3. Calculate the amount of time it would take for a S wave to travel from Reading to Allentown. Be sure to fill in each measurement and calculation you perform!

Reading to Allentown: 3.0 cm 90.0 km 30.00 seconds

4. Calculate the amount of time it would take for a P wave to travel from Trenton to Bethlehem. Be sure to fill in each measurement and calculation you perform!

Trenton to Bethlehem: 4.9 cm 147.0 km 29.40 seconds

5. Calculate the amount of time it would take for P and S waves to travel from Lancaster to Philadelphia. Be sure to fill in each measurement and calculation you perform!

P Wave Values

Lancaster to Philadelphia: 5.25 cm 157.5 km 31.50 seconds

S Wave Values

Lancaster to Philadelphia: 5.25 cm 157.5 km 52.50 seconds

6. Calculate the amount of time it would take for P and S waves to travel from Wilmington to Trenton. Be sure to fill in each measurement and calculation you perform!

P Wave Values

Wilmington to Trenton: 4.25 cm 127.5 km 25.50 seconds

S Wave Values

Wilmington to Trenton: 4.25 cm 127.5 km 42.50 seconds

Determining the epicenter of an earthquake

Each of the problems below will require you to determine the location of the earthquake's epicenter. In each situation, the engineers will have previously synchronized their clocks. Then shortly afterwards an earthquake happened. The P and S waves were recorded by all stations, which provide information about how far away the earthquake's epicenter may be. Your job is to determine the exact location of the epicenter. In your calculations, be sure to calculate the number of centimeters on the map, number of kilometers in real life and the number of seconds in travel time of either the first P or S wave for each site. Use the compass to triangulate the location of the epicenter based on the number of centimeters the epicenter must be from each station.

7. At 12:53:00 PM, engineers at stations in Trenton, Wilmington, and Reading synchronized their clocks. Shortly afterwards, the first P wave of an earthquake was recorded at each station at the times specified below.

Reached Trenton at 12:53:15.6 PM: 15.6 seconds 78.0 km 2.60 cm

Reached Wilmington at 12:53:9.6 PM: 9.6 seconds 48.0 km 1.60 cm

Reached Reading at 12:53:24.6 PM: 24.6 seconds 123.0 km 4.10 cm

8. At 4:12:35 AM, engineers at stations in Lancaster, Philadelphia, and Wilmington synchronized their clocks. Shortly afterwards, the first S wave of an earthquake was recorded at each station at the times specified below.

Reached Lancaster at 4:12:55.0 AM: 20.0 seconds 60.0 km 2.00 cm

Reached Philadelphia at 4:13:22.5 AM: 47.5 seconds 142.5 km 4.75 cm

Reached Wilmington at 4:13:10.0 AM: 35.0 seconds 105.0 km 3.50 cm

9. At 10:05:10 AM, engineers at stations in Allentown, Trenton, and Reading synchronized their clocks. Shortly afterwards, the first P wave of an earthquake was recorded at each station at the times specified below.

Reached Allentown at 10:05:22.0 AM:	12.0 seconds	60.0 km	2.00 cm
Reached Trenton at 10:05:25.0 AM:	15.0 seconds	75.0 km	2.50 cm
Reached Reading at 10:05:31.0 AM:	21.0 seconds	105.0 km	3.50 cm

10. At 5:59:45 AM, engineers at stations in Philadelphia, Wilmington, and Trenton synchronized their clocks. Shortly afterwards, the first S wave of an earthquake was recorded at each station at the times specified below.

Reached Philadelphia at 6:00:42.5 AM:	57.5 seconds	172.5 km	5.75 cm
Reached Wilmington at 6:00:50.0 AM:	65.0 seconds	195.0 km	6.50 cm
Reached Trenton at 6:00:35.0 AM:	50.0 seconds	150.0 km	5.00 cm

Earthquake Map Answers

