Activity Overview

Students explore several aspects of a simple model of a seismometer, the instrument used to record earthquake waves. They examine seismograms, the record of the passing waves, in detail. Using a graph, they determine the distance to an earthquake focus. In a web-based exercise the students will gain an understanding of the variables involved in locating an earthquake.

At the conclusion of **Activity 2**, students should be able to describe how a seismometer works and recognize different waves on a seismogram. They should be able to determine the distance to the focus and describe how the location of the focus is determined.

Preparation and Materials Needed

Once you have gathered the appropriate materials your preparation is complete. The students will design and operate their simple seismometers.

Materials

- Spiral spring or thick rubber band
- Small heavy weight with hook (like a non-lead fishing-line sinker)
- Rectangular open-sided box (like a milk crate)
- Piece of heavy paper or light cardboard
- Very soft pencil or felt-tipped marker
- Timer or stopwatch
- Roll of adding-machine paper

Think about It

Student Conceptions

The two questions seek to elicit students' ideas about how earthquakes are studied. The questions focus on what to observe if you want to study an earthquake and how you might detect and record the information. Likely responses to the first question include: the motion of the ground, seismograph records, and damage caused to buildings. Common conceptions about how to detect and record earthquake waves include using seismographs or some type of sensitive instrument that records the movement of the ground. Some students will reflect upon what they learned in the last activity and differentiate between how to measure or detect the three different types of waves.

Answer for the Teacher Only

Observations students may want to make to study an earthquake may include: kinds of seismic waves; amplitude of the waves; where the waves originated; nature of ground motions; damage to structures; appearance of surface breaks, where the fault surface intersects the land surface; offset on surface breaks.

In order to detect and record the arrival of earthquake waves students would probably design an instrument to record waves somehow or go to a functioning seismic station.

Investigate

Teaching Tip

Students should appreciate the need for a fixed reference point relative to a shaking instrument and ground surface. Circulate from group to group, asking questions that help the students better understand the process of designing a seismometer and recording passing waves. Some guiding questions might be:

- Why do you need the heavy weight? (*It remains relatively motionless, because of its inertia, while the crate shakes with the passing wave.*)
- Would the crate be bolted to the ground or would it be allowed to bounce around? (*The crate would be bolted down or buried, so that its motion would be representative of the passing waves.*)
- Why does the pin need to be in a fixed position? (*It provides a reference point as the instrument shakes. It also writes a record as the wave passes.*)
- Why do you need to record time on the record of the passing wave? (*So that the time that certain events, like the arrival of P waves and S waves, can be determined.*)

2. **a**) When the box is moved rapidly back and forth, the pendulum swings back and forth. (It may move up and down as well if it is affixed to a spring or a rubber band, but the predominant motion will be horizontal.) When the box is moved up and down, the weight "bounces" up and down.
   b) In this exercise, students will observe components of back-and-forth and up-and-down movements with both kinds of shaking. They did not observe this when shaking the Slinky.
   c) The box and weight initially will move together, but the weight will continue to swing and bounce after the box is stationary.

3. **a**) Student observations will vary. Most likely, their writing will be shaky.

4. **a**) The line should be straight and relatively smooth.
   b) The line traces the movement of the paper so it will also be "jiggled".

Assessment Tool

***EarthComm* Notebook Entry-Checklist**

Refer students to the ***EarthComm* Notebook Entry-Checklist** to remind them of the criteria against which they will be assessed. The checklist also provides a quick guide for student self-assessment and also provides you with an opportunity to quickly score student work.

Teaching Tip

The seismogram on page 135 of the Student Book is available as **Blackline Master Earthquakes 2.1**. If students are having trouble interpreting the record, you may wish to produce an overhead and do this part of the investigation as a class. Alternatively, visit the *EarthComm* web site and download sample seismograms which can be made into overheads and used as examples to explain how to read a seismogram.

6. **a**) The height of the recorded wave is variable, starting small and then increasing to a maximum before tapering down.

b) The shape of the recorded wave is also variable.

7. **a**) The P wave arrives first, at about 80 seconds, or the first "blip" in the record. The S wave arrives at about 320 seconds, at the first significant amplitude change.

b) About 240 seconds separate the two waves.

c) Note: Students need to use *Figure 3* on page 138 to answer this question, so you might wish to assign it as homework for students to complete after they have read **Digging Deeper**. In the previous question, it was determined that the difference in arrival times between the P and S waves is about 240 seconds or 4 minutes. Lay a piece of paper along the vertical axis of *Figure 3* (on page 138). Make tick marks at 0 and 4 seconds. The distance between the "ticks" represents the travel-time differential. Place the paper parallel to the vertical axis of the graph, and slide the paper along the two curves of the graph. When the 0 second "tick" matches up with the "first P waves" curve and the 4-second "tick" matches up with the "first S waves" curve, read the distance off the horizontal axis. This is the distance from the epicenter to the seismometer, and it is approximately 2700 km.

Reflecting on the Activity and the Challenge

This is an opportunity to note the observations the students should have made. Perhaps the most important observation is that instruments have been designed and built that can record earthquake waves. The first seismometers to use a heavy mass as a reference were built almost two hundred years ago. Refinements to this basic design continue to be made and allow seismologists to study the interior of the Earth in even greater detail. Seismometers are a good example of how technology and science work together to solve problems.

Digging Deeper

Assign the reading for homework. The questions in **Check Your Understanding** on page 138 can be provided as a homework assignment.

Assessment Opportunity

Use an essay question to assess the extent to which students have developed an understanding of the connections between what they explored in **Activity 1** (the motions of different kinds of seismic waves) and what they learned in **Activity 2** (how seismographs detect these three different types of motion).

For example:
Explain how seismographs detect the seismic waves you explored in the first activity. Sketch and label a seismogram as part of your answer.

A high-level response would indicate primary waves, shear waves, and surface waves (in order of arrival time and relative amplitudes) on the seismogram. It would explain that a seismograph records the movement of the ground in north–south, east–west, and up–down directions, that compressional waves move the fastest and arrive first, shear waves move more slowly and arrive next, and surface waves not only move the slowest, but they have the greatest amplitude and period (distance between wave crests).

Check Your Understanding

1. A seismometer detects seismic waves.

2. **a)** Three.

b) Measurement have to be made in three orientations, e.g., up-and-down, north – south, and east – west, because the waves can be arriving from any orientation below the plane of the Earth's surface.

3. The record of arrival of seismic waves. Traditionally this is a pen mark on a long strip of paper, although the recording can be electronic, with the information stored digitally.

4. The travel-time curve gives the time of travel of seismic waves since an earthquake occurred, versus the distance from the epicenter of the earthquake. See *Figure 3*.

Assessment Tool

Check Your Understanding Notebook Entry-Evaluation Sheet
This evaluation sheet is used to help you evaluate the extent to which students understand the key concepts explored in the activity and explained in the **Digging Deeper** reading section.

Understanding and Applying What You Have Learned

Stress that answers to the questions and related explanations are to be based on evidence.

1. **a)** If the seismometer is in the building it should be in a place that has little or no man-made vibrations, far from busy hallways, the gym, or the physical plant. Ideally, the seismometer would be away from the building in a quiet area away from roads and footpaths, and on solid bedrock rather than loose soil, if possible.

b) Locations where man-made vibrations are common should be avoided. A seismometer near a road would record the passing of every car and truck. One near a footpath would record when people walk by. Even a seismometer out in a field will record passing helicopters and low-flying airplanes.

c) A park or nature preserve might be a good place, because there would be a minimum of man-made vibrations.

d) A busy traffic intersection or next to an airport would be an unwise location, because the constant arrival of ground vibrations might lower the quality of records received from earthquakes.

2. a) The device is a good model because it works on the same basic principles as a real seismometer. It provides as fixed reference as the ground shakes.

   b) It is a poor model because it is not very sensitive and needs a large magnitude of vibration to produce a record.

   c) To improve the model, we could use a heavier mass or stiffer springs or rubber bands. This might allow detection of smaller vibrations. A second mass could be mounted on the side of the crate to record up-and-down motion while the mass hanging from the top of the crate records side-to-side motion.

3. This question could be answered in two ways. In any scientific endeavor, comparing results from different instruments always improves the final accuracy of measurements. The students might interpret this question in a different way: three seismometers are needed in order to measure the three components of the vibrations (up-and-down, north – south, east – west).

4. Strong local vibrations are caused by passing trucks, trains, helicopters, landslides, thunderstorms, etc. Even rather distant explosions, man-made or volcanic, can be recorded by seismometers. The details of the seismic waves differ, in various ways, among natural earthquakes, other natural phenomena, and human activities. The seismograms would have different shapes, reflecting different frequencies and durations. Distinguishing between natural earthquakes and nuclear detonations has been a major element in the controversy over nuclear weapons testing.

Preparing for the Chapter Challenge

Students should be encouraged to prepare a concise, simple, but accurate description of how to detect earthquake waves and locate epicenters. Also, decide where to place a seismometer at your school (or somewhere else in your community) and explain why they chose this location. (The summary is intended as homework and can be used as an embedded assessment of the students' knowledge as they apply it to the **Chapter Challenge**.)

Inquiring Further

1. History of science

The earliest device for recording earthquakes, a seismoscope, was constructed in AD 132, by the Chinese philosopher Chang Heng. The instrument resembled a wine jar with eight dragon heads (to represent the eight principal directions of the compass). Each dragon head held a ball which would drop into the mouth of a toad (located directly below each dragon head) in the event of an earthquake. The direction of shaking determined which dragon dropped its ball. In the eighteenth century, J. de al Haute proposed filling a bowl with mercury. During an earthquake, the mercury would spill into one of eight cups. The amount of mercury spilled indicated the size and epicentral distance from the earthquake. As scientists began to gain a greater understanding of the causes of earthquakes, instruments became more sophisticated. The inverted-pendulum "seismometer", a device similar to that constructed by students in this activity, was constructed by James Forbes in 1844. This device set the stage for the use of pendulums in seismic study. The first true seismograph was constructed in Italy in the 1870s by the Italian seismologist Cecchi. Advancements in technology and scientific knowledge have since produced progressively more accurate and sensitive instruments. It is interesting to note that the inverted-pendulum seismometer constructed in 1898 by German seismologist E. Weichert, is still used by many today. Direct students to the *EarthComm* web site www.agiweb.org/earthcomm to find further information.

2. Recent seismic activity

Direct students to the *EarthComm* web site www.agiweb.org/earthcomm. This final inquiry is web-based and open-ended. It allows the students to visit data recorded for recent earthquakes and look at real seismograms with specific waves identified. The students repeat tasks that they learned in this activity.

3. Virtual earthquakes

Go to the *EarthComm* web site www.agiweb.org/earthcomm to link to the Virtual Earthquake web site. Students can follow the directions to take them through the exercise. They can choose to examine data from three separate locations. You may wish to tell them which region to select to help standardize the answers. Have students stop the exercise prior to calculating the magnitude of the earthquake. This will be completed later on in the chapter.