IV

Measuring Earthquakes

Earthquake Curriculum, K-6 — Scope and Sequence Chart

Unit IV: Measuring Earthquakes

Level	Concept	Laboratory	Mathematics	Language Arts	Social Studies	Art
K-2	Earthquakes have different strengths. Earthquakes cause different amounts of damage.	Simulation of relative strengths of earthquakes.	Ordinal numbers Concepts of most and least	Vocabulary development of earthquake words	Effects of earthquakes on buildings and people	Constructing earthquake simulation model
3-4	Earthquakes differ in the amount of energy they release. Earthquakes may be measured by their effects (intensity) or by the amount of energy they release (magnitude).	Seismograph simulation	Measurement of distances Graph of measurement data Roman numerals	Vocabulary development of earthquake words Written descriptions of Mercalli illustrations	Impact of earthquakes on society Biographical study of earthquake scientists	Illustration of the Mercalli scale
5-6	Earthquake waves are either surface or body waves. Earthquake body waves are either primary or secondary. Earthquake waves detected by a seismograph are recorded as seismograms.	Slinky™ simulation of earthquake waves. Shoebox and rubber band simulation of earthquake waves. Seismograph simulation. Earthquake wave simulation game.	Ratio of earthquake wave speed Metric measurement of wave amplitude Computation, reducing fractions	Vocabulary development of earthquake words	Impact of earthquakes on society	Model designing

IV

Measuring Earthquakes

Magnitude and intensity are both measures of an earthquake, but they describe different characteristics. Magnitude is a measure of the amplitude of the earthquake waves. Wave amplitude is related to the amount of energy the earthquake releases. Intensity is a measure of the effect that the earthquake had on natural and human-made structures. Each earthquake has a single magnitude and a range of intensities.

Measuring Earthquakes

With few exceptions, earthquakes occur because of the release of energy stored in the rocks of the Earth's lithosphere. In order to understand how this release of energy is measured, however, we must first understand how it occurs.

Stress and Strain

Compressional Stress
When rocks are squeezed we say that they are under *compressional stress*. The rocks will behave elastically. That is, they will absorb the stress by changing their shape, like the soles of good running shoes. This change in shape is called *strain*. But, just like rubber soles, or rubber balls that are squeezed, strained rocks will rebound to their original shapes when the stress is removed. When the rocks rebound we say that their strain energy has been released.

Tensional Stress
Alternatively, if lithospheric rocks are being pulled apart, we can say that they are under *tensional stress*. In this case the rocks will tend to stretch like a stretching rubber band. They will rebound to their original shapes when the tensional stress is removed.

Earthquake!
However, if the stress exceeds what the material can bear, the material will rupture, or break. What happens when you pull too hard on a rubber band?

When rocks are strained too much, they break, and the original pieces rebound to their original shapes. In the Earth's lithosphere this rebounding and release of strain energy is accompanied by rubbing, grinding, and crashing, as the rock masses move past each other. The result is what we call an earthquake.

Waves and Vibrations

Regardless of the depth of the earthquake focus, vibrations from the release of strain energy travel in all directions. The earthquake vibrations are transmitted through the surrounding lithosphere, and even through the Earth's mantle and core, by a variety of wave-like motions. Earthquake waves are of two kinds, body waves and surface waves.

Body Waves
Body waves that travel through the Earth are either P- (for Primary) waves or S- (for Secondary) waves. P-waves travel faster than S-waves. The two types together are called body waves because they travel through the body of the Earth. Body waves are important because they allow us to locate the epicenters of earthquakes. They also enable us to study the structure and composition of the Earth's interior.

Surface Waves
Earthquake waves that travel at or near the surface of the Earth are called surface waves. The two main varieties are Love waves, which move sidewise, and Rayleigh waves, which have an up-and-down (rotary) motion. Surface waves spread for thousands or tens of thousands of square kilometers around an earthquake's epicenter. They are primarily responsible for the shaking of the ground and damage to buildings that occur in large earthquakes.

Two Ways of Measuring Earthquakes

The Mercalli Scale: A Measure of Intensity
Earthquake intensity is a measure of the effects of an earthquake at a particular place. Intensity is determined from observations of an earthquake's effects on people, structures, and the Earth's surface. A ten-value intensity scale which had been in use in Europe since 1883 was refined in 1902 by an Italian seismologist, Giuseppe Mercalli. The Mercalli scale we use today is a modification of Mercalli's 12-value scale developed by two Americans, H.O. Wood and Frank Neumann, in 1931. The scale uses Roman numerals from I to XII to rank relative levels of destruction, ground motion, and human impact.

The intensity (or impact) of an earthquake in a given area will depend on the type of geological structures in the area as well as the type of buildings. Houses built on rock, for example, will receive less damage than houses built on sediments at the same distance from a quake's epicenter. Poorly built houses will receive more damage than those that have been reinforced to withstand earthquakes. In general, though, the further a site is from the earthquake's focus, the lower the amount of damage it will sustain.

Far-Ranging Effects

Even though the main shock lasts for such a short time the effects of a major earthquake may reach a long way in both space and time. People hundreds of miles away from the epicenter may experience shaking or damage. This is especially true in the eastern United States, where quakes are felt over a much larger area than they are in the West.

An isoseismal map shows zones or bands where earthquake effects of the same intensity have been reported. For example, the U.S. map on the next page shows the areas that reported Modified Mercalli intensities of VI or greater for two major earthquakes. All of the areas between the isoseismal line labeled VI and the line labeled VII could experience effects of Mercalli intensity VI. The effects would be less strong in the area outside the line labeled V.

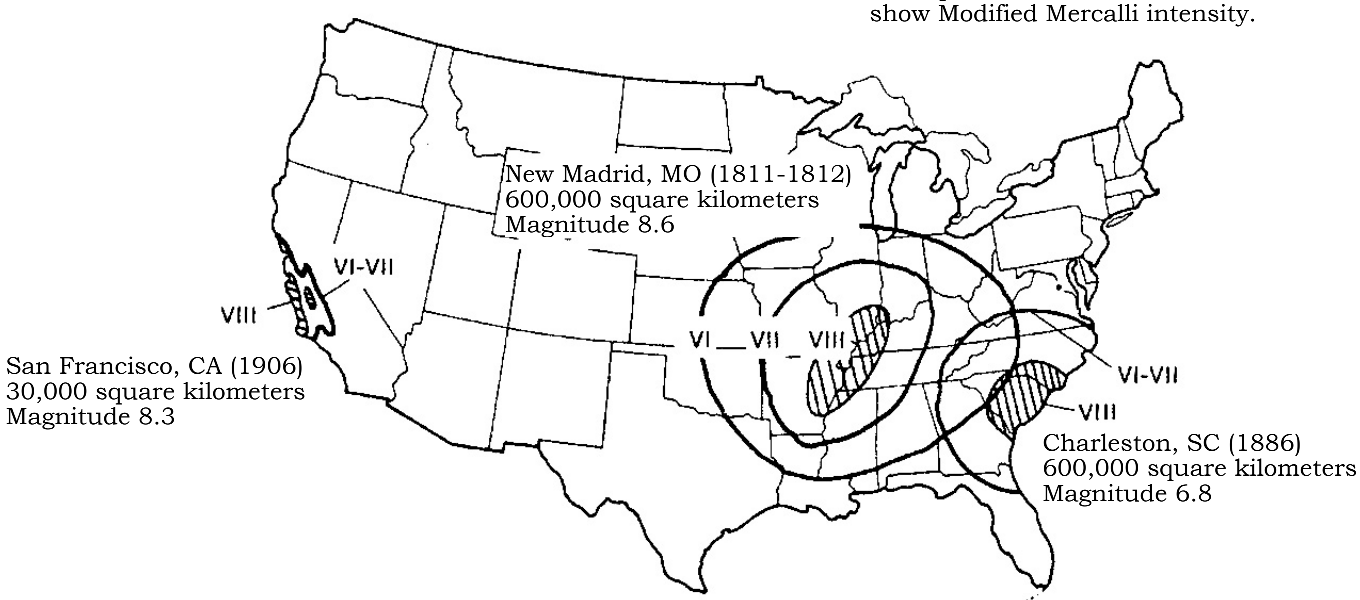
The San Francisco earthquake of April 18,1906, and the New Madrid earthquake of December 16, 1811, had roughly the same magnitude on the Richter scale. However, the area which registered VII or above on the Mercalli scale was twenty times larger for the New Madrid quake than for the one in San Francisco.

The main shocks in the New Madrid area were followed by fifteen strong aftershocks. All were felt strongly enough to waken sleepers in Washington D.C. In the three months following the main shock, nearly 2,000 aftershocks were reported at Louisville, Kentucky, 320 km (or 200 miles) from the New Madrid fault zone.

The Charleston earthquake of August 31, 1886, had a Richter magnitude of 7 and a Mercalli intensity of X at the epicenter. Events of Mercalli intensity II to III were reported as far north as upper New York state and western New England and as far south as the tip of Florida.

The Magnitude Scale: A Measure of Size
A method of rating the size of earthquakes is by using scientific instruments to measure the amplitude of body waves and surface waves recorded on seismograms. The amplitude is the height of the wave tracing above the center line on the seismogram.

Isoseismal map of three U.S. earthquakes. Areas with lines show Modified Mercalli intensity.



The instrument's reading indicates the amount of strain energy released by an earthquake. This measure is called the earthquake's magnitude. The greater the wave amplitude, the greater the magnitude.

A magnitude scale was devised by the American seismologist Charles Richter in 1935. It uses Arabic numerals. Richter's scale is logarithmic and open-ended; that is, there is no upper or lower limit to Richter magnitudes. Each whole-number increase in the magnitude of an earthquake represents about a thirty-fold increase in the amount of energy released.

The original Richter magnitude scale was devised to measure earthquakes in southern California. Later, over the years other types of seismographs have been developed. Precision in locating distant earthquakes and accuracy in determining their magnitudes have improved as the number and sophistication of seismograph designs have increased. Today computers are being used to analyze seismographic data—something your students may want to research on their own.

However, Richter and his colleague Beno Gutenberg devised a scale to measure distant earthquakes. This scale is based on the amplitudes of surface waves. Body waves from distant earthquakes can also be used to determine magnitude.

The Seismograph

The instrument used to record earthquakes is called a seismograph. The first seismographs were designed by British scientists working in Japan between 1880 and 1890. The most famous of these early seismographs was a horizontal pendulum model built by John Milne.

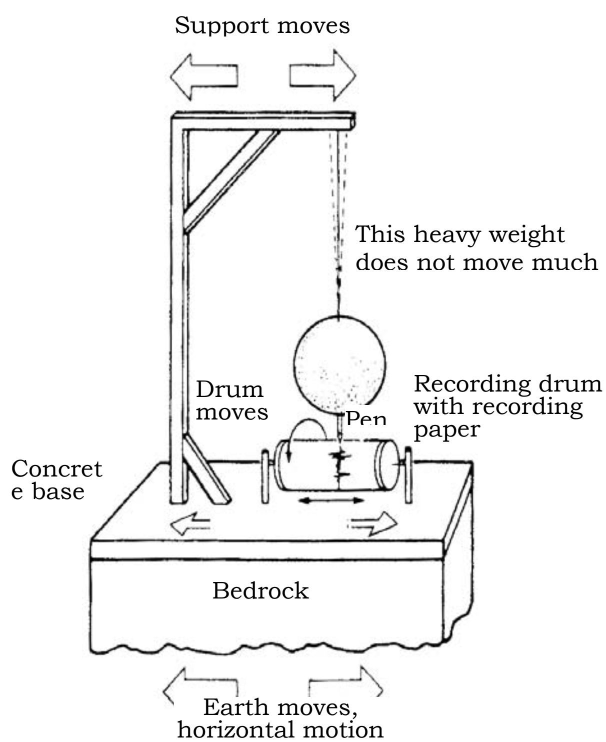
Pendulum seismographs rely on a simple principle of physics, the principle of inertia. A heavy weight that is allowed to move freely will tend to remain in its original position when the ground beneath it begins to move in response to earthquake waves.

Mechanical or electrical devices can be used to sense the motion of the ground relative to the heavy pendulum of the seismograph. Up-and-down or sideways ground motion sends a mechanical or electrical signal to a pen attached to a paper-covered drum. As the drum turns, the pen wiggles, producing an amplified recording of the ground motion. This recording is called a seismogram. Scientists use the amplitudes of earthquake waves recorded as seismograms to determine the magnitude ratings of earthquakes.

Table: Earthquake World Records

Location	Date	Magnitude
Ecuador	January 31, 1906	8.9
Assam, India	June 12, 1897	8.7
Alaska	March 28, 1964	8.6
Alaska	September 10, 1899	8.6
Southern Chile	May 21-30, 1960	8.5
San Francisco	April 18, 1906	8.2
Kwanto, Japan	September 1, 1923	8.2
Erzincan, Turkey	December 27, 1939	8.0
Indonesia	August 19, 1977	8.0
Mexico	September 19, 1985	7.9
Bolivia	June 9, 1994	8.2

From Master 29, Seismographs



Earthquakes Great and Small

Content Concepts

1. Earthquakes have different strengths.

2. Earthquakes cause different amounts of damage.

Objectives

Students will
— demonstrate two types of energy.
— demonstrate that earthquakes have different levels of strength.
— construct a model to simulate earthquakes and earthquake damage.
— compare the movement in the earthquake model to ground movement during a quake.
— compare different levels of earthquake strength in terms of their effects on structures.

Assessment

Students will experiment with building shapes and methods of construction. Ask students to describe the effects of gentle and strong shaking on their buildings.

Vocabulary

energy

Learning Links

Language Arts: Discussion/oral communication, vocabulary building, reading (optional)

Social Studies: Discussing effects of earthquake damage on people and their property

Math: Using ordinal numbers

Art: Constructing earthquake simulation model

Activity One: Weak and Strong

Procedure

1. Conduct a class discussion on the concept of energy. Establish that energy has many forms (such as mechanical energy, heat, sound, and light) and many different strengths.

2. Have students demonstrate two familiar types of energy.

a. Ask them to clap their hands loudly and describe the sound; then to clap them softly and describe the sound.

   Do you hear a difference? (Yes)

   Why is there a difference? (Soft clapping releases a smaller amount of sound energy than loud clapping does.)

b. Ask them to rub their hands together slowly and describe how they feel, then rub them together quickly and describe how they feel.

   How does the amount of energy change? As the amount of energy increases, what do you notice?

   Why do you feel a difference? (Quick rubbing releases a greater amount of heat energy than slow rubbing does.)

Activity Two: Shakes Makes Quakes

Materials for the teacher

- A small table or desk that moves easily. See also Teacher Note and Master 27, Shake Table

Materials for each pair of students

- A shallow box partially filled with sand or soil
- Paper
- An assortment of objects for building structures:

small blocks	Legos™	penne pasta
sugar cubes	Lincoln Logs™	Play-Doh™ or flubber

Teacher Take Note: **Before beginning this activity, you may want to have small groups or pairs of students construct their own shake table (Master 27).**

Procedure

1. Hand out paper and materials to each pair of students.

2. On one side of the paper, have students design plans for building a few structures of different heights that would withstand an earthquake. Students should include sentences that describe what they intend to build with and why they think it would withstand an earthquake.

3. With their partner and with the materials provided, have students construct the structures they just drew and wrote about above.

4. When their structures are completed, have partners take turns testing their structures on the shake table, or desk, shaking it gently the first time. (Nothing should happen to the structures.)

5. Shake it three more times, increasing the amount of force each time so that eventually the structures will gradually disassemble.

a. Each time the table shakes, have partners discuss the observations they are making.

b. On the other side of their paper, have students draw the results of the table shaking on their structures. Include with their drawing some reflective writing as to:

What caused the buildings to fall down? (the shaking of the table)

What caused the table to shake? (the students)

What did the students give to the table? (energy)

What happened to the buildings? — the first time? — second time? — third time? (They eventually broke apart.)

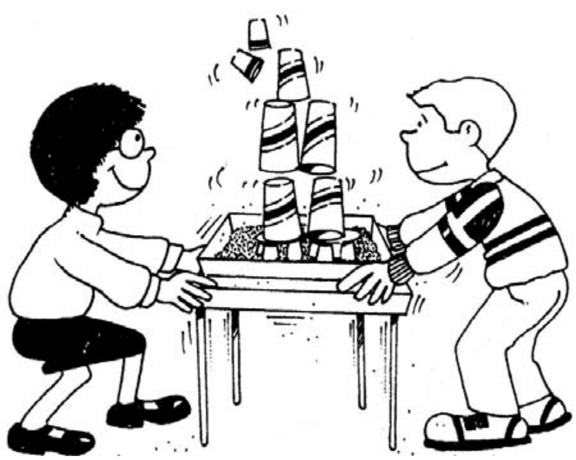
Are earthquakes always the same? (No. Some are weak and some are strong.)

Does it make any difference what building materials are used? (Yes. Have students look at other people's designs and models. Compare buildings made of stacking blocks with buildings made of materials that are connected to each other.)

What are some of the strongest shapes and materials used?

How did those factors affect the structures?

Summary: Different earthquakes have different amounts of energy, and cause different amounts of damage.



Activity Three: Shake a Minute

Materials for the teacher

- Large clock with second hand
- Blackboard and chalk

Materials for each student

- Pencils
- Paper

Procedure

1. Ask students to estimate on a piece of paper how long they think an earthquake lasts. (How long will the ground shake?)

2. Collect the estimates and list them on the board.

3. Explain to students that in most earthquakes, shaking rarely lasts for as long as a minute in any one area. Strong shaking from a major quake usually lasts for 30 to 60 seconds. The 1906 San Francisco earthquake lasted about 40 seconds. In the 1964 Alaskan earthquake, the shaking lasted 3 to 4 minutes—an extremely long time. This does not happen very often.

4. Tell students that they are going to estimate how long a one-minute earthquake is without looking at a clock. Have them break up into pairs. One of each pair will be the timekeeper and recorder, while the other is the "earthquake."

5. When you give the signal, the earthquakes are to begin shaking, and the timers are to begin timing. Ask the quakes (whose backs are to the chalkboard) to continue shaking until they think that a minute has passed.

6. Once the timing and shaking start, write the time elapsed on the board every five seconds. The timers, who can see the board, should record the last time listed when their partners stop shaking. Instruct the timers not to share the time with the earthquake students yet.

7. Ask the timers to report the actual times that each “quake” lasted. Write all the times on the board. Have the class compare the times:

How long was the shortest “earthquake”?

How long was the longest?

What was the average time for this group?

8. Have partners switch roles and repeat steps 5 and 6, then step 7. Ask the class:

Did the second group come closer to one minute than the first?

If the answer is yes, why? (Perhaps because the second pair of students had the advantage of observing the first pair.)

9. Now have everyone in the class shake for one minute at the same time. Tell them when to start and stop, but ask them not to watch the clock. Then ask:

Did the time you shook seem like more or less than a minute? (Explain that even though an earthquake is over in a short time, it usually seems much longer to those people experiencing it.)

What might happen to objects in this classroom if the ground shook strongly for a minute? (Answers will vary.) Explain that we will learn more about this in our next activity.

Different Shakes for Different Quakes

Content Concepts

1. Earthquakes differ in the amount of energy they release.

2. Earthquakes may be measured by their effects (intensity) or by the amount of energy they release (magnitude).

Vocabulary

energy

earthquake wave

amplitude

earthquake intensity

earthquake magnitude

modified Mercalli scale

seismograph

seismogram

Objectives

Students will
- — construct drawings to illustrate the Mercalli scale as a measure of earthquake effects on, people, structures, and the Earth's surface.
- — identify the magnitude scale as a measure of energy released by earthquakes.
- — construct and use a seismograph to demonstrate the measurement of earthquakes.
- — chart the number of earthquakes that occur each year in different damage categories, mild to severe.

Learning Links

Language Arts: Reading sentences, sequencing ideas, discussing, building vocabulary, constructing paragraphs

Social Studies: Discussing the human impact of earthquakes

Math: Using Roman numerals, interpreting data

Art: Making illustrations

Assessment

Display a seismogram and explain what it represents and how it can be used to identify earthquake magnitude.

Activity One: Measuring with Mercalli

Materials for the teacher
- Master 28, Modified Mercalli Scale
- Large Roman numerals I through XII

Materials for each student or group
- A copy of the Mercalli scale made from Master 28, Modified Mercalli Scale
- A large sheet of drawing paper
- Art supplies-colored pencils, crayons, felt markers
- Scissors
- Tape

Procedure

1. Introduce the Mercalli scale by explaining its purpose: to measure the intensity of the damage an earthquake causes. You might want to add other information from the unit introduction. Explain that the use of Roman numerals distinguishes Mercalli measurements from those on another scale (The magnitude scale will be introduced in Activity Two.)

2. Teach or review Roman numerals.

3. Distribute copies of the Mercalli scale and have students take turns reading the descriptions aloud.

4. Divide students into groups and ask them to draw scenes illustrating the Mercalli numbers. Provide art supplies. Intensity I may only require one drawing, but the higher numbers may require more.

5. Distribute large Roman numerals I through XII around the classroom wall in order from lowest to highest. As students bring up their illustrations, the class will try to assign each to its correct numeral. Students may hang their pictures on the wall under the correct numeral.

6. Either before or after a class discussion about the social impact of each step on the scale, have students write paragraphs describing their illustrations and add them to the wall display.

Shortened Mercalli Scale

I. Only instruments detect it.

II. People lying down might feel it.

III. People on upper floors of buildings will feel it, but may not know it is an earthquake.

IV. People indoors will probably feel it, but those outside may not.

V. Nearly everyone feels it and wakes up if they are sleeping.

VI. Everyone feels the quake. It's hard to walk.

VII. It's hard to stand.

VIII. People will not be able to drive cars. Poorly built buildings may collapse; chimneys may fall.

IX. Most foundations are damaged. The ground cracks.

X. Most buildings are destroyed. Water is thrown out of rivers and lakes.

XI. Rails are bent. Bridges and underground pipelines are put out of service.

XII. Most things are leveled. Large objects may be thrown into the

earth • quake in • ten • si •ty

Earthquake intensity is a measure of ground shaking based on damage to structures and changes felt and observed by humans. It is expressed in Roman numerals on the Mercalli Scale.

earth • quake mag • ni • tude

Earthquake magnitude is a measure of the amount of energy released by an earthquake. It is expressed in Arabic numerals on the magnitude scale.

seis • mo • graph

A seismograph is an instrument for recording the motion of earthquake waves.

seis • mo • gram

A seismogram is a recording of the wavy lines produced by a seismograph.

Activity Two: Movin' with Magnitude

Materials for the teacher

- Transparencies made from Master 29, Several Seismographs; Master 30, Seismogram Worksheet; Master 31, Earthquake Magnitudes; and Master 32, Seismogram Showing Amplitude
- Overhead projector

Materials for each small group

- Free-flowing overhead marker with fine tip for marking transparency
- Blank transparency sheet
- A light weight table or desk

Materials for each student

- Worksheet of seismogram tracings made from Master 30

Procedure

1. Place a blank overhead transparency on a light weight table or desk.

2. Have students take turns as holders and shakers. The first student holds the marker lightly with thumb, index, and middle fingers so it just touches the surface of the transparency sheet. As he or she holds the marker suspended, the other student shakes the movable object back and forth, varying the intensity of the shaking as much as possible. The markings that result will be similar to a seismogram. Show students the transparency of several types of seismographs (Master 29) and then Master 32, Seismogram Showing Amplitude.

3. Discuss the concepts of magnitude and amplitude. (Refer to the teacher background if necessary.) Explain that the amplitude of the earthquake waves (their height measured from a fixed reference line) reflects the amount of Earth movement, and therefore the magnitude of the earthquake. Magnitude is expressed as an Arabic number. Project the transparency of Master 31, Earthquake Magnitudes, and discuss.

4. Distribute the worksheets made from Master 30, and ask students to rank the seismograms from A to D, least amplitude to greatest.

Activity Three: Little Shakes and Big Quakes

Materials for the teacher
- Overhead projector
- Transparency made from Master 33, Earthquake Severity Worksheet

Materials for each student
- Worksheet of Master 33, Earthquake Severity Worksheet
- Pencils

Procedure

1. Tell students that seismographs record over 3 million earthquakes every year. They are going to estimate how many of those cause serious damage.

2. Distribute worksheets. Have students place the numbers from the answer section at the bottom of the sheet where they think they belong in the right hand column, Estimated Number per Year.

3. Project the transparency and invite students to compare their answers with the actual figures. Discuss their reactions. Ask them to write in the correct figures on their own sheets.

4. Have students add the four lower numbers to see how many earthquakes cause slight to serious damage every year (about 15,141).

Extension

Read Steven Kellogg's "How Much Is A Million?" to the class. Measure a ream of paper (500 sheets). Have students figure out how many reams it would take to get a million sheets. How tall would the stack be? If you were to type asterisks on a page, and it takes 500 asterisks to cover a page of paper, how many pages would it take to get to a million?

Master 33: Earthquake Severity Worksheet

Magnitudes	Earthquake Effects	Estimated Number Per Year Worldwide
1.0-3.0	Generally not felt but recorded.	3,000,000
3.1-4.0	Often felt, but only minor damage.	50,000
4.1-6.0	Slight damage to buildings.	15,000
6.1-6.9	Can be destructive in where people live.	120
7.0-7.9	Major earthquake. Causes serious damage.	20
8.0 or greater	Great earthquake. Total destruction to nearby communities.	1

Sizing Up Earthquake Waves

Vocabulary

earthquake wave
wave amplitude
earthquake intensity
earthquake magnitude
seismograph
seismogram
focus
epicenter
body waves
P- (primary) waves
S- (secondary) waves
expansion
compression

Learning Links

Language Arts: Discussing, following directions, taking notes

Social Studies: Discussing effects of earthquakes on people and structures; comparing effects to Mercalli intensity

Math: Metric measurement, computation, reducing fractions, computing ratios

Art: Creating models

Content Concepts

1. Earthquake body waves are either primary or secondary.

2. Earthquake waves detected by a seismograph are recorded as seismograms.

3. Scientists, can use isoseismals to compare the effects of different earthquakes.

Objectives

Students will

—distinguish between primary and secondary body waves (P-waves and S-waves).
—construct a model to simulate S-wave motion.
—construct a model seismograph, and identify its parts.
—identify different amplitudes of simulated earthquake waves by using the seismograph.
—draw isoseismals on a map which includes Mercalli intensity data.
—compare and contrast P and S wave motions using their body movements

Assessment

Use knowledge about seismic waves to relate this transfer of energy to the amount of damage following an earthquake.

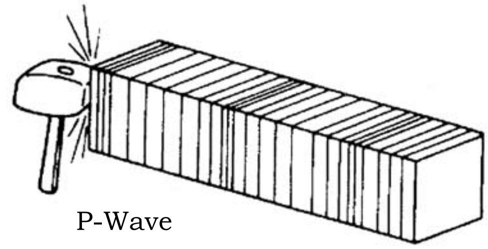
Activity One: Popping P-Waves

Materials for the teacher

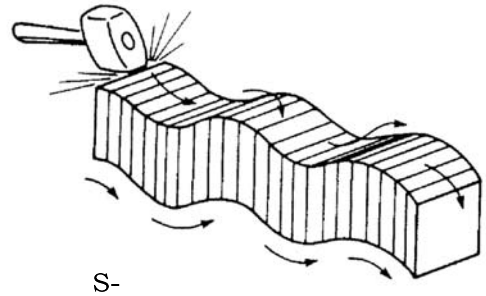
- Transparencies made from Master 34, P-Waves Motion and S-Wave Motion, and Master 10a, Earthquake Terms
- Overhead Projector

Materials for each student

- Slinky™ toys (One for every two students is ideal.)
- Sign post labeled **Focus** (Teacher or student volunteers can make it ahead of time.)
- Safety goggles



P-Wave



S-

Teacher Take Note: Metal Slinkies will be more effective than plastic ones for this activity. Mark one spot on each coil with bright permanent marker or a bit of white tape to make it easy for students to see the wave motion. Also note that P-waves vibrate in the direction in which they travel. Use the transparency of Master 34, P-Wave Motion and S-Wave Motion.

Procedure

1. Elicit from class the definition of an earthquake. Review or explain that the energy of an earthquake is released in the form of waves. (Use Master 1Oa, Earthquake Terms.) Point out that, all the energy moves out from the focus.

2. Divide students into pairs or groups of even numbers, depending on the number of Slinkies available. Distribute Slinkies.

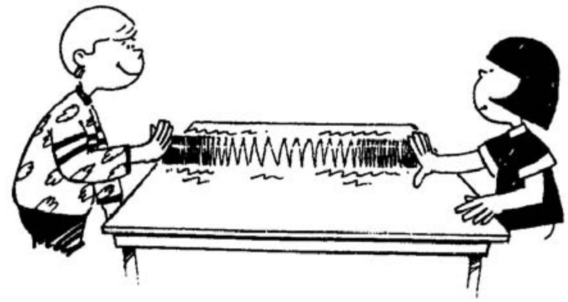
3. Two students will hold each Slinky, one on either end. Instruct them to stretch it to a length between 6 and 9 feet (2 and 3 meters) on the floor or a wide work surface.

4. Ask one of each pair to compress between ten and twenty coils and then release them rapidly. Both students continue to hold the Slinky during compression and release.

5. Ask students to describe what they see, and let this lead into your explanation of body waves, P-waves, and S-waves (see unit overview). Be sure to point out that the Slinky's motion simulates the expansion and compression of P-waves.

6. Place the sign post labeled **Focus** in an open area of the classroom. Have all the students compress and release their Slinkies in this one area at the same moment. This demonstration will help students to realize that earthquake waves radiate in all directions from the focus.

Children demonstrating compression and expansion of P-waves



fo • cus

The focus, or hypocenter is the place inside the lithosphere where an earthquake's energy is first released.

sur • face waves

Surface waves are earthquake waves that travel only on the surface of the Earth.

bo • dy waves

Body waves are earthquake waves that travel through the body of the Earth. They are of two types, P-waves and S-waves.

P-waves

P- (or Primary) waves are the fastest body waves, which travel by compression and expansion.

S-waves

S- (or Secondary) waves are body waves which travel more slowly than P-waves, and create elastic vibrations in solid substances.

Activity Two: The S-Wave Machine

Materials for the teacher

- Handout or transparency made from Master 35, The S-Wave Machine
- Transparency made from Master 34, P-Wave Motion and S-Wave Motion
- Overhead projector

Materials for each group

- 1 shoe box without its top, or a 1- or 2-qt. paper milk carton, cut as shown
- Compass point or other punching tool
- A rubber band long enough to stretch the length of the box or carton
- Scissors
- 2 metal washers 2 cm or larger
- 5 to 7 metal paper clips

Procedure

1. Gather students in pairs or small groups and distribute materials. Inform students that they are going to build and operate a device to illustrate the type of body waves called S-waves. Project Master 35 or hand out copies.

2. Instruct students to assemble their machines, referring to the projected illustration or the handout.

a. Stand box on end and punch a small hole in the top and bottom, near the center.

b. Cut open a rubber band and thread it through the top hole, tying the end to a washer to keep it from pulling through.

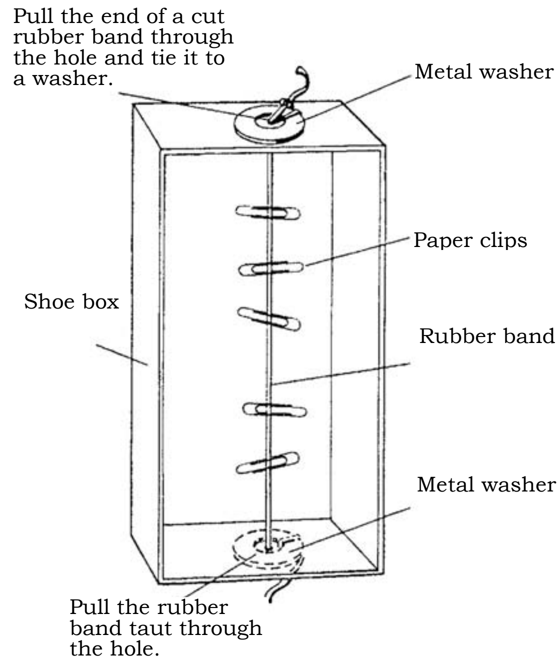
c. While another student holds the band stretched, thread the free end through the bottom hole and fasten it with the second washer. (The rubber band should be taut enough to twang when it is plucked.)

d. Attach 5 to 7 paper clips evenly along the length of the band so they are centered horizontally and they all face in the same direction. Allow the band and clips to come to rest.

e. Pluck the band and observe the motion of the clips.

3. Ask students to describe what they see. (They'll see paper clips swinging in all directions, at right angles to the movement of the wave up and down the rubber band.)

4. Project the wave transparency, Master 34, and explain the motion of S-waves through the Earth in terms of the demonstration. Point out that S-waves cause vibrations perpendicular to the direction of their movement. Compare this movement with the movement of P-waves.



Master 35. The S-Wave Machine

Teacher Take Note: To increase visibility of wave action try these ideas: Use dark paper in the back of the box. Illuminate the box by shining a light into it (an overhead projector light works great). As a teacher demonstration, cut out the back of a box, lay the S-wave machine on the lighted overhead surface. Project the enlarged silhouette on the screen.

Activity Three: Drum Rumbles

Materials for the teacher

- A drum (any type that's portable—a coffee can will do)
- 2 posters, one labeled S-wave and one labeled P-wave
- A watch that indicates seconds (Most digitals would work.)

Materials for each student

- A pencil and a notebook

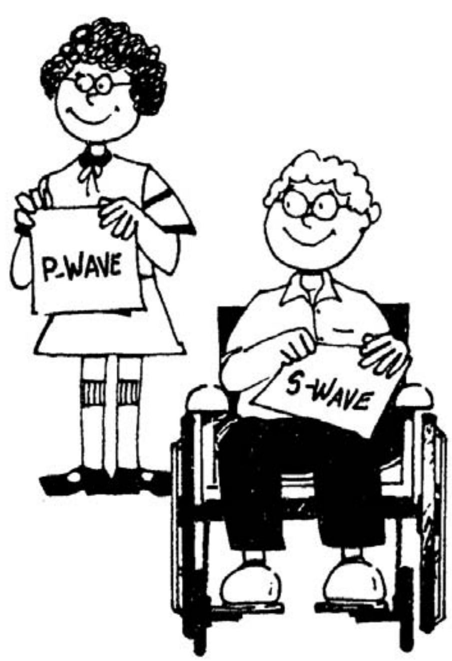
Procedure

1. Line students up single file in a long corridor indoors, or outdoors along a wall or fence.

2. Choose three volunteers: two to hold the S-Wave and P-Wave posters at a starting point (call it the focus) and one to beat the drum.

3. Students assemble in two parallel lines: S-waves on one side and P-waves on the other. The drummer will begin a steady beat of one tap per second. The P-wave line and S-wave line start walking: P-wave students take one step per second and the S-wave students take one step every two seconds for 20 seconds and stop.

4. Ask students to compare where lines ended. (P-waves travel approximately twice as far in the same amount of time. This 1:2 ratio approximates the 3:5.5 ratio of the actual P- and S-waves' traveling times.)



Activity Four: Set Up a Seismograph

Materials for the teacher

- Transparencies made from Master 29, Several Seismographs: and Master 32, Seismogram Showing Amplitude
- Overhead projector

Materials for each small group of students

- Three blank sheets of paper
- Thick-point felt marker
- Quart to gallon size container with handle
- Approximately 16 oz. of sand or water
- Strong string, 1 to 3 feet (depends on student height)
- Table or desk
- Tape
- Scissors
- Timing device

Procedure

1. Inform students that they are going to build and operate a simple seismograph. Display the several seismographs on Master 29. Point out the basic parts they have in common: weight, support, pen, and recording paper. Give students these directions:

a. Attach string to handle of container.

b. Pour the sand (or water) into the container.

c. Firmly tape the felt tip marker to the outside of the container with the tip sticking out below the bottom of the container.

d. Hold the sand-filled container over the desk.

e. Place a sheet of paper on the desk and position the container over one end of the paper with the felt marking tip just touching the end of the paper. One member of the group will hold the container in this position.

Extension

Students may wish to build other types of seismographs, such as those described in the references. Master 29 suggests some possible designs, but you might be surprised at what students can do on their own, without following a pattern.

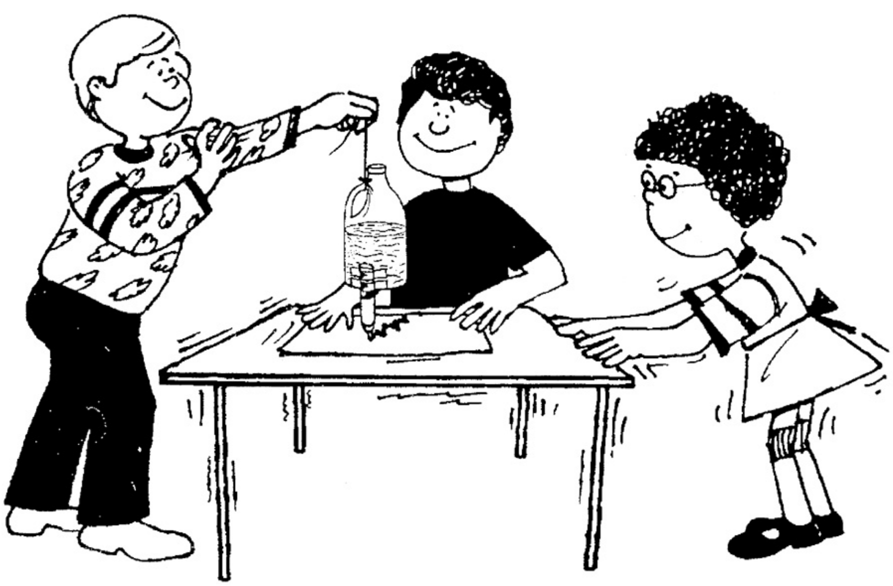
2. While one member of the group gently shakes the table, another member gently and steadily pulls the paper under the felt marker. Use a timing device so that the pull lasts between 5 to 10 seconds.

3. Have students label the sheet of paper "Gentle Shaking," and tell students that they have made a seismogram.

4. Ask the students to make two more seismograms, shaking the desk harder each time. Ask students to number the seismograms that result from 1 to 3, with 1 being the most gentle shaking.

5. Explain and define "wave amplitude," using Master 32, Seismogram Showing Amplitude. Help students to measure the amplitude of their own seismograms and relate them to the degree of force with which they shook their desks. Ask:

> How does the amplitude of the wave on the seismogram (Master 32) relate to the magnitude of the earthquake it records? (The higher the wave amplitude, the higher the magnitude.)
>
> Which of your own seismograms would have the highest magnitude? (The one with the highest amplitude, or the one which received the hardest shaking.)



Activity Five: The Mercalli Scale – Calling Station KWAT

Materials for the teacher

- Overhead projector
- One copy of Master 36a, KWAT Television Script
- Transparency made from Master 28, Modified Mercalli Scale
- Transparency made from Master 36b, Wattsville Map Key

Materials for each small group of students

- Handouts made from Master 28, Modified Mercalli Scale
- Handouts made from Master 36b, Wattsville Map
- Handouts made from Master 36a, KWAT Television Script
- Pencil and colored pens

Procedure

1. Project the transparency of Master 28, Modified Mercalli Scale, and distribute copies to students. Review the background information about the two earthquake scales. Explain that the magnitude scale measures the amount of energy released by an earthquake. The Mercalli scale measures the observed effects (amount of damage) caused by an earthquake. Emphasize that a single earthquake will have only one magnitude, but several measures of intensity. If some students in the class have experienced an earthquake, ask them to estimate its intensity from the Mercalli scale.

2. Ask students to compare and contrast the differences between the two types of measurements. Ask: Why do you think magnitude is more often reported than intensity? (Most earthquake-prone areas have equipment already in place to determine magnitude, so this measurement can be quickly established. Measures of intensity are sometimes not arrived at until several days later, when a full estimate of the damage can be made.)

3. Tell students that in this activity they will be using data adapted from reports of an earthquake that struck California in 1989. Distribute copies of Master 36b, Wattsville Map. Appoint one student to be Jake Wilde, a television news anchor, and tell the other students that they are the citizens of Wattsville and the surrounding area. The town has just been struck by an earthquake.

4. Distribute the strips cut from Master 36a, KWAT Television Script, and have students take turns reading them in order, starting with the news anchor's report. Distribute student copies of the script as well.

5. As each student reads a part, have the other students locate the site of the report on their maps, scan the Modified Mercalli Intensity Scale, and mark a Mercalli intensity (using appropriate Roman numeral) in pencil next to the location on the map.

6. After the last student has read, have each student use a colored pen to connect areas with equal intensity ratings to develop an isoseismal map. (They will be drawing a series of concentric lines.)

Unit IV. Measuring Earthquakes

Materials List

Grades K-2
shallow box
sand or soil
pencils & paper
small blocks
sugar cubes
Legos™
Lincoln Logs™
penne pasta
Play-Doh™ or flubber
large clock
blackboard
chalk

Grades 3-4
drawing paper
colored pencils
crayons
felt markers
scissors
tape
overhead projector
blank transparencies
overhead marker
pencils

Grades 5-6
overhead projector
Slinky™ toys
safety goggles
shoe box or 2 qt. paper milk carton
punching tool
long rubber band
scissors
metal washers
paper clips
drum
colored paper
timing device
pencils
notebooks
paper
felt markers
quart- to gallon-size container with handle
sand
strong string
tape