ShakeAlert
Version of activity from:
IRIS
www.iris.edu/earthquake

Earthquake Machine Model: 1 of 2*

Defining an Earthquake

Version 3.0

Incorporated Research Institutions for Seismology (www.iris.edu/earthquake) activity modified with permission for ShakeAlert (www.shakealert.org). See link in footnotes for educator version.

OVERVIEW

Earthquakes are associated with displacements on faults. Faults lock and a displ acement occurs when the stress across the fault builds up to a sufficient level to cause rupture of the fault. This stick-slip process is known as elastic rebound.

In this activity, learners work collaboratively in small groups to explore the earthquake cycle (Appendix A) by using a mechanical model (Figure 1). To make learners' prior knowledge explicit and activate their thinking about the topic of earthquakes, each learner writes their definition of an earthquake on a sticky note. Next, through a collaborative process, small groups of learners combine their individual definitions to create a consensus definition for an earthquake. Using an open-inquiry approach, they then experiment with the *Earthquake Machine* and compare their group's definition of an earthquake to the behavior of the model. Finally, the entire class discusses how the model is both like and unlike the actual phenomena of an earthquake (Table 1).

OBJECTIVES

Learners will be able to:

- Summarize the earthquake cycle in a short paragraph
- Use the *Earthquake Machine* model to demonstrate the causes of earthquakes, noting the flow of energy through the system
- Describe the role of models in the process of science.

AUDIENCE

This activity can be used for informal education or public outreach venues as a demonstration. The hands-on manipulation of the model in both this activity (Activity 1) and Activity 2* could be done with most any novice geoscience learning group.

It is best if the learners have some knowledge of plate tectonics and earthquakes. It works well to do this activity just after Fault Models

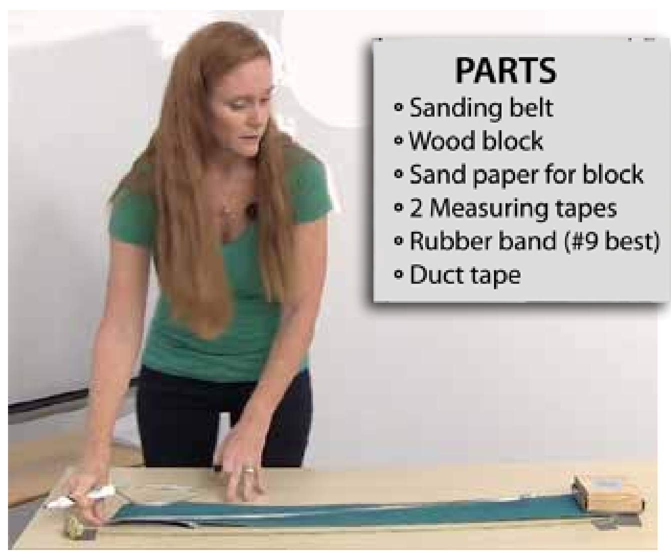

Figure 1: *Earthquake Machine Lite setup duct taped to desk. One tape measure is duct taped to the table adjacent to the sand paper. Tape measure is tugged slowly and steadily. (Screen grab of Dr. Wendy Bohon demonstrading the model from video:* www.iris.edu/hq/inclass/video/583*)*

*The original IRIS activity with more instructional material can be found at IRIS: www.iris.edu/hq/inclass/video/583
Activity 2, https://www.iris.edu/hq/inclass/video/584, is not a required followup.

MATERIALS

- One *Earthquake Machine* for every group of 3 to 4 learners. Materials list at right, and prep below.
- Computer with projection system
- Videos: Store.mp4 and Kathmandu_2015_UNAVCO.mp4 [note url links to be added when they have a home]
- One sticky note (or scrap paper and tape) per learner.

TEACHER PREPARATION

Background Information

- "Teacher Background" in Appendix A describes the "*Science of the Model*".
- Watch a video demo of an introduction to the model: www.iris.edu/hq/inclass/video/583
- Watch a video of the construction and use of the model (click related-resources tabs above video to learn more): www.iris.edu/hq/inclass/video/126

Construction:

1) Trace one of the 4" wood blocks on the back of the sheet of sandpaper, adding one inch to the length.
2) Place the sandpaper over the bottom of the block and fold the long edges up on to the ends of the block. Staple the sandpaper to the edges (Figure 2).
3) Screw one 12x1-3/16 screw eye into the cut end of the block about 1/2 inch from the base (Figure 2).
4) Feed rubber band into the screw eye and loop to knot.
5) Attach the first cloth tape measure by folding 1/2" of the end of it through the rubber band loop and back on itself. Use duct tape to secure it to the rubber band.
6) Use scissors to cut sanding belt so it is no longer a loop.

Setting up the *Earthquake Machine* for use

1) Smooth the sanding belt out on the lab table, grit side up, so that there are no waves in it. It helps to roll it backwards on itself to help flatten it.
2) Use duct tape to secure each end to the table.
3) Note! ***Optional*** for this activity, but essential for Activity #2 (*Investigating an Earthquake's Frequency and Magnitude*): Tape the second measuring tape down parallel to the sanding belt, metric side up!)
4) Place block on one end of sanding belt (Figure 1).

Materials & tools for each Earthquake Machine

- 1 – 4" blocks cut from 2x4 lumber
- 1 – 4"x36" Sanding belt with the heaviest grit possible (50-60 Grit)
- 1 – Sheet of sandpaper, with the heaviest grit possible (e.g. 60 Grit)
- 4 – Screw eyes 12x1-3/16 (or similar)
- 1 – Rubber band (size 19 is best)
- 1 – 16-in strip of Duct Tape
- 2 – Cloth tape measure with metric markings

Tools:

- Saw
- Scissors
- Heavy-duty staple gun & staples

Time Required for construction:

~ 2 hours for a class set

OPTIONAL

Appendix A (Figure 3) has a model for a paper building to affix to the block to show how a building shakes during an earthquake.

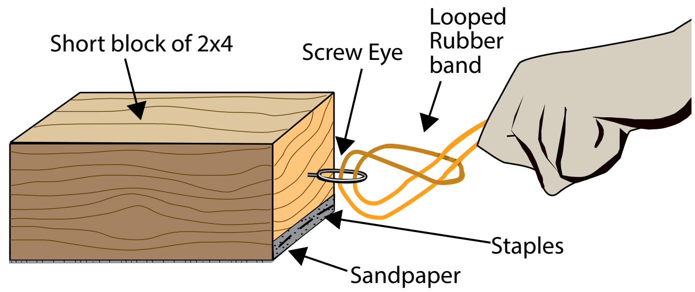

Figure 2: *Block A setup with looped rubber band and sandpaper.*

ACTIVITY DEVELOPMENT

1. Optional Introduction:

Play videos: **Store.mp4** and **Kathmandu_2015_UNAVCO.mp4**

Ask the class: *"What is happening in these videos?*.

2. Creating a Concept Statement

a) Ask learners to individually answer the following question: *"What is an earthquake?"* on a sticky note.

b) Have learners work in groups of 8-10 to discuss their ideas.

- Each learner reads what they wrote and places their sticky note on the table grouped by similar ideas.
- Next, the learners look at the groupings and identify themes. The group should then come to consensus on one definition of an earthquake that includes the entire group's ideas.
- Finally, each group shares their definition of an earthquake with the entire class, and as a class, discuss what an earthquake is and is not.

3. Exploring the *Earthquake Machine*

a) Show and describe the materials and assembly of the *Earthquake Machine* model. Before communicating how the setup models earthquakes, demonstrate what happens when you pull slowly on the tape connected to the block on the sandpaper.

NOTE: Slowly pull the measuring tape parallel to the surface of the sanding belt (Figure 2). The block should stick in place initially and the rubber band will stretch. When a threshold is reached, the block will slip forward as the potential energy stored in the rubber band is suddenly converted to kinetic energy. Once the block stops, the stick slip process begins again.

b) Ask learners what each part of the *Earthquake Machine* represents. **Answers**:

- The sandpaper represents the contact between one plate and another plate
- The moving block represents an earthquake
- The block of wood, rubber band, and pulling tape together represent a single tectonic plate
- The wood block represents the edge of the plate that is locked
- The rubber band represents the elastic materials that are storing potential energy inside the Earth
- Pulling on the measuring tape represents the force causing the plate to move

Note: If you are only doing the *Earthquake Machine* Activity #1, you will not be using measuring tapes for collecting and recording data – only for exploration.

c) Divide class into as many small groups as there are model setups . Have one learner from each group come up and pick up the materials for the model. Groups will assemble their models.

Allow adequate time for groups to freely explore the behavior of the model. If measuring tapes are used in the set-up, learners only use the measuring tape for making relative comparisons for how far the block slips.

4. Refining the Concept Statement "*What is an earthquake?*"

Once groups have had an opportunity to explore the model, ask the learners to revisit the original concept statement the class wrote at the beginning of the class. Display the original class definition of an earthquake.

a) Based on the model and its behavior, describe what you got right?

b) What would you change or add to your definition based on your experience with the model? Make any changes to the original definition.

c) What surprised or impressed you about the *Earthquake Machine* model?

d) Ask the learners how the model is like and unlike the earth? (See Table 1.) Ideas could be written on a flip chart or data projector as they are presented. Finally ask, why do we use models to study earthquakes?

Table 1. *Whereas the Earthquake Machine has many features that are* LIKE REALITY, *it also has a number of features that are UNLIKE REALITY that also must be made explicit to learners.*

LIKE REALITY	UNLIKE REALITY
The wood block represents the edge of a tectonic plate that is locked.	The materials are notably different.
The measuring tape represents the bulk of the tectonic plate where motion is constant.	The temporal and physical scale the model operates on is notably different.
Slow pulling on the measuring tape represents the force causing the plate to move.	In Earth, elastic energy is stored over tens to hundreds of years in rocks spanning an area of up to hundreds of kilometers rather than the seconds it takes to store energy in the small rubber band.
The rubber band and its deformation represents the elastic materials inside Earth that also store potential energy.	The block always has fixed dimensions while a fault may be much larger and could slip at any point along it and vary for each earthquake.
The sandpaper represents the contact between one plate and another plate.	In the model, the boundary between the two plates (or sides of the fault) is parallel to the surface. However, in Earth, plate boundaries (and fault planes) are not this horizontal.
When the locking (frictional in this case) forces are overcome, the potential energy is suddenly converted to kinetic energy.	Friction only occurs along the bottom of the wooden block in the model, but in a fault, friction is more complex and likely on the sides of the block as well.
The moving block represents an earthquake.	Energy in the model comes from our hand pulling on the block, but in Earth, the internal heat of the earth and gravity drives the complex forces causing plate movement.
Vibrations from the block moving are elastic waves, like seismic waves these radiate out in all directions.	Horizontal tension represents only one type of force causing movement on faults. Compression

FORCES, FAULTS, & FRICTION

The *Earthquake Machine* is effective at illustrating the interplay of:

- ***Forces***: proportional to extension of the rubber bands
- ***Faults***: represented by the interface between the strip of sandpaper on the board and the sandpaper on the brick
- ***Friction***: between the two pieces of sandpaper in contact with each other.

TIP 1

During open exploration, learners tend to want to pull aggressively on the tape. If this is occurring, guide them to see that the model behaves differently (and more interestingly) with a slower rate of pull.

TIP 2

If the block tends to creep along slowly rather than slip suddenly, you can add weight to the block.

APPENDIX A
TEACHER BACKGROUND

Science of the model

The simplicity of the *Earthquake Machine* allows learners to visualize the inputs and outputs of a fault system and explore stick-slip fault displacement behavior on a transform or lateral strike-slip fault. The model's wooden block and sandpaper base represent an active fault section. Learners' pull on the measuring tape attached to the block is analogous to continuous plate motions away from the boundaries. For example, this represents the continuous tension occurring on the San Andreas Fault in western California, which causes horizontal movement characterized as right-lateral strike-slip fault displacement. In this case, the Pacific Plate (on the west) moves northwestward relative to the North American Plate (on the east). The rubber band represents the elastic properties of the surrounding lithosphere, storing potential energy. When the frictional forces between the block and sandpaper are overcome, the block lurches forward with a stick-slip motion. Learners get to "experience" an earthquake by seeing the release of energy stored in the rubber band and feeling the propagation of seismic waves from an elastic source. Visualizing the energy released by the slip of the block is further enhanced by the motion of the optional model building, made of strips of lightweight poster board or manila folder material (Figure 3).

While this model accurately simulates the strain energy that slowly accumulates in rock surrounding a locked fault that is released in a sudden slip event, a process known as the elastic rebound theory [next section], it is ultimately a simplification of a complex Earth system. Such simplifications must be understood to interpret the model accurately. Therefore, the relationship between the model and reality should be clearly emphasized to learners (Table 1). This is particularly important for middle- to high-school-aged learners, who often think of physical models as copies of reality rather than representations.

The model not only provides a physical perspective on the generation of earthquakes, but it also illustrates the concept of an earthquake's magnitude, and how this can be calculated based on the physical features of the fault (see inset Vocabulary box right, *Seismic Moment*). In our model, the length and width (area; A) of the fault section that slips during an event (represented by the dimensions of the block of wood) as well as the rigidity of Earth materials (μ, represented by the elasticity of the rubber band) are constant for every event generated. The only factor that can vary is the displacement (D) or slip of the fault. As a result, there is a direct correlation between the amount of slip of the block and the moment magnitude of the event. While aspects of the mathematical relationship discussed in the inset box may be premature for some learners' experience, all learners will physically see this relationship by noting how much the "building" on top of the block moves in relation to the amount the block slips. The further the block slips, the more energy is released, and the more violently the building shakes.

OPTIONAL

Cardboard Building

(1) Cut four strips out of the manila folder; two that are ½″ wide and 5″ long (floor and roof), and two that are ½″ wide and 12″ long (vertical uprights).

(2) Fold ½″ on each end of the roof and tape it to the top of the uprights.

(3) Fold ½″ on each end of the floor and tape it inside of the upright about halfway up the structure.

Figure 3: *Optional building*

APPENDIX B—NGSS SCIENCE STANDARDS & 3 DIMENSIONAL LEARNING

Touch the url links to get more information.

Earth's Systems

MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=224

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.	**ESS2.A: Earth Materials and Systems** The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.	**Scale, Proportion, and Quantity** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.