Shake It Up!

Target Grade: Middle School
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Site: Longfellow B
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Brief Overview

This lesson aims to teach the science and engineering behind earthquakes and damage control! The first module introduces the science of waves in the context of earthquakes--specifically, the types of wave that we experience when one hits. The second module delves into the seismograph, a common way that we detect earthquakes. Finally, the third module allows the mentees to utilize the engineering design process to build and test their own shake-proof structures. By the end of the lesson, the mentees should have an idea of how earthquakes propagate, how we are able to detect and analyze earthquakes, and how we can prevent the amount of damage that an earthquake does.

Teaching Goals

- All earthquakes produce and propagate through waves. The main types of waves are S and P waves, the latter of which moves through solids, liquids, and gases.
- A seismograph is an instrument that measures the movement of the earth's surface, and can inform us of the presence of an earthquake as well as its relative magnitude.
    - All objects have inertia--resistance to changes in movement.
- Horizontal forces determine how structurally sound a building is.
- Engineers use different materials and structures to increase the stability of a building.
    - Engineering design process!

Careers and Applications

Geologists and Environmental Scientists use waves to understand what is going on deep inside the Earth. Architects and engineers need to think a lot about waves and their effect on structures when designing and building bridges and skyscrapers. Engineers come up with creative solutions, like the cables holding up the Golden Gate bridge, to help make these structures withstand earthquakes better.

These concepts and tools are also used to help keep us safe. Using seismographs and other tools, scientists watch for movements of the Earth's crust that help them predict when earthquakes are coming

Agenda

- Introduction (5 min)
- Module 1: Wave Box (10 min)
- Module 2: Seismograph (15 min)
- Module 3: Sturdy Structures (25 min)
- Conclusion (5 min)

Introduction

In this lesson, students will learn about earthquakes work, and how engineers deal with the threat they pose when building structures. Introduce the concept of earthquakes by reviewing what knowledge students already have of geology and plate tectonics, as well as asking whether they remember learning about recent catastrophic earthquakes (such as Haiti's 7.0 magnitude earthquake in 2010). Throughout the lesson, make sure to relate these ideas to how earthquakes propagate and affect people living in earthquake-prone areas.

Module 1: Wave Box

Introduction

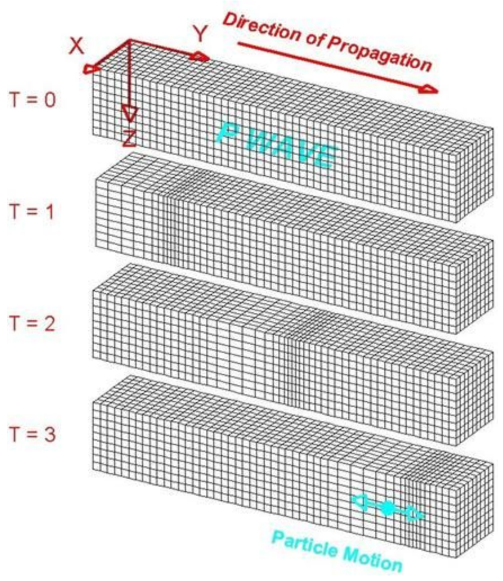
This module will guide the students through creating a wave box that demonstrates how earthquake waves travel through different kinds of materials.

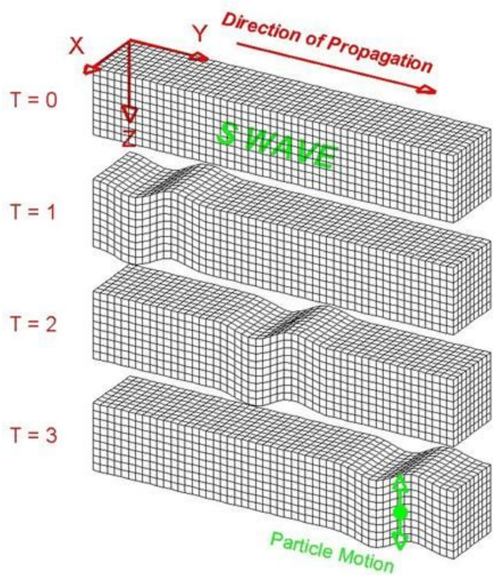
Teaching Goals

1. All earthquakes produce waves.
2. There are two kinds of waves: S and P waves.
3. P waves travel through all three mediums: solid, liquid, and gas.

Background for Mentors

An earthquake actually produces more than just S and P waves: it produces **body** waves (S and P waves are subtypes of body waves) and **surface** waves, which are further divided into **Love** and **Rayleigh** waves. A P or Primary wave is the fastest wave and the first to arrive. They are also called compressional waves due to the way they move, through pushing and pulling, like how sound moves in the air. As a P wave travels, it shakes the ground back-and-forth along the direction it's moving.





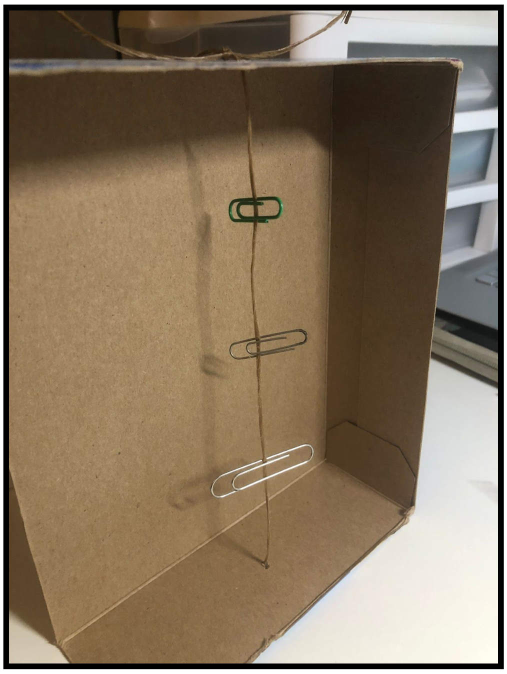
S waves, on the other hand, are slower and can only move through solid rock. They move the ground rock up and down or sideways, like a transverse wave. For the purposes of this experiment, we are specifically focussing on how P waves travel through different kinds of solids and are not concentrating on surface waves.

Materials

- 1 empty shoe box without lid per student
- 1 string per student
- Nail pick/scissors
- 1 box of mixed-size paper clips per site

Procedure

1. Using the nail pick or scissors, make a small hole on the top and bottom wall of the shoebox when held lengthwise.
2. Tie a string from one hole to the other through the inside of the box. You can use paper clips to keep the string from slipping through the hole.
3. Place 4-5 paper clips on the string at different intervals.
4. Place the box on a table or another surface that you can strike to make it vibrate.
5. Strike the surface hard enough to make the paper clips move back-and-forth on the string.
6. Try placing the box on different surfaces and repeating the experiment.
7. Try placing different sizes of paper clips and seeing how the vibrations vary.
8. Optional: Use a different thickness of string to see how it affects the vibrations.



Additional Notes for Mentors

- If the students are confused as to how the waves propagate on the ground, try to relate the lesson back to the lesson on refraction and how waves can be longitudinal or transverse.
- An analogy you can use is the ocean wave analogy. P waves resemble ocean waves in the sense that they push and pull in the forward-backward direction. S waves resemble the waves produced when you give a slinky a jerk in the sideways direction.

Module 2: Seismograph

Introduction

In this module, mentees will be introduced to seismograph and how it works. Mentees will also apply their knowledge of waves and earthquakes from module 1 into the making of the seismograph.

Mentors should ask whether the mentees know how a seismograph works. If they do know, most likely, they would think that when the Earth's surface moves, the pendulum moves. The seismograph actually uses inertia, where the pendulum remains in place while the rest of the machine moves. This point can be emphasized by asking the mentees first.

Teaching Goals

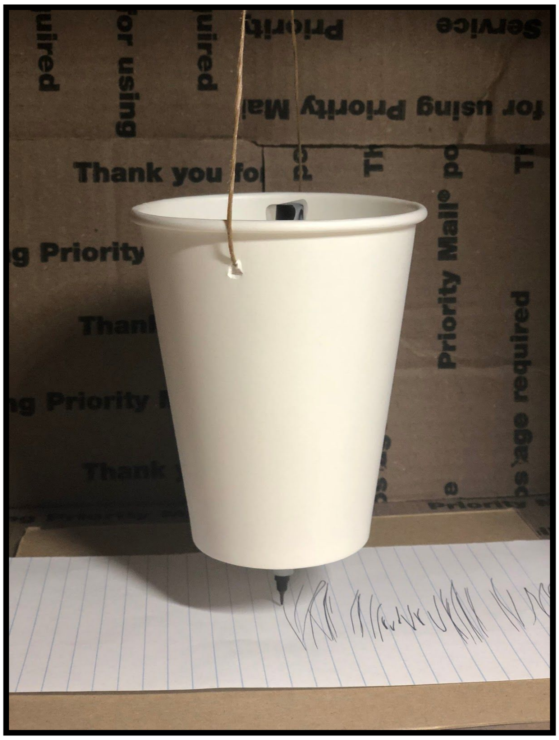
1. **Seismograph**: an instrument that measure the movement of Earth's surface, mostly earthquakes.
2. **Inertia:** resistance of an object to change its motion, whether from rest or from some kind of movement.

Background for Mentors

A seismograph is consists of a frame, a pendulum within the frame, and a surface to record the any disruptions to the resting pendulum. Most people think the seismograph detects movements of the Earth's surface/earthquakes by using the shakes/waves to move the object within the frame, which records the movements. Contrary to this, seismographs has a fixed pendulum inside its frame. When the Earth's surface moves, the entire frame, thus the instrument moves. However, there is a weight attached to the pendulum inside the frame, which, due to inertia, tends to stay in rest rather than move with the frame. This causes a relative motion of the pendulum to the frame, which results in "movement" and records it.

Materials

- Box (cereal box is ideal)
- Pencil (one per group)
- Scissors
- Tape
- Paper cup with lids (one per group)
- Sand (or weights to fill the cup)
- String
- Strips of paper



Procedure

1. Cut rectangular windows on both sides of the box and make a small hole at the center of the top side.
2. Cut two small openings at the bottom edge of the sides in order to slip in the strips of paper.
3. Punch two holes on the cup, one at the bottom and one on the lid.
4. Punch two additional holes (small) on the side towards the top and thread a string through both holes.
5. Slide a pencil through the other two holes with the lead pointing downwards.
6. Put sand in the cup (doesn't have to be full) and put on the lid.

7. Tie the string on the cup onto the hole at the top of the box.
8. Slide in the strip of paper and adjust the length of the string so the tip of the pencil touches the paper.
9. Shake the box and see the movement recorded onto the paper.

Additional Notes for Mentors
Make sure not too much sand is added into the cup so that the top of the box bends inward or the string snaps.

Module 3: Sturdy Structures

Introduction

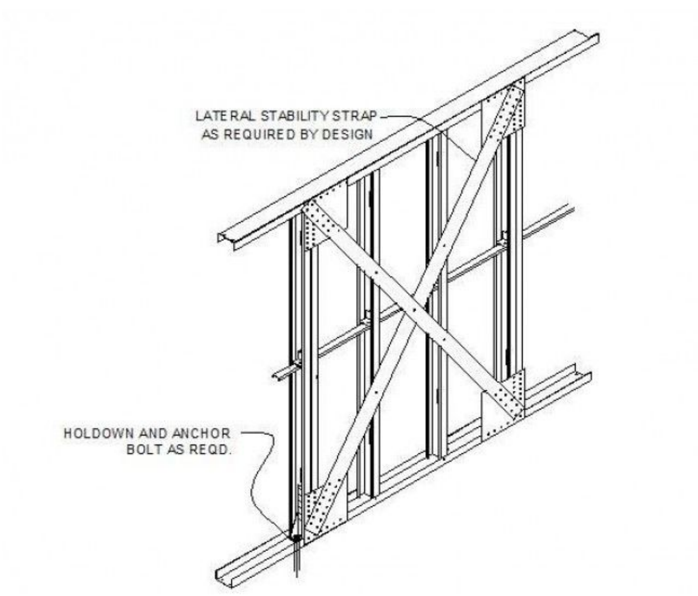
Now that we have gone over how earthquakes work, we can take a look at what engineers do to build lasting structures. In this module, we will be building our own “earthquake-resistant” structures.

Teaching Goals

1. Horizontal forces are a critical factor in weakening the structural integrity of a building
2. Engineers can use different building materials and specific building formations to mitigate the risk of a building collapse
3. **Engineering Design Process:** The process of planning, testing and improving designs that engineers use to create the best product possible!

Background for Mentors
Buildings are designed to withstand vertical forces, but the waves of an earthquake often apply extreme horizontal forces (as we learned earlier in this lesson). The side-to-side movement of these horizontal forces can greatly weaken the building’s structural elements (ex: columns, walls, floors..etc.) and cause an otherwise stable building to collapse. In earthquake-prone areas, engineers must then build sturdier structures that can survive the shaking of an earthquake.

There are numerous ways in which engineers can design sturdier structures. For example, engineers can choose to use more resilient and flexible building materials like steel, which is more ductile than concrete or brick. This alleviates the stress on the structure when shaken. Engineers can also choose to use stronger structural formations. **Cross-bracing** is when two beams are placed in an X-formation in order to build braced frames. This distributes the stress placed on the frame and allows it to withstand a heavier burden.



Cross-Bracing

Several other ideas you can consider are changing the base size and experimenting with the use of squares vs. triangles as building blocks.

Materials

- 1-2 pans of jello
- 10 marshmallows per group
- 20 toothpicks per group

Procedure

1. Divide the class into groups of 2-3 people and distribute the materials
2. Have the students plan out their building designs before actually building
3. Once the students have an idea of how they want to design their structure, let them start building!
    - The marshmallows can be used to connect toothpicks together
    - Try to have students build the highest possible structure they can
    - Also, try to encourage the students to experiment with different bases and formations when building their structure!
4. When students are finished building, they can come up to the mentor handling the pan of jello and begin testing their creations
    - Before testing, allow the students to present their structures:
        - How does their design allow for the structure to withstand earthquake tremors?
        - How do they think their building will hold up when we shake the jello pan?
    - After testing, have the students reflect on their structure:
        - If successful, ask them to think about why features allowed their

structures to hold
- If unsuccessful, ask them what in particular they could improve in the future

Additional Notes for Mentors
This can get a little messy so make sure only the mentors handle the jello pans!

Conclusion

Wrap up by talking about how the concept of waves and earthquakes is particularly relevant to us living in the Bay, since we are on a major faultline, and how by studying them, we can be better prepared for earthquakes when they do happen.

References

- "Elementary Science Experiment: Earthquake Waves," STEM-Works. http://stem-works.com/external/activity/570
- "Make Your Own Seismograph," KFVS12. http://www.kfvs12.com/story/307729/make-your-own-seismograph/
- "Seismic Shake-Up!," PBS Kids. https://pbskids.org/designsquad/pdf/parentseducators/DS_SeismicActivity_LN.pdf

Summary Materials Table

Material	Amount per Group	Expected $$	Vendor (or online link)
Shoe box without lid	1 per student	N/A	Bechtel
String	1 roll per site	N/A	Bechtel
Scissors	4 per site	N/A	Bechtel
Mixed-size paper clips	1 box per site	N/A	Bechtel
Cereal boxes	1 per group	N/A	Bechtel
Pencils	1 per group	N/A	Bechtel
Tape	2 rolls per site	N/A	Bechtel
Paper cups with lids	1 per group	N/A	Bechtel
Cup weights	Some per group	N/A	Bechtel
Paper	Lots	N/A	Bechtel

Jello	1-2 pans	$5?	Mix from Safeway (prepare beforehand)
Marshmallows	10 per group	$8?	Safeway
Toothpicks	20 per group	$8?	Amazon/Safeway