

# EDUCATOR GUIDE

# **EARTHQUAKE ENGINEERING**

**CREATED FOR BOTH HOME AND SCHOOL** 



PERFECT FOR THE CLASSROOM

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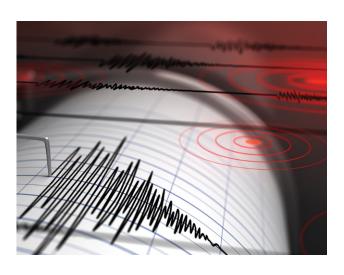
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## **LESSON OVERVIEW**

#### **Class Information**

This lesson plan provides material on the science and study of earthquakes. It will go over tectonic plates and how the fault lines create different boundary interactions to form different land formations. As well as discussing the seismic waves that create earthquakes, how scientists measure their magnitude, and how engineers protect buildings from the seismic activity.

# CONCEPTS What is an Earthquake **Tectonic Plates Fault Lines Seismic Activity Earthquake Artchitecture**



## **LESSON OBJECTIVES**

- Describe what an earthquake is and how it is formed.
- Understand that the crust of the earth is broken up into pieces called tectonic plates.
- Explain how seismic waves are measured to determine the magnitude of the earthquake.
- Understand how engineers design buildings to prevent damage from earthquakes.

## **EDUCATIONAL STANDARDS**

#### **NGSS - Next Generation Science Standards**

#### **Engineering Design**

- K–2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
- 3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3–5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

#### Earth's Place in the Universe

- 2-ESS1-1 Use information from several sources to provide evidence that Earth
  events can occur quickly or slowly. [Clarification Statement: Examples of events
  and timescales could include volcanic explosions and earthquakes, which happen
  quickly and erosion of rocks, which occurs slowly.] "
- 4-ESS1-1. Identify evidence from patterns in rock formations and fossils in rock formations and fossils in rock layers for changes in a landscape over time to support an explanation for changes in a landscape over time.

#### **Earth and Human Activity**

- 3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
- 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.\* [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.]

#### Earth's Systems

 4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth's features. [Clarification Statement: Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes.]

## INTRODUCTION

Today we will be discussing earthquakes! We will learn about how they are formed, how we measure them and why they happen. As well as learning about how engineers design buildings to withstand earthquakes and keep people safe. Once we have learned about the science behind earthquakes, we are going to build our own earthquake simulator and test different building styles against the earthquakes it creates.

## **VOCABULARY**

**Tectonic Plates** - The large pieces of Earth's crust which are composed of rock. Movement of these pieces, where they are rubbing against one another, is what causes earthquakes.

**Fault line** - A crack or break in the crust of the Earth near or along a plate boundary.

**Seismic Waves** - When tectonic plates move, they create powerful vibrations. These vibrations are called seismic waves, or shock waves, and are what cause an earthquake.

**Earthquake** - Caused by the movement of tectonic plates rubbing against one another.

**Triangulation** - Method that uses distance information from 3 seismic stations to locate the epicenter of an earthquake.

**Epicenter** - The point on the earth's surface directly above the focus of an earthquake.

**Focus** - The place inside the earth's surface where the earthquake originates.

**Magnitude**- The size of the waves measured by a seismograph showing how much energy is released.

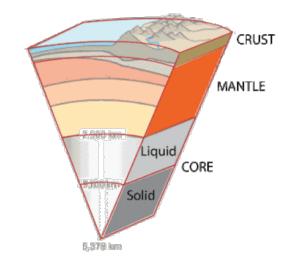
**Intensity** - How powerful the shaking of the earth is based upon the location from the epicenter of the earthquake.

## WHAT IS AN EARTHQUAKE?

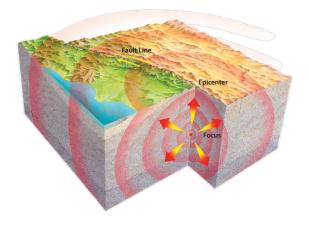
An earthquake is what happens when 2 plates of the earth's surface suddenly slip past one another. When the pieces of the earth's surface move past each other, the boundaries of the plates are rough and get stuck in place. Since the plate is massive, the rest of the plate continues to move until it moves far enough to unstick the edge of the plate along one of the faults. When this unsticking happens it causes an earthquake.

## WHAT CAUSES AN EARTHQUAKE?

o understand what causes an earthquake, we have to understand how the earth is formed. The earth is made of 4 major layers: Inner core, outer core, mantle and crust. The inner core is a solid mass, but the outer core and mantle are liquid. The crust and upper part of the mantle make up what we call the surface of the planet or the lithosphere. The lithosphere is broken up into pieces that float around on the mantle sliding past and running into one another. When the pieces interact with each other, sticking and bumping into each other we feel the effect as earthquakes.

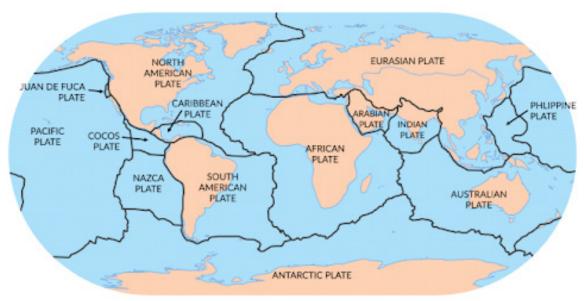


Every earthquake is broken down into 3 pieces: fault line, epicenter, and focus/hypocenter. The fault line is the pieces of land that are interacting with each other causing stress in the crust. The focus is the starting point of the earthquake in the crust of the earth. And the epicenter is the point on the surface of the earth that is directly above the focus



## **TECTONIC PLATES**

The pieces of the crust of the earth are called tectonic plates. These plates are made up of both oceanic and continental crust meaning they hold both oceans and continents/ land masses. There are 7 major tectonic plates (African, Antarctic, Eurasian, Indo-Australian, North American, Pacific and South American) and 8 minor tectonic plates (Scotia, Nazca, Cocos, Caribbean, Juan de Fuca, Arabian, and Philippine). There are also micro tectonic plates that fill in the remainder of the earth's surface. The largest plate is the Pacific plate, measuring 39,768,522 square miles.



## **FAULT LINES / PLATE BOUNDARIES**

The spots where the tectonic plates meet are called plate boundaries. There are only three types of tectonic plate boundaries: convergent, divergent, and transform. The type of boundary dictates the direction the two plates are rubbing against one another.

Fault lines are cracks or breaks in the crust of the earth near or along the plate boundary interactions. The type of fault is determined by the relative position of the fault planes or flat surface of the earth in that spot. As well as the type of stress that is being formed at this spot. Plate boundaries are always fault lines, but not all fault lines are plate boundaries.

#### NORMAL FAULT

A Normal fault is caused by a tension stress. Tension is pulling or stretching away from each other. This causes one side to drop down below the other piece. The term "normal" came from miners in germany who interacted with this type of fault often so they called it normal since it was what they were familiar with. These faults typically occur at a divergent plate boundary where the crust is pulling apart.

## **REVERSE FAULT**

A Reverse fault is caused by a compression stress. Compression is a squeezing or pushing force. This causes a piece of the ground to be pushed up on top of the other or thrust up above the original ground level. Since it is the opposite stress of a normal fault, it gained the name "Reverse" fault. These typically occur on a convergent plate boundary.



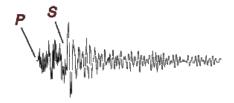
## **STRIKE - SLIP FAULT**

A Strike-Slip fault is caused by a shear stress. The shear force is a force applied along a surface in the opposite direction of another force such as sliding next to something. In this fault, the 2 plates are sliding horizontally in opposite directions. This takes place along a transform plate boundary.



## **SEISMIC WAVES**

When the tectonic plates are moving and running into each other, the edges can get stuck together. Since the plates are massive, the majority of the block is still moving. Since the plate is stuck in place, the movement is storing energy until it builds enough to break past each other. This immediate release of the energy travels outwards in all directions in the form of seismic waves that shake the earth. The Seismic waves consist of both P & S waves.



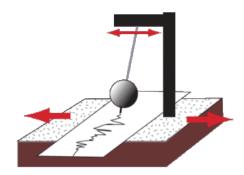
#### **Types of Seismic Waves**

P waves, or primary waves, move through the earth by compressing and stretching the earth's crust horizontally as it goes. S waves, or secondary waves, cause the earth's crust to move up or down vertically as they travel. The P & S waves can be compared to lightning and thunder to understand how they are recorded. P waves are like lightning and S waves are like thunder. In a thunderstorm, The lightning happens first and the thunder follows after. The further from the lightning strike, the longer in between the lightning and thunder. Seismic waves work the same with the P waves happening first and then the S waves follow afterwards. The further away from the epicenter of the earthquake, the more time will take place in between the two waves.

#### **Wave Measurement**

Seismologists can measure the earthquake by using an instrument called a seismograph. A Seismograph draws out the wavelengths of the seismic wave so it can be measured and recorded.

Seismologists can look at the amount of time between the P & S waves that are recorded by a seismograph to determine how far away the earthquake took place. If they use 3 seismographs to measure the distance and magnitude of the earthquake, they can use triangulation to find the location of the epicenter.



## MOMENT MAGNITUDE SCALE

The Moment Magnitude Scale (MMS) is the scale currently used by seismologists to measure earthquakes magnitude. This scale determines the strength of an earthquake by calculating the total moment release of an earthquake. A moment is the product of how far a fault has moved and how much force was required to move it. Unlike the Richter Scale, which was previously used to measure earthquakes, the MMS is able to be used over a wider range and be used globally. The larger the number, the larger the earthquake. Unless an earthquake reaches at least a level 3 on the MMS, it likely won't be noticed.

	Magnitude	Effects of Earthquake
Micro	1.9 or less	Not felt; can be measured on seismograph
Minor	2.0 - 3.9	Might be felt; no damage.
Light	4.0 - 4.9	Often felt; only causes minor damage
Moderate	5.0 - 5.9	Slight damage to weak structures.
Strong	6.0 - 6.9	Damage in populated areas
Major	7.0 - 7.9	Serious damage
Great	8.0 or greater	Can completely destroy communities near epicenter.

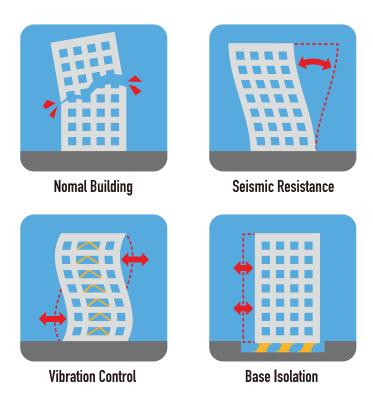
## **MODIFIED MERCALLI SCALE**

The Modified Mercalli Scale (MM) is the scale used to measure an earthquake's intensity at that location. Measuring the intensity of an earthquake tells the severity of the shaking and the effects it has on humans, animals, communities, and the environment. Each intensity level is represented by a number, the shaking felt, and a description of what was felt along with the damage the earthquake caused. Since the measure of the intensity of the earthquake is relative to the location from the epicenter of the earthquake, this is a less widely used form of measurement.

Intensity	Shaking	Description/Damage
I	Not felt	Not felt, except for a few special conditions.
II	Weak	Felt by very few, mostly those on upper floors of buildings.
III	Weak	Felt mostly by those indoors, especially on upper floors of buildings.  Vibration like that of a truck passing on a road.
IV	Light	Felt mostly indoors, felt by some outdoors, during the day. Felt by some at night, some will wake up. Home items and structure may move and make noise. Cars may appear to rock.
V	Moderate	Felt by mostly everyone; some home property may be damaged, and pendulum clocks may stop.
VI	Strong	Felt by all, and people are likely to be frightened. Heavy furniture may be moved, some fallen plaster. Only some damage.
VII	Very Strong	Well built structures/construction may have some damage; poorly built structures, or structures of poor design will have much damage.
VIII	Severe	Some damage in specially designed buildings, more damage at regular structures, and some with partial collapse. Poorly built structures will have great damage. Column-like structures (chimneys, factory stacks) likely to collapse. Heavy furniture overturned.
IX	Violent	Damage to specially designed structures; well-designed frames thrown out of place. Damage great in major buildings, with some collapse.  Building moved off of foundation.
X	Extreme	Most well-built structures destroyed, most frame structures destroyed, and rails bent.

## **EARTHQUAKE-PROOF BUILDINGS**

Despite the multitude of natural disasters, earthquakes are one of the most destructive forces the Earth has to offer. Earthquakes may often leave buildings destroyed, injuries or loss of life to humans and animals, leading to significant financial damages. While engineers and architects can use a variety of technologies to keep a building somewhat intact during and after an earthquake, there will almost always be some amount of damage done to a structure.



To understand how engineers and architects have improved building designs, it is important to learn how earthquakes actually impact structures. Buildings are generally built to withstand vertical forces such as weight and gravity. When an earthquake passes through a building, it sends shockwaves horizontally through the building structure opposite of the force that buildings normally experience. This horizontal force causes the structural components of the building to vibrate side to side causing extreme stress on the frame of the building. This ultimately results in the structure collapsing. Engineers can design buildings to be more earthquake resistant by building with special techniques, structures and materials.

## **BUILDING TECHNIQUES**

There are a few building techniques that help to make buildings more earthquake resistant including:

#### **FLEXIBLE FOUNDATIONS**

Building a structure base on top of flexible pads. These pads can be made of steel, rubber, and/or lead. When an earthquake hits, these pads absorb the majority of the earthquake's impact. This keeps the vibration from traveling through the structure and causing stress on it.



#### **VIBRATIONAL DAMPING DEVICES**

These devices are connected to beams in the structure, and as the earthquake hits, the motion caused by the earthquake is converted into heat, ultimately absorbing the shock.



#### SHIELD THE BUILDING FROM VIBRATIONS

Concrete and plastic rings are placed underground, around the building, at least three feet below the foundation. When an earthquake hits, the rings absorb the shock.



#### **PENDULUM POWER**

A large ball, connected to steel cables and hydraulics, is positioned at the top of a building. As the building begins to move, the ball reacts and moves to the opposite side of the building. As the building continues to move, the ball swings back and forth to either side. This motion balances and stabilizes the movement caused by the earthquake.



## REINFORCED STRUCTURES

Buildings are often designed with special ways to redistribute the forces from earthquakes, and reinforce the frame to avoid collapse. A few examples of building reinforcements include:

#### **DIAPHRAGMS** [A]

These horizontal frames keep tension from the floor and place the force on the vertical portions of the building.

#### **MOMENT-RESISTING FRAMES [B]**

These frames allow columns and beams to bend, while the joints remain rigid, allowing the building to resist forces from the earthquake.

#### SHEAR WALLS AND CROSS BRACES [C]

These walls are made from panels, supported by cross braces. These help to support compression and tension, keeping pressure off the building's foundation.

## **EARTHQUAKE RESISTANT MATERIAL**

#### STRUCTURAL STEEL [D]

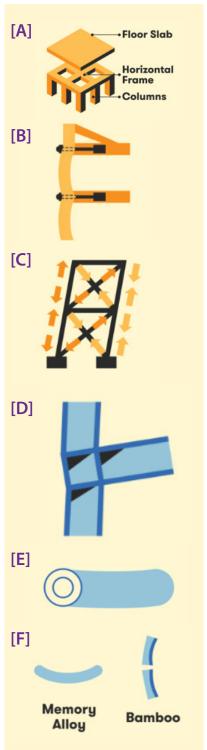
Steel that comes in many shapes, and allows for a structure to bend without breaking.

#### WOOD [E]

Significantly strong while being lightweight.

#### **UP-AND-COMING MATERIALS [F]**

Scientists and engineers are always looking into materials that can better support a structure during an earthquake. Materials being studied include: spider silk, bamboo, 3D printed material, and fiber-reinforced plastic wrap.



## **PROJECT OVERVIEW**

Today's project will be the students building and testing the wooden Brainstorm earthquake simulator. These machines will create vibrations that simulate an earthquake on a small scale that students can use to test their buildings on. Students will make 3 different buildings with a variety of levels and supports to see how long their buildings survive on the earthquake simulator.

## **SAFETY WARNINGS:**

Please read all safety warnings before use:

**Choking Hazard:** Small parts not for children under 6 years or any individual who have a tendency to place inedible objects in their mouths.

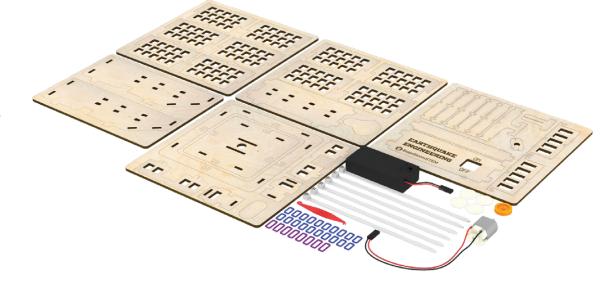
Eye protection should be worn at all times.

Adult supervision required.

## **MATERIALS**

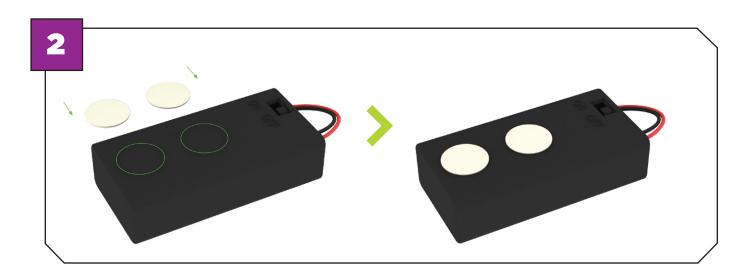
Durable wooden constructions pieces

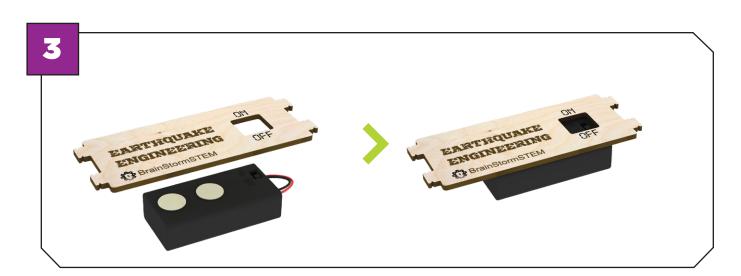
O-Ring fasteners
Motor
Battery pack
Small rubber bands
Dental rubber bands
Pulley wheel
Mounting tape
Zip ties

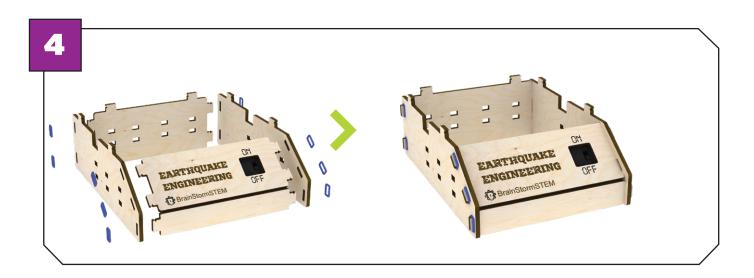


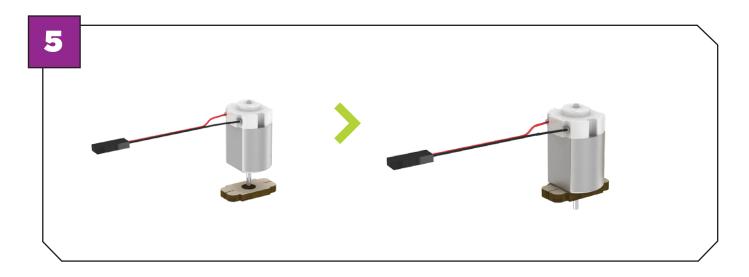


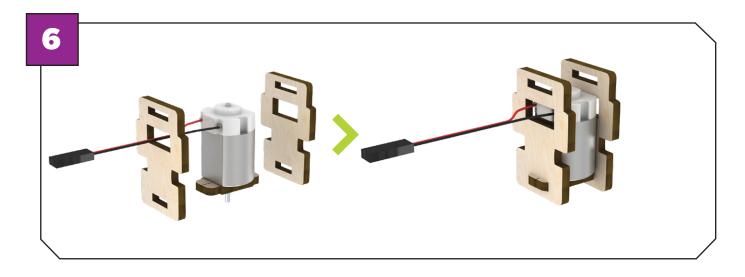
**NOTE:** If you can not break out the pieces by hand, use a blunt tool or a small knife to cut or punch them out. If you have no experience with tools or use a knife, get help from an adult. If there are any burrs, points or rough spots do to breaking or cutting, smooth them with a piece of sand paper.

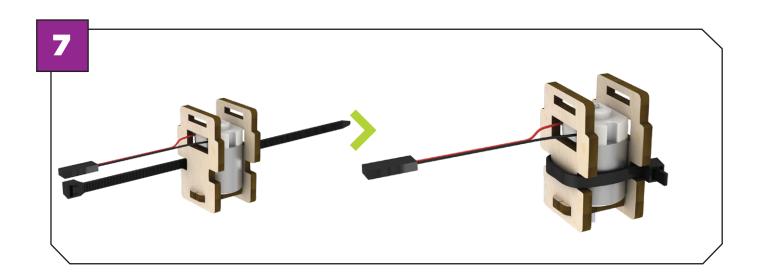


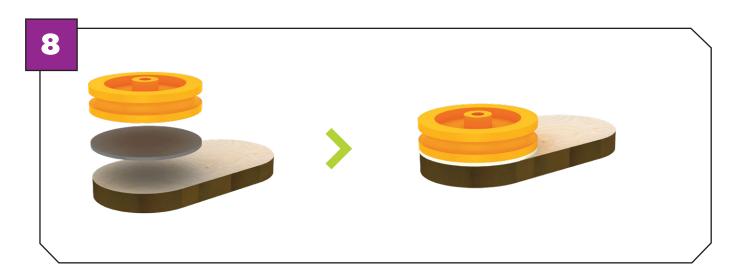


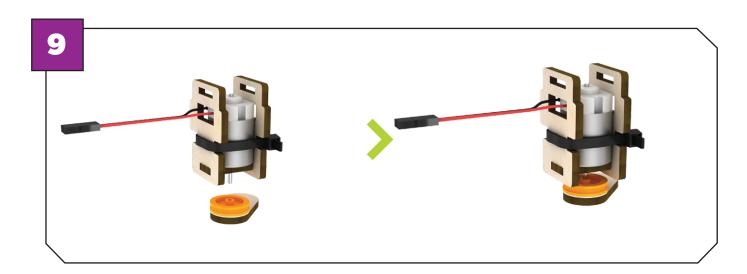


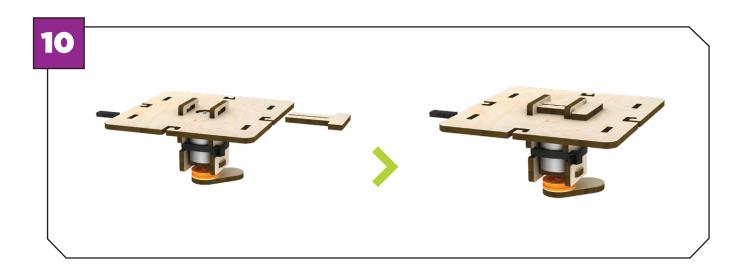


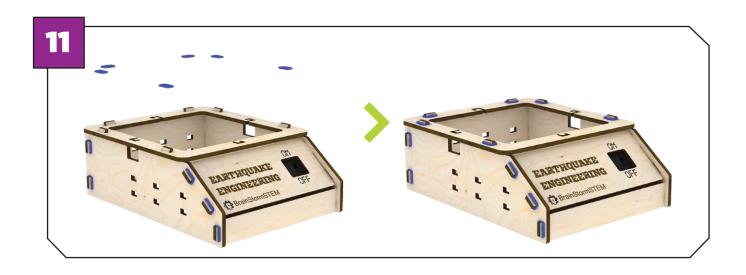


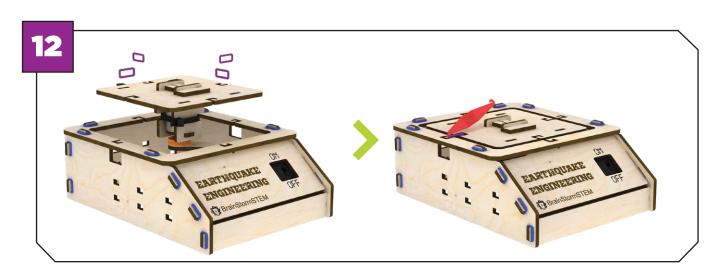


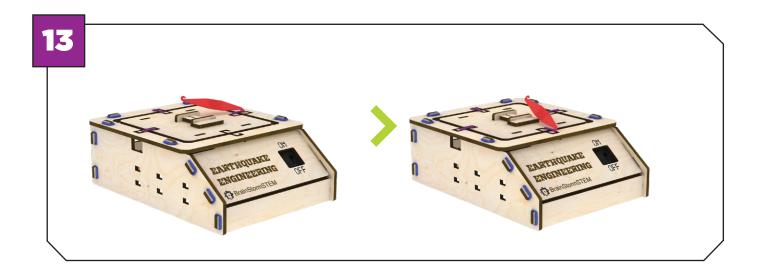


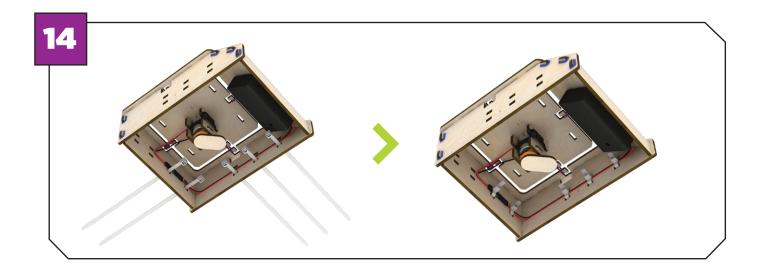


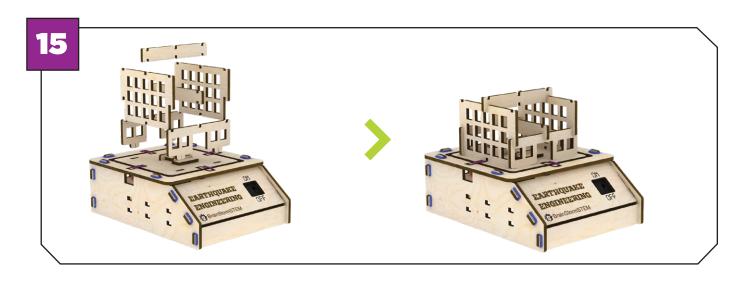












# **HOW TO USE**



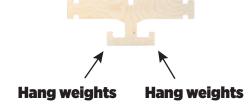




HAVE FUN & BE SAFE

# **EXTENSION**

Use this piece to add weights to your building.



For example, place a metal washer onto the hooks. Get creative and use different objects and weights to observe how the different variables effect the stability of the building.

#### If you enjoyed this STEM Kit, check out some of our other Kits!









WIND TURBINE

AND MORE!

## **ACTIVITY FOR PROJECT**

The Brainstorm earthquake simulator can be used just to build, test and have fun. But if you would like the earthquake simulator to be used as a more engaging classroom activity, it can be paired with the provided worksheets. There are both a beginner and advanced worksheet in order to adjust to the level of your students' understanding.

The Earthquake simulator will allow students to test different building methods to make the strongest building. Students will be able to make buildings of different levels or stories to see how high of a tower can withstand the earthquakes. They can also add support structures into the building to provide more support to the walls and ideally make the buildings more stable.





Each of the worksheets is geared towards having the students figure out what building techniques will allow the students towers to withstand the earthquake simulator. On the beginner worksheet, students will build 3 different towers and time how long they stand on the simulator. On the advanced worksheet, students will build their towers with certain constraints and see how long the builds last on the simulator.

Students will be able to see how changing the number of levels and adding supports will change the stability of their structures against the earthquake machines.

## **WORKSHEET (BEGINNER)**

Name(s):

Date:

#### **INSTRUCTIONS:**

Once you have built your earthquake simulator, design a building that will best withstand an earthquake!

You will be performing 3 tests. For each test: build your building, draw it in the space below, and time how long it survives!

Test 1

Test 2

Test 3

How long did it last?

How long did it last?

How long did it last?

(Circle)the test number that lasted the longest.

Why do you think it lasted the longest?

Name(s):		
Data		

#### **INSTRUCTIONS:**

Once you have built your earthquake simulator, design a building that will best withstand an earthquake!

For each test you will have a set of constraints. Follow the instructions and time how long each tower stands against the earthquake generator. Fill in the information in the table below.

Test #	# of Levels	Supports (Yes or No)	Time Standing
1	2	No	
2	2	Yes	
3	3	No	
4	3	Yes	
5	4	No	
6	4	Yes	

Which test was the most effective against the earthquake simulator and why?

Based upon our tests and the information provided in class, what is important to add to buildings to make them "earthquake-proof"?