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Simulating Earthquakes Unit Guide

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Summary

In the Simulating Earthquakes Unit, students program a Shake Table and use it to design and test models of earthquake-safe structures. Students experiment in Cubit Workshop to write code to model the motion of seismic waves by shaking the 3D-printed Shake Table platform, then construct their earthquake-safe building model and conduct controlled testing to make claims about the safety of their structures. An optional activity provides supplemental mathematics and science support in which students learn about different properties of different types of seismic waves, and compute the frequency of the waves they are modeling

Lesson Details

Duration: 1.5 - 3 hours (May be adjusted, divided, or extended to fit time available)

Optional lesson duration: 1 - 3 hours

Recommended Grade Range: Middle School

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Simulating Earthquakes
Cubit STEM Unit

Learning Objectives

S Science

Explore wave motion as a cycle of push and pull forces ● Predict the motion of the Shake Table using understanding of push and pull forces (force vectors) ● Evaluate the advantages and limitations of the Shake Table as a model ● Optional: Contrast wave properties of different types of seismic waves: P-Waves, S-Waves, Love & Rayleigh Waves ● Investigate wave frequency of modeled seismic activity by measuring the frequency of Shake Table motion in cycles per second

T Technology

Program push and pull motion with Servo Motor Smartware ● Develop solutions to work around hardware limitations of Servo Motor Smartware ● Create code with loops to yield repeating behavior ● Calibrate parameters of Servo Motor shaking to adjust speed and frequency of shaking behavior ● Design code to measure time for testing purposes

E Engineering

Design a solution to earthquakes as a natural hazard ● Engineer structures that can survive earthquakes using the best practices of engineering design ● Analyze testing results to inform ideas for revisions ● Consider the effect of structural attributes (e.g. shape, material, weight distribution, etc.) on the stability of the design

M Mathematics

Engage in geometric thinking to program Servo Motors to move along a semicircular path ● Determine changes in Servo Motor position by computing differences between desired positions in negative and positive terms ● Optional: Calculate wave frequency in cycles per second (Hertz) using timekeeping devices (optional)

Scope and Sequence

Lesson 1: Simulating Earthquakes with the Shake Table

- Design Challenge Introduction and Understanding Wave Motion of Earthquakes
- Simulating Earthquakes: Programming Servo Motors
- Simulating Earthquakes: Programming *Wait* Blocks

Lesson 2: Earthquake-Safe Structure Design Challenge

- Design Challenge Part 1: Design an Earthquake-Safe Structure
- Design Challenge Part 2: Prototype and Test the Earthquake-Safe Structures

Lesson 3: Testing Analysis and Prototype Revision

- Reflection on Shake Table Testing Results
- Revising and Re-prototyping

Lesson 4 (optional): Properties of Earthquake Shaking

- Calculating Frequencies of Seismic Wave Models
- Evaluating the Shake Table as a Model of Seismic Wave
- Modeling Properties of Earthquake Shaking for Structure Testing

Vocabulary

Simulate	Seismic Wave
Wave	Frequency
Motion energy	Compress
Structural Engineer	Criteria
Architect	Constraints
Servo Motor Positions	Prototype

Smartware Required


Computer with Cubit Workshop Installed


Cubit Controller


Cables x3


USB Power Connector


Battery Pack


Servo Motor x2

3D-Printed Materials Required

3D-Printed Cubit Shake Table
These can also be printed on school 3D printers or at a local Makerspace.
CAD model files can be found here: https://goo.gl/WCSn2h

Other Materials

The following list provides ideas for materials to be used for prototyping the earthquake-safe building. It is recommended to provide a selection of materials, and solicit additional materials from students' homes.

1. Cardboard
2. Paper
3. Toilet rolls or paper towel rolls
4. PVC pipe
5. Wire
6. String or yarn
7. Straws
8. Popsicle sticks
9. Paper clips
10. Binder clips
11. Toothpicks
12. Rubber bands
13. Pipe cleaners
14. Fabric
15. Plastic containers
16. Water bottles or other beverage containers
17. Small cereal boxes
18. Small snack containers
19. Particleboard
20. Pegboard
21. Paper cups
22. Hot glue guns
23. Various types of tape (double-sided, cellophane, packing, masking, painters, duct, electrical, etc.)
24. Cotton swabs
25. Modeling clay
26. Construction paper
27. Rulers
28. Plastic wrap
29. Fishing line
30. Thread
31. Transparencies
32. Take-out boxes
33. Hook and loop strips
34. Wooden dowels
35. Construction toy sets
36. Shoeboxes
37. Aluminum foil
38. Any other materials students find in their own homes

Lesson 1: Simulating Earthquakes with the Shake Table

Design Challenge Introduction and Understanding Wave Motion of Earthquakes S T E

- Introduce the project and the structure design challenge. Students will be programming Servo Motor Smartware to shake the platform of the Cubit Shake Table to simulate earthquakes. They will then prototype and test model buildings on the platform, and conduct analyses to evaluate the simulation and impacts on their building.
- The accompanying slideshow includes information to introduce the project. It can be shown to the whole class, printed out as handouts for students to work through self-guided, or adapted to fit the classroom's needs.
- Introduce students to the wave motion that causes and characterizes shaking in earthquakes.
- If desired, solicit students' experiences with earthquakes or news about earthquakes. Consider researching earthquakes in your local area or famous earthquakes ahead of time for this discussion. A list of suggested earthquakes to discuss is included in the notes of slide 2 of the accompanying slideshow.
- Guide students to connect the motion they will be modeling with the Shake Table with the passing of seismic waves through solid earth. Use this explanation to help students break down the idea of shaking into component parts, which students will later translate into their Cubit Workshop programs. The term seismic waves will be introduced later in the lesson.
    - The explanation on the slide accompanying this step can serve as a point to elaborate on the physical scientific concepts of force, motion, and kinetic energy.

Simulating Earthquakes: Programming Servo Motors T M

- Introduce students to how the Servo Motor Smartware can be used to push and pull the Shake Table to create shaking, using the appropriate slides in the accompanying slideshow if desired.
- Provide students with the Shake Table materials (3D-printed pieces, rubber bands, and wires), and Shake Table Assembly instructions. Circulate to support students in assembling their Shake Tables.
    - A common difficulty is fitting together the pieces of the base. If too tight, these may need to be pushed together with force (try carefully striking with a heavy object or closed fist) or filed down with emery boards; if too loose, try layering tape or taping small slips of paper between the pieces.
    - Another common difficulty is sliding the wires in the small holes in the Servo Motor "star" attachment. Assist students with this if needed.
- When students have assembled their table, encourage them to predict how the table will move and think about the vector of force when the Servo Motors move the table in different directions. A diagram of arrows to support prediction is provided on slide 6 of the accompanying slideshow.
- Support students in programming the Set Servo Position block, if students are not already familiar. Point out to students that they will need to experiment and calibrate the position of their Servo Smartware for the way they attached the wire. Slide 7 in the slideshow provides support for using this block.
    - Note that the Servo Motor has a 180° range of motion, but is NOT programmed in degrees, it is programmed in positions specific to the mechanics of the Servo Motor. This is why there are 255 positions and not 180 positions.
- Support students with understanding the Rotate Servo Motor block. Slides 8 - 10 of the accompanying slideshow address different ways the Rotate Servo Motor block can be used, including rotating in both directions, and what happens when the block instructs the Servo Motor to move past its range of positions.

Lesson 1: Simulating Earthquakes with the Shake Table (cont'd)

Simulating Earthquakes: Programming *Wait* Blocks T

- The need for a *Wait* block to provide time for the Servo Motors to move can be unintuitive for students. Slide 11 intentionally presents a program example that does not work, in order to illustrate the need for the *Wait* block presented in the subsequent slide. The program showed on the slide will appear to activate both blocks simultaneously. Direct students to use Debug mode to observe which blocks are active (blocks that are highlighted blue are actively firing).
- Allow students to try out the example program, and solicit their explanations of why it did not work.
  - If students are familiar with the *Wait* block as a solution to simultaneous activation with other Smartware (e.g. LED Strip, DC Motor), encourage them to compare their solutions from other programs as a possible solution to this problem.
- Encourage students to experiment with the *Wait* block in their programs, and to calibrate the amount of time to get the Servo Motor to push and pull the table the way students want and expect.
- A sample Workshop plan program example is provided as an image in the Unit Guide and in the accompanying Cubit Workshop plan file.

Lesson 2: Earthquake-Safe Structure Design Challenge

Design Challenge Part 1: Design an Earthquake-Safe Structure E

- **Prep:** Make materials for prototype construction available for students to survey, but not use. After designing and planning, they will use the materials. At this stage it is recommended that students not begin prototyping, to encourage students to practice good engineering design practices, modeling how professional engineers, architects, and designers work.
- Introduce the first part of the challenge, to design the structure.
  - It is preferable to avoid starting to build right away, to reinforce the importance of planning in engineering design. It may be helpful to make connections to professional architects and engineers, who do not begin building prototypes immediately without making some kind of plan.
- If using, distribute copies of the first three **Engineering Design worksheets**. Allow students time to complete the **Brainstorming**, **Specifications,** and **Design Sketching** handouts.
  - Students often struggle to brainstorm multiple ideas; encourage them to generate as many as possible. Remind them to write down any ideas, even ideas that seem "unrealistic". Remind them that historically, many innovations and great ideas seemed unrealistic or "wacky" at the time they were invented.

Design Challenge Part 2: Prototype and Test the Earthquake-Safe Structures T E

- **Prep**: Materials should be ready for students to use. Also provide tools such as scissors and rulers, and adhesive materials such as tape and glue, and/or more creative adhesives like marshmallows, gumdrops, or modeling clay (take caution with food and allergy safety concerns).
- Prompt students to prototype their structure, using their design plans from the previous activity, and test it on their Shake Tables.
- If structures slide across the Shake Table surface, consider affixing dots of hot glue, furniture leg cushions, or adhesive putty to the structure base, or taping the structure down to the platform.

Lesson 3: Testing Analysis and Prototype Redesign

Reflection on Shake Table Testing Results S T E

- Students will review their structures' performance, and reflect on how they could make revisions to their model.
- The **Reflection Questions handout** is provided to help students reflect on their design, review what issues they encountered, and consider improvements to make if they were to redesign the prototype.
- If desired, this is an opportunity for students to share their results, observations, and insights about the advantages and disadvantages of their designs.
- Guide students in making claims about how their model structure would survive a real earthquake if their model were built into a real structure.
    - Students may make their claims and present evidence to each other in groups, across groups, or with the whole class; this may also be done by individual or group journaling.

Redesigning and Re-prototyping E

- Unless time does not permit it, guide students through the process from the previous few lessons to redesign their models and conduct the same testing as in the preceding activity.
- Encourage them to start by planning their redesign before trying a new prototype
- Students can return to their initial prototype drawing and mark up their sketch to reflect desired changes, or use the initial sketch to create a sketch of a new prototype (especially if the redesigns are substantial).
- Encourage students to try to build structures that can survive as many different earthquake strengths and frequencies as possible.

Lesson 4 (optional) : Properties of Earthquake Shaking

This optional lesson provides supplemental activities supporting content in mathematics (frequency rate), geology/physical science (types of seismic waves), and additional engineering

Calculating Frequencies of Seismic Wave Models S T M

- Slides are provided in the accompanying slideshow to support the idea of wave frequency, in terms of earthquake shaking and graph representations of waves.
- If students are just becoming familiar with the properties of waves, it may be helpful to supplement with videos, demonstrations, or other instructional support for these ideas.
- Prompt students to try changing their programs to model high-frequency and low-frequency shaking.
    - This is done by changing the value of the *Wait* block; shorter values lead to higher-frequency shaking.
- Slide 18 discusses Hertz as a measurement of frequency, defined as 1 cycle (peak to peak) per second.
- Students may calculate the frequency of their table's shaking at a particular shaking speed, and of the structure at that shaking speed. Blocks that are useful for this are shown in Slide 19. It is recommended to allow students to decide the strategy they wish to use to calculate the frequency of their table's shaking.
    - Students can use the *Get Time Since Start* block or the *Timer* block to keep track of time while counting the number of shake cycles their table goes through. More information is included in the slideshow instructional notes. Sample plans are also included in the guide and as sample .plan Workshop files.
    - Another strategy students may use is to sum the *Wait* block time values until they reach 1 second.

Lesson 4 (optional): Properties of Earthquake Shaking (continued)

Evaluating the Shake Table as a Model of Seismic Waves S

- Slides 20-22 of the accompanying slideshow introduce four types of seismic waves: P-Waves, S-Waves, Love Waves, and Rayleigh Waves.
- Because the Shake Table can only model shaking in two directions (X and Y axes), it is only possible to model P-Waves and Love Waves using the table. P-waves involve compression motion, and Love Waves involve side-to-side motion. S-Waves and Rayleigh Waves involve up and down motion (Z axis). See the diagrams in Slides 21 and 22 of the accompanying slideshow for further support.
    - Guide students to understand the different properties of these waves, and thus the affordances and limitations of the Shake Table as an earthquake model.
    - If desired, guide a discussion about the use of models in science and engineering, and how the limitations of the model also limit the generalizability of claims made using the model.
- Background: An earthquake may include several different types of waves, and they may change over time and vary by location over the course of a single earthquake.

Modeling Properties of Earthquake Shaking for Structure Testing S T E

- Students will choose to model variation in earthquake shaking and test how well their structure survives this shaking. Two to five different tests of properties is recommended, so students can compare at least two properties. Encourage students to use what they have learned about seismic wave properties when determining what different properties they will test.
- The **Earthquake Properties Testing Grid handout** is provided to help students structure their test design, identify variables to keep constant and variables to change.
- Encourage students to use their results as evidence for a claim about how their design would perform in real earthquakes with these properties.

Plan File Resources

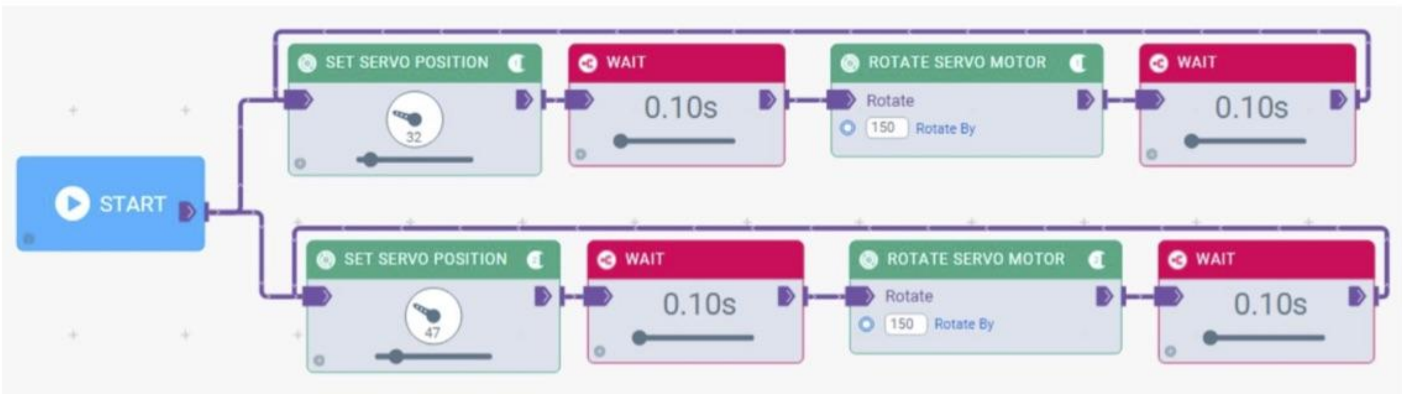
Plan files can be found here: https://goo.gl/BDgwRq

Port Numbers for Plan file

Port 1: Servo Motor (#1)

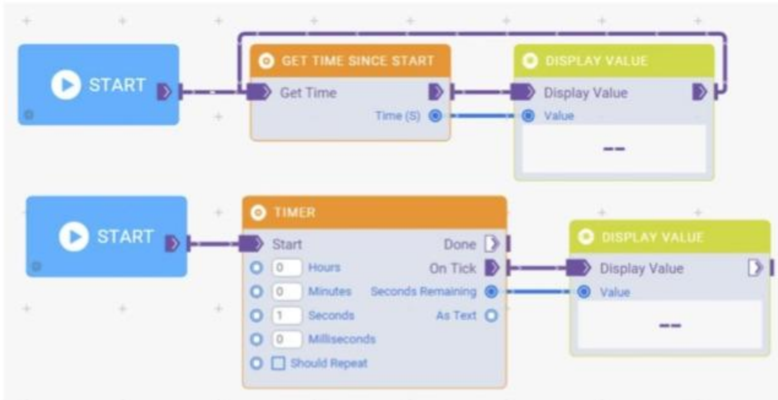
Port 2: Servo Motor (#2)

Example earthquake shaking plan file:

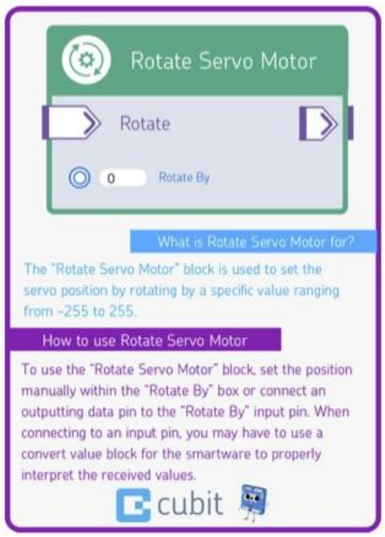


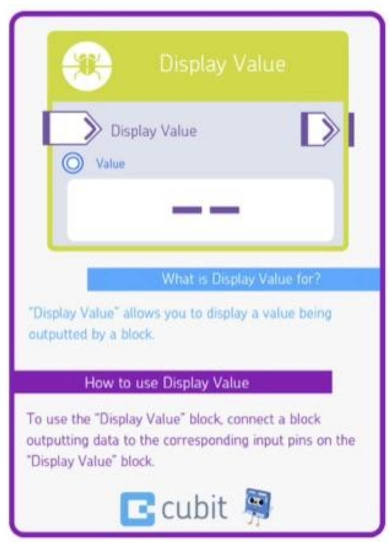
Plan File Resources

Example program from optional lesson 4, with two different methods for tracking time to compute frequency:



Block Informational Cards





Interdisciplinary Extensions

- **Social Studies**: A research project on destructive earthquakes throughout history allows students to investigate their impact on the people in the affected area such as how the event changed the culture, technological development, infrastructure, and city planning in the area. A list of major seismic events is provided in the accompanying slideshow.
- **Language Arts**: Provide students with books about the experiences of people who have survived earthquakes, or other literary responses to the impact of an earthquake on society and culture.
- **Science - Plate Tectonics**: Expand on students' understanding of tectonic forces at convergent (subductive) plate boundaries, (such as in the Ring of Fire) as a cause of earthquakes, as well as motion along fault lines.
- **Science - Ocean Science**: Students investigate the science and impact of tsunamis caused by earthquakes.
- **Industry & Human Impacts**: Mine collapse and hydraulic fracturing are two human-generated causes of earthquakes; students can explore the science and processes of earthquakes caused by human activity.

Differentiation Opportunities

- **Support:**
  - Use strategic grouping to partner students that may need extra help with students that are proficient with computers or experienced with programming. This can help facilitate the exchange of information and clarify activities for some students.
  - Provide background information about earthquakes to give students context for the unit and science content, such as through videos, texts, or other media.
- **Scaffold:**
  - Provide students additional time and brief, structured tasks to experiment with each Workshop block prior to programming it into the Shake Table program.
  - Assist students with breaking down the steps in their program by asking questions to deconstruct tasks into subtasks that correspond to Workshop block commands.
  - Provide students with the attached Cubit block cards as support. Students can use the block cards to think out, plan, and analyze a program before they create it in Workshop.
  - Additional student supports are provided in slideshow resources and plan files.
- **Challenge:**
  - The Custom Function block can be used for students who are more comfortable with programming. Students can use this block to create their own custom functions in Workshop.

Community Connection Opportunities

- Students can conduct research on past earthquake events that have happened in the local area. If the earthquakes were recent and were felt nearby, students could visit areas affected by the shaking and/or talk to community members who experienced the shaking.
- Many regions have first response, warning system, or natural disaster plans that may take effect during an earthquake. Students can research these in the local area or nearby regions.
- Invite professionals in engineering and geoscience careers to speak to the class or to connect with students over electronic communication. Potential candidates are: civil engineers, structural engineers, geotechnical engineers, architects, construction firms, geologists, safety professionals, architects, and city planners.

Summarize the design challenge:

Brainstorm different solutions. As many as you can!

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Criteria:

Constraints:

Ideas from brainstorming that meet criteria and constraints

The top four ideas that meet our needs

1)

3)

2)

4)

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Sketch Idea #1 here

List +'s

List -'s

Sketch Idea #2 here

List +'s

List -'s

Sketch Idea #3 here

List +'s

List -'s

Sketch Idea #4 here

List +'s

List -'s

Draw your prototype here

What worked best in your prototype?

What were some problems in your prototype? How did you fix them?

If you had to do this again, what would you do differently?

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What are the different properties of earthquake shaking that you could model? Use what you know about seismic waves to brainstorm.

Test 2-5 different properties of earthquakes.

	What property of earthquakes does this model?	What stayed the same across all tests?	How did you change your Workshop program?	What happened to your structure?
Test 1				
Test 2				
Test 3				
Test 4				
Test 5				

Make a claim about the kinds of earthquake shaking your structure could survive.