Earthquakes and Resonance

Introduction

An earthquake with a magnitude of 8.5 struck Mexico on September 19, 1985. Mexico City, 250 miles from the epicenter, sustained considerable damage. A high percentage of 6- to 15-story buildings suffered damage while a very small number of one- and two-story buildings were damaged. A 48-story building experienced only minor damage—a few broken windows. While many variables affect the amount of damage a building suffers as a result of an earthquake, the natural frequency of a building is a major contributing factor.

Concepts

- Natural frequency
- Resonance
- Seismic waves

Materials

Chenille wires, 12″, 3
Rigid foam base, 15 cm × 5 cm
Ruler
Scissors
Styrofoam® balls, 1½″ diameter, 3

Safety Precautions

While unlikely, vigorous shaking of the apparatus may cause the Styrofoam balls or the wires to shake loose. Wear safety glasses during this activity. Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines.

Preparation

1. Obtain three chenille wires. Cut the wires to the following lengths: 25 cm, 20 cm, and 15 cm. *Caution:* The ends of the cut wires may be sharp.
2. Obtain three 1½″ diameter Styrofoam balls. Gripping one wire near the end, carefully push the end into a ball with a twisting motion. Push the wire so it is inserted more than half way through the ball, keeping the wire as centered in the ball as possible.
3. Repeat step 2 for the other two wires and balls.
4. Obtain a 15 cm × 5 cm rigid foam base. Insert the free end of the 25-cm chenille wire into the center of the base, being careful that the end of the wire does not poke through the bottom of the base.
5. Centering the wire width-wise, insert the 20-cm wire one cm from one end of the base.
6. Insert the 15-cm wire one cm from the opposite end of the base, in line with the other two wires (see Figure 1).

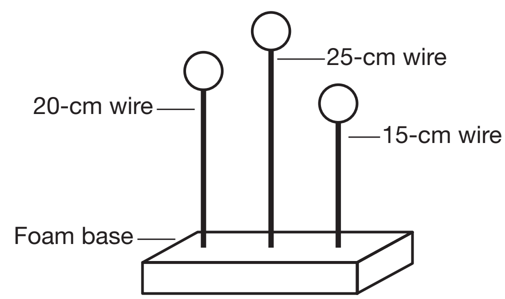

Figure 1.

Procedure

1. Place the foam base of the resonance apparatus on a flat surface.
2. Slowly slide the base forward and back as shown in Figure 2. Start with a low frequency and gradually increase the frequency until the tallest wire begins to resonate. Keep this frequency constant and observe the motion of the other two wires.
3. Gradually increase the frequency of the back-and-forth motion of the base until the 20-cm wire begins to resonate. Keep this frequency constant and observe the motion of the other two wires.
4. Once again, gradually increase the frequency of the back-and-forth motion of the base until the shortest wire begins to resonate. *Note:* This will be a very vigorous back-and-forth motion. Keep this frequency con-

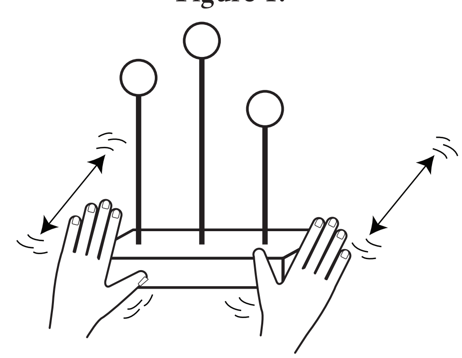

Figure 2.

stant and observe the motion of the other two wires.

5. Stop the motion of the base and instruct students to record all observations. Repeat steps 2 to 4 as needed to confirm observations.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-ESS2 Earth's Systems
ESS2.A: Earth's Materials and Systems
ESS2.B: Plate Tectonics and Large-Scale System Interactions
MS-PS4 Waves and Their Applications in Technologies for Information Transfer
PS4.A: Wave Properties

Disciplinary Core Ideas: High School
HS-ESS2 Earth's Systems
ESS2.A: Earth's Materials and Systems
ESS2.B: Plate Tectonics and Large-Scale System Interactions
HS-PS4 Waves and Their Applications in Technologies for Information Transfer
PS4.A: Wave Properties

Science and Engineering Practices
Developing and using models
Planning and carrying out investigations
Constructing explanations and designing solutions

Crosscutting Concepts
Patterns
Cause and Effect
Scale, proportion, and quantity
Systems and system models

Tips

- The foam base may be made from rigid foam insulation or florist foam. Use caution when using a sharp knife to cut the foam.
- If desired, stop all movement of the chenille wires before increasing the frequency.
- Flinn Scientific's *Exploring Earthquakes—Activity Stations Kit*, Catalog No. AP7406, is a great way for students to examine what causes earthquakes, why they are so unpredictable, and investigate factors that impact the effects of seismic activity.

Discussion

All objects including buildings have a *natural frequency* or set of natural frequencies at which they vibrate. The frequency of a vibration is the number of back and forth cycles *(oscillations)* that occur per second. The natural frequency of an object depends on its size and composition. Seismic waves traveling through the ground cause the ground to vibrate at its natural frequency. If the natural frequency of the ground matches the natural frequency of a structure built on that ground, then the motion of the building will be amplified, resulting in a vigorous oscillating movement. This higher amplitude oscillation is known as *resonance*. A common occurrence of resonance is a child being pushed on a swing. If the push is given in rhythm with the natural frequency of the swing, the child will swing higher and higher.

This demonstration illustrates how the length of a material affects its natural frequency. Three chenille wires of different lengths topped with identical Styrofoam balls are placed into a rigid foam base and moved back and forth, causing the wires to vibrate. When the back-and-forth motion of the base matches the natural frequency of one of the wires, that particular wire will vibrate vigorously, achieving resonance. By varying the frequency of the back-and-forth motion of the base, each wire will resonate at a different frequency.

Sample Data Table

Frequency	Observations
Low	*The longest wire resonated, moving back and forth vigorously. The medium-length wire only moved slightly and the shortest wire barely moved at all.*
Medium	*The medium-length wire resonated, moving back and forth vigorously. The longest wire and shortest wires vibrated slightly, but neither resonated.*
High	*The shortest wire moved back and forth very vigorously. The medium-length wire and the longest wires vibrated slightly.*

Sample Questions and Answers

1. Summarize the observed relationship between the resonance frequency and the length of the wire.

   The longer the wire the lower the frequency at which the wire resonates.

2. Based on your observations, do any of the wires share the same natural frequency? Give reasons for your answer.

   None of the wires shared the same natural frequency since none resonated at the same time.

3. Based on your observations, explain why a high percentage of 6- to 15-story buildings suffered considerable damage during the 1985 Mexico earthquake, while shorter and taller buildings did not.

   The middle-sized buildings must have had the same natural frequency as the ground shaking during the earthquake. This caused the6- to 15-story buildings to resonate. The shorter buildings would require a higher frequency and the tallest buildings would require a much lower frequency to resonate.

Reference

Geis, D.; Arnold, C. Mexico City as Seismic Laboratory. *Architecture*, July 1987, pp 75–77.

Materials for Earthquakes and Resonance are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8862	Chenille Wires, Black, pkg/10
AP2280	Styrofoam Balls, 1½″, pkg/12

Consult your *Flinn Science Catalog Reference Manual* for current prices.