Name: ____ Date: _________________________

Structures Shaking During Earthquakes

1. All things and all objects vibrate at different **natural frequencies**. **Frequency** is how often something repeats in a certain amount of time, so **natural frequency** is how often an object vibrates back and forth each second. An instrument string is one of the simplest ways to observe these natural frequencies. The **tone** you hear when the string is plucked is the natural frequency of that string. Many material properties determine the tone of different objects.

Brainstorm a list of material properties that might affect the natural frequency of an object.

Using a stringed instrument, test some of these properties.

a. Choose a string and pluck it without pressing down on it. Now pluck the same string when it is halved (press the string down hard against the neck of the instrument).

Which way did the string have a higher frequency?

Which way did the string have a lower frequency?

b. Pluck the string with the largest diameter. Now pluck the string with the smallest diameter.

Which string had the higher frequency?

Which string had the lower frequency?

c. Choose a string and pluck it. Now tighten the string using the tuning key or peg. Pluck the string again. Loosen the string and Pluck it again.

When was the frequency the highest?

When was the frequency the lowest?

Summarize your findings about how and which material properties can affect the natural frequency of an object:

2. Human-made arches and towers and natural rock arches and towers also vibrate at natural frequencies, and those tones are determined by similar material properties that you just explored. Go to the following website: https://geohazards.earth.utah.edu/bear/.

Scroll down to near the bottom of the page where the 3D Digital Models are. Look at Big Arrowhead Arch and Sunset Arch. Pan around them and describe or draw how they look. Are they thick, thin, smooth bumpy, curved, flat, etc.?

Scroll to the Audible Motion section. These recordings are of the natural vibrations of the arch. They've been sped up to a frequency that is audible to humans, but this isn't actually sound. Listen to them for 30 seconds each. What does each arch's vibration sound like to you? How does it make you feel?

Based on what you discovered about how different material properties affect the natural frequency or tone of an object, which do you think is the larger arch and why?

3. An important factor that determines how a structure will respond to a given earthquake is the structure's natural frequencies and the frequency of the applied shaking. Imagine pushing a younger sibling, cousin, or friend on a swing: you can push at any interval you want and the swing will move, but if you push it at the right frequency, the swing will go higher and higher. This phenomenon is called **resonance**, where the interval or frequency of the incoming energy (you pushing) matches the natural frequency of the swing, and the swing responds by going higher.

Brainstorm more examples of resonance that you've observed in your everyday life:

To test how structures might respond to and resonate from different earthquakes with different frequencies of shaking, construct two stable towers of different heights out of toothpicks and marshmallows. Secure them to your foundation. Describe and draw both of them, noting similarities and differences.

Tower 1	Tower 2

Based on what you learned about how different material properties affect the natural frequency or tone of an object, hypothesize which tower vibrates at a lower natural frequency and which tower vibrates at a higher natural frequency.

4. While keeping the foundation flat on the table, create a gentle “earthquake” by shaking the foundation back and forth, beginning slowly at first (**low-frequency** shaking) and getting incrementally faster (**high-frequency** shaking).

How did the two structures behave? Which one resonated more during the low-frequency shaking? During the high-frequency shaking? Did this support your hypothesis?

Imagine you are an engineer responsible for designing safe and strong buildings that withstand shaking from earthquakes along the Wasatch Front. Based on what you knew before and what you learned about resonance today, what are some considerations you should have while designing these buildings?