Wave Energy and Natural Vibration

Background:

Many systems and objects have a natural vibration. If a forced vibration adds energy to the system at or near the natural frequency of vibration, it can cause very large increase in vibration.

A good example of this is a typical playground swing. With added energy, a person will swing back a forth with a natural frequency. If energy is added at the right time, "in tune" with the natural frequency, the swing will go higher and higher. But if the energy is added "out of tune" with the natural frequency, it will result in the swing losing height to their swing.

Consider if energy is continually added to the natural vibration of an object or system - could this energy eventually do damage?

One of the most famous examples of wave energy doing structural damage is the Tacoma Narrows bridge. On November 7th 1940, the only months-old Tacoma Narrows bridge shook itself apart.

In this activity, you will investigate the natural frequency of vibration of a system and the effects of adding energy to that system.

The Questions:

What is the natural frequency of vibration of a system? What is the effect when energy is added to the system at different frequencies?

Materials:

- motion sensor
- USB link
- dynamics track
- lab clamp and lab stand
- 2 springs
- dynamics cart
- 2 - 250 g dynamics cart masses
- 4 cm square piece of cardboard

Materials note:

Pasco Scientific has harmonic springs (ME-9803) that are well suited to this activity.

Procedure:

Step 1:

Plug the sensor into the USB link (that is connected to the computer). Attach the motion sensor to the lab stand in such a way that it will oriented about 1 cm above the end of the dynamics track.

Step 2:

Attach a spring to each end of the dynamics track. Connect the ends of the two springs to a dynamics cart so that the cart is held by the two springs in the middle of the track.

Attach a piece of cardboard to the end of the cart. This is an optional step that often produces better results by allowing the motion sensor to "see" the cart more effectively.

Step 3:

Configure the DataStudio software to display a position-time graph. Click the "Setup" button in DataStudio and increase the sampling rate of the motion sensor to 50 Hz.

Step 4:

Push the cart so that it moves 5 cm toward either end of the track. Release it, and it will begin to move back and forth on the track. Click "Start" in the DataStudio software and record data for a few seconds before stopping. Gently stop the cart from vibrating.

Step 5:

Repeat step 4, but start the process by giving the cart a larger push. To do this, push the cart so that it moves 10 cm toward either end of the track.

Release it, and it will begin to move back and forth on the track. Click "Start" in the DataStudio software and record data for a few seconds before stopping. Gently stop the cart from vibrating.

Step 6:

Position your fingers on the spring so that you are a few centimetres from the end of the track. If you are doing this at the end near the motion sensor, make sure your hand in beneath the motion sensor so that it does not interfere with the motion sensor detecting the cart. Lightly pinch the spring between your index and middle fingers.

Step 7:

Push the cart so that it moves 10 cm toward either end of the track. Release it, and it will begin to move back and forth on the track. Click "Start" in the DataStudio software and begin recording data.

Move your fingers about 3 cm horizontally back and forth - **the motion of your fingers should attempt to match the back-and-forth motion of the cart as closely as possible. Make sure the motion of your fingers is smooth and steady**.

Observe what happens to the motion of the cart. After about ten seconds of moving your fingers with the spring, stop recording data and gently stop the motion of the cart.

Step 8:

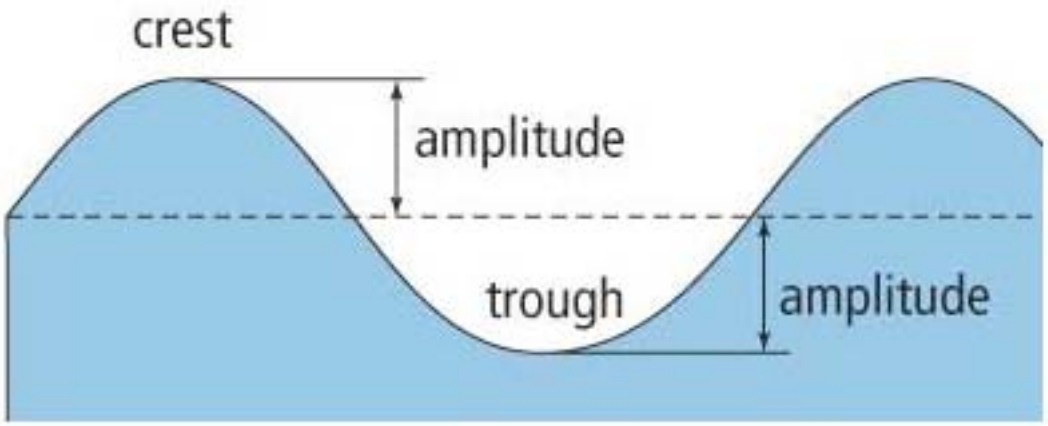
Repeat steps 7 and 8, but this time, you will move your fingers differently.

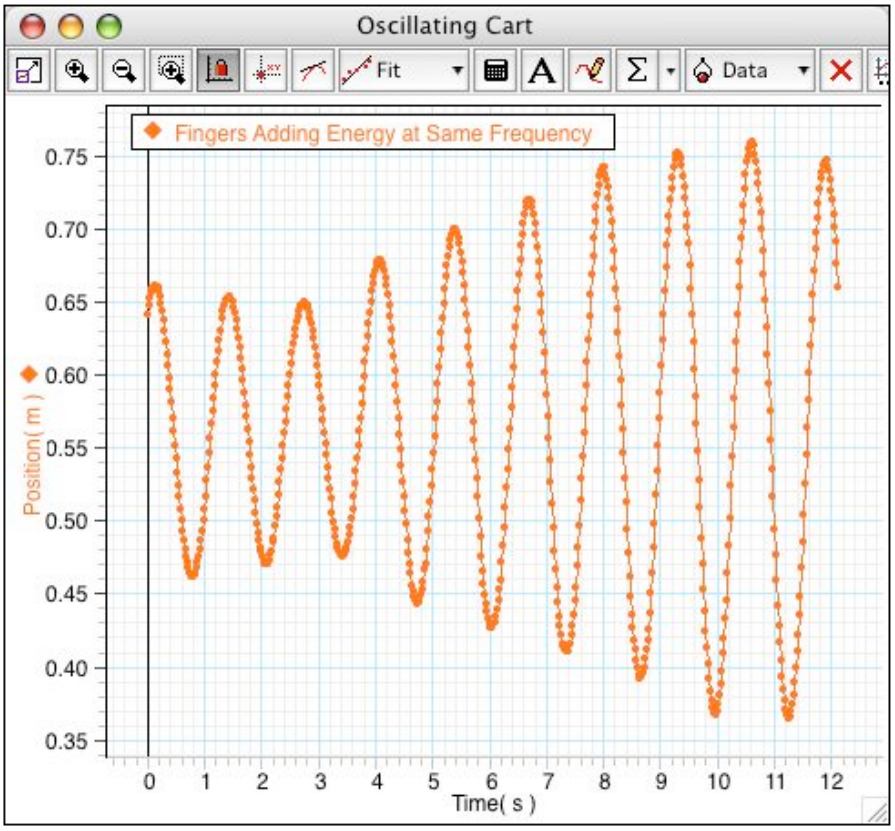
Move your fingers about 3 cm horizontally back and forth - **the motion of your fingers should be considerably faster than the back-and-forth motion of the cart. Attempt to move your fingers about 3 times faster than the back-and-forth motion of the cart (the exact speed of your fingers is not important, but it must noticeably faster than the back-and-forth motion of the cart). Make sure the motion of your fingers is smooth and steady**.

Observe what happens to the motion of the cart. After about ten seconds of moving your fingers with the spring, stop recording data and gently stop the motion of the cart.

Step 9:

Compare the position time graphs generated by the trials in steps 7 and 8 by closely observing the amplitude of vibration. Optional - this can be done accurately by printing out your graph, drawing an line through the middle of the waves, and measuring the amplitudes of each pulse.





Analyze:

1. What effect does adding energy at a similar frequency have on the frequency of the back-and-forth motion of the spring system?

2. What effect does adding energy at a different frequency have on the frequency of the back-and-forth motion of the spring system?

Conclude and Apply:

3. What part of your experiment demonstrates a situation that could cause damage to a system?

4. What effect is the effect when energy is added to a system at different frequencies?

Extending:

5. Compare the vibration in your spring system to the vibration occurring in a tall brick building as a result of the added energy from earthquake vibrations. Discuss the consequences of such vibrations.