PocketLab Voyager/Vernier: Forced Oscillations and Resonance

By Richard Born
Associate Professor Emeritus
Northern Illinois University

Do you need some salt or pepper?—use a shaker. Do you want that gallon of paint mixed?—use a paint shaker. Do you want to compact your loose product in a box to save space before shipping?—use a compaction shaker. Do you want to test the performance of a structure in response to earthquakes?—use a shake table.

With growing interest in STEM disciplines, children of all grade levels are learning what seismic engineering is by building their own shake tables and structures for testing. Their buildings may be made of Styrofoam balls and sticks, sugar cubes and glue, or anything else that their ingenious minds can conjure.

In all of the above examples, objects are subjected to oscillating external forces. When the frequency of the external oscillations matches the natural frequency of the object, then oscillations of large amplitude can result. These large oscillations are known as *resonance*. Children on a playground swing quickly learn that pumping at the right time intervals makes the swing go higher and higher. A motor may vibrate wildly and undergo resonance due to an irregularity in the shaft. The famous Tacoma Narrows Bridge collapse back in the year 1940 was caused by wind producing an oscillation matching the natural frequency of the bridge. Troops commonly break unison step when crossing a bridge in order to avoid resonance. The possibility of destructive resonance is a reason behind why children are told not to jump in an elevator.

Tall buildings can experience resonance due to wind or earthquake waves. Numerous skyscrapers worldwide are equipped with dampers to avoid resonance. One of the most famous is the Taipei 101. Its damper, which can significantly reduce the amplitude of oscillation, is a huge pendulum located in several of the upper floors of the skyscraper.

This lesson can be used to provide a demonstration of forced oscillations and resonance in a small model structure. This lesson is possible by teaming Vernier Software & Technology with PocketLab. The forced oscillations of the structure are produced by the use of a Vernier power amplifier, LabQuest® 2 function generator, and accessory speaker. When driven at known and carefully controlled frequencies, it becomes possible to determine the *resonant frequency* of the structure. PocketLab Voyager is firmly attached to the top of the model structure and set to record acceleration at the highest possible point per second rate. Meanwhile, the sine wave frequency of the forced oscillations is gradually increased from 1 to 10 Hz, by steps of 1 Hz each. Analysis of the acceleration vs. time graph produced by the PocketLab app can then be used to determine the natural frequency of the structure.

Two movies accompany this lesson. The first is combined data and video showing the real-time acceleration graph as the structure vibrates. The initial driving frequency is 1 Hz and is increased by one Hz each time the author adjusts the frequency of the function generator. A second movie includes ***sound*** to provide another sensory perception for what happens as resonance is approached. The graph of acceleration in Figure 1 was constructed in Excel from the csv file produced by the PocketLab app on an iPhone. It shows what appears to be resonance at 5 Hz.

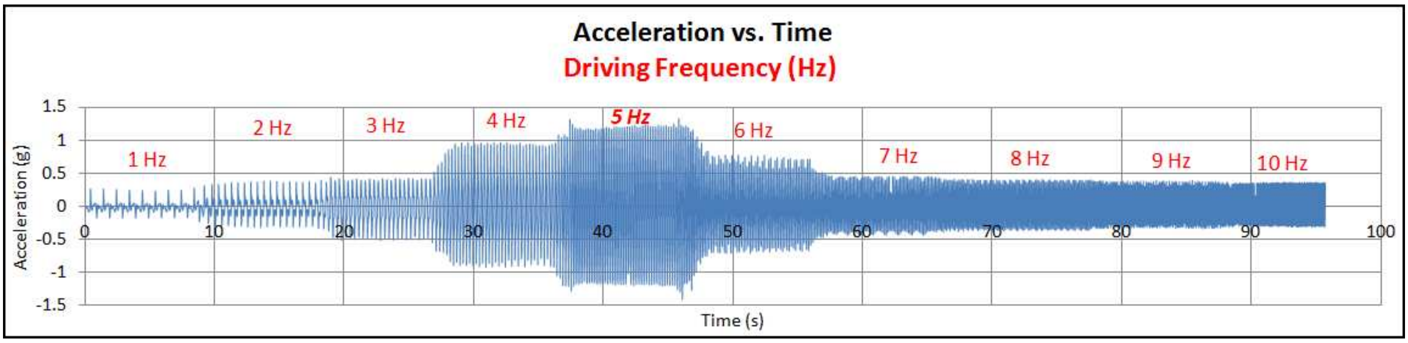

Figure 1

Figure 2 contains close-ups of various parts of the apparatus setup.

Figure 2