PocketLab Voyager Quantitative Experiment: Standing Waves on a Suspended Slinky

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Introduction

In addition to being a fun toy, the "Slinky" is commonly used in physics classes to *qualitatively* investigate a variety of wave properties: longitudinal versus transverse traveling waves, superposition of waves, wave reflection from a solid barrier or a free end, and standing waves and resonance. Many of these investigations work well when the Slinky is stretched out on the surface of a floor. However, to do a *quantitative* study of standing waves and resonance, suspending the stretched Slinky from the ceiling offers the advantages of less friction, easier observation of more harmonics, and improved numeric data collection, particularly if PocketLab Voyager is attached to the vibrating Slinky.

Experiment Setup

Figure 1 shows the experiment setup. The Slinky is a "Super Size Wave Spring" from teachersouce.com. It has about 200 coils and has been stretched to a total distance of about 15 feet. Strings suspended from the ceiling are tied to paper clips which are in turn attached to loops spaced 16 coils apart. The paper clips are then taped to the slinky to reduce sliding of the paper clips while the Slinky vibrates back and forth. Transverse waves in the *yz* plane are produced at the other end of the Slinky by a person holding that end. The picture to the left of Figure 1 shows a close-up of the fixed end of the Slinky, held in place by attaching the end to a ring stand weighted with some books. Voyager has been taped to a coil on the Slinky about 1½ feet from the fixed end using masking tape, with the *y*-axis pointing to the right. By taping Voyager near the *fixed* end of the Slinky, much smoother collection of *y*-acceleration data is possible. Data collection rate is set to 50 points/second.

Figure 1

Results

Figure 2 shows a snapshot from a Voyager combined data/video taken when the Slinky was vibrating with three antinodes. The entire *mp4* video for three nodes is included with this lesson. The video was taken with a fisheye lens attached to the iPhone so that the entire length of the Slinky can be seen. The author is standing on the far left shaking the Slinky, and Voyager is attached to the Slinky at the far right. The periodic sine-wave nature of the acceleration is clearly evident from the snapshot.

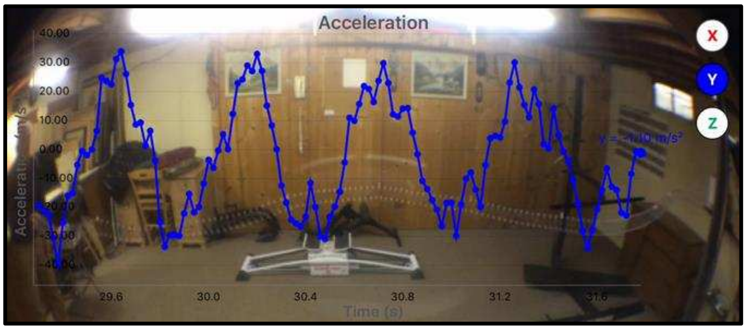

Figure 2

Figure 3 shows an Excel graph constructed from acceleration data from a csv file created using Voyager and the PocketLab app. As shown in the top half of Figure 3, data was captured for standing waves with 1, 2, 3, 4, and 5, antinodes in a single run of about 200 seconds. The periodic nature of the vibrations shows that the frequency increases (or wavelength decreases) as the number of antinodes increases. By zooming in on the data for each of the five standing waves, it is quite easy to compute the period of vibration. As an example, the red highlighted region of the top half of Figure 3 is zoomed in and shown in the bottom half of the figure. We see from the bottom graph that the period T of oscillation for a standing wave with three antinodes is about 0.743 seconds.

An alternative method for determining the period can be used if you have access to curve-fitting software. You would fit a sine curve $y=A*\sin(Bx+C)+D$ to the data for a given number of antinodes. The value of the parameter B is the angular frequency ω, from which one can determine the period $T = 2\pi/\omega$. The author has found that Vernier Software & Technology's Logger Pro® serves this purpose very well. The author wouldn't be surprised if PocketLab were to offer some curve-fitting analysis capabilities in the not too distant future.

Figure 4 shows the relationship between the length L of the stretched Slinky and the wavelength λ of the standing waves that are produced as a function of the number of antinodes n: $\lambda = 2L/n$. Since the frequency $f = 1/T$ and $v = f\lambda$, we can determine the velocity of the waves in the Slinky. The results for standing waves with 1, 2, 3, 4, and 5 nodes are summarized in the table below. We find that the velocity of the waves appears to average at around 5 m/s. (The length L of the stretched Slinky was 4.65 m).

Number of antinodes, n	Period, T (s)	Wavelength, λ (m)	Velocity, v (m/s)
1	1.58	9.30	5.89
2	1.03	4.65	4.51
3	0.74	3.10	4.17
4	0.46	2.33	5.02
5	0.33	1.86	5.60
		Average →	***5.04***

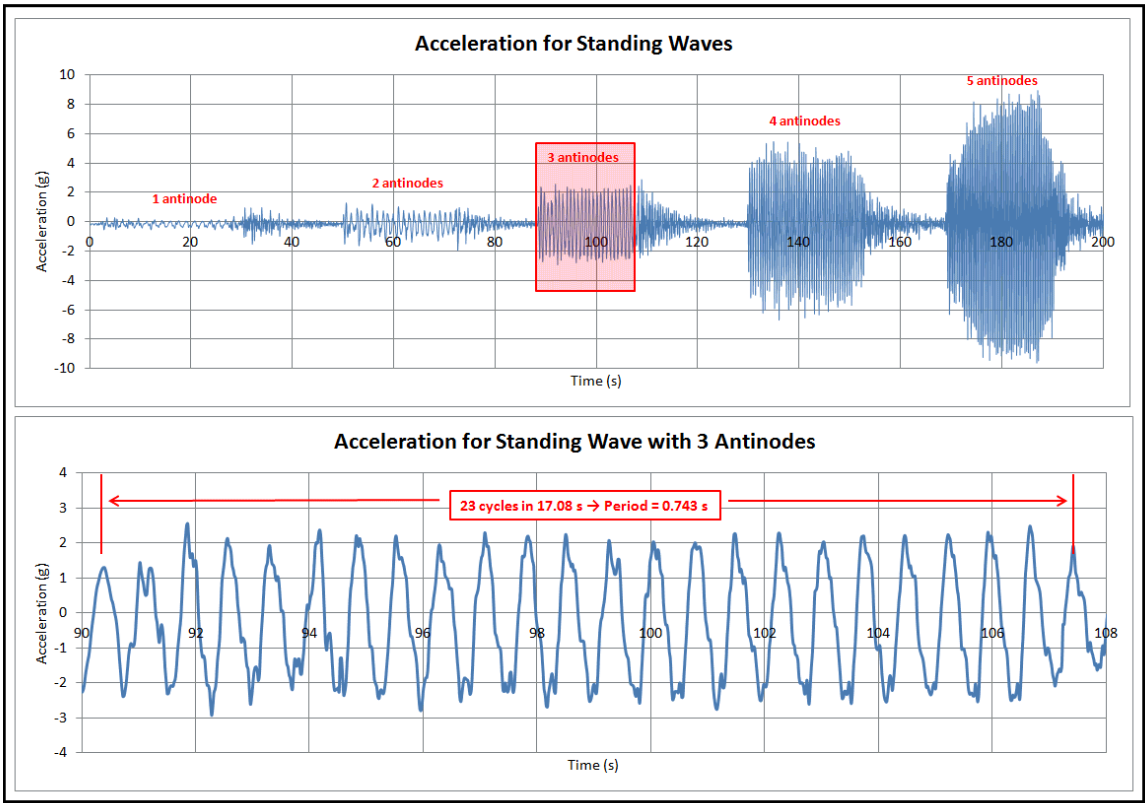

Figure 3

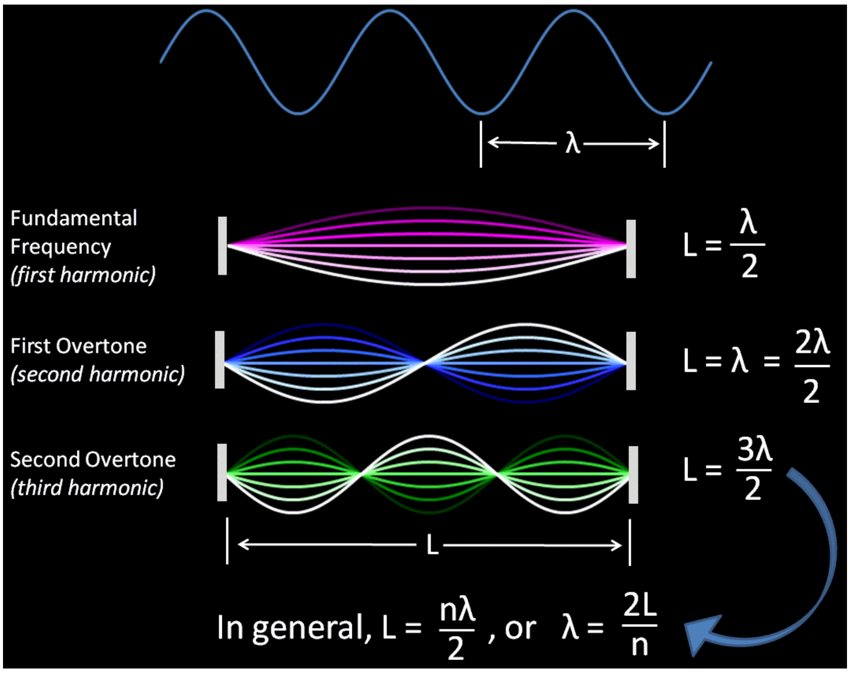

Figure 4