

DEVICE Soda Bottle Resonance Demonstration

TOPIC Wave Mechanics

THEORETICAL BACKGROUND Longitudinal motion is produced when the elements of air within a bottle or tube move parallel to the x-axis. The wave produced in the column is termed a longitudinal wave. Blowing across the open end of a bottle causes an air element to push against the next air element in turn and thus this air element pushes the next subsequent air element, repeating the process continuously throughout the length of the bottle. The motion of each air element and the change in pressure caused by the motion travels along the bottle as a sound wave. The displacement of air elements is written as,

$$s(x, t) = s_{\max} \cos(kx - \omega t)$$

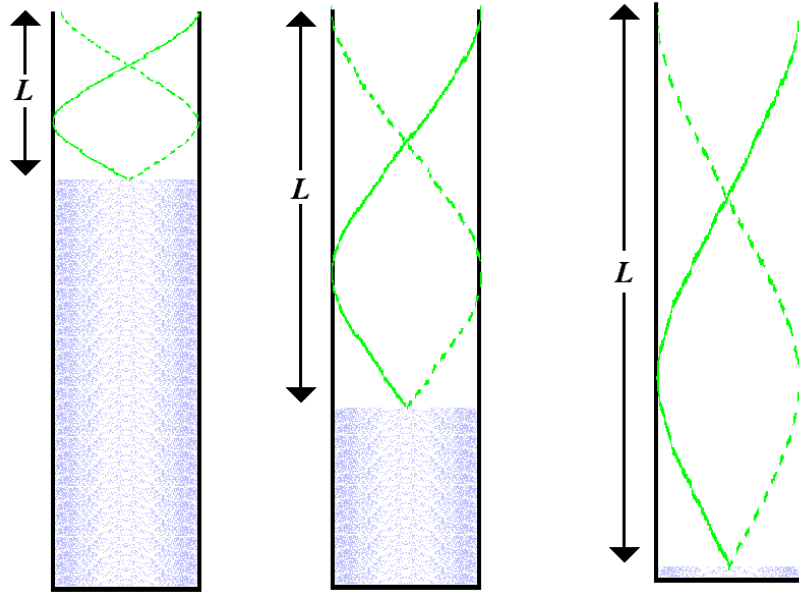
and the pressure variation along the bottle is,

$$\Delta p(x, t) = \Delta p_{\max} \sin(kx - \omega t) .$$

As sound waves travel through the air in a bottle, they reflect at each end and travel back through the bottle. If the wavelength of the sound waves closely match the length of the bottle then the superposition of the waves traveling in opposite directions through the bottle creates a standing wave pattern. The wavelength required of the sound waves for this matching is one that corresponds to a resonate frequency of the bottle. Therefore the bottle is said to resonate that this measured frequency. The bottle demonstrates an open and closed end resonator. Across the open end there exists an anode and across the closed end there is a displacement node. In the bottle, which is closed at one end, only odd harmonics are present, producing resonate frequencies along the length of the bottle with corresponding wavelengths of:

$$\lambda = \frac{4L}{n}, \text{ for } n = 1, 3, 5, \dots$$

Adding water to the bottle decreases the length of the air column, thus, creating new resonate frequencies. A small air column, i.e. a bottle near full of water, indicates higher frequencies and higher pitches while an empty bottle has lower frequencies and lower pitches.



$$n=3, \lambda = \frac{4L}{3}$$

This holds true for the variable L , as shown above.

DESCRIPTION The demo consists of 9 soda bottles.

PROCEDURE

1. Choose three bottles and pour unequal amounts of water in two of them.
2. Proceed to blow warm air across the opening of the bottles until a sound is produced. This should be done in a manner similar to how a flutist would play a flute.
3. Notice the differing tones produced as the column is decreased by the water.

SUGGESTIONS “Play” them, like a skilled musician! “Mary Had A Little Lamb” is not too trivial a tune to play on these bottles but it’s worth the effort....