Helmholtz Resonance

Introduction

This activity was developed to introduce students to Helmholtz resonance, and to give students practice making
measurements and calculations.

Material

Empty glass coke bottles

Metric Ruler

Graduated cylinder

Calculator

Water

To Do and Notice

Have each student blow across the top of an empty coke bottle to produce a sound. The sound created when you blow across the top of an empty bottle is due to Helmholtz resonance.

Have the students add varying amounts of water to the coke bottle to see how the tone changes. What happens when you add water? What happens when you remove water?

The frequency of the tone produced in each bottle can described by the following equation:

$$f_H = \frac{v}{2\pi}\sqrt{\frac{A}{Vl}}$$

where f_H is the Helmholtz frequency, v is the speed of sound in air (343 meters/s), A is the cross sectional area of the opening, V is the volume of air in the resonator cavity, and *l* is the length of the opening.

Use this equation to determine the volume of water needed produce a certain frequency. Remember to use consistent units while making the calculation.

The volume of water needed will be the total volume of the bottle cavity minus the volume of air needed to produce a certain tone, or frequency.

$$V_{water} = V_{bottle} - V_{air}$$

where V_{air} is calculated by rearranging the frequency equation as shown below:

$$V_{air} = \frac{A}{l}\left(\frac{v}{2\pi f_H}\right)^2$$

What's going on?

Air blown across the opening of the coke bottle acts as a spring compressing the air in the bottle beneath the neck. When air is forced into a cavity, the pressure inside increases. This high pressure surge of air flowing out of the bottle will then overcompensate, and the pressure inside the bottle will decrease creating a low pressure cavity. This then causes air to flow back in, increasing the pressure inside. This process repeats until equilibrium or atmospheric pressure is reached. By changing the volume of air in the cavity, we change the frequency with which the pressure wave resonates.

Going Further

Challenge the students to produce a C major scale with the coke bottles by first calculating the amount of water to add to each bottle, and then testing the accuracy of their calculations by adding the water and blowing. The frequencies of the C major scale that can be produced in a typical coke bottle are in the table below:

Note	**Frequency (Hz)**
C4	261.63
D4	293.66
E4	329.63
F4	349.23
G4	392
A4	440
B4	493.88
C5	523.25