Sound Visualization

First Team Project

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MCEN 4151

Flow Visualization: The Physics and Art of Fluid Flow

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Background

The purpose of the Team First image assignment is to capture a fluid, or combination of fluids, to understand the physics of the flow in the experiment. The experiment must be controlled so it can be repeated. In this experiment, I wanted to examine how the vibrations of the air inside an enclosed environment reacted when different sound waves passed through the air.

Setup

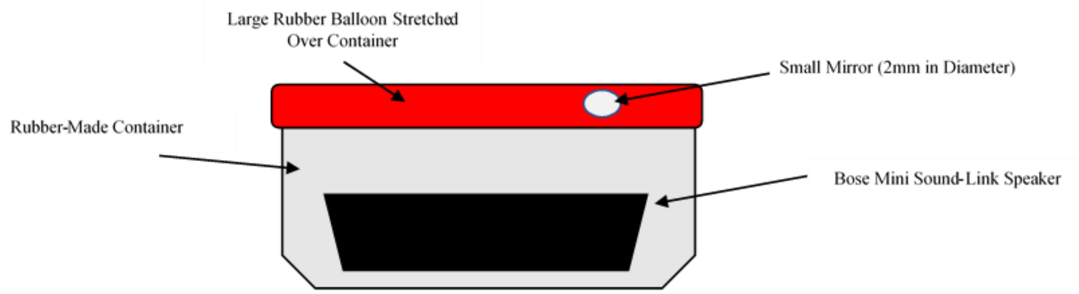

Figure 1: Setup of enclosed container with speaker in it

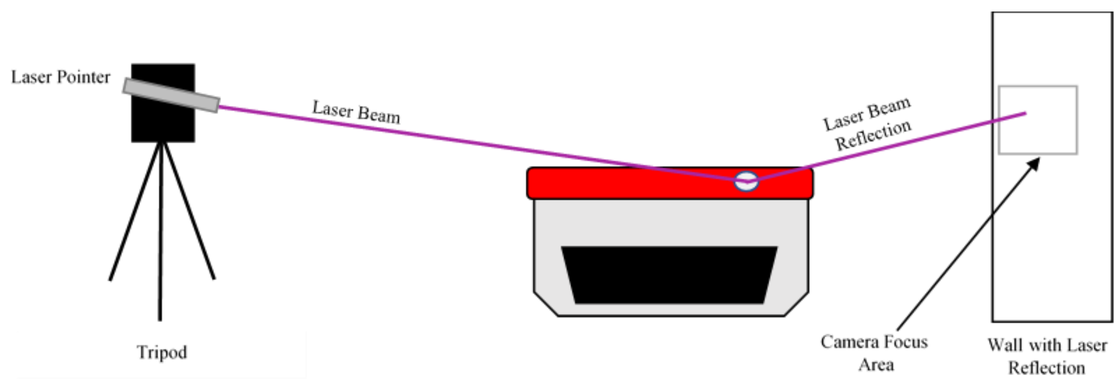

Figure 2: Laser pointer interaction with enclosed container

To set up this experiment, I put a Bose Soundlink Mini Bluetooth speaker inside a Rubbermaid container and stretched a large balloon over the opening in the container. To make sure the balloon didn't come loose during the experiment, I used packing tape to tighten the balloon to the Rubbermaid container. I then glued a two-millimeter diameter circular mirror to the surface of the balloon. This setup is demonstrated in Figure 1.

To make sure the laser pointer would always shine directly on the mirror, I used a tripod and an iPhone mount to clamp the laser pointer and angled it to it was always pointed toward the mirror. The reflection of the laser was shown on a wall about a foot away from the mirror. The camera, a Nikon D3100 was then positioned to have the reflection of the laser pointer in the center of the frame and to have about six inches to the top of the frame and about ten inches from the edges of the pointer. The camera was positioned on a tripod about three feet away from the wall. The camera was positioned here because the smallest focal length lens available at the time for me was a 55mm lens. This setup is demonstrated in Figure 2.

Fluid Dynamics

The fluid motion in this experiment is the motion of the air trapped in the enclosed container visualized through the vibrations in the rubber membrane. These vibrations were visualized using a laser and a mirror to reflect the laser beam off the surface of the balloon, demonstrating what the motion of a small cross-section of the membrane. I kept the volume of the speaker and volume output of my phone constant throughout this experiment. While performing a sweep of frequencies playing though the speaker, it can be noticed that the volume of the speaker seems to increase. I believe this is happening when one resonant frequency of the air in the container is hit, causing the volume to appear to increase. If we were to model the air inside the container as a closed air cylinder, we can calculate the resonant frequencies of the air [1]. This formula is described as:

$$\lambda_1 = 4L$$

$$f = \frac{c}{\lambda} \; where \; c = 340\frac{m}{s}$$

With a length $L = 9 \; inches = 0.226 \; m$, we can calculate the resonant wavelengths and frequencies in the container. $\lambda_1 = 4 * 0.1 \; m = 0.4 \; m, f_1 = \frac{340\frac{m}{s}}{0.226 \; m} = \; 371.82 \; Hz$. If you use this number and the corresponding frequencies that are associated with resonance, we can find a resonant frequency closer to the observed resonant frequency in the video. This is demonstrated below:

$$f_2 = \frac{f_1}{2}, f_3 = \frac{f_1}{4}$$

$$f_2 = \frac{371.82 \; Hz}{2} = 185.91 \; Hz$$

$$f_3 = \frac{371.82 \; Hz}{4} = 92.95 \; Hz$$

This third resonant frequency is very close to the observed resonant frequency in the video.

Visualization Technique

After I had the experiment was setup, I used a function generator application on my iPhone to play different frequencies through the speaker. I recorded all the videos at 1920x1080 pixels and 24 frames per second. In the video, I started with individual notes, which created unique, uniform patterns on the wall. After this, I recorded a video of a sweep of frequencies ranging from 63 Hertz to 120 Hertz. After 120 Hertz, the patterns of the laser became too difficult to see with the naked eye, as well as the camera. This concluded the scientific portion of my experiment. I then recorded the laser's motion when a song was played through the speaker. In the video, the large, low frequency sounds showed the largest motion of the laser, and the high frequency sounds didn't move the laser though to see the pattern. This portion of the video confirmed what I found in the scientific portion of the video; low frequencies tend to give better visualization results.

Photographic Technique

As explained in the previous sections, I used a Nikon D1300 filming at 1920 x 1080 pixels at 24 frames per second to capture my video. When filming the sweep of frequencies and the visualization of the song being played, I noticed something strange in the video. There seemed to be some starting and stopping points of the laser instead of being a continuous loop, which I saw when performing the experiment. This phenomenon is outlined in Figure 3. I believe that this is occurring due to the relatively low frame-rate I was recording at. If I had a higher frame rate, I believe the visual start and stop points of the laser would be reduced if not eliminated completely.

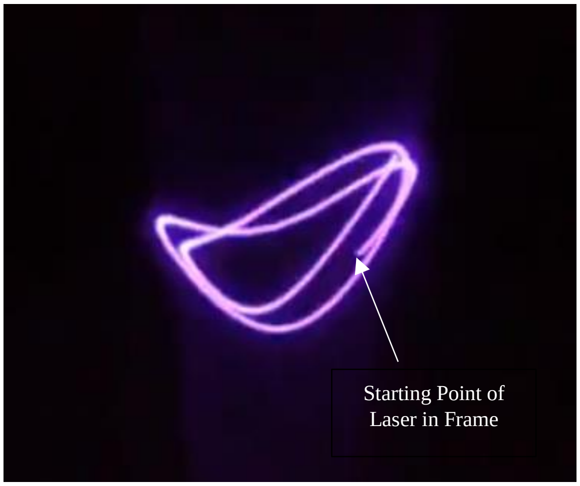

Figure 3: Screenshot of video at 2:23 of video, showing a distinct starting point in the frame

Sources:

[1] "Closed-End Air Columns." The Physics Classroom, www.physicsclassroom.com/class/sound/Lesson-5/Closed-End-Air-Columns.