Group Project 3

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Mechanical Engineering

"Dancing Windex"

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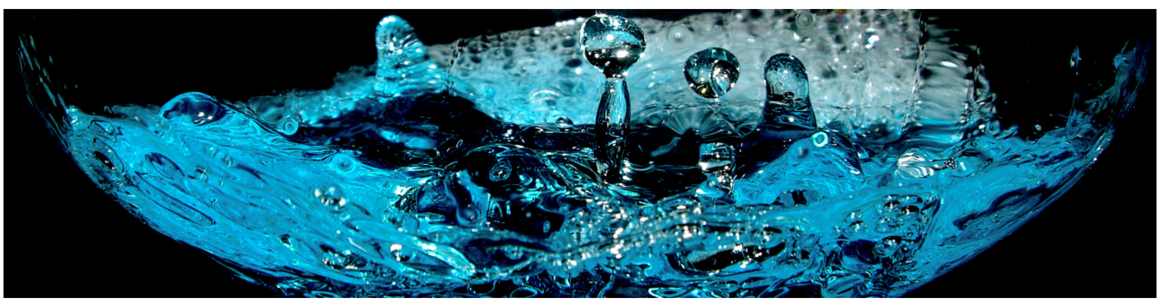


I. Background

A. Initial Idea & Attempt

Although the group had initially decided to work with the Fog machine, we did not take into account signing up for the Black Box and obtaining lighting set-up assistance. As a result, we were limited to spaces not as optimal with regards to lighting as the Black Box. However, the group still attempted to capture images with the fog machine in the Media Shack space. While all of us were aware that a 120° angle from the light source was the best spot to capture the fog, it appeared incredibly difficult in the Media Shack room to obtain a well-focused, well-lit image. At the same time, no team member felt incredibly motivated to continue with the fog machine.

While working on stereo equipment one night, it occurred to me that the interaction of sound waves and different types of fluids could be extremely interesting.

B. Interaction of Sound Waves & Windex via an Eight Inch Subwoofer

My idea for this project was to place a fluid into a glass container of any sort, place the glass apparatus onto an eight inch subwoofer, record the frequencies occurring throughout the song, and then relate the movement of the fluid to how the sound waves interact.

The physics involved in the interaction of Windex and sound vibrations, such as constructive and destructive sound waves as well as the Reynolds number, will be discussed in detail later in the report.

My artistic approach to this was project was to capture well-focused "splashes" created by the sound vibrations as well as creating a lighting scheme that did not cause too much reflection in the glass apparatus. This will also be discussed later in the report.

My final image illustrates the interaction of Windex and sound vibrations via a glass apparatus and an eight inch subwoofer.

II. Materials

The following materials were used for this project:

- Glass Apparatus (Shown in Figure 1)
- Windex

- Corn Syrup
- Water
- 3ft Sony Speaker
- Construction Paper
- Magazine
- Tape

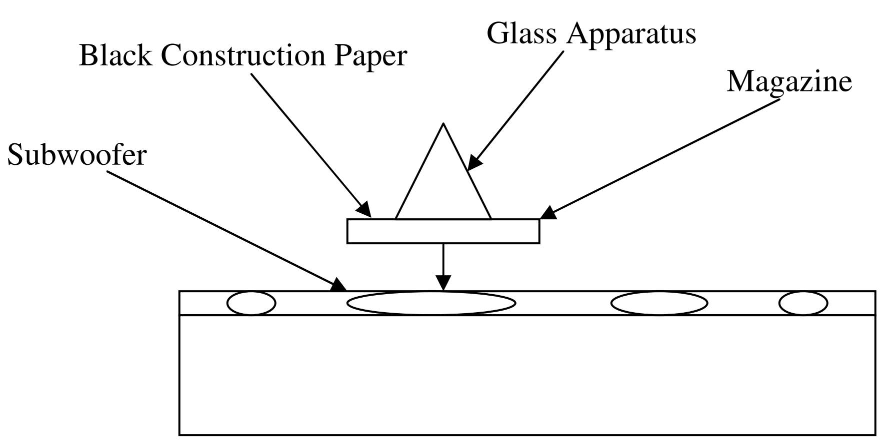
Figure 1

Side View **Top View**

III. Setup

The setup for this image involved laying a 3ft. Sony speaker on the floor, taping a magazine on top of the eight inch subwoofer, and taping a piece of black construction paper onto the magazine so that any images shot from above would not show the cover of the magazine. The glass apparatus was then taped to the speaker. Black construction paper was also setup on items around the glass apparatus so that any images shot from the side would not show items in the apartment. Figure 2 illustrates the basic setup for the final image.

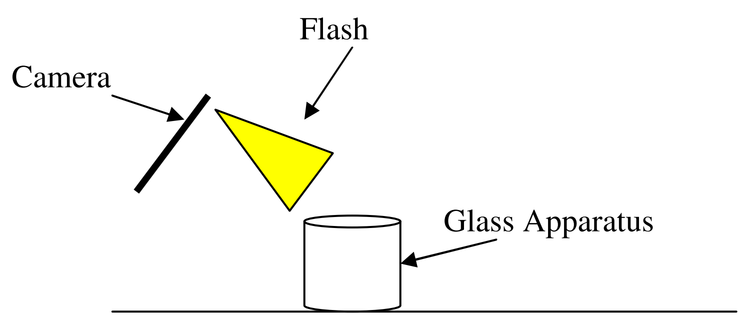
Figure 2: Side View



IV. Lighting

The lighting for the final image was simple. This means all the lights were off except for the flash. The tricky part was angling the camera to minimize the flash reflection in the glass. For the final image, I believe I was roughly four inches away with the camera at a downward angle so the flash was hitting only the rim of the glass. I was then was able to crop out the rim from the image and have a relatively low amount of reflection in the final image. The approximate position of the camera with respect to glass apparatus is roughly illustrated in Figure 3.

Figure 3



V. Sound Wave Basics

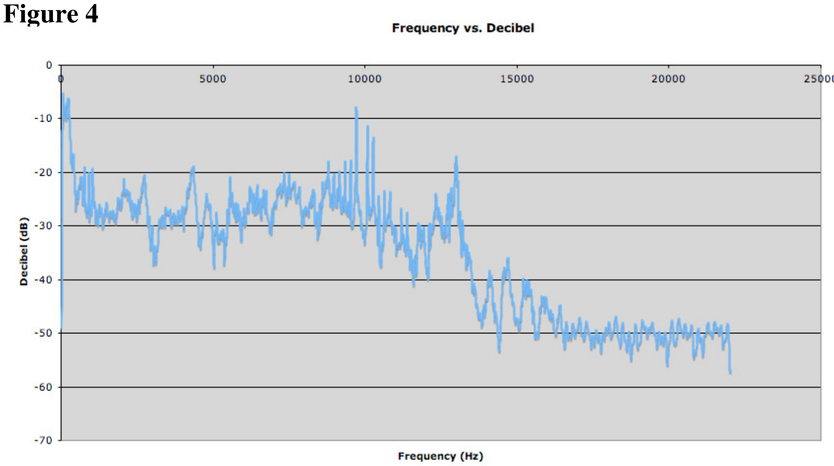
A sound wave is caused by a disturbance moving through various mediums, such as air, water, etc., and can occur when an object vibrates. It is important to understand that it is the disturbance and not the particles that move though the medium. For instance, when a subwoofer vibrates, the air particles in close proximity begin to move and those particles begin disturbing air particles near them and so on.

An especially important concept to understand for the final image is constructive and destructive sound waves because of the enclosed containment surrounding the windex. As a result of the enclosure, the constantly changing frequency waves begin to bounce off and around the enclosure and run into one another. As the speaker continues to produce sound waves, more and more waves begin bouncing off the container while at the same time, a continuous stream of new sound waves are still entering the container. The interaction of multiple waves has a tremendous effect on how the Windex reacts and depends highly on the sign and frequency of the sound wave.

When waves of equal sign hit one another, they combine and produce a larger amplitude and this is known as constructive interference. Destructive interference occurs when opposite wave signs hit one another and decrease the resulting amplitude. However, since most of these waves have different frequencies when hitting one another, the crests and troughs will not match up exactly since they are moving at different speeds. The result is that part of the sound wave will experience constructive interference and part of the sound wave will experience destructive interference and this is what creates "beats" in music.

Using an audio program called Audacity, the frequency of the song was recorded while shooting the final image and is shown in Figure 4. Over a 20 second span, sound waves of multiple frequencies are being emitted by the subwoofer into the container and as a result, "beats" of all sorts are being created. So while it appears that lower frequencies trigger the dancing motion of the Windex, it is truly an accumulation of all the interacting sound waves, or "beats", that leads up to the erratic behavior of the Windex. Therefore, there is no one specific frequency that causes a major disturbance in the Windex and the time before and after the erratic behavior of the Windex definitely play a role in it's motion.

Figure 4



While I refer to the behavior of the Windex in the final image as erratic, does that mean it is turbulent? What type of Reynolds number does this fluid flow demonstrate?

VI. Reynolds Number

While the fluid flow appeared to be erratic, it is not considered turbulent. It is categorized as laminar flow and involves both steady and unsteady flow. Steady flow is characterized as having a Reynolds number below 1000 while unsteady flow is characterized as having a Reynolds number above 1000 but below 2000.

I believe the final image is mostly steady flow, but at times when the constructive interference was high, sections of this flow became unsteady.

To determine the Reynolds number for the Windex, many variables needed to be determined. They include the density of the fluid, the velocity of the fluid, the characteristic length, and the absolute viscosity. The Reynolds number equation is shown in Equation 1 and illustrates the relationship among these variables.

Equation 1

$$R_e = \frac{\rho v_s L}{\mu}$$

The following few pages describes how I determined the variables needed to calculate the Reynolds number.

A. Absolute Viscosity

While the absolute viscosity of Windex was not listed, the three important ingredients in Windex are shown in the MSDS data sheet. Those three important ingredients were Ammonium Hydroxide, Isopropyl Alcohol, and water. The absolute viscosities for those three ingredients were 1.5, 3, and 1, respectively. I then took the average and assumed it was as accurate of an absolute viscosity I could obtain. The absolute viscosity of Windex was found to be 1.834 centipoises.

B. Velocity

Assuming fluid flow motion to be ~ 0.01m/s.

C. Final Reynolds Number

Using a velocity of ~ 0.01 m/s, a density of 996 kg/m^3, a length of 0.15 m, and absolute viscosity 1.834 centipoises (milliPa*s), a Reynolds number of 816.393 was calculated using Equation 1. This Reynolds number indicates a steady flow for the Windex, which I believe is correct for the majority of the Windex. However, I do believe at certain times the fluid flow is experiencing an unsteady flow and think a Reynolds number revealing unsteady flow could be found with better information on the fluid's velocity.

VII. Photographic Technique

Focal Length	6.20 mm
Size of the Field of View	~ 20 cm
Distance from Object to Lens	4 inches
Type of Camera Digital Width X Height (Original) Width X Height (Cropped)	 Casio Exilim EX-Z700 3072 X 2304 2531 X 634
Exposure Specs Shutter Speed Aperture ISO	 1/60 4.3 50

VIII. Adobe Photoshop

For the final image, I cropped it down so the main focus was on the fluid flow and there were no distracting elements in the background. In order to completely remove distracting elements from the background, I also had to edit the contrast. This removed some odd background spots and also dimmed out the glass to allow the viewer to focus on the fluid flow.

IX. Final Thoughts

I am very pleased with the final image and it was rewarding in many ways. First, I had been listening to music one afternoon and out of nowhere began wondering what effects a subwoofer would have on fluids. It is nice to know that after a semester of doing flow visualization, it has become somewhat of a second nature to pick out certain everyday interactions and wonder how they affect fluid flow. Secondly, I am also pleased with how my image turned out. Out of 200 shots, I had only about five or six good images and it reiterates that patience is a virtue when it comes to flow visualization. If I were to redo this image, I do not believe I would change anything. In fact, I would keep the exact same setup and just take more images of different fluids. Once again, I was very pleased with the final image.

X. References

1.) http://www.generalmonitors.com/downloads/msds/10272.pdf
2.) http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html
3.) http://www.airgasspecialtyproducts.com/UserFiles/laroche/PDF/AAPhysical.pdf
4.) http://www.engineeringtoolbox.com/sound-frequency-wavelength-d_56.html
5.) http://www.installer.com/tech/freqandwave.html
6.) http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/tornado/beat.html&edu=mid