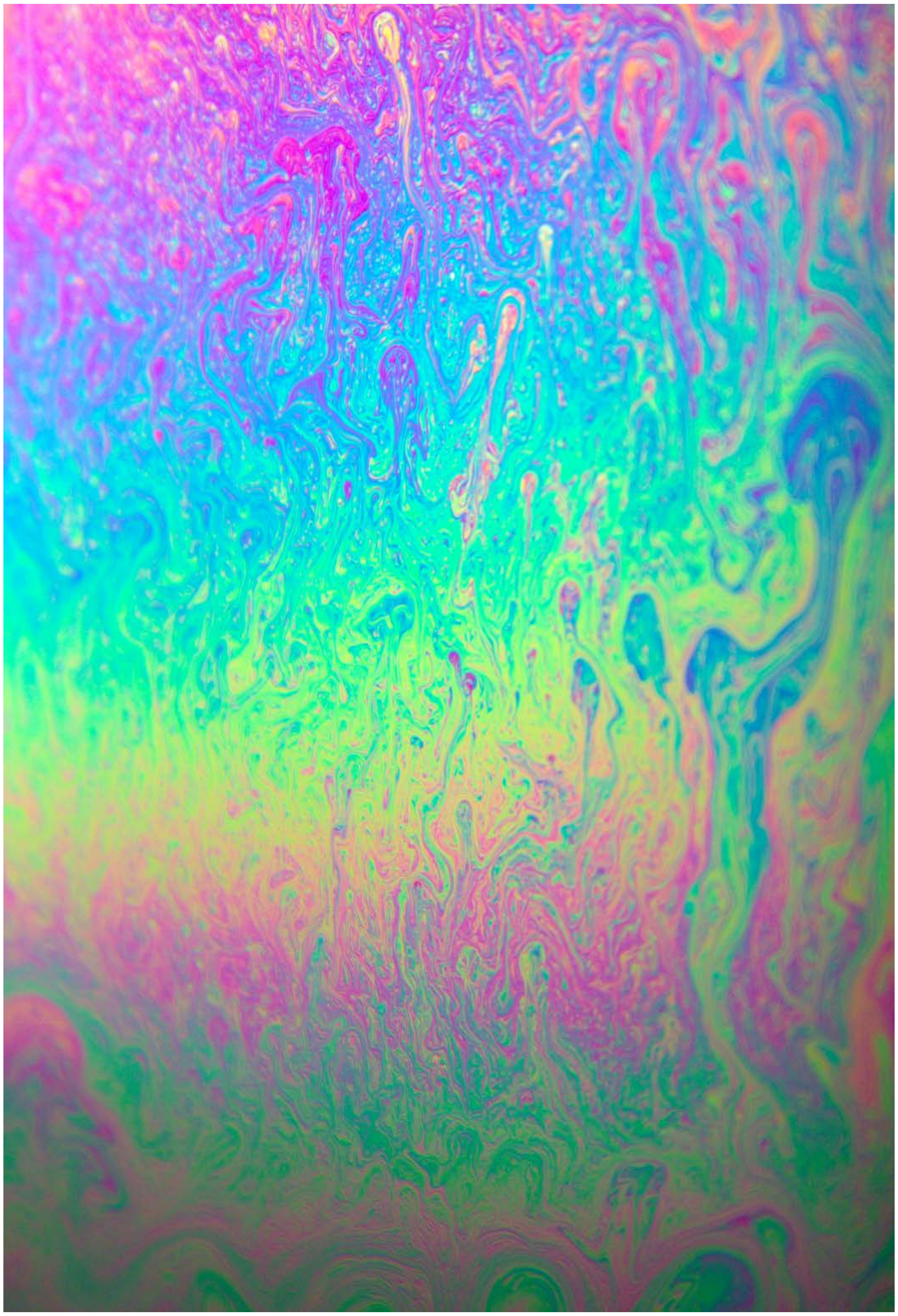
Group Project #1 – Soap Film Interference



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Professor Hertzberg
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Purpose

The purpose of this image is the first group project for MCEN 5151: Flow Visualization, taught by Professor Hertzberg at the University of Colorado at Boulder in Spring 2012. The image is meant to adequately show and demonstrate a fluid flow that can be physically explained in the accompanying report.

Team

I worked with a group consisting of the following members to acquire and analyze this image

1. Andrew Fish
2. Doug Schwichtenberg
3. Ryan Kelly
4. Nicholas Travers
5. George Seese

Materials

The image was created using all commonly used materials, save for the camera, which can be found at any hardware store. The materials are as follows:

1. Water
2. Ajax soap
3. Glycerin
4. 40 W light bulb
5. 1/8” white translucent plastic
6. 5” Diameter glass vase
7. Black paper background
8. Canon EOS REBEL T2i DSLR Camera

Procedure

The apparatus used to create the image is as shown in Figure 1, below. It consists of a cylindrical glass vase that is used to create the soap film, a black background, both incandescent and fluorescent light sources at varying angles, and a camera at an angle.

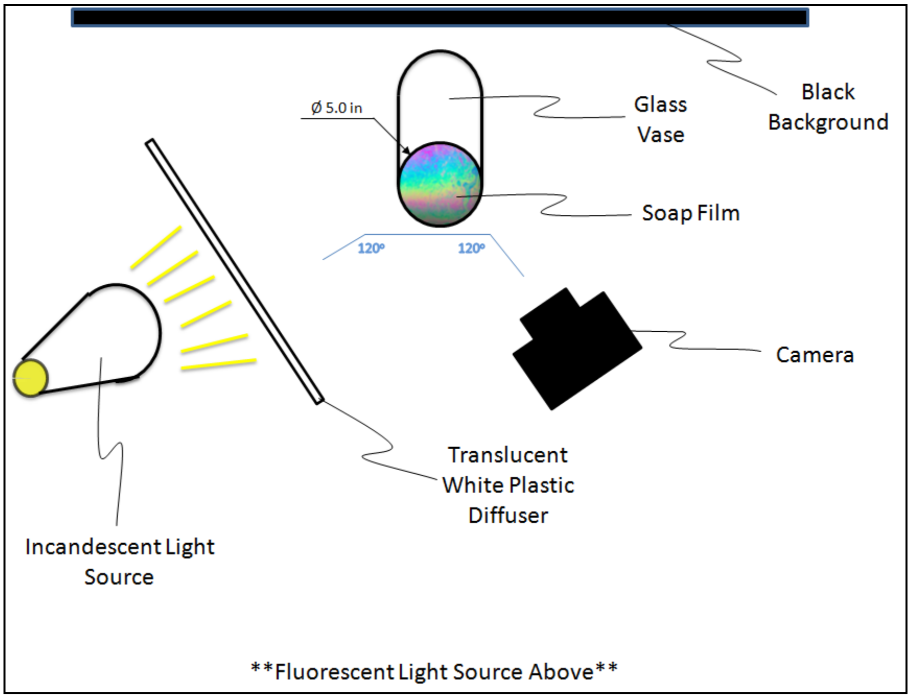


Figure 1: Experimental Setup

The soap film was created by dipping the open end of the glass vase into a bowl of soapy solution consisting of 2 tbsp Ajax soap, 9 tbsp glycerin, and 1 cup water. The vase was then placed horizontally on a table, so that the soap film was vertical. A combination of overhead fluorescent light and diffused incandescent light at a 120° angle, 1 foot away, was used to illuminate the soap film, which was captured by a camera at 120°, 3 inches away, as shown in the diagram. The black background absorbed all the excess light, which produced the best possible image of the flow experienced in the soap film. Each soap film would last for 5 to 10 minutes, allowing many images to be captured.

Fluid Dynamics

This fluid flow can be described as interference within a soap film. This is referring to the interference of the soap film with light reflecting off the surface of the film. A vertical soap film that is perturbed will have varying thicknesses of the film at the flowing portions, which reflect different wavelengths of light. When viewed at the proper angle, the reflection wavelengths show how the flow is moving throughout the film. Only about 4% of the incoming light will reflect off the surface, with the rest refracting through or being absorbed by the surface[1]. This is the reason why such an ample light source is needed to view the soap film flow. The light rays, however, can reflect off both surfaces of the soap film. The light rays initially hit the top surface of the film, and some are reflected, but many are refracted through the film because the index of refraction of the film is higher than that of air ($\eta_{film} > \eta_{air} = 1$). The light that is transmitted through the top surface is then either reflected off the bottom surface, absorbed, or refracted through the surface back into the air. This concept is shown in Figure 2.

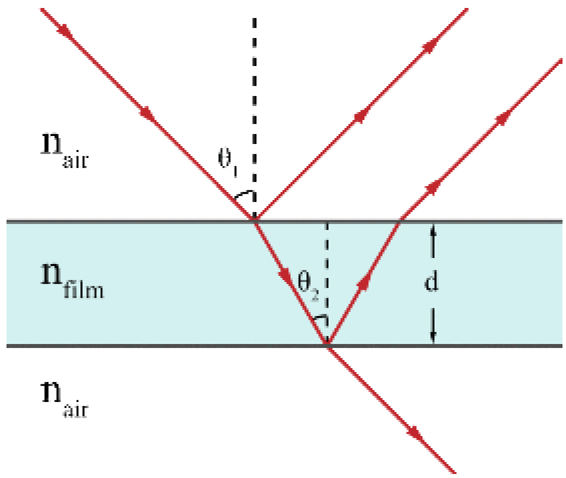


Figure 2: Light Interacting with a Soap Film[2]

The light rays that reflect off of either surface either cause constructive or destructive interference. Constructive interference is governed by the equation below[2].

$$2\eta_{film} d\cos(\theta_2) = \left(m - {}^{1}\!/_{2}\right)\lambda$$

Destructive interference is governed by the following equation[2].

$$2\eta_{film} d\cos(\theta_2) = m\lambda$$

Most of what can be seen is destructive interference, which shows the varying thicknesses in the film. Yellows and reds in the image show thicker sections of film while blues and purples display thinner sections of film, comparatively. As can been seen, there are several plumes of film in blue and purple that are traveling up the film through yellow sections. Soap films have only three main forces acting on them, which are gravity, surface tension, and viscous friction[3]. Gravity is predominant in creating the plumes seen in the film. These plumes are thinner than the surrounding areas and therefore weigh less, so they move up relative to the rest of the film. These flows are instigated by perturbations in the air as subtle as breathing.

Visualization Technique

There was no external visualization technique used in acquiring this image such as dye, smoke, etc. The fluid flow can be visualized by the reflection of light off the film, as described above. The light source was a combination of overhead fluorescent lights and directed, incandescent light, both diffused.

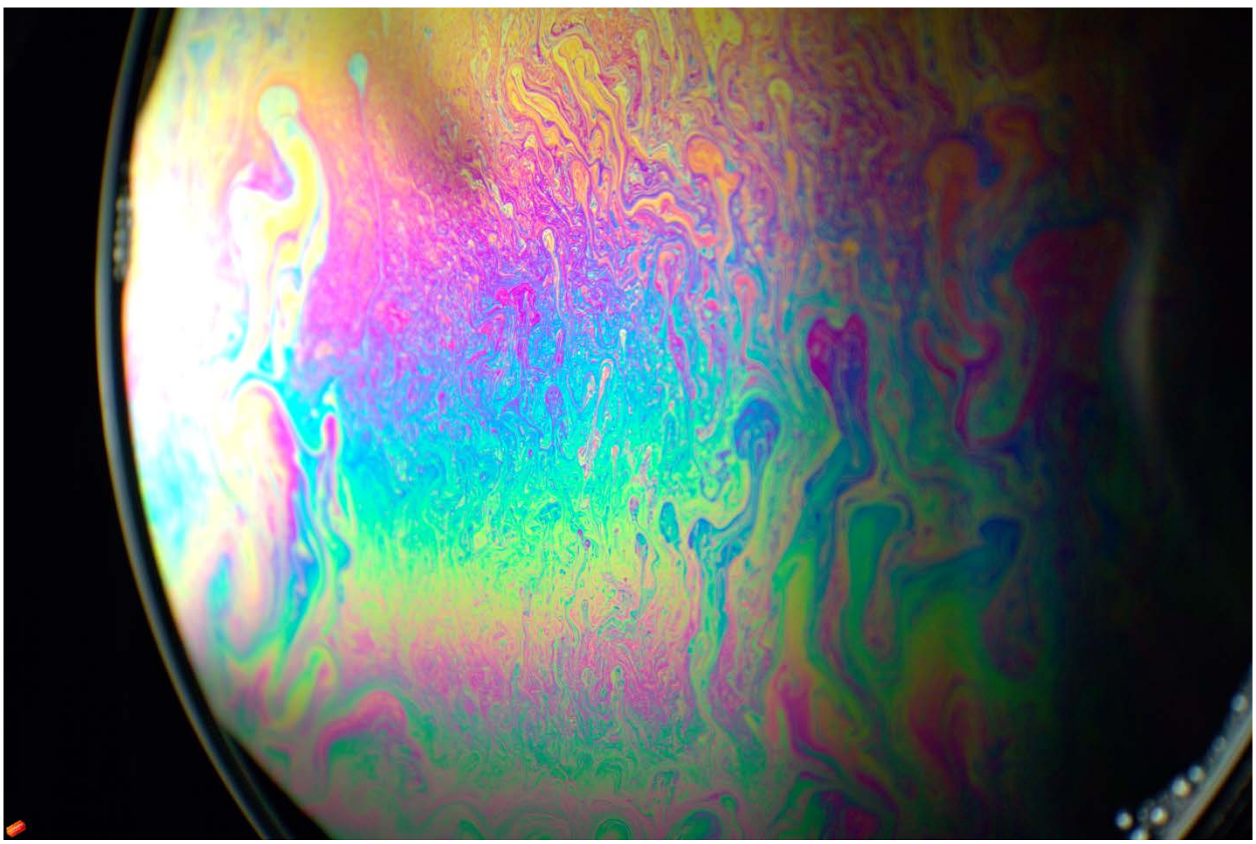
Photographic Technique

The size of the field of view is 3in tall by 1in wide, which was the largest rectangular portion of the soap film in the original image. The soap film was about 3 inches from the camera lens, which provided less need for zooming. The lens had a focal length of 55mm with an f-stop of f/5.6. A Canon EOS Rebel T2i digital camera produced a 1740x2559 final image. The camera settings were a shutter speed of 1/100sec and ISO 100. These were chosen to accommodate the tricky situation of capturing only the reflected light of the film, and not any other excess light in the frame. The only post processing that was performed on the image was simply cropping. Nothing else was manipulated because the original image was so vibrant and clear, it did not need augmentation.

Conclusion

In the pursuit of capturing the constructive and destructive interference of a thin soap film, I believe that the team succeeded in spades. I really like how clear and vibrant the image is which meant that it did not need any post processing save for cropping. The core concept of the image is shown very well, as are the fluid dynamics. The intent of the image was fulfilled, and in the future I would like to purposefully perturb the film and possibly capture a vortex in the film.

Original Image



References

1. *The Science of Soap Films and Soap Bubbles*. Isenberg, C. Toronto, Ontario, Canada: General Publishing Company, Ltd. 1992.

2. “Thin-Film Interference”. *Wikipedia: The Free Encyclopedia*. http://en.wikipedia.org/wiki/Thin-film_interference. Accessed 4/1/2012.

3. *Hydrodynamics of Soap Films*. Couder, Y., Chomaz, J.M., & Rabaud, M. Physica D (37), 384-405. 1989.