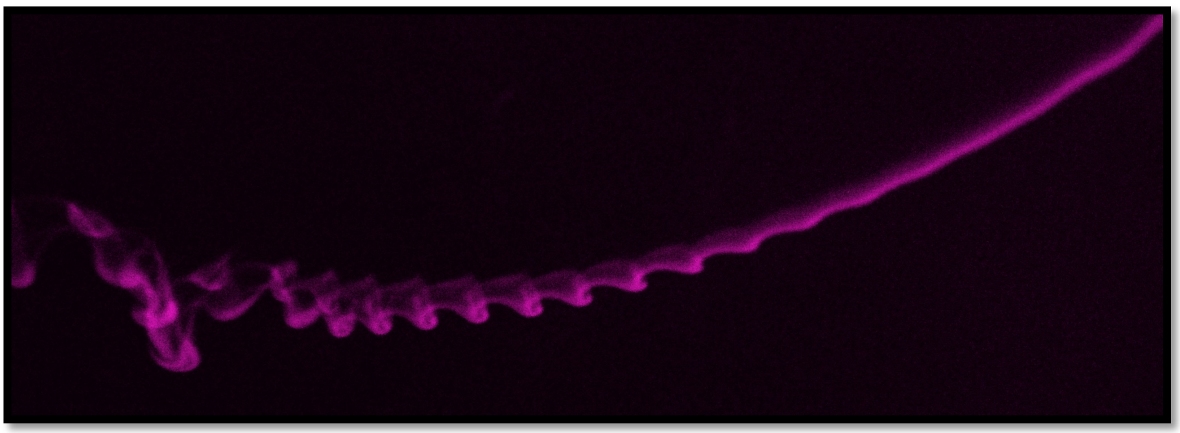
Flow Visualization – Team First
Kelvin Helmholtz Instability



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Introduction

The purpose of the first team project for the flow visualization course was to create an image that captures and interesting fluids phenomenon and to highlight the beauty of the phenomenon. For my image I worked with several team members in order to create my image Daniel Bateman, Jeremiah Chen, and Jason Savath. The help of my teammates was crucial in creating my image. Daniel deserves special acknowledgement for providing his house and camera. Through the use of professor Hertzberg's laminar flow fish tank my team and I worked with florescent dies and water to create our images. There was a lot of trial and error working with the fish tank. Our initial design was not successful and we attempted to capture several different kinds of fluid phenomenon. In the end I was able to create my image witch clearly illustrates the Kelvin Helmholtz instability.

Setup and Physics

The setup for this image took a lot of time to adjust in order to obtain a clear image of the fluid physics. The setup consisted of a fish tank with a black wall offset about two inches off the front of the tank. This wall provides a channel in which fluid flow experiments can be conducted and imaged. PVC pipes with 3/8-inch holes drilled into the pipes at 2-inch intervals act as the supply points for the flow into and out of the tank. The supply pipes were placed at both ends of the tank in the channel. For my image the right pipes supplied water through a pump that sucked water through the left supply pipe (see in image 1 below). The holes were evenly spaced to help create a uniform flow rate in the tank. Honeycomb plastic was used to create a laminar flow within the tank. Two desk lamps were used with ultraviolet light bulbs also know as black light bulbs because of the use of the florescent dye. They were placed about 6-inchs to each side of the flow. The Camera was on a tripod placed about 12-inches from the tank and perpendicular to the flow. In image 1 below, the right image is a zoomed in image of the left one. It was taken just left of the white cercal in the left image. This is the point at witch my image was also taken. This is the location of the florescent dye injection tube.

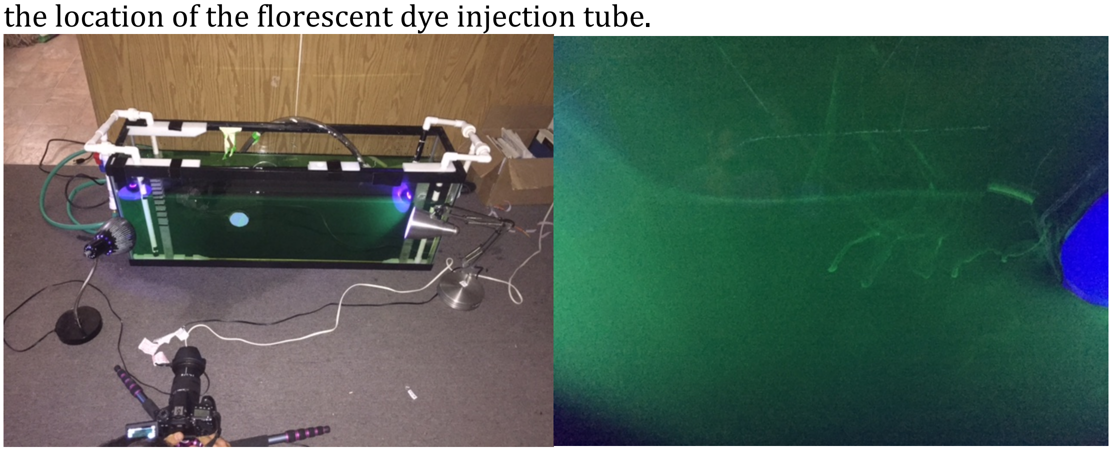

Image 1 - Setup

After failing to achieve sufficient flow to create the originally intended image we tried several reconfigurations and types of experiments. After turning off the pump and allowing the flow to decrease, we allowed the florescent dye to be slowly pulled into the flow. Because of the circular PVC obstruction in front of the injection point the Dye would drift down into the increasingly higher velocity flow below. This was due to gravity. Kelvin Helmholtz Instability occurred in the flow because of this setup.

Then Kelvin Helmholtz Instability is a hydrodynamic instability in which the velocity and density profiles are uniform in each layer, but discontinues at the plane of interface between the two fluids. (Matsuoka, 2014) Vortices accrue due to the shearing affect at the interface of the two fluids. The magnitude of the difference in velocity is important in understanding if vortices will occur. In my image, the Kevin Helmholtz instability vortices are clearly seen. The vertices were produced for several reasons. First the difference in velocities as the Dye flowed down into the water, which was traveling at a higher velocity. The difference in the densities and buoyance force helped to create the shear plane that allowed for the vortices to accrue. One of the fascinating aspects of this image is the fact the Dye is semi transparent. This allows the viewer to see in Kevin Helmholtz instability in 3D. Calculating the Reynolds number will give interesting insight into the behavior of the Dye by taking the ratio of viscous and inertial forces. (Benson, 2014) The density of water is $1\frac{g}{cm^3}$ at room temperature. Due to the similarity in density of the dye and water I choses $0.950\frac{g}{cm^3}$ for the density (ρ). The dynamic velocity for water is $8.9Mpa * s$. So for a dye which I similar to water I assumed a dynamic velocity of $8.7Mpa * s$.

$$\upsilon = \frac{\mu}{\rho} = (0.95Mpa * s)/\ (0.870\frac{g}{cm^3})$$

This means that the kinematic velocity υ equals $1.09\frac{mm^2}{s}$. The velocity was chosen do to distance traveled during the exposure.

$$R_e = \frac{UD}{\nu} = \frac{0.031(\frac{m}{s}) * 0.127(m)}{1.09e^{-6}(\frac{m}{s^2})}$$

This gives a Reynolds number of 3,612. This would make since for our water like liquid entering a turbulent flow state.

Visualization Technique

For this image my team and I were working with florescent dye. Due to this the flow itself essentially acted as the light source for this image. In order to visualize the flow two ultraviolet lights were used. Florescence accrues when the florescent fluid absorbs the incoming ultraviolet light and then releases it as light at a lower energy level. That is why the color of the dye in the original image is green not violet .The room was made as dark as possible in order to allow for the black lights and florescent fluid to be the only light sources. The background was black in order to provide good contrast with the florescent liquid. Due to the minimal amount of light the final image was slightly blurry and grainy. The florescent dye was taken from many highlighters. Finally to clearly show the physics of the flow the color was changed to pink in editing. The pink color improved the contrast with the background.

Photography Technique

The field of view of the edited image is about 5 inches wide and 3 inches high. The focal length was 55mm. The lens I was using is called The Cannon EF-S 17-55mm f/2.8 IS USM. The camera I used is a Cannon ESO 70D. The original raw image was 3,648 pixels high and 5,472 pixels wide. The final image after cropping and editing was 710 pixels high and 2,040 pixels wide. The ISO setting was ISO 2,000. The ISO needed to be somewhat high due to the low light levels provided by the florescent Dye. The higher ISO made for a slightly grainy image. The aperture was set at F3.2 with a shutter speed of 1/50. After taking the photo I made adjustments using GIMP photo editor. I cropped the photo to only include the area of interest. The original image also had a lot of negative space that was unnecessary. I slightly brightened the image using the contrast map. I was unable to brighten it more because it would become blown out. To compensate for the lack of brightness I changed the color of the dye to pink to help increase the contrast and clarity. Below is a before and after edited comparison.

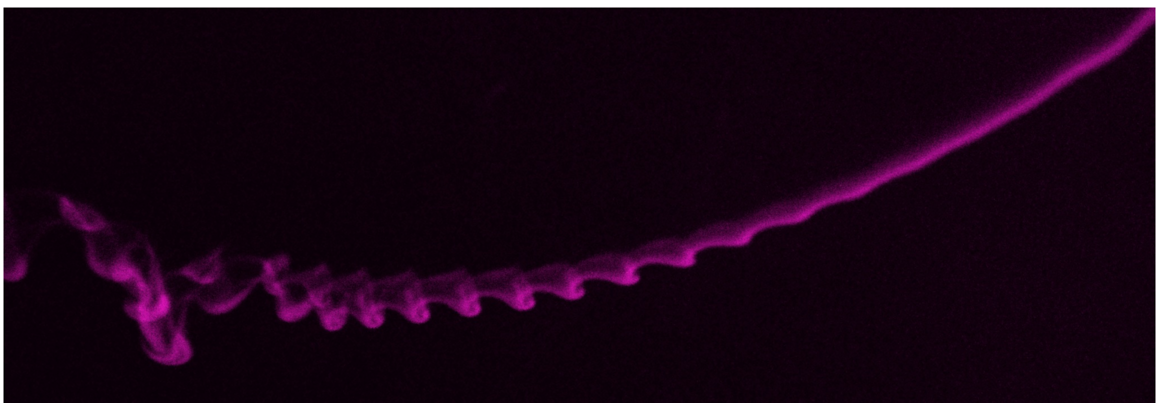

Image 2 – Original vs. Edited Image

Conclusion

In conclusion I believe that my team first image was a success. The physics of the Kelvin Helmholtz Instability was clearly visualized. The florescent flow created an interesting and beautiful lighting affect and contrast. It would have been nice to have a crisper image but due to the minimal light I am pleased with the final results. The transition from laminar flow was key in showing how the instability developed. If I were to do this again I would try to supply the florescent fluid with more ultraviolet light. This would help to reduce the need for high sensitivity and allow for a clearer image. Overall I am extremely pleased with my image for this project.

References

Benson, T. (2014). *Reynolds Number*. Retrieved 10 26, 2016, from NASA: https://www.grc.nasa.gov/WWW/BGH/reynolds.html

Matsuoka, C. (2014). *Kelvin-Helmholtz Instability and Roll-up.* Ehime University, Department of Physics. Matsuyama: Scholarpedia.