Team Photo 3

Kelvin-Helmholtz Instability

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MCEN 4151: Flow Visualization

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Special Thanks to Dr. Kittleman

Purpose

The purpose of this assignment was to satisfy requirements for the third team photo assignment and experiment with flow visualization techniques within a group. The requirements of this assignment were to make an aesthetically pleasing picture of fluids that demonstrate a phenomena being observed. For the purpose of this lab, the project chosen was to produce the Kelvin-Helmholtz instability. The intent was to observe this phenomenon of the instability as well as capture this fluid flow in an interesting way.

Flow Apparatus

The experiment was performed in a rectangular clear plastic flume. The container was chosen to give a clear surface for the instability to be visualized from as to not distort or take away from the phenomena. It was also chosen as the flume setup was necessary to not have any air pockets form within the apparatus setup. The size of this container is approximately 1 foot tall with a width of 6 inches and overall length of approximately 6 ft. The flume was filled with both the blue and red fluid seen in the image above. The blue sits on the bottom and the red on top. Both fluids are room temperature tap water with either blue or red food coloring added to them. However, the blue fluid's density was increased by 2 percent with the addition of salt in order to be able to obtain the instability. The flume was then set on a desk with a wooden block at one end (to stabilize the flume once it would be tilted) and a raised platform on the other end (to set the end of the raised flume on). The fluids had to set overnight to make sure all air pockets would escape and there was no motion in the fluid that would cause pre-mature mixing once the stability was performed. The next day, one team member braced an end of the flume while the other lifted one end and put it on the platform. The apparatus was raised about 14 inches on one end to encourage a velocity shear between the two fluids.

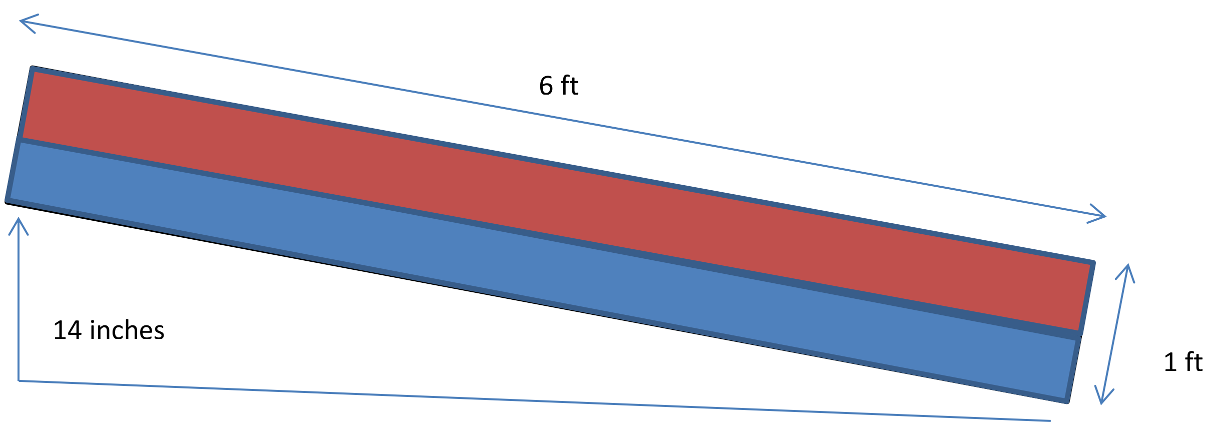

Figure 1: Flow Apparatus Setup

Flow Dynamics

The Kelvin – Helmholtz instability occurs where there is a velocity difference across the interface between two fluids. For this instability to work, one needs two incompressible, inviscid fluids in two horizontal parallel streams of different velocities and densities. The faster stream needs to be above the other. In our case, the faster stream is the red fluid. In this instability, there is a shear layer present. This is the horizontal boundary corresponding to a significant difference of velocity. In this layer, vorticity is uniform but equal to zero outside of the layer where velocities are uniform. This causes the shearing layer to appear as a vortex sheet inside an irrotational flow which causes the roll-ups seen in the image above. [1]

Visualization Technique

We had a team of four people to set up the apparatus, lift the flume, and photograph the phenomena. After the flume is lifted, the phenomena happens within about 20 seconds so there is not much time to waste and cameras need to be focused and ready as soon as the flume is lifted. If the photographer wanted to achieve the look of the phenomena seen in this image, they would need to go about this quickly. The photograph used to represent this experiment was taken early on right when the rollups started occurring. This was done to demonstrate the early stages of the Kelvin-Helmholtz instability before the two fluids started mixing. In this setup, a white background was used. This was achieved by placing a white cardboard piece behind the container. The backdrop was placed on the desk behind the flume. A white backdrop was chosen over a black one since the colors of the fluid show up more clearly in front of white. The lighting used was two handheld lamps with 60 watt bulbs that we suspended above the flume using stands and clamps. This experiment was performed in otherwise a dark room to avoid any excess lighting that would cause reflections on the surface of the flume. Once the apparatus was all set up and the camera was set about 3 feet from the flume, a piece of paper was placed behind the flume to set our focus on our cameras before the experiment was run since we did not have time to focus during the instability.

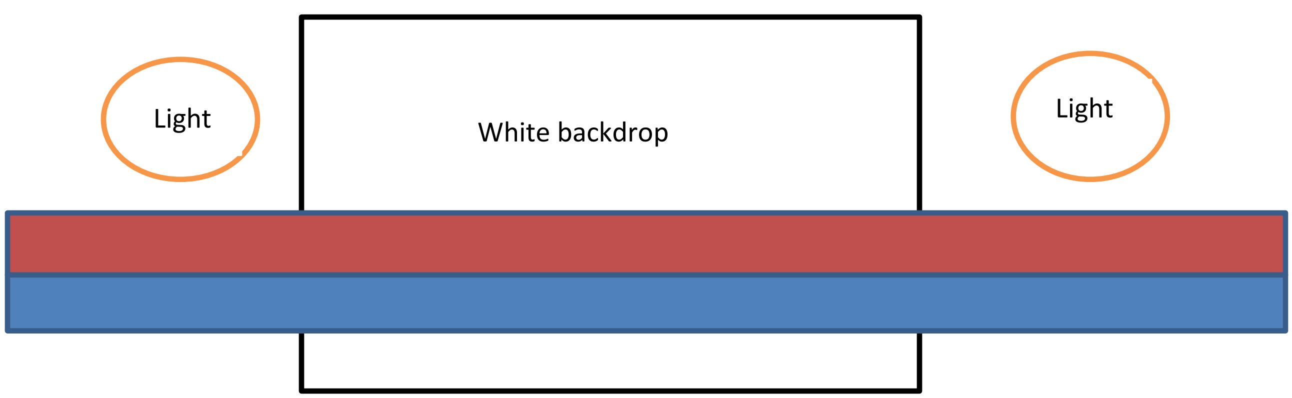

Figure 2: Camera Setup

[1] http://hmf.enseeiht.fr/travaux/CD0001/travaux/optmfn/hi/01pa/hyb72/kh/kh_theo.htm

Photographic technique

This photograph was shot using a Sony α 5000 E-mount camera with an attached 16 – 50 mm power zoom lens. This point and shoot mirrorless camera has manual focus capabilities with an ISO up to 16,000.[2] The image size shot is 5456 x 3632 pixels and the final image after processing is 5112 x 832 pixels. The focal length used for this shot was 50 mm which is equal to 75 mm for a 35mm equivalent range. The image was captured using a shutter speed of 1/160s and the ISO was 640 to capture all the information in the instability. These settings in addition to the setup described earlier and the exemption of the flash led to the photo in figure 3 below. Use of an open – source photo editing program Gimp was then used to create the final image. The image was first rotated so that the instability could be seen horizontally and then cropped to focus only on the phenomena and to get rid of the container. The image was then saturated a little but most importantly the contrast was increased to make the instability stand out more against the white backdrop. The post – processing after image is also shown below in figure 3:

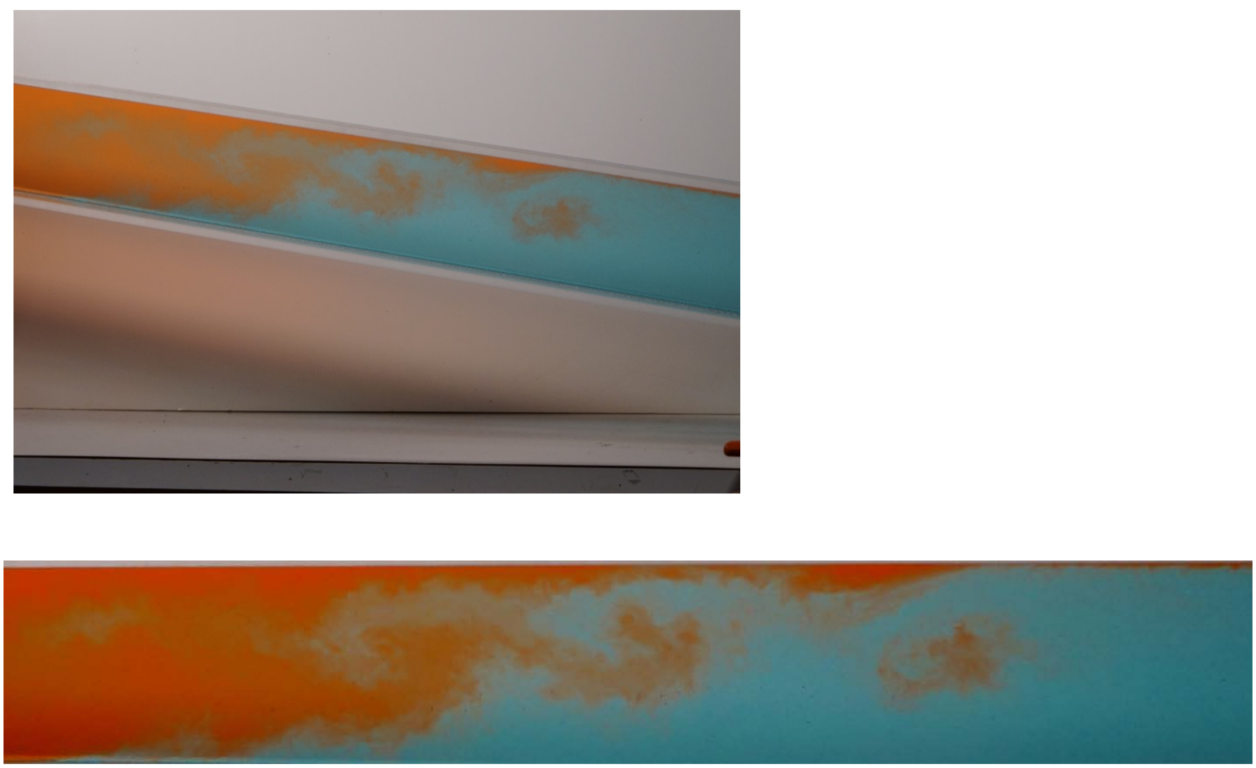

Figure 3: Raw image (top) and processed image (bottom)

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[2] "Sony α5000 E-mount Camera with APS-C Sensor." *Sony*. N.p., n.d. Web. 16 Oct. 2015.

Conclusion

The project was successful in experimenting and understanding flow visualization techniques within a team. Being able to work on a team allowed us to create more original and complicated designs to demonstrate the Kelvin-Helmholtz instability as well as collaborate on understanding the physics behind the fluid flow. By adding the colors to the experiment, we were able to view this phenomenon in a more dramatic light. This experiment is another proof of the importance of having a good apparatus and flow setup to create a proper image of the phenomena.

The image revealed important fluid concepts in an artistic and new way. I really enjoyed that I was able to capture so many rollups in this image. I was also able to capture a little bit of a turbulent effect in the fluids. I also think my focus is nice on the boundary layer of the instability. If I were to perform this experiment again, I might try to take the image closer to the container so I wouldn't have to crop so much and the image might look more resolved. I would also try to increase the contrast a little more to really make the colors pop and make the instability more defined and dramatic. However, I was able to capture a lot of interesting physics of fluid flow in this image and I feel like because of this, I fulfilled my intent with this photograph. If I were to develop this idea further, I would try fluids other than tap water. It would be cool to see someone achieve this idea with pearl swirl.