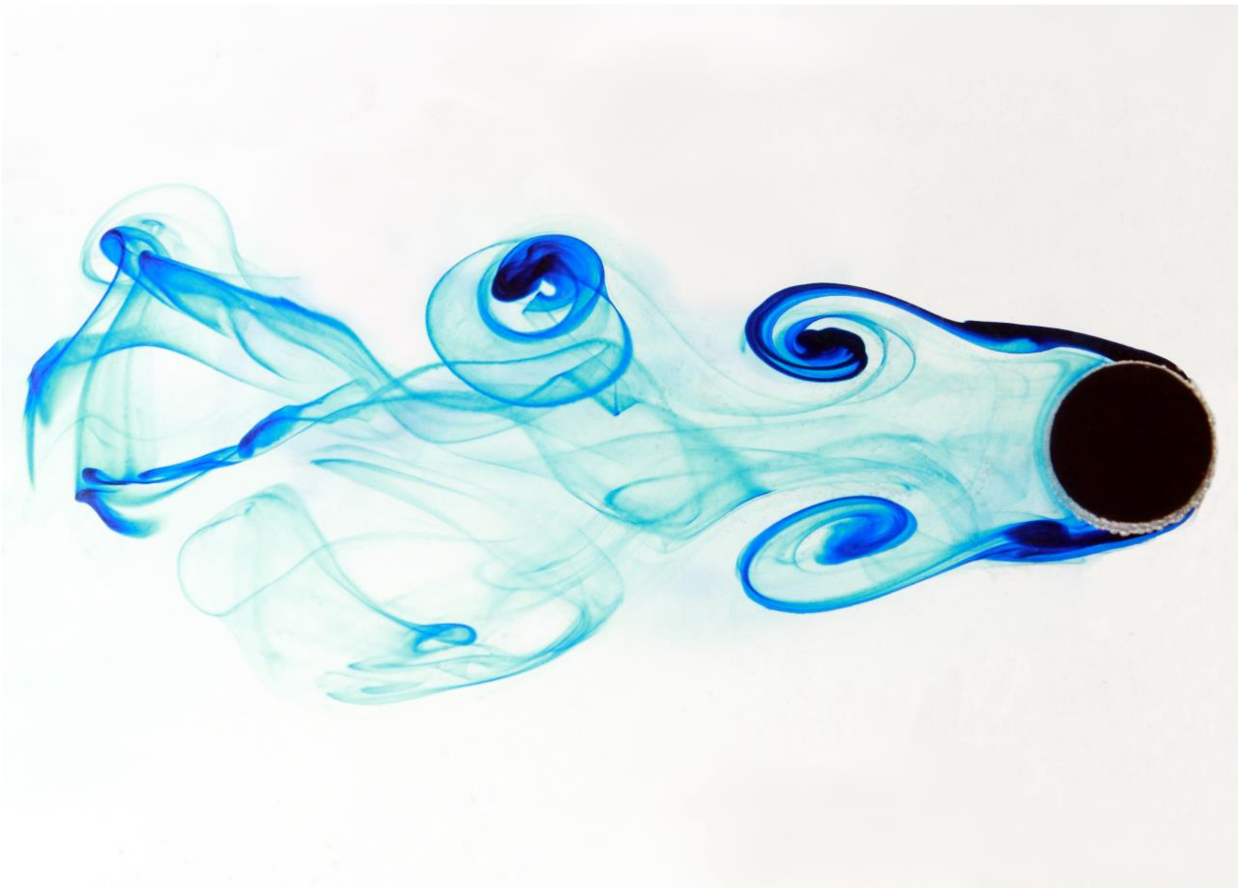
# Team Third 2016

Peter Brunsgaard



Flow Visualization

Professor Jean Hertzberg

2016

## Introduction

The purpose of this assignment was to explore a fluid flow from an artistic perspective. The project chosen for the "Team Third" assignment was intended to explore Karman Vortex Streets in a laminar flow. Karman Vortex Streets occur when an object is placed in the stream of a laminar flow, and cause the flow to spiral due to different velocity profiles meeting at a boundary. This experimental setup was intended to capture Karman Vortex Streets in water using food dye as a tracer. The entire experimental setup was researched, designed, and fabricated by Joseph Straccia with the help of teammates Max Scrimgeour and Jeremy Parsons.

## The Apparatus and Analysis

Karman Vortex Streets are a widely studied flow phenomena seen in cloud formations over islands, vortex shedding around skyscrapers, and all kinds of unique flow situations. A Karman Vortex Street is simply a series of offset vortexes following an object in a laminar fluid flow. As a fluid approaches an object in its path the fluid follows the typical streamlines around an object, until the widest part of the object, known as the point of separation. This point of separation is the limit between forward and reverse flow in the boundary layer in the immediate neighborhood of the wall [1]. At this point the flow is at a high pressure state and creates a shear boundary with the fluid directly behind the object. At this point, vortexes begin to form in the wake. These vortices then fold on each other and create a wake of offset vortices. This image captures the initial formation of a Karman Vortex Street as the two vortices closed to the cylinder are in line with each other.

The setup for this image based around the water flume on the bottom floor of the Integrated Technology and Learning Laboratory. We desired a Reynolds number between 70 and 200 in order to capture the effect in a laminar flow. This was calculated using the known profile of the tank, 0.2mm x 7.2mm x 250mm, and the Reynolds equations for flow in a square profile. We were able to calculate the volumetric flow rate by simply timing how long it took for an inline tank to fill up 5L of water. The volumetric flow rate at the time of my image was approximately 0.279 L/s which placed the water flow into the laminar flow category.

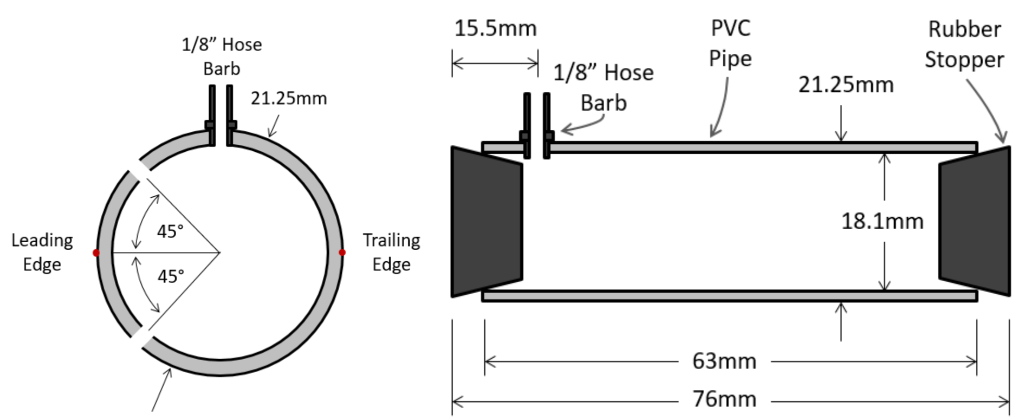



*Figure 1: Cylindrical object delivering dye into the fluid flow (Image Credit: Joseph Straccia)*

The setup for this image was intricate with the control of the volumetric flow rate of the water being the most critical aspect. In order to achieve a low enough flow rate, we had to place a hose with a slow stream of water feeding into the inlet tank, while adjusting the sluice gate at the rear of flume to maintain an even flowrate through the flume. Once the proper flow rate was achieved, a PVC pipe with 2 slits cut at a 45° offset above and below the centerline was placed into the flume, held in place by rubber stops on either end, as shown in Figure 1. The dye was then fed into the PVC cylinder using a gravity fed system. In order to achieve a neutrally buoyant dye mixture, 95% ethanol was added to the mixture. Initially the dye was too dense, so more ethanol was added which hit a sweet spot before completely diffusing, resulting in the dye being too buoyant. The setup in its entirety can be seen in Figure 2.

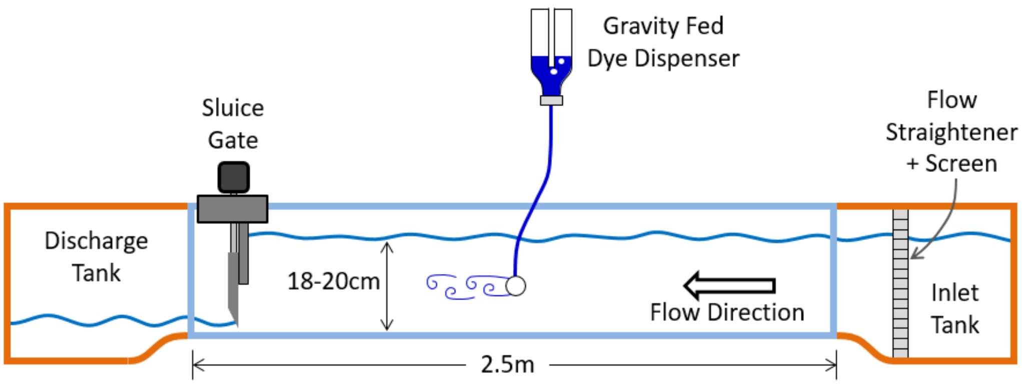



*Figure 2: Experimental setup from the perspective of the camera. (Image Credit: Joseph Straccia)*

The photographic setup consisted of the camera being placed approximately 66cm away from the flow at a slight offset angle to the flow. Two LED panel lights placed on tripods were placed facing the image from a 45° and 60° offset from perpendicular to the flume. A large poster board was taped to the back of the flume in order to create a white background. The poster board was then backlit from an off camera flash to illuminate the background and eliminate some of the shadowing from the lighting in the front. The camera was manually focused on a tripod and shots were taken using an off camera trigger. This setup can be seen in Figure 3.

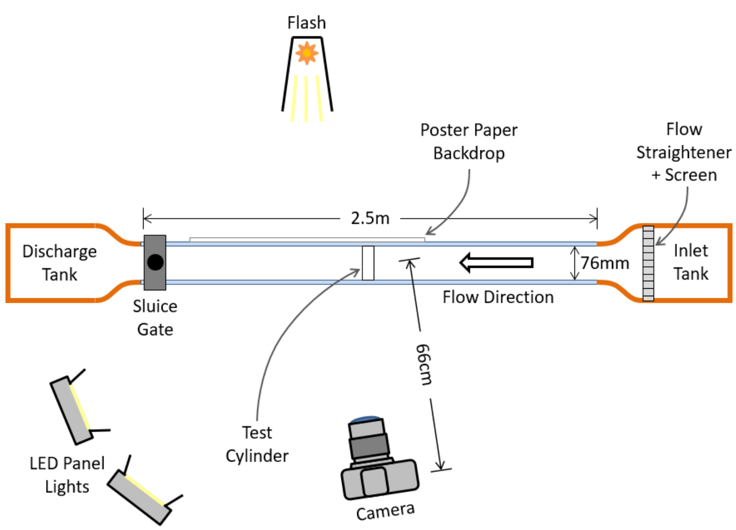



*Figure 3: Camera and lighting setup for taking the image. (Image Credit: Joseph Straccia)*

## Photographic Technique

This photograph was taken on a Canon EOS 7D DSLR camera using a Canon 24-70 f/2.8 lens. The camera was set on a tripod and the camera was set facing the fluid from a horizontal reference point. Focus was manually set using a ruler placed in the center of the flume as a reference. The camera lens was about 18" away from the flume with a focal length of 42 mm to capture a large enough reference to view the Karman Vortices. Image resolution was 18 MP shooting in Canon's proprietary RAW format. A shutter speed of 1/200s was used in order to try to eliminate any potential motion blur in the fluid flow and get a crisp image. The fluid flow was essentially frozen in time over the exposure period as a result of the quick shutter speed and as a result of plenty of lighting, the ISO only needed to be set to 1000. This entire setup was using Joseph Straccia's camera, equipment, and experience to capture the image.

*Table 1: Camera settings*

| | |
|---|---|
| Camera | Canon EOS 7D (DSLR) |
| Lens | Canon 24-70mm f/2.8 |
| Original Image Size | 5184 x 3456 |
| Final Image Size | 3250 x 2329 |
| Field of View | ~ 3.5" x 4" |
| Focal Length | 42 mm |
| Aperture | f/6.3 |
| Shutter Speed | 1/200s |
| ISO | ISO-1000 |
| Flash | 2 LED fixtures, detached flash, overhead lighting |

The image was edited from the raw shot using GIMP 2. The unedited image can be seen in Figure 2. Throughout the shoot tiny air bubbles formed on the acrylic of the flume which were edited out using the clone stamp as they detracted from the artistic intentions of the image. Additionally, the hose line used to feed ink into the chamber was edited out for similar reasons. Due to the lighting setup, the dye casted a shadow onto the backdrop which was removed to give a truer white background. Additionally, the image's contrast curves were altered to try to achieve a greater contrast between the highlights and shadows of the dye in the fluid flow.

*Figure 4: Unedited image*

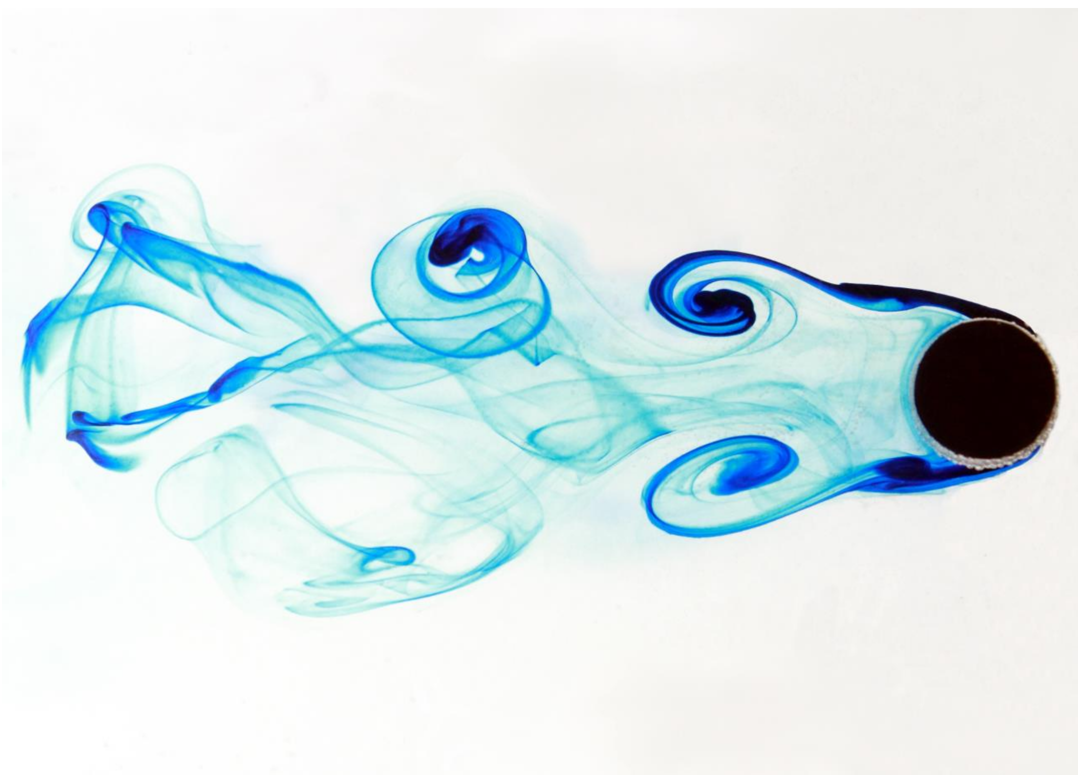


*Figure 5: Edited image*

## Image Intentions

The intention of this image was to capture a 2D Karman Vortex Sheet using dye in water. The image turned out better than intended. While being clean and aesthetically appealing, the image also manages to capture a unique flow phenomenon. Although unable to capture a 2D Karman Vortex Sheet, the effects of the 3D vortex add depth and makes the image more interesting. If I were to repeat this experiment, I would try using a wider water flume in order to make the boundary conditions at the acrylic walls negligible and achieve a constant velocity profile. This would give a truer 2D representation of Karman Vortex Streets.

## Acknowledgements

A HUGE thank you to Joseph Straccia for researching, designing, and fabricating the entire setup for this image. It simply would not have happened without him. Thank you to Jeremy Parsons and Max Scrimgeour for their invaluable input and assistance in executing this project. Thank you to Professor Jean Hertzberg for enabling this project to come to fruition.

## References

http://hmf.enseeiht.fr/travaux/CD0102/travaux/optmfn/gpfmho/01-02/grp1/phy_know.htm

http://disc.sci.gsfc.nasa.gov/education-and-outreach/additional/science-focus/ocean-color/science_focus.shtml/vonKarman_vortices.shtml