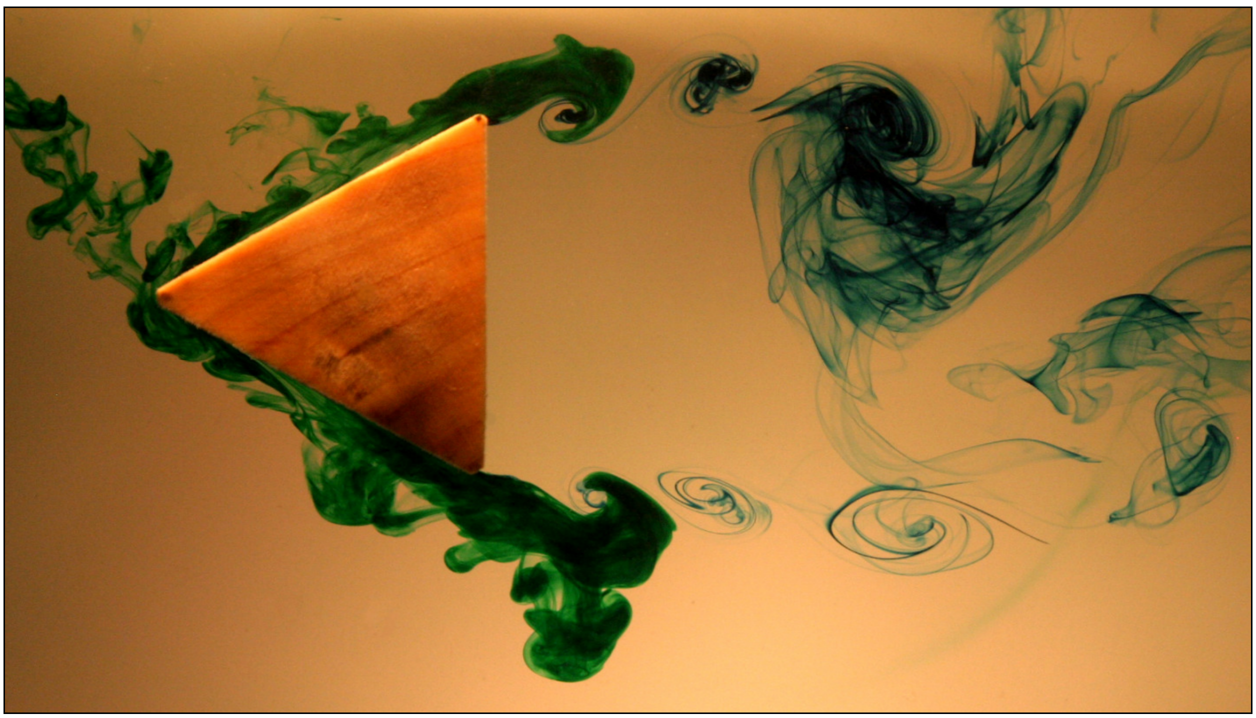
Vortex Shedding Past a Triangular Prism



Eli Luke

Flow Visualization

Prof. Jean Hertzberg & Prof. Alex Sweetman

Project #4 (Team Beta)

Due 11/8/07

Purpose:

This is the fourth project of the semester, and our group experimented with bathtub vortices as well as separation flow past bluff bodies in the ITLL flume available on campus. We were originally experimenting with visualizing different flows by use of the smearing method, and found that it was really difficult to control. We then decided to produce some bathtub vortices in an upside down 2-liter bottle with the top cut off. We experimented with some different ways of visualizing these vortices, and decided that we needed more pictures. This is when we came up with the idea of visualizing flow past a cylindrical prism as well as a triangular prism in the ITLL flume. The photograph specific to this paper visualizes a separation flow past a triangular prism.

Experiment Setup:

The open channel flume in the ITLL was used to visualize this flow. A triangular prism was cut to slightly greater than the width of the channel so that it could fit somewhat snug down in the flow. The leading point of the triangle was orientated opposing the direction of flow. To visualize the flow past this bluff body, some food coloring was injected just upstream of the prism. The upstream velocity was calculated using a stopwatch and a ruler to see how fast the dye was moving. There was lighting from behind and from above to brighten the flow for capturing the image. An actual picture of the flume is shown below (figure 1) as well as a sketch of the setup (figure 2) used to create this flow.

Figure 1: ITLL Flume

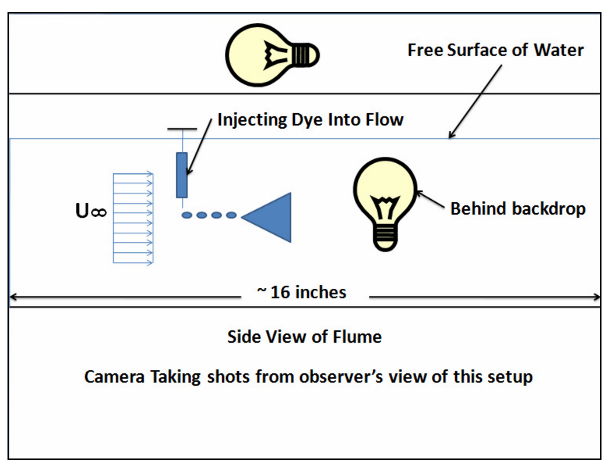


Figure 2: Experimental Setup

Physics:

The primary thing happening in this flow is called flow separation, and happens during most flows past bluff bodies with high enough Reynolds numbers. In a normal boundary layer flow, such as that across a flat plate, the velocity is zero at the face of the plate, and increases as a function of the vertical height of the plate, giving a nice uniform velocity profile. Well, during separation flow, there is a region next to the wall where the flow slows down because of the existence of an uphill pressure gradient[1]. When the separation point has been reached, flow is observed to reverse direction on the downward side of this separation line. That is why we get vortex shedding, or eddies as a result of this separation. With a triangular prism, there is a drastic change in geometry, which gives us a very observable separation line. The figure below (figure 3) shows this separation line.

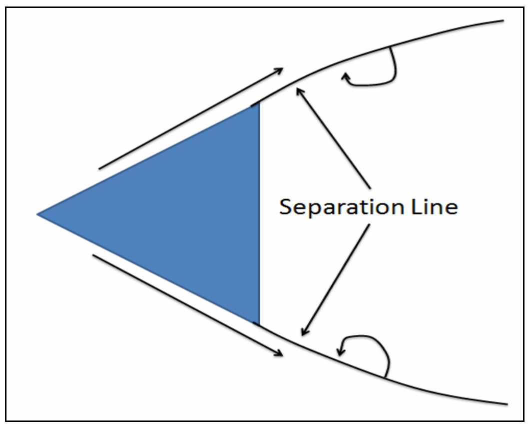


Figure 3: Separation Line

So, because of this separation in the flow, we can see in the photograph that vortices are being shed off of the tips of the triangular prism.

Reynolds Number:

The Reynolds number for this type of flow can be approximated as follows:

$$Re = \frac{U_\infty L}{\nu} = \frac{\left(0.04\frac{m}{s}\right)(0.04m)}{\left(1.004E-6\frac{m^2}{s}\right)} \approx 1968$$

Where U_∞ is the upstream velocity, estimated to be 0.04m/s, L is the characteristic length scale, or height of the triangle, which was 2 inches, and ν is the kinematic viscosity of water at room temperature. The flow is laminar, and we can see this vortex shedding even at higher Reynolds numbers, up until the point where the flow becomes turbulent, and then there will be an observable turbulent wake behind the bluff body.

Photographic Technique:

The temporal resolution was important in this flow, because of the moderately high velocity of the flow in the channel. The shutter speed was high enough to cut out any motion blur that would occur otherwise. This photo was also taken up fairly close, and so a macro lens was used to give ideal focus. The flow was lit from above the channel and from behind the backdrop. This proved to provide ideal lighting for the visualization.

- Make/Model: Canon EOS Digital Rebel   2048 X 1360 Pixels
- X res: 180 lines/inch   Y res: 180 lines/inch
- Actual specs for photo: 92mm focal length, 8.0 F-Stop
- Field of View: ~ 6 inches
- Exposure Specs: 1/320 sec exposure, aperture value of 6.0, ISO speed rating of 400

There wasn't much done in Photoshop other than some touchups, including some contrast and brightness changes. The touchups included removing distracting elements, such as drops of water on the flume itself. The only other thing that was done was cropping the image down a little to capture the desired part of the flow only. A pre-Photoshop picture is shown below (figure 4).

Figure 4: Pre-Photoshop (Original) Photograph

The Image:

The image is really resolute, and shows the concept of vortex shedding really well. The fact that there are such sharp corners for the flow to separate is a nice for the visualization, because the separation is extreme. The image itself is really artistic in the fact that it shows a past-present type of scenario, where you have vortices being formed right at the moment of image capture, but you also have vortices that had been shed a moment or so previously. The previously formed ones were visualized using blue dye, and the present ones were visualized using green dye, so this gives it a nice aesthetic touch.

References:

[1] Kundu, Pijush K. (1990). Fluid Mechanics. San Diego: Academic Press, Inc.