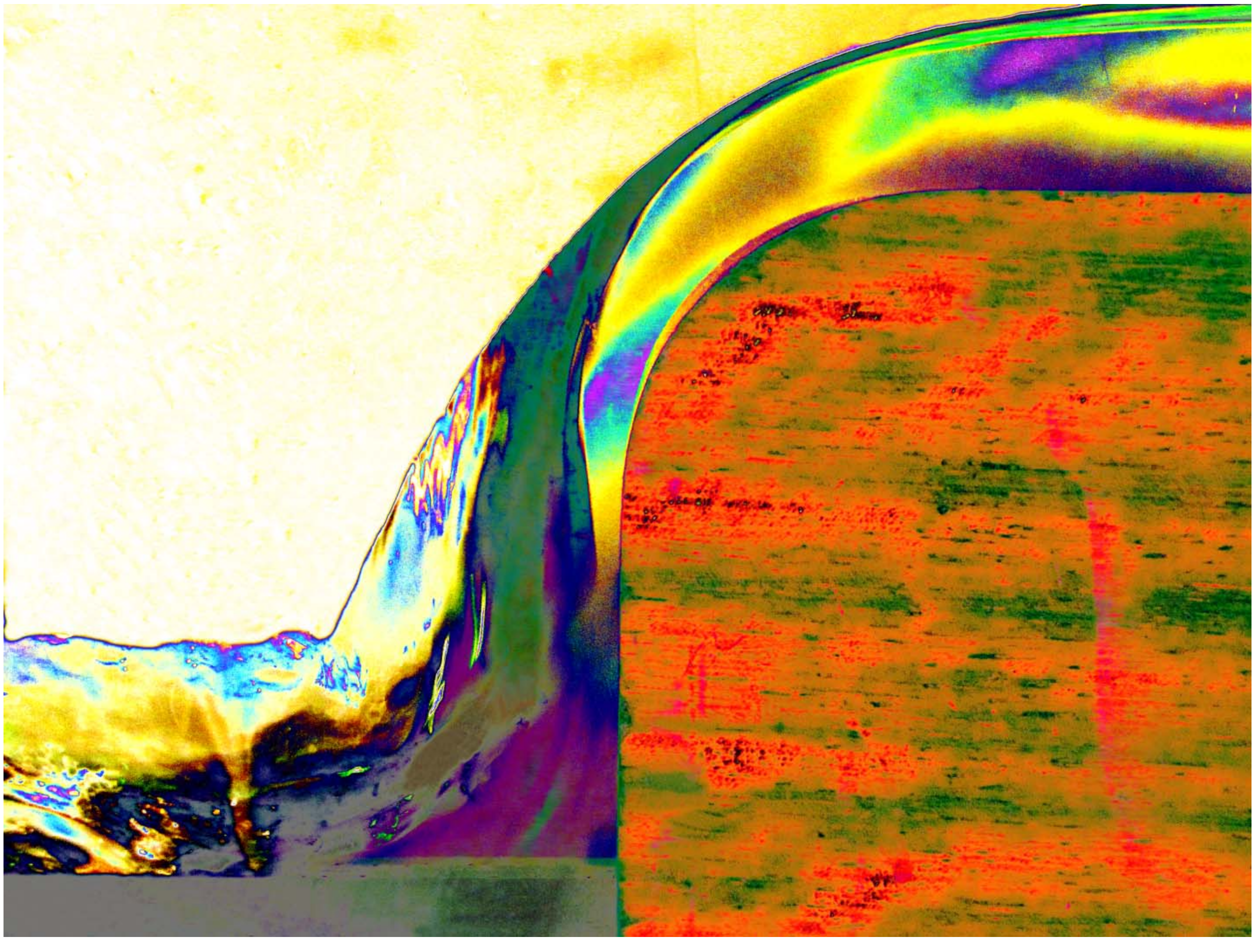
Laminar to Turbulent Flow of Water



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MCEN 5151

Flow

Visualization

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Purpose:

The purpose of this assignment was to “get our feet wet” and use some basic photographing techniques to demonstrate phenomena related to fluid flow. The key requirement for this image was to make the fluid the star and highlight the phenomena. The goal for this specific image was to demonstrate the transition of laminar to turbulent flow. An example of this phenomenon occurring in real life, of similar fashion, is in a river step down dam. Water from the higher water level is flowing over the dam, then accelerates while falling, and then creates turbulences as it enters the water again.

Flow Visualization Apparatus:

The Apparatus used to demonstrate the phenomenon was the open-channel flume exhibit located on the base floor of the ITLL building on the University of Colorado Boulder campus. This specific flume has a flow bed of 2.5 meters long, 25 cm tall, and 7.6 cm wide. The sides of the flow channel are made of clear Plexiglas for a clear view of the fluid. In the base of the flow channel there are several adjustable hocks to attach a variety of obstacles. The overall angle of the flow channel can be adjusted to make the fluid flow go “uphill”, so a positive angle, and a negative angle to make the fluid flow “downhill”. The adjustment for this angle ranges from -3^o to 1^o. A Picture of the flume exhibit can be seen in Figure 1.

Figure 1: ITLL Open-Channel Flume Exhibit

The object submerged in the channel was a wooden block about 4 inches tall, 14 inches long, and the same width of the flow channel. An approximate representation of the flow over the submerged object can be seen in Figure 2.

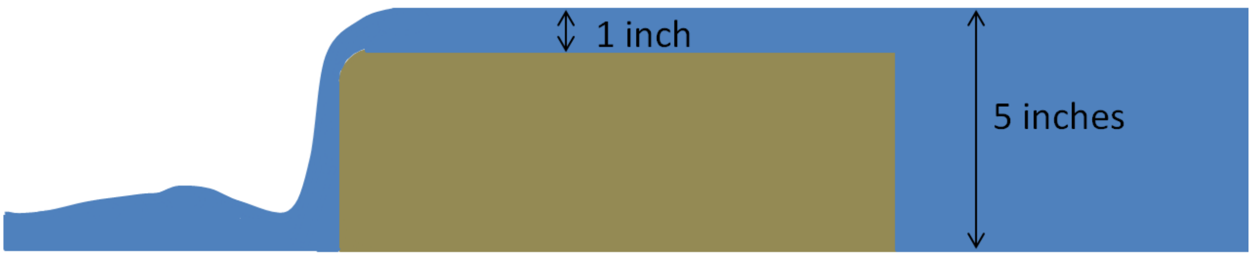

Figure 2: Approximate representation of flow over object

Looking at the Reynolds number of the flow on top of the wooden block, we see that at the end of the wooden block the flow enters a transitional phase where the flow transitions from laminar to turbulent flow. This transition usually occurs for a flow over a flat plate at RE approximately equal to $5*10^5$ [1]. Now the water drops about 10cm and converts the potential energy into kinetic energy and therefore the velocity of the water increase. As the velocity increase, the Reynolds number increase and transitions the flow into fully turbulent flow at the bottom of the obstacle.

$$RE = \frac{inertial\ forces}{viscous\ forces} = \frac{\rho VL}{\mu} = \frac{VL}{\nu}$$

$$RE = \frac{\left(.02\frac{m}{s}\right).35m}{1.307 * 10^{-6}\frac{m^2}{s}} = 5355$$

A graphical representation of the transition of laminar to turbulent flow can be seen in Figure 3. The curved lines represent laminar flow and the curled arrows represent turbulent flow. After some distance away from the base of the drop-off the flow calms down again and goes back to laminar flow.

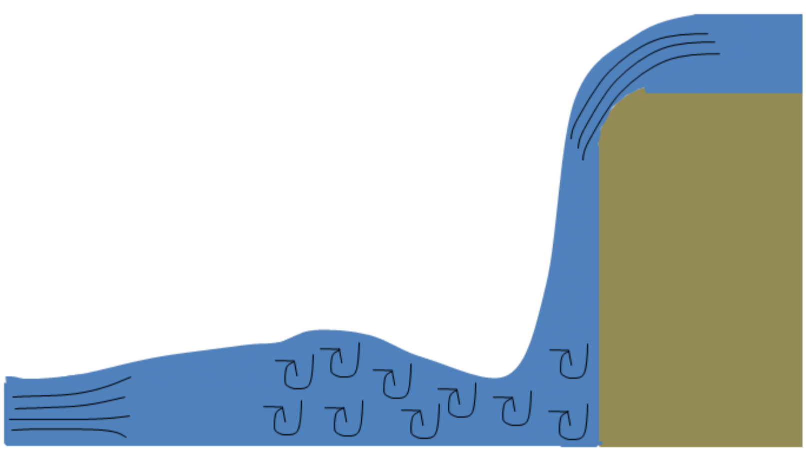

Figure 3: Curved lines represent laminar flow, curved arrows represent turbulent flow

Visualization Techniques:

As you can see in Figure 4, some green dye was used highlight the fluid flow and was intended to show the difference between laminar and turbulent flow in this setup. If you look closely, the green dye in the top right corner of the picture is stretched out along the top surface of the water, while the dye at the bottom of the drop is mixed up throughout the entire flow of water. Using a white background as a contrast helped to highlight the dye and the air bubbles formed within the turbulent flow at the bottom of the drop. Two 500 watts lights were used to illuminate the area of interest. In addition to these lights, since this image was taken indoors, there was overhead fluorescent lighting approximately four feet above the flume.

Photographic Techniques:

This picture was taken with a Cannon Power Shot SX20 IS digital camera. The original image was 3840 pixels wide and 2160 pixels tall, and the processed image ended up being 2823 pixels wide and 2109 pixels tall. The F-stop was 3.5, the shutter speed was 1/100 of a second, and the ISO was 400. The field of view was about 9 inches wide and 5 inches tall. For post processing I used Adobe Photoshop. I used the clone tool to remove some of the water drops on the side of the acrylic as well as remove some reflection of myself that occurred in the lower left corner. The cropping tool was used to focus in on the portion of interest, and then using curves, the overall colors and contrasts were adjusted to arrive at the final image.

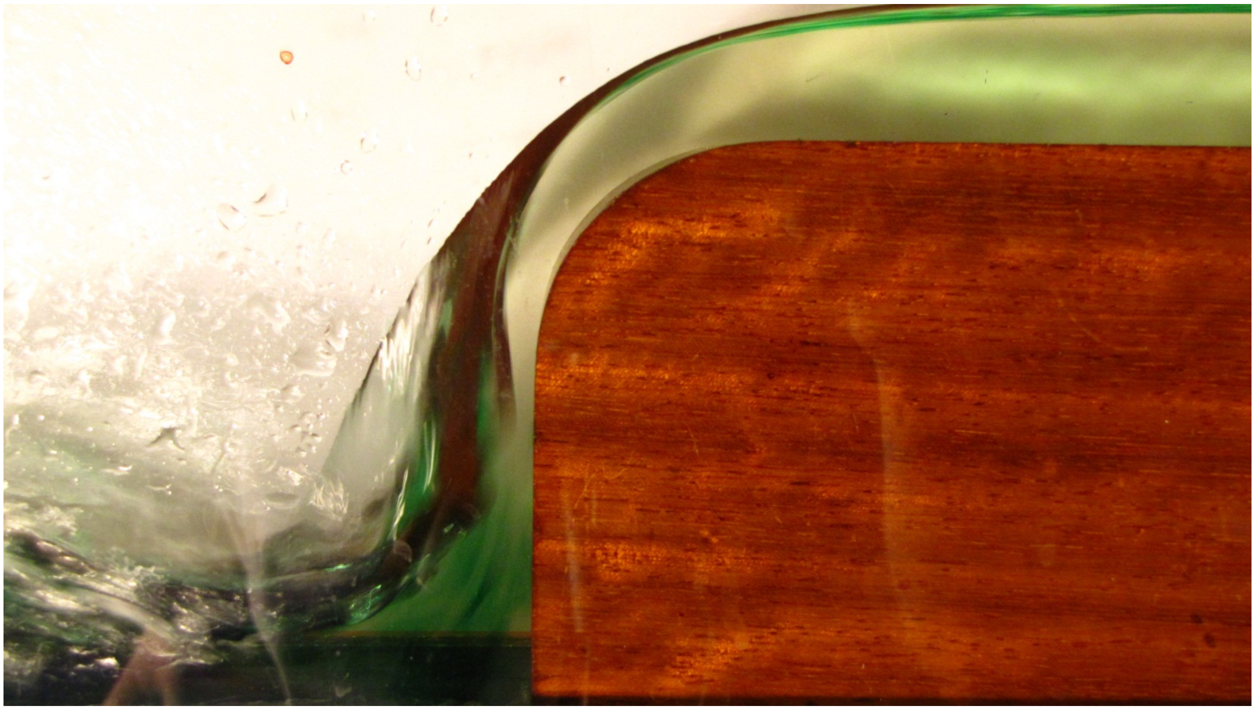

Figure 4: Original image

Conclusion:

In the end I'm actually quite happy with the final image. One can clearly see the difference between laminar and turbulent flow. The final colors have a psychedelic feel and therefore make the image interesting to look at even if you don't know what this is supposed to reassemble. One thing I hadn't thought about before taking this picture were the underlying physics behind this fluid flow. If I were to display the difference between laminar and turbulent flow again, I would try to set up a more classic experiment with a vertical flat submerged plate, where the visualization could be used in a classroom setting.

References:

[1] De Witt, D. P. (1990). *Fundamentals of Heat and Mass Transfer*. New York: Wiley.