The Mesmerizing Laminar Flow

Leo Steinbarth
MCEN 4151 - 001
Get Wet Report
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Introduction:

In the video I captured for this Get Wet project, I demonstrated the fluid phenomenon of laminar flow using a simple apparatus consisting of a water-filled balloon, electrical tape, and an X-Acto knife. When a small incision is made on the balloon's surface, I revealed the laminar flow, characterized by its parallel and unison fluid motion, creating a still-like illusion. This experiment beautifully illustrates fluid mechanics principles, including the Reynolds Number. This visually stunning display serves as a fluid phenomenon and an educational tool, providing insight into the fundamentals of fluid mechanics. I would like to express gratitude to my assistant Paige Herbert, whose contributions were crucial to the success of this experiment.

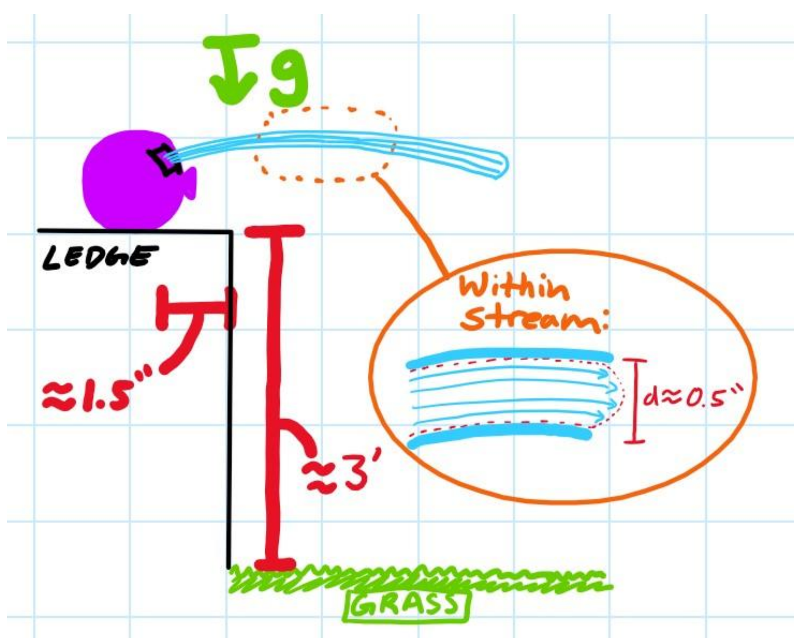

Figure 1: *Schematic of the experiment setup showing the laminar flow*

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The Fluid Mechanics Behind the Flow:

Using the items mentioned above, Figure 1 shows a general schematic of the experiment setup. The volume of the balloon decreased with time from the atmospheric pressure pushing out the stream of water through the incision thus affecting the still-like phenomenon towards the end of the experiment. The size of the incision determined the flow's boundaries. Below is the rough calculation of the Reynolds number in the stream.

$$Re = \frac{\rho \times u \times D}{\mu} = \frac{(0.001002 \frac{kg}{m \times s})(1.5 \frac{m}{s})(0.0127m)}{(1.002 \times 10^{-6} \frac{m^2}{s})} = 19.05 << 2000$$

The stream in my experiment had a diameter of about half an inch (0.0127 m). The stream traveled about 2.5 feet (≈0.75 meters) within 0.5 seconds of the incision which makes the velocity at 1.5 m/s. The density of water is 0.001002 $\frac{kg}{m \times s}$ [1]. For a flow to be laminar, the Reynolds number needs to be under 2000. With the Reynolds number being approximately 19.05, this theoretical calculation proves that the flow was indeed laminar.

Referring to Figure 1, the blue arrows within the stream indicate the directional flow of the stream. Notice that the arrows seem to be in unison creating a semi-circle-like shape at the tip. This defines the boundary of this flow. Each blue arrow represents a "layer" of the stream as well as the path that individual fluid molecules follow. In the context of laminar flow, the layers of fluid move parallel to each other with no mixing nor turbulence thus, creating a nicely smooth flow [2]. It should be noted that towards the end of the experiment when the volume of the balloon decreases, the layers within the stream start mixing and transition into turbulent flow. This is because the transition from laminar to turbulent flow occurs as the balloon deflates. This increases the fluid velocity and Reynolds number. The transition causes the fluid flow to be chaotic and not smooth.

Setup & Procedure:

The experiment materials included a handful of balloons, electric tape, a spoon rest, and an X-acto knife. I first filled the balloon with cold tap water to a comfortable handheld size. I then made a hashtag shape with the electrical tape to ensure the incision was not going to expand. I placed the spoon rest on a ledge and then placed the balloon in the spoon rest to ensure the balloon stayed in its place. The ledge gave me the space to capture the flow in mid-air. Lastly, I took the X-acto and made a small slit in the middle of the hashtag shape to create the channel for the flow.

Figure 2*: Experimental setup*

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Capturing the laminar flow was not a difficult process either. The digital camera used in this project was a Canon EOS Rebel T6 with EF-S 18-55mm f/3.5-5.6 i.s. II Lens. I used a tripod setup to keep my shot steadily focused on the slit to capture the still-like flow. I recommend setting this experiment outdoors to get natural lighting as I did to capture the nice reflective effect the sunlight provided.

Photographic Technique:

My photographic technique was to simply catch the still-like flow as steadily as possible. Using the tripod setup, I was able to capture a frame size of 1920x1088 pixels with a frame rate of 29.97 frames per second. The balloon was approximately 2 feet (0.6096 m) away from the lens as shown in Figure 2. When compiling my video, I used Microsoft Clipchamp to edit the video to showcase the laminar flow in real-time and at 0.5 playback speed (which also allowed me to screenshot Figure 3).

Figure 3*: Screenshot of the exact moment my finger disturbed the laminar flow*

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Conclusion:

In summary, the goal of my project was to capture the still-like fluid phenomenon of laminar flow. I took a well-filmed video using a simple setup consisting of a water-filled balloon, electrical tape, spoon rest, and an X-acto knife to showcase the laminar flow. The best part of this experiment is that doing many iterations of this experiment was pleasant because the phenomenon never got old. Something I should improve on if I were to carry out this experiment again would be to not wave my hand around over-excessively as I did in the video since it was distracting. In addition, I should have matched the balloon and electrical tape color to make the contrast between the two distracting. If I had the resources, I would like to capture this phenomenon in ultra-slow motion.

References:

[1]"Kinematic Viscosity." *www.ksb.com*, www.ksb.com/en-global/centrifugal-pump-lexicon/article/kinematic-viscosity-1117008#:~:text=The%20SI%20unit%20is%20m. Accessed 25 Sept. 2023.

[2] Britannica, The Editors of Encyclopaedia. "laminar flow". Encyclopedia Britannica, 4 Sep. 2023, https://www.britannica.com/science/laminar-flow. Accessed 25 September 2023.