

Team First 2026

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1 Introduction

This image serves as my entry for Team First 2026. Our team wanted to image laminar flow and found that using a balloon with some duct tape is able to guarantee that flow. While there aren't any physical visualizers in the flow, the way the water contorts the light to reflect the ground provides some interesting context into what is going on.

2 Flow Set Up

Setting up our flow involved a latex balloon, some duct tape, scissors, and a lot of water. We began by filling up the balloon with water, and then sectioning off a triangle of the balloon with duct tape. Figure 1 below roughly depicts this set up.

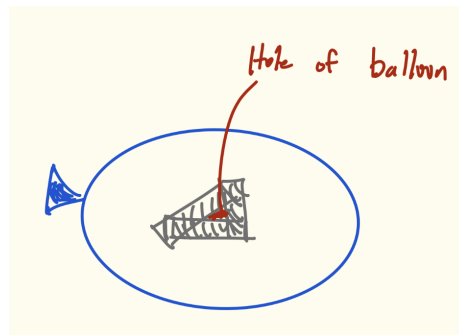


Figure 1: Sketch of setup

Typically, a balloon would burst when popped. All of tension of the elastic latex needs somewhere to go; however, when you secure that tension with duct tape, when you pop the balloon, the latex contracts into the tape, but not beyond that. This then creates an opening that does not change.

3 Fluid Behavior

The first key aspect to address about this flow is that it is laminar. Laminar flow occurs when, "parallel portions of the fluid (laminae) move steadily past each other" [1]. Since the flow is full of these parallel layers, it can cause the fluid to look still as there is no variation in the flow over time.

One other aspect that helps is the pressure being fairly steady throughout. If the pressure of the water were changing over the course of the experiment, it

could increase the chance of inducing a turbulent flow.

Further, laminar flows implies that the Reynolds Number, Re , is less than 50,000 for flow over a flat plate or in an open stream. The Reynolds Number equation states that

$$Re = \frac{\rho v L}{\mu}$$

for a flow in open air. Within this, we have ρ , the fluid density, v , the fluid velocity, L , the characteristic length of the fluid, and μ , the dynamic viscosity of the liquid.

Since we are using water in this experiment we know that $\rho = 1000 \frac{\text{kg}}{\text{m}^3}$ and $\mu = 1.02 * 10^{-3} \frac{\text{m}^2}{\text{s}}$. To estimate the velocity, we will begin by estimating the distance the water traveled. Using the original image, Figure 2, we see the water is very nearly in plane with the width of the bowl. Knowing the bowl width is



Figure 2: Original image

2134 pixels. The length of the water is 2236 pixels by the time it gets cropped out of the final image. Knowing that the length of the bowl is 7.5 inches, it can be calculated that the water travels

$$\frac{2236}{2134} * 7.5 = 7.85 \text{ inches}$$

Converted, this is 0.199m.

If we employ the equation

$$v^2 = v_i^2 + 2\alpha\Delta x$$

we can find the velocity. If we velocities solely in the direction of the y-axis, we can say that, when the flow begins to turn down which is when the final image is cropped, $v = 0$, $\alpha = 9.81$, and $\Delta x = 7.85$. Combining this we get that

$$v_i = 1.98 \frac{\text{m}}{\text{s}}$$

For the characteristic length, we will use the diameter of the water, D , which is roughly 0.002m. Such we find that

$$Re = 3900$$

This falls below the critical threshold of 50,000 indicating the flow is indeed laminar.

Another facet to explore is how the light bends. You may notice in the image that the images within the fluid not only are flipped, but seem to warp and curve. This is due to the way the light interacts with a laminar flow, and how the flow develops due to its exit profile. To begin, the light refracts through the water due to the angle of the stream, "The critical angle of 49° is such that total internal reflection will occur in the stream even when it is reduced to almost a trickle. Imperfections in the stream (and scattering agents added) allow some of the light to escape" [2]. This information is provided from a similar experiment setup by Harvard. As such, the stream of water creates what is essentially a lens. Since there are no imperfections in the lens, we get a very clear image. Further, because the stream bends, we see the image follow that axis along the length of the water. As such, we end up with what was an upright level background becoming a curved upside down image.

However, this doesn't explain the parts of the flow that seems to move backwards. Notice how the image occasionally seems to fold over itself. This is due to capillary oscillations and axis switching. A broad example of capillary oscillations can be described as, "The initial disturbance is provided by fluctuations in the jet radius at the orifice caused by natural effects, such as radial variation of flow, eddies, turbulence, vibration, etc" [3]. Since no flow is free of disturbances, there will be some introduction of minor eddies or vibrations into the flow. In our case, part of this is likely self induced from the balloon as it slowly deflates and any minor changes in air currents. These added changes can cause the flow, which is still laminar, to have minor variations embedded within it causing changes in how it interacts with the light.

The other method, axis-switching, is the primary reason. As a flow develops, depending on the shape of the orifice it left from, the central the flow develops can twist, causing the flow to twist as well. Our "nozzle" the water left was triangular which led to a change in shape, "observed that the different spreading rates in the sides and corners of a triangular jet induced inversion of the jet shape" [4]. This explains why the images in the water seem to twist and double back. It is attributed to the actual laminar layers of water twisting due to the angle it left causing axis-switching.

4 Visualization Technique

Due to the flow appearing as a solid, we opted to not add any visual markers that could potentially make the illusion disappear. Instead, we took the image in a brightly lit area which allowed for the light itself to serve as our visualization technique. As mentioned earlier, laminar flow acts like a lens which causes images in the background to flip within the flow. As such, have a flipped version of the sky and ground in the flow served as our method of visualizing the stream.

5 Photographic Technique

This image was taken roughly three feet away. The field of view can be derived using the following equation.

$$FOV = 2 \arctan\left(\frac{d}{2f}\right)$$

d is the dimensions of the sensor, either length or height, and f is the focal length. The camera used was a Canon EOS 80D which has a sensor size of 22.3mm by 14.9mm. We will use the length, 22.3mm, to be d . The focal length, f , is 50mm. Combining this we find

$$FOV = 25.14^\circ$$

The lens used as a 18mm x 55mm variable lens. The image exported at dimensions of 6000 pixels by 4000 pixels. A very short shutter speed was used, at 1/1000 seconds. The f number also sat at $f/10$. This implies that the aperture was at 5mm.

As for the post processing, the only things I added were some cropping and increased contrast. Below, Figure 3 displays a side by side of the original image and the edited image.

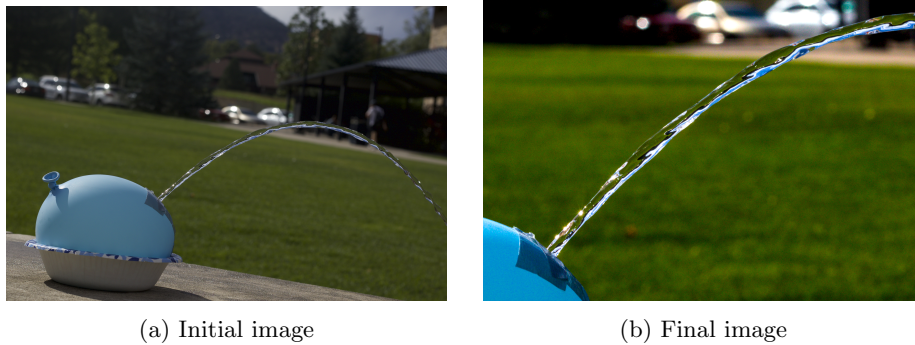


Figure 3: Initial and final image of flow

6 Image Assessment

This image reveals the nature of laminar flow, showing it as a glassy solid fixture rather than a flowing stream of water. I like that because of the complex nature of the background, you can see how well the flow captures and flips those images. I also like the inclusion of the balloon as it adds context and grounds the flow. If I were to repeat this, I would have aimed to use a background that was all in the same plane. While the complexity of the background shows up in the flow, it's still fairly distracting. Having a background that isn't as bright and distracting would fix that issue.

Overall, the intent to setup an experiment to capture laminar flow was fulfilled. Going further, I would like to experiment with adding visual markers such as glitter. I feel it could capture the light in an interesting way and depending on shutter speed, still keep that feel of a solid object. I would also like to experiment with shape of nozzle. As the most interesting aspect of this image was the distortion of the background, experimenting with different nozzle shapes could lead to different ways the image is contorted.

References

- [1] Anthony Peter Farrell et al. *Encyclopedia of Fish Physiology : From Genome to Environment*. London ; Waltham, Ma: Academic Press, An Imprint Of Elsevier, 2011. ISBN: 9780123745453.
- [2] *Bucket of Light*. Accessed 2026-10-02. sciencedemonstrations.fas.harvard.edu. URL: <https://sciencedemonstrations.fas.harvard.edu/presentations/bucket-light>.
- [3] Grover C. Wetsel. “Capillary Oscillations on Liquid Jets”. In: *Journal of Applied Physics* 51.7 (July 1980), pp. 3586–3592. DOI: 10.1063/1.328210.
- [4] Kim Won Hyun and Park Tae Seon. “Inflow Characteristics for Generating Axis-Switching Phenomenon of Heated Rectangular Jets”. In: *Computers & Mathematics with Applications* 86 (Mar. 2021). Accessed 2026-10-02, pp. 73–89. DOI: 10.1016/j.camwa.2021.02.001. URL: <https://www.sciencedirect.com/science/article/pii/S0898122121000377>.