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Image-Video Report 1
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Image-Video 1 Report: Leaf under Laminar Flow

This image is taken of a leaf under a source of laminar flow. The laminar flow is from a kitchen sink, and the leaf is stuck to a mirror. The pressure of the flow keeps the leaf adhered to the mirror, while also creating the interesting flow patterns that the image captured. The leaf is thought to be from a Norway Maple, and was observed to be quite stiff, and somewhat water resistant.

When the water hits the leaf, it is spread per the geometry of the surface, flattening into a sheet that is broken in symmetric locations by the leaf's sharp edges. I wanted to capture this phenomena in my image, and show the interesting wrinkles and ripples that were created in the sheet. Different sources of light play off the spray, displaying the contours of the water as it fluctuates from laminar to turbulent. The surface tension of the water is also visible in its rounded shape as it flows.

The apparatus that were used in this image were a hinged mirror, a kitchen faucet, and a leaf. The mirror was placed at an angle such that the flow from the kitchen faucet would spread over the leaf. The mirror also had its own base, so it was able to stand on its own. Refer to Figure 1 for a visual representation.

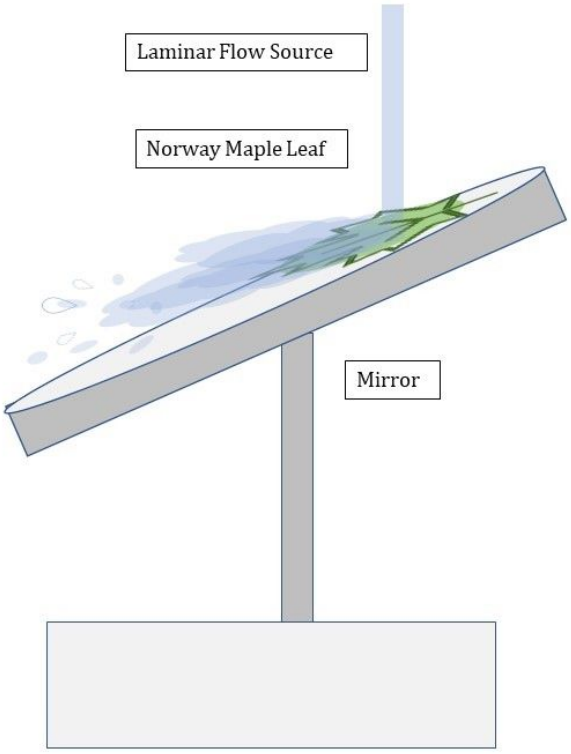

Figure 1: A sketch of the image set up, including the laminar source, leaf, and mirror

Some of the flow phenomena that can characterize this image are the behaviors of an impinging liquid jet on a plane, diverging flow, and free surface flow down an inclined plane. Primarily, the flow represents a liquid jet impinging on the plane. In this case, a laminar jet falls vertically onto the representation of a horizontal plane (inclined, in this case), and “spreads out radially in a thin layer” (Watson). If the water were allowed to continue on the horizontal plane, it would also display a ring where the depth increases, but this does not occur due to the non-flat plane. In this case, the plane is the surface of the leaf, which was approximately 2-3 inches across. This impinging caused a sheet of water to form, that spread smoothly off the surface. The leaf was not a perfectly flat plane, and the edges and veins caused the sheet to begin to break and create wrinkles and ripples in the laminar flow. However, as visible particularly in the far point of the leaf on the middle-left of the image, the water tension created by hydrogen bonds from the large dipole of the water molecules holds the water together. This is a form of intermolecular bonding, from both covalent and electrostatic forces (Lower). Since the water is laminar, or very nearly laminar throughout the image, the Reynolds number is far less than 2100 for almost all the water. At the very edges of the image, the water begins to transition, and at the very fringes displays turbulent flow. In this case, the Reynolds number is greater than 2100, and greater than 4000 as it becomes turbulent (Smith).

The Reynolds number is particularly small coming directly from the faucet. In this case, based on the geometry of the source, this can be estimated with pipe flow at the moment it is released from the source.

Reynold’s number for pipe flow, for the laminar flow coming out of the sink faucet:

$$Re = \frac{\rho V d}{\mu}$$

Where rho is the density of the fluid (997 kg/m³ for water), V the velocity (approximately 9 x 10-4 m³/s), d the diameter of the pipe (approximately 0.0127 m in this case), and mu the dynamic viscosity (8.90 × 10−4 Pa·s)

$$Re = \frac{997 * 9 * 10^{-4} * 0.0127}{8.9 * 10^{-4}}$$

$$Re = 12.8$$

This approximation clearly displays that water directly out of the faucet is extremely laminar. The water maintained this laminar property throughout its impingement on the leaf. As it impinges, the water’s radial diverging flow is very clear. The inclined plane was created by the adjustable mirror.

The visualization technique I used to capture this photo were water, and numerous light sources to produce the reflections that highlighted the geometry of the flow. I used light from three different sources. Five recessed can lights in the kitchen ceiling created a source of diluted, warm light. Two overhead spotlights created focused warm light. Finally, a hand-held LED flashlight created very focused white light. These lights also reflected off the mirror to

create a slight backlight. The photo was captured at a side angle that would avoid any sharp reflections, while still displaying the flow pattern.

This image was captured on a Canon Rebel XT. The aperture used was f/5.6 for a moderate level of light let in, and a slightly shallower depth of field for some foreground and background blur. The shutter speed was set to 1/60 for a relatively quick exposure. This was used to capture a moment in the quick flow, and keep the picture blur-free where it was desired. The ISO was a moderate 400, so that the photo was bright enough, but was also not grainy. The photograph was captured less than a foot from the flow, with a focal length of 51mm in order to zoom very close to the details. This means that the field of view is less than a half foot. The image was taken at 3456x2304 pixels, and was not cropped. The only edits made to the photo were to adjust the color to be slightly warmer, and intensify the highlights and lowlights to best display the geometry of the flow, and the details of the leaf.

Original

Edit

To me, this image reveals some beautiful aspects of laminar water flow in an unexpected environment. The image seems like it would be a still from a rapidly changing, turbulent flow. However, in reality, the shape of the flow was quite static. I like the ripples and wrinkles that are visible coming off the edges of the leaf, and at the bottom of the image. I also like the warmth of the reflecting lights that contrast with the bright green of the leaf. I think the orange in the photo resembles flames, so I think it looks quite poetic with the natural leaf. Something I think could be changed with the photo is the blur in the foreground and the background. While it draws attention to the center of the photo, I also think the image would have looked interesting without the blur, since it might have resembled a snapshot in time. One thing I definitely think could be improved in the photo is the dark line at the top of the image. I think it is distracting, and I would have preferred a smooth background. I like the fluid physics that are shown, because I think this phenomenon is particularly beautiful. I definitely fulfilled my intent when taking this photo. I am very much an amateur photographer, so I was pleasantly surprised with the final result. I think this fluid phenomenon could be further explored with laminar flow impinging on flatter planes. I liked the wrinkles that came off the edges of the leaf, but I also love the super smooth sheets that come off of spoons or knives under laminar flow in the sink.

References

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Watson, E. (1964). The radial spread of a liquid jet over a horizontal plane. Journal of Fluid Mechanics, 20(3), 481-499. doi:10.1017/S0022112064001367