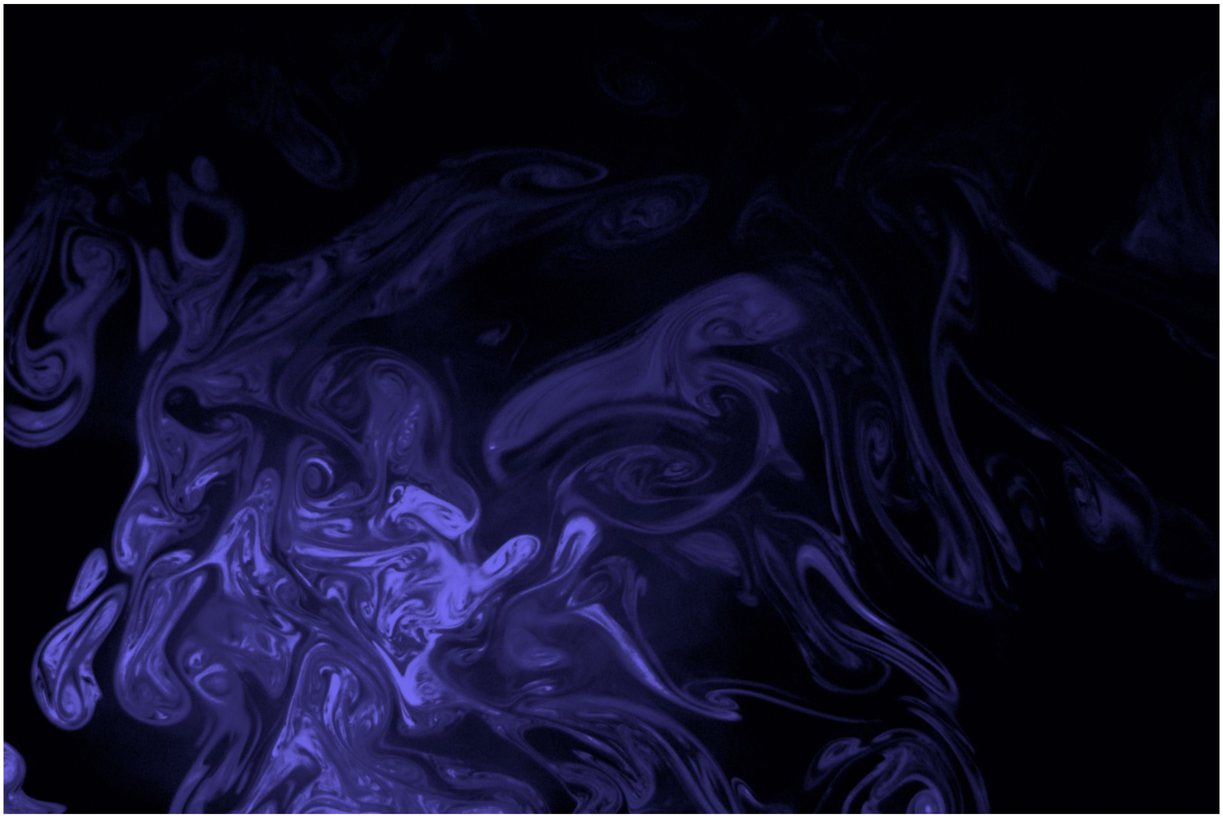
IV 2 Report: Alessandro Villain

9/26/2022 Section 1



Fog machines are a popular method of visualizing flow due to their ease of use and commercial availability. However, in order to analyze flow caused by a fog machine, we must understand how one operates.

The fog machine we were using works by using glycerol as the vaporizing fluid. It begins by heating the fluid in a chamber and letting the pressure build. Once a requisite pressure is stored the machine informs the user it is ready to be used. When the user is ready, they push a button which opens a valve, allowing the vaporized glycerol to exit via a small opening. The rapid change in pressure causes the glycerol to condense while aerosolizing, creating the microdroplets. However, the expanding gas dumps a lot of heat into the surrounding air, causing the ambient air, as well as the glycerol, to convect freely and diffuse.

The flow coming out of the nozzle shows free convection, and is a transitional flow. We can assume the glycerol has the same properties as the surrounding air, and will use this in our later calculations. The Rayleigh number to calculate the laminar turbulent transition is defined by:

$$Ra_{x,c} = \frac{g\beta(T_s - T)x^3}{v\alpha}$$

The Rayleigh number can also be made as the product of the Grashof and the Prandtl numbers:

$$Ra_{x,c} = Gr_{xc}Pr$$

Because the boltzmann constant for air is 1, we can assume this is true for the glycerol:

$$\beta = \frac{1}{k_b T_f} = \frac{1}{1 \cdot 3000} = 3.34 \cdot 10^{-3} K^{-3}$$

Looking at tables of correlations, we find that T_s = 310k, T = 293K, g=9.81, x=2, v = 2, and alpha = 22.6*10^-6. Most of these values were estimated, however, they give a good idea of the regime of the rayleigh number. Plugging this in yields:

$$Ra_{x,c} = \frac{(9.81)(3.34 \cdot 10^{-3})(310 - 293)(2^2)}{(2)(22.6 \cdot 1^{-6})} \approx 101274$$

The rayleigh number describes where convective flow transitions from laminar to turbulent. This happens at Ra = 10^9, which tells us that the flow is transitional.

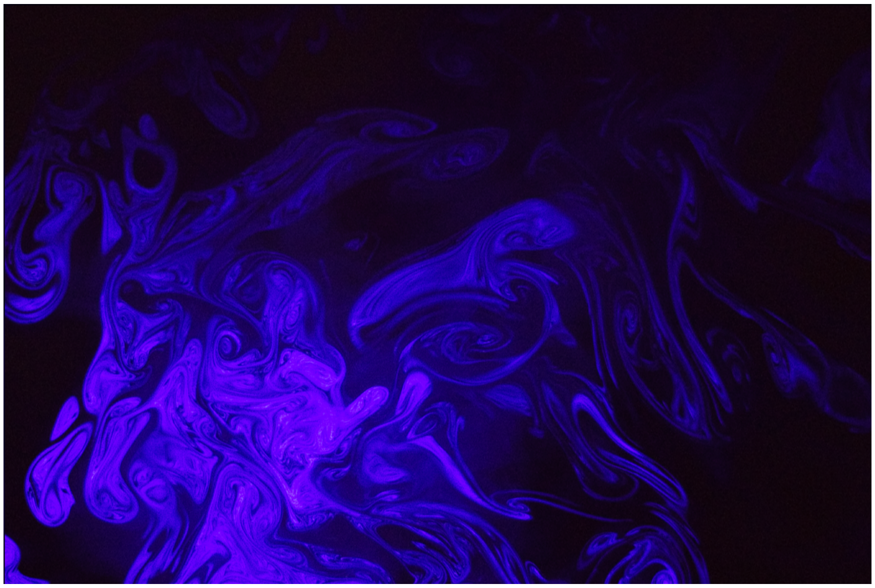
The main visualization technique to show the flow was shining a planar laser of 475 nanometers into the path of the glycerol. This particularly excited the blue receptors on the camera which allowed for an easy de-noising process. Because we knew all our light was in a single spectrum, we killed all the information from the red and green channel, giving a very clear image of the flow. This was not intentional, but was a welcomed surprise.

The specs for the photo are as follows:

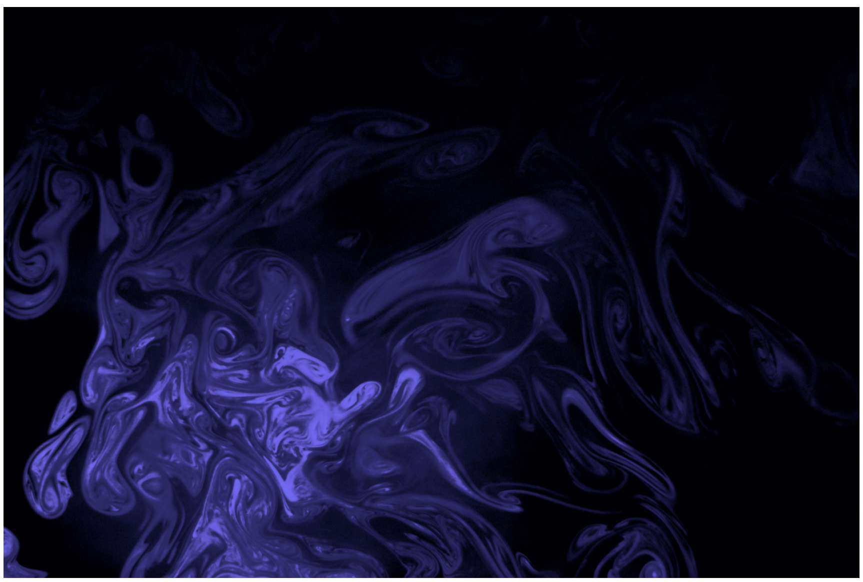
Camera	Canon EOS 250D
Lens	Canon EF 50mm 1.4 Ultrasonic
Aperture	f/1.4
ISO	6400
Shutter Speed	1/2000

The photo was taken about 2.6 meters away from the subject. The 50 mm lens was used due to it being the only one available with an appropriately low aperture. Due to the low light conditions, and the quickly moving flow, this was the only way to capture a still frame. However, using a low f-stop meant that the depth of field was very shallow. This proved to be a problem with many of the other shots. It took a while to hone in the settings since it was unclear whether a photo was blurry due to it being out of focus or due to the shutter speed. Additionally, the planar laser was parallel to the focal plane, causing only portions of the photo to be in focus.

I like the detail of the photo and how the swirls of the fluid are very visible. This is what I think about when I think of flows, and this image does a great job of capturing that. However, the photo isn’t perfect. The photo is a little blurry and grainy, due to the focus and shutter speed. The easiest way to improve this is to raise the f-stop and align the camera to the laser plane. Regardless, I really enjoyed this photo.



Original photo (4000x6000)



Edited Photo (4000x6000)

References:
The smoke machine: https://lelit.com/

Equations for the minimal surface area were taken from the University of Chicago:
https://math.uchicago.edu/~may/REU2019/REUPapers/Zheng,SiqiClover.pdf

Information on Plateau-Rayleigh instability was found at:
https://ui.adsabs.harvard.edu/abs/1995PhFl....7.1529P/abstract
https://arxiv.org/abs/chao-dyn/9612025

Supplemented by wikipedia:
https://en.wikipedia.org/wiki/Plateau%E2%80%93Rayleigh_instability#cite_note-Papageorgiou1995-1