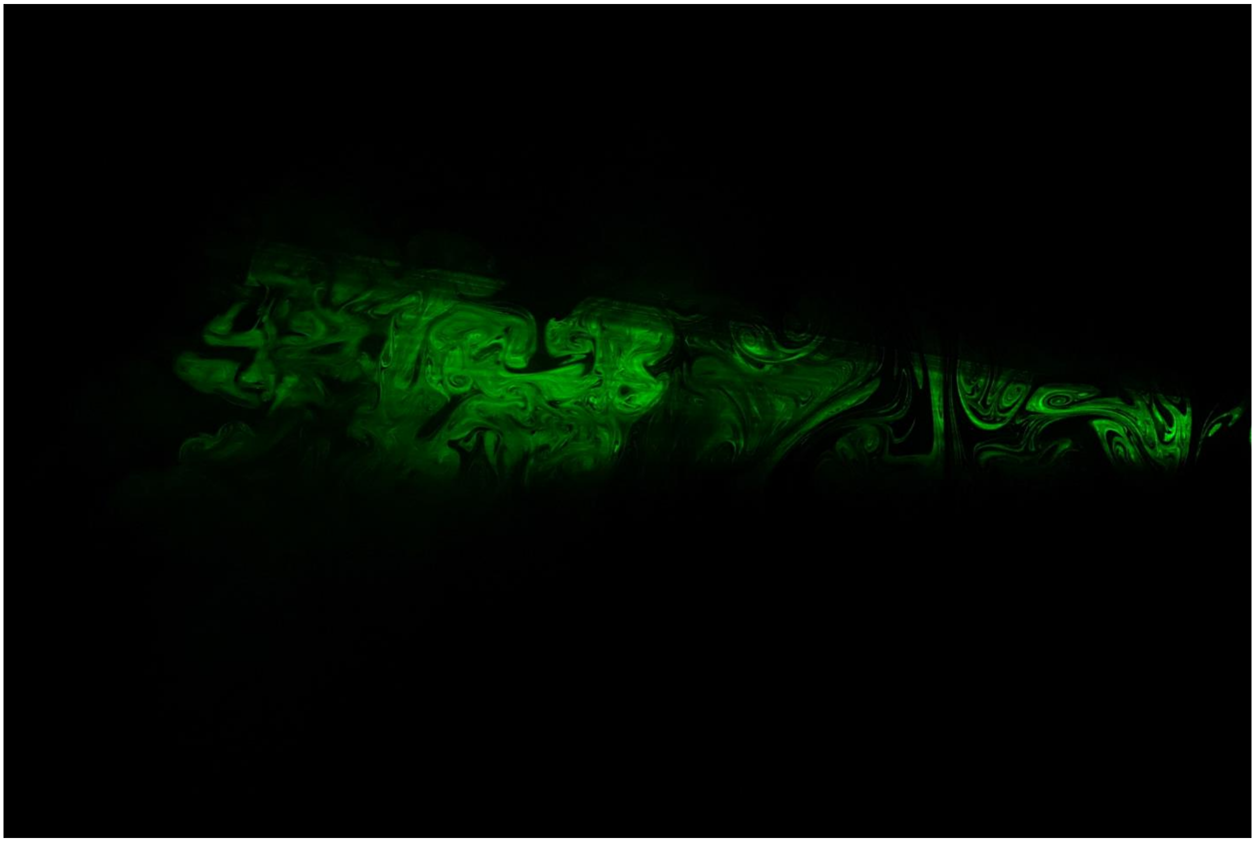

Team Third Project

MCEN-5151 Flow-Visualization 2024

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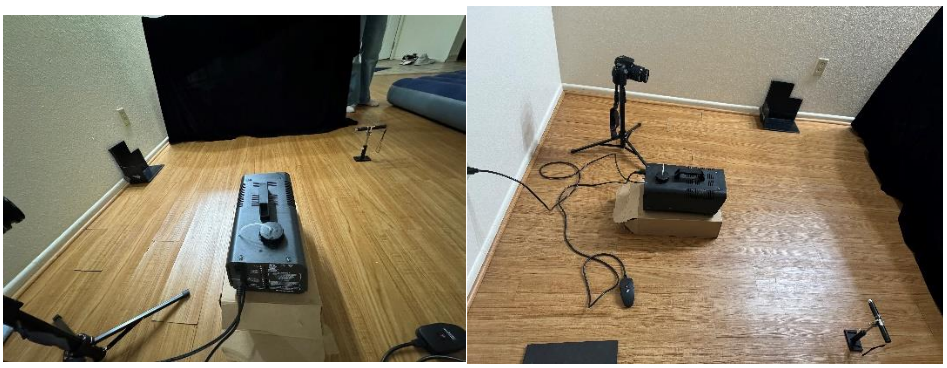
Team Members: Adiba, Alex, Jesssica

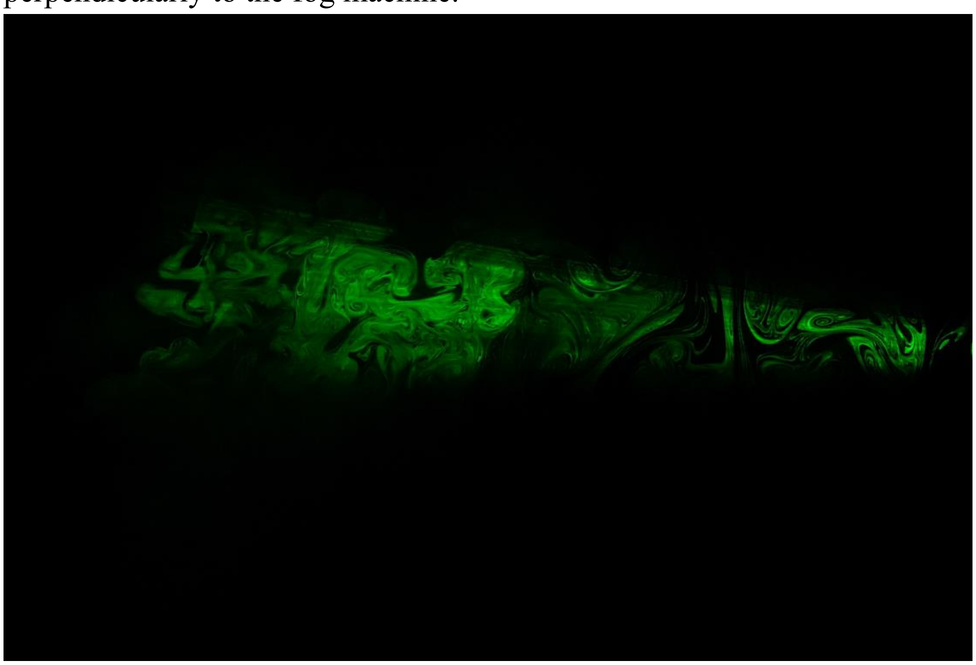
1. **Context and Purpose**: The purpose of my team third project was to visualize what kind of flow pattern changes occur when a green laser beam is hit perpendicularly to the fog droplets. The flow phenomenon I was trying to observe was vortex formation, swirling patterns, and nature of the flow, if it's laminar or turbulent or a transition between laminar and turbulent. I did this experiment with my team members, they helped me in setting up the laser, fog machine and light absorbing cloth to run the experiment. They helped me to precisely align the laser beam perpendicularly to the fog droplets and gave me ideas on positioning the light absorbing velvet cloth to correctly minimize laser reflections.

2. **Flow Physics**: To construct our flow apparatus, we used a green laser pointer, a fog machine and a light absorbing black velvet cloth. The laser pointer, placed in a clamp was positioned perpendicularly to the fog particles generated from the fog machine, so that the laser beam can interact with a large cross-section or volume of fog particles. The flow apparatus for this experiment has been shown in figure (1). As for the flow, we could see some swirling patterns and vortices when the laser and the fog machine was turned on. The laser beam's intensity could induce local heating of fog particles. The heated fog becomes less dense and rises, generating buoyant convection current. Rising warm fog particles creates swirling pattern or vortices as cooler air rushes in to fill the void. So, the heat gradient results in the formation of vortices [1],[2]. Turbulent flow occurs when the layers of fluid mix vigorously to create eddies and turbulence to form spinning fluid elements and in laminar flow there is no mixing of fluid layers. I think there is a little bit of mixing between fluid layers in this experiment that caused the formation of small vortices and flow instabilities to grow. Since the vortices are small scaled in our experiment, I think there is a flow transition from laminar to turbulent due to local heating effect [3].
3. **Visualization Technique**: We visualized our flow using a green laser pointer, fog machine and a black velvet cloth. The velvet cloth was for minimizing reflections and glare from the laser by absorbing light. It also acted as a dark background to enhance the visibility of the green laser beam for imaging. I think the type of green laser pointer we have used for our experiment is a diode pumped solid state laser, which uses non-linear crystals to double the frequency of IR light in order to produce green light at 532 nm. To reduce the accidental

exposure of scattered light and to focus the laser beam better, we have introduced a small glass part inside the opening of the laser. The fog machine we have used in our experiment generated fog particles by vaporizing water. We wore safety googles to minimize our exposure to laser beam in order to protect our eyes. We captured our images in a completely dark room. This experiment was conducted in a room with low public access so that people don’t get accidental exposure to laser. We used a water-based fog machine because it’s environmentally friendly.



Figure(1): Setup of the experimental flow apparatus, where the laser is placed perpendicularly to the fog machine.



Figure(2): Edited Image

Figure(3): Original Image

4. **Image Acquisition Details**: Sony alpha 7 was used to capture this image. This digital camera has a focal length of 28-70 mm, ISO range from 100 to 51200, and a 24.2MP full-frame Exmor R CMOS sensor. The picture was taken with an ISO of 4000, 48 mm focus, aperture of f2.8 and a shutter speed of 1/640. The original image had 1616*1080 pixels and the edited image also has 1616*1080 pixels. As for editing, I enhanced the brightness, increased the exposure and reduced the contrast a little bit to pop up the green vortices in the black background. Since I captured the image in a completely dark room, it was getting difficult to focus the images which is why I increased the ISO. Increasing the ISO makes the camera sensor more sensitive to light, allowing it to capture more light in dark environments. And, Iphone 15 pro was used to record the video which has a lens has a focal length of 13 mm, aperture of f/2.2 with a field of view of 120 degrees. My video has 1920*1080 pixels. I increased the brightness of my video and used clipchamp to reduce the speed of my video to observe intricate details of flow patterns, which might have been difficult to see if the video was too fast in real-time. The frame rate of my video is 30 frames per second.

5. **Conclusion**: The image reveals beautiful vortices and swirling flow patterns of fog in the presence of green laser lighting. I like the presence of asymmetric and symmetric vortices in my image and I also like contrast where the green vortices popped up nicely in the dark background. I think my image displays vortices flow behavior and transitional flow type physics pretty well and I think I have fulfilled my intent of visualizing flow vortices. However, I think that increasing the ISO of my camera even higher would have increased the quality of my photo. And I feel like there is a lot of black background in my image, cropping the image would have solved the problem. But I also wanted to keep the conical flow shape intact, which is why I did not crop my image. As for future direction, I could try using lasers of multiple colors to give more color dimensions and depth in my image.

6. References:

[1]. Shugaev, M.V. *et al.* (2020). Laser-Induced Thermal Processes: Heat Transfer, Generation of Stresses, Melting and Solidification, Vaporization, and Phase Explosion. In: Sugioka, K. (eds) Handbook of Laser Micro- and Nano-Engineering. Springer, Cham. https://doi.org/10.1007/978-3-319-69537-2_11-1
[2]. Raj Sha, M.M., Mathew, S., Udayan, S. *et al.* Ultra-pure silicon nanofluid by laser ablation: thermal diffusivity studies using thermal lens technique. *Appl. Phys. B* **124**, 213 (2018). https://doi.org/10.1007/s00340-018-7081-z
[3]. Types of Fluid Flows – Introduction to Aerospace Flight Vehicles