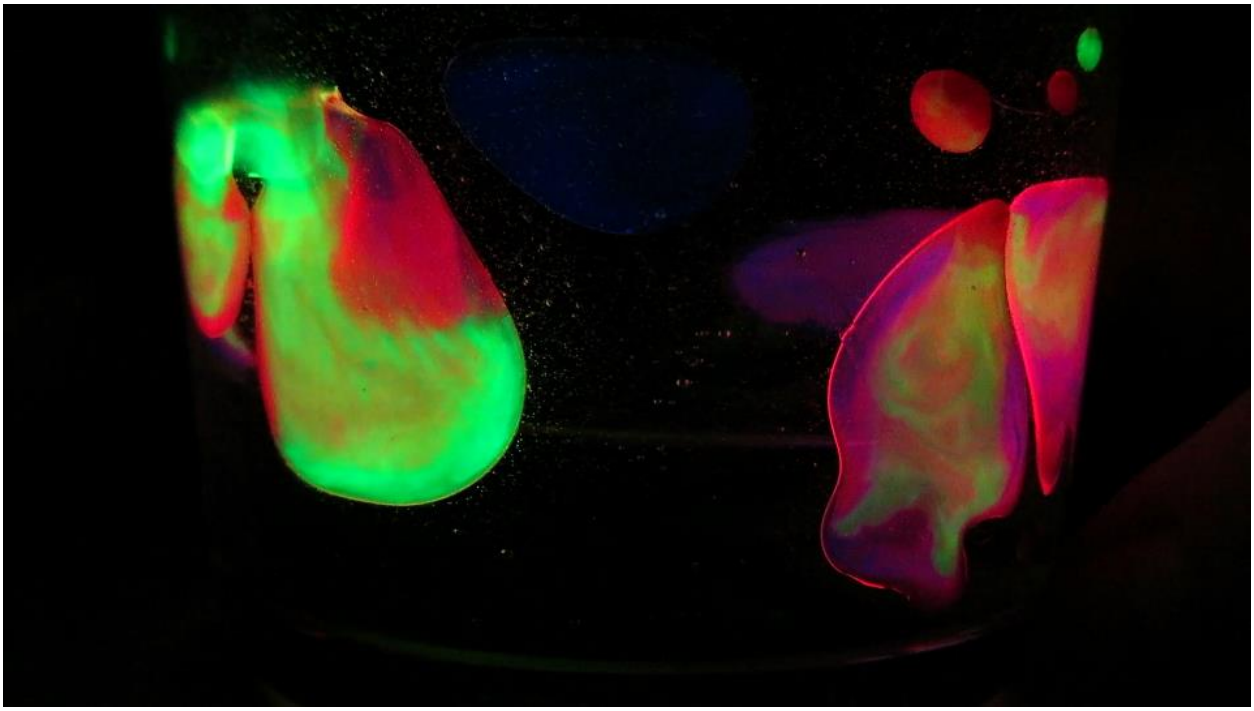
Team 1 – Glow Twists



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Team Eta

MCEN 4151

Professor Hertzberg

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Introduction

This image was taken for the “Team First” assignment of the 2018 spring semester course “flow visualization” at the University of Colorado at Boulder. The experiment aimed to demonstrate an effect that occurs when a fluid is suspended in a highly viscous fluid, and is then disturbed with laminar flow. When the suspended fluid is forcibly moved in one direction, the suspended fluid will move with the viscous fluid. If the flow is reversed, then the fluid will separate and return to its own original components. Prior to the recorded video, this was tested and executed in a prototype setup with food coloring and hand soap. The subject video however did not exhibit the same phenomenon. The only difference in setup was that in place of food coloring, liquid from a glow stick was used. While the intended effect was not able to be achieved, the final product still provided an excellent flow visualization.

Contributors

For this team we were assigned groups. I am on team eta. However, I did not work with my team on this assignment. However, I did receive contributions to this assignment through the aid of my roommates Aidan Duggan and Aidan Jared. Both lent me some material around the setting of the filming, and it allowed the video to be greatly improved.

Materials

The materials used in this visualization are mostly obtainable at any store local household items are sold except for the illuminating fluid from a glow stick. While most materials used in the experiment are harmless, the chemical from a glow stick can be toxic if ingested and can be harmful if put on skin. If replicating this exact experiment with a glow stick in place of food coloring, readers are advised to take ample precaution when working with the chemicals. The materials are as follows:

- Hand Soap
- 2 blue glow sticks
- 2 pink glow sticks
- 2 green glow sticks
- A separate bowl for each color of glow sticks
- Large tumbler or glass (3.3 inches in diameter, 4.3 inches in depth)
- Second glass smaller in diameter than the larger glass (must be taller than the larger glass.) (2.4 inches x 6.5 inches)
- 4 Paper Binding Clips
- Small eye dropper/pipet
- 2 Toothpicks
- Canon SC260 HS

Procedure

To construct the apparatus, the large tumbler was filled to about 1/5 of its capacity with hand soap. The four binding clips were then attached on each side of the tumbler glass. Two small toothpicks were placed at the bottom of the glass, and then the smaller glass is then pushed down into the hand soap and rests on top of the toothpicks. The toothpicks help to minimize the friction caused by the two glass surfaces interacting with one another in motion. The paper clips are then "opened" so that the center glass cannot move in an x or y direction. The glass can only rotate and be pulled out. This apparatus is pictured below:

Figure 1: The glass setup. The binding pins on the sides provide support to the glass so that the only degree of freedom is the degree to rotate in place. (The fourth binding pin is not pictured in this photo, but this clip should be added last so that the glow stick fluid may be injected into the sides.)

To inject the glow stick liquid, the glow sticks were broken apart and drained into a small bowl, and were mixed with a small amount of hand soap. The mixture was then picked up with the small pipet, and injected into the hand soap mixture which is now in between the two concentric glasses. After adding a few drops, a similar process was repeated with the two other glow stick colors, taking care to keep the colors separate. The colors did not remain separate however, and began to mix at this stage, so the experiment had to be quickly conducted. The setup itself was conducted in a dark room with no light, with a camera placed at level with the subject. This setup is illustrated in Figure 2.

To induce fluid movement, the smaller concentric glass was slowly rotated with the fluid counter-clockwise by hand, taking care to keep the glass centered in the larger glass. This rotation was conducted slowly, as moving too fast would disrupt the flow of the suspended fluid in the overall

hand soap pool. After around 30 seconds of rotating, the glass was then rotated by hand for another 30 seconds.

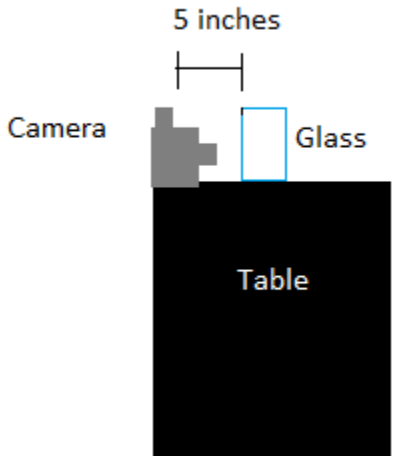

Figure 2: The setup of the camera and glass in the dark room. What is not pictured is that a person is in the room spinning the "internal" glass, but the positioning of the person is not important so long as they do not interfere in the shot.

Fluid Dynamics

While the fluids do not separate back into their components, the fluids remain separate rather than dispersing throughout and mixing with each other into one mixture. First, consider the glow stick. The glow sticks create light through the process of chemiluminescence, a process that occurs when a mixture of dye, diphenyl oxalate, and hydrogen peroxide, a chemical reaction takes place which creates the light. The exact mixture of chemicals and dyes depends on the color, but it is through this process the liquid is illuminated. It's worth discussing why the glow stick fluid did not exhibit the same suspension the water coloring did. There are no conclusive densities to be found on what the properties of hand soap are, but generally most places agree that it is slightly less dense than water. Since it is a highly viscous fluid, the food coloring does not sink in the hand soap. The chemicals in the glow stick however are marginally denser than the food coloring, and thus sink at a faster rate than the food coloring (which can be seen in the video during long pauses.) Since the fluid moves more in the viscous hand soap, the desired effect couldn't be achieved.

Next, let's evaluate the flow region of the overall fluid. The Reynolds number of a fluid is given by

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

Where ρ is the density, u is the velocity, L is the characteristic length, and μ is the dynamic viscosity of the fluid. The dynamic viscosity of hand soap is approximately 0.085 Pa-s [1], and the

density of hand soap is approximately 932 kg/m^3. L is the diameter of the inner glass, so this means that it is necessary to approximate the velocity. Since a full rotation took around 20 seconds, let's assume the cylinder rotated at 3 RPM. To calculate tangential velocity:

$$u = \omega r = (3\ RPM)\left(2\pi \frac{rad}{sec}\right)\left(\frac{1}{60}\frac{min}{sec}\right)(3.3\ in) = 1.04\ \frac{in}{sec} = 0.0264\ \frac{m}{sec}$$

Thus, the Reynolds number is

$$Re = \frac{(932\ \frac{kg}{m^3})(0.0264\ \frac{m}{s})(0.08382\ m)}{0.085\ Pa \cdot s} = 24.3$$

Note that the Reynolds number is extremely low in this case, which is ideal for this type of experiment. While wakes would begin to form in parts of the cylinder, the flow remains laminar, hence why the flow remains separate when the cylinder rotates and doesn't deform the injected glow stick fluid.

Video Technique

This video was captured at 24 fps with a canon SC260. The camera was initially placed approximately 5 inches from the subject, and gave a field of view of 3 inches x 4 inches when properly placed, as the camera did not capture the whole tumbler glass. The original video was a 57-second-long .mov video file which was captured at 1920 x 1080, with an ISO of 100 and f/4.0. To edit the video and create a final rendering, the software "Shotcut" was used, a free, open-source video editing program. Editing of the actual video was kept to a minimum, only two filters were applied. The first filter applied was a basic sharpening algorithm. The settings used are pictured below:

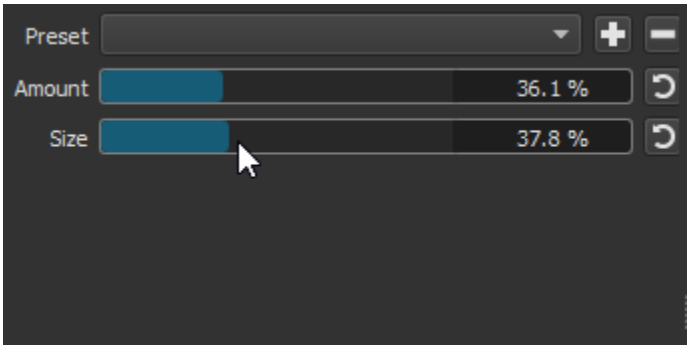

Figure 3: Shotcut sharpening settings

The next filter applied was a contrast filter. Increasing it over 50 would stretch the overall contrast, while decreasing it below 50 percent lowered overall contrast. The contrast was set in the following way:

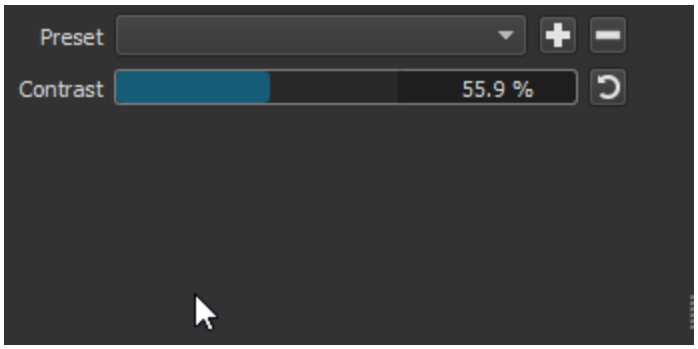

Figure 4: Shotcut contrast settings.

The final filter applied was a saturation filter, which aimed to increase the overall saturation of already saturated colors. The settings applied are pictured below:

Figure 5: Shotcut saturation settings.

The audio was muted, and a song was added titled “Observation”, a modern jazz arrangement by Lobo Loco. The track is licensed under a creative commons license, allowing the track to be used for noncommercial pieces. The track was found on the Free Music Archive. [4] This music was chosen to highlight the smooth, psychedelic nature of the flow being captured. The video was then rendered as a 1920 x 1200 .mp4 file with the highest quality settings that vimeo would allow, and the new video was 1:13 long.

Conclusion

While the initial intention of the flow was not realized, the result still produced a captivating flow that still highlighted interesting details about laminar flow. The experiment was just limited by the nature of other physics that were at play, and prevented the separated flow from being shown. Choosing a different liquid other than hand soap might be enough to mitigate the issue, but the video still highlights an interesting fluid flow using the mixing glow stick fluids. In the future, a video of this nature would greatly benefit from a more stable setup, as well as being filmed with a higher quality camera setup capable of high framerate recording.

References

[1] http://support.nextlimit.com/display/rf2014docs/HyFLIP+-+Viscosity+Values

[2] https://hypertextbook.com/facts/2005/VirginiaAllard.shtml

[3] http://www.thermopedia.com/content/1216/

[4]http://freemusicarchive.org/music/Lobo_Loco/My_Scifi_Sofa_Visions/Repeater_Station_-_Observation_ID_204

Image Assessment Form

Flow Visualization

Spring 2013

Name(s): Casey Cooter

Assignment: Team First Date:5 March 2018

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Comments
Intent was realized	√	
Effective	!	
Impact	!	
Interesting	!	
Beautiful	!	
Dramatic	!	
Feel/texture	!	
No distracting elements	√	
Framing/cropping enhances image	!	

Flow	Your assessment	Comments
Clearly illustrates phenomena	!	
Flow is understandable	!	
Physics revealed	!	
Details visible	!	
Flow is reproducible	!	
Flow is controlled	!	
Creative flow or technique	!	

Publishable quality	√	

Photographic/video technique	Your assessment	Comments
Exposure: highlights detailed	!	
Exposure: shadows detailed	!	
Full contrast range	!	
Focus	!	
Depth of field	!	
Time resolved	!	
Spatially resolved	!	
Photoshop/ post-processing enhances intent	!	
Photoshop/ post-processing does not decrease important information	!	

Report		Your assessment	Comments
Collaborators acknowledged		!	
Describes intent	Artistic	!	
	Scientific	!	
Describes fluid phenomena		!	
Estimates appropriate scales	Reynolds number etc.	!	
Calculation of time resolution etc.	How far did flow move during exposure?	!	
References:	Web level	!	
	Refereed journal level	x	Much of the resources I needed weren't present in any scientific journals I found

Clearly written		!	
Information is organized		!	
Good spelling and grammar		!	
Professional language (publishable)		!	
Provides information needed for reproducing flow	Fluid data, flow rates	!	
	geometry	!	
	timing	!	
Provides information needed for reproducing vis technique	Method	!	
	dilution	√	The levels are dependent on glow stick quality
	injection speed	√	
	settings	!	
lighting type	(strobe/tungsten, watts, number)	!	
	light position, distance	!	
Provides information for reproducing image	Camera type and model	!	
	Camera-subject distance	!	
	Field of view	!	
	Focal length	!	
	aperture	!	
	shutter speed	!	
	Frame rate, playback rate	!	
	ISO setting	!	
	# pixels (width X ht)	!	
	Photoshop and post-processing techniques	!	
	"before" Photoshop image	!	