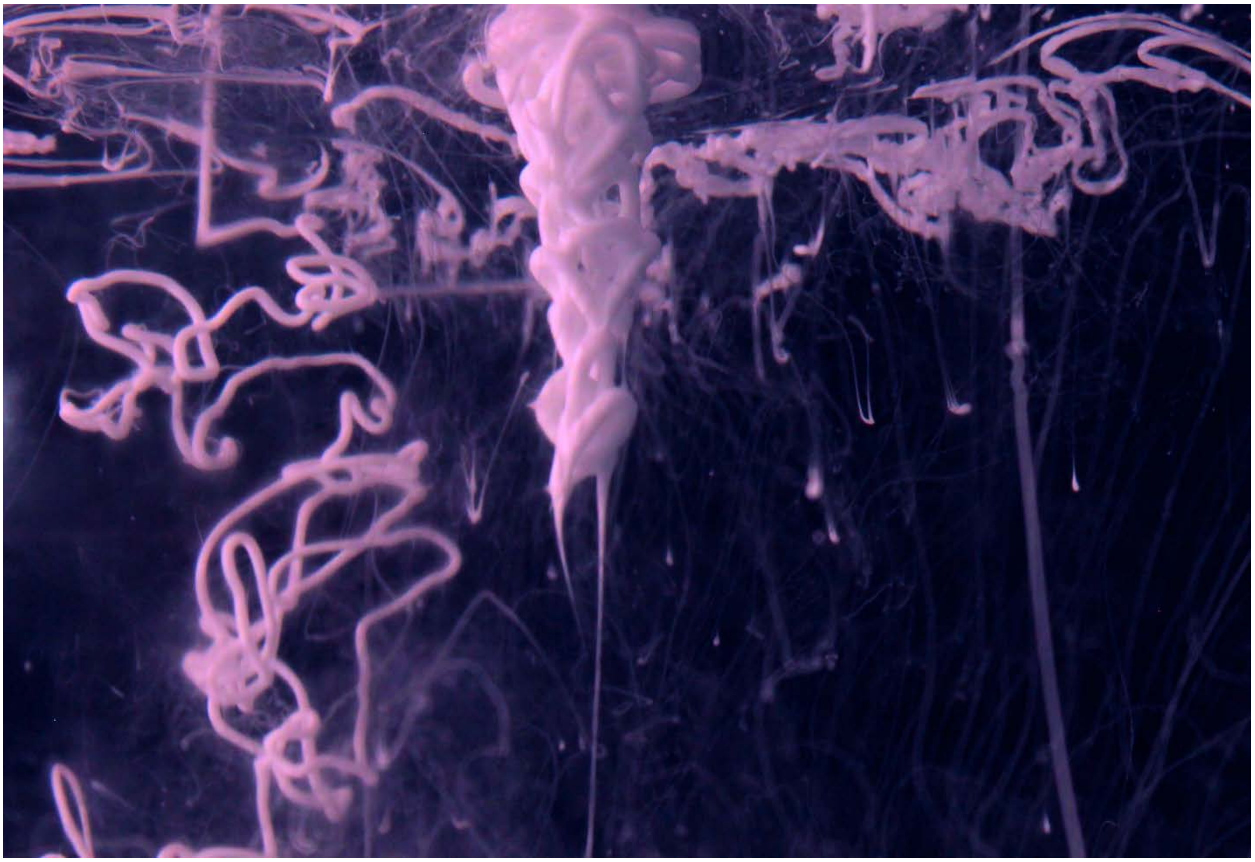
Second Team Project:

Surface-Tension/Rope-Coil Effect:

The Tornado Squid



Adam Sokol

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Professor Hertzberg

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Purpose

Going into this experiment, the original intent for a second team project was to create some sort of liquid rope coiling instability. Materials were gathered that might be able to create this effect such as corn syrup and Elmer's glue. A rope stability with both materials was successful, but the effect proved very difficult to photograph due to its tiny stature. So, we decided to try the effect in water. The corn syrup could not be seen well but the glue contrasted well against the water. The glue did not mix with the water for a very long time, creating a very interesting effect. Unaware of the science that may surround this phenomena, we proceeded.

Procedure/ Visualization Technique

To create the flow visualization technique, a 20x10x12 (LxWxH) inch aquarium was first filled with water ten inches high. A black curtain was draped across the top, back, and right sides as seen in Figure 1. This was used to create maximum contrast of the white Elmer's glue against a black background. The room this experiment was set in was well-lit, but the slow shutter speed desired required more light to see details. So, an additional light was added to the left side of the aquarium. This provided ample light to see the fluid flow.

To create the fluid phenomena, Elmer's glue was randomly dispersed around the top of the aquarium. To make the tornado-like vortex in the center of the photograph, the bottle of Elmer's glue was held in one place four or five inches above the surface of the water allowing the glue to gather on the surface in a coil. Once the coils continued to break, the glue bottle was also moved around in a circular fashion to add additional spiral effects.

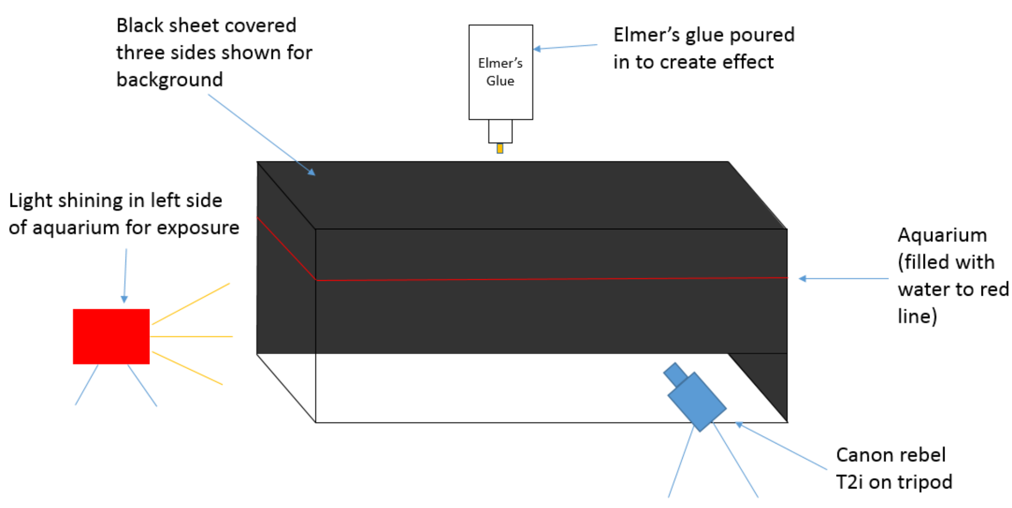

Figure 1: Schematic of flow visualization apparatus

Physics Involved

The tornado-like figure in the middle of the picture will be analyzed to attempt to describe the underlying physics. Clearly, the glue did not diffuse easily with the water. The glue stayed completely separate from the water for many minutes. Although both liquids are polar, the drastic differences between densities (8.7 g/cc for glue vs. 1 g/cc for water) and viscosities (10,000-14,000 cP for glue vs. .890 cP for water[i]) cause an extremely slow diffusion.[ii]

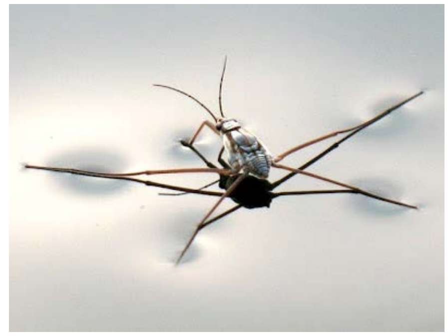

Figure 2: Picture of water strider displaying the surface tension effect. From http://compassrosebooks.blogspot.com/2013/08/amazing-water-skates.html

In addition, the surface tension effect from the water allowed the glue to sit on the surface until it broke through the surface. This is similar to how water striders float on the surface of water as seen in Figure 2. The maximum volume of glue that can sit on the surface of the water without breaking through the water's film is calculated:

$$Surface\ tension\ of\ water = 72.8\ \frac{dynes}{cm}^{\text{iii}} = .0728\ \frac{N}{m} \cong\ .0728\ N\ on\ aquarium\ surface$$

$$\rho_{Elmer's} = 8.7\frac{g}{cm^3}^{\text{iv}} = .0087\frac{kg}{cm^3}$$

$$How\ many\ cubic\ centimeters\ of\ glue\ can\ accumulate\ on\ the\ surface\ of\ the\ water?$$

$$.0087\frac{kg}{cm^3} * V * 9.81\frac{m}{s^2} < .0728N$$

$$V < .85\ cm^3 = maximum\ volume\ of\ glue$$

$$that\ can\ accumulate\ without\ falling\ through$$

So, with this amount of glue being able to rest on the surface, other phenomena were able to present itself. The surface tension effect allowed a liquid rope instability on the surface of the water. Glue was able to coil onto itself. Because the height that the glue was dropped from was small, the glue naturally formed into a spiral, because the fluid had to get out of the way of itself.[v] As seen in the final picture from the cover page, once the surface tension was exceeded on the water surface, the coiled rope fell through and may have inverted.

Photographic Technique

This photograph was taken with a Canon Rebel T2I with two different sources of artificial light. The original image, shown in Figure 3, was 5184 x 3456 pixels and the final edited image is 3767 x 2575 pixels. The light source of the photograph was from a large lamp on the left of the aquarium and from the room's light. The distance from the object to the lens was about four inches, and the aperture was at 5.6. The shutter speed was at 1/100, the focal length at 47 mm, and the ISO at 800.

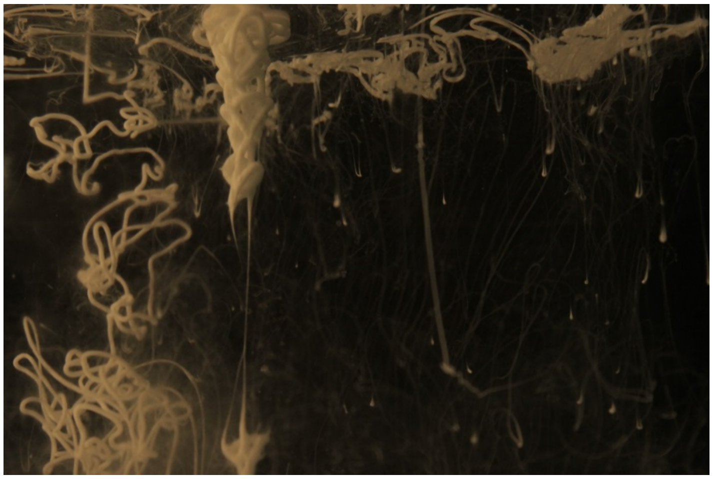

Figure 3: Original image

For post-processing, iPhoto was used. The picture was cropped down, the exposure slightly increased to 1.05, the contrast increased to 22, the saturation up to 100, and the highlights up to 29. The temperature was changed to -40 and the tint was changed to -98 to change the white color to a pink.

Conclusion

I believe this image reveals a lot of incredible fluid dynamics with the diffusion and liquid rope coiling effects captured. I like the unique type of fluid flow we were able to think of and the variety of pictures that resulted from it. In addition, the spiral was an incredible phenomena and is very visually appealing but I do not like the possible difficulty it may be to reproduce the same effect. The fluid physics are shown well, but they are very complex so explaining them correctly is also difficult. The intent of creating something with rope instability was achieved, but an improvement could be having a simpler phenomenon. This can be done by recreating another liquid rope coiling experiment using honey or another very viscous fluid which can be explained thoroughly.

Special thanks to my group: Ryan Coyle, Philip Latiff, and Michael Mccormack

Bibliography

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[i] http://en.wikipedia.org/wiki/Viscosity
[ii] http://www.scienceisart.com/A_Diffus/DiffusMain_1.html
[iii] http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html

[iv] http://www.elmers.com/msds/me375_c.htm
[v] http://fuckyeahfluiddynamics.tumblr.com/post/24411801909/the-liquid-rope-coiling-effect-occurs-in-viscous