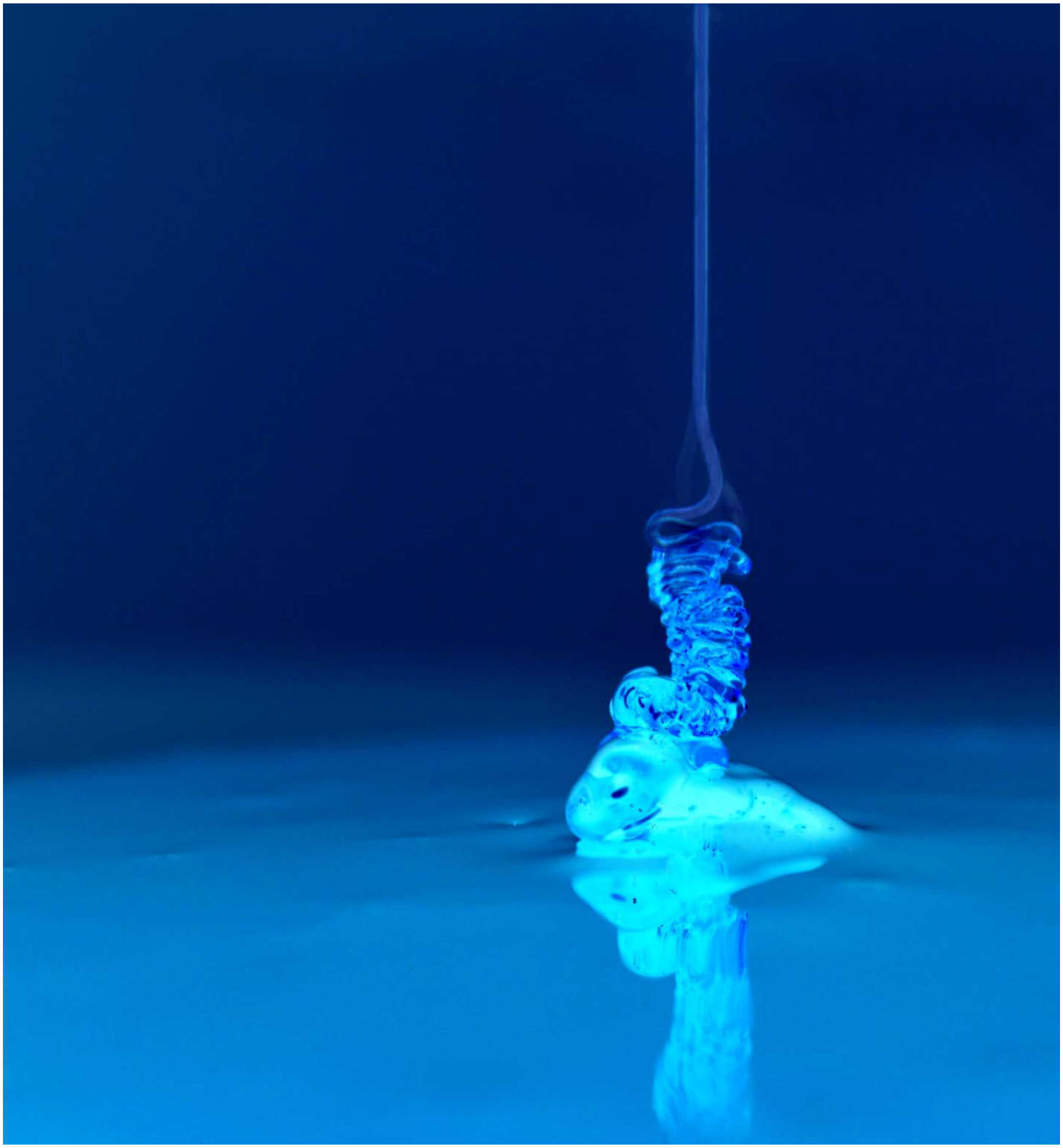

TEAM IMAGE II

MCEN 5151

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I. Introduction

The purpose of the Team Image assignment was to capture any fluid phenomena with a group of students. Each student would attempt to capture their own image in a common set-up and then complete their own post-processing on the image. The specific flow visualization that was desired to be captured in this report was the liquid rope coiling effect produced from dropping a viscous fluid onto a flat surface. This fluid dynamic behavior has long been studied and although much of it can be understood, parts of this phenomena are still unexplained. Aside from the interesting and complex fluid dynamics associated with the coiling effect, an artistic beauty can be found in the interaction of the fluid with itself. Therefore, because of its overall interesting nature the coiling effect was sought after in the photo. As it can be seen on the cover page, the coiling effect was successfully captured in an image by dropping honey on a flat surface.

II. Experimental Setup

The viscous fluid that was chosen for this particular image, as stated earlier, was honey. After experimenting with corn syrup, it was determined that at room temperature (72° F), the viscosity of the corn syrup ($\eta = 3\ Pa\ s$)[1] was not large enough for it to stack and coil, whereas honey ($\eta = 11\ Pa\ s$)[1] worked well. Different heights were experimented with as well and it found that the radius of the flow was too thick when the bottle was too low off of the surface, and too thin when it was too high. Thus the honey was dropped from a height of roughly 6". The camera shot the image from the side with a white background. Additional light was added from an incandescent lamp located above the honey dropping. The experimental set up in its entirety can be seen in Figure 1.

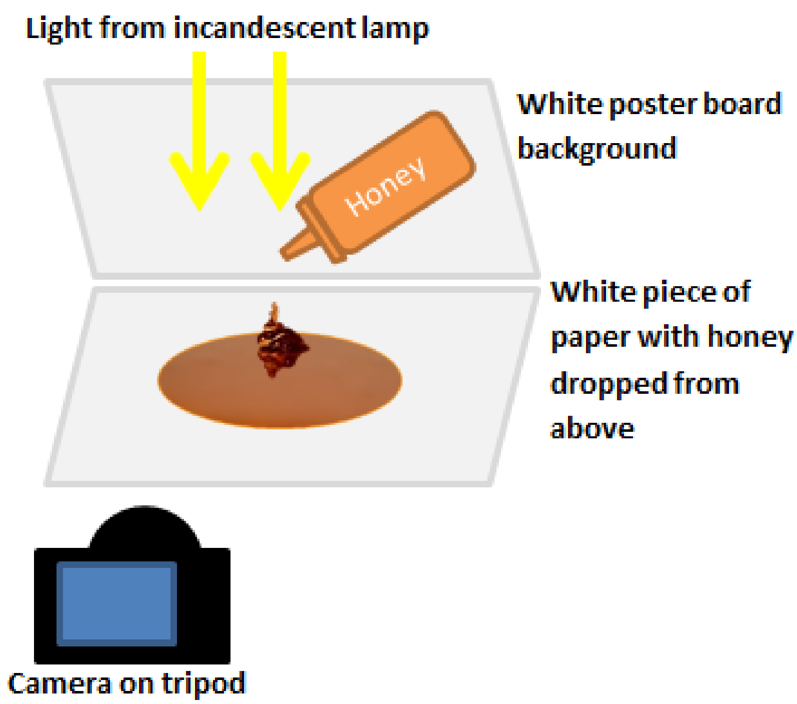

Figure 1: Experimental Set-Up

The fluid dynamics of the any dripping liquid can be divided up into four different regimes: the viscous regime, gravitational regime, inertial regime, and inertia-gravitational regime[2]. During the viscous regime, the radius of the liquid is too large, which ultimately makes the liquid too heavy for it to stack on itself. This is attributed to the length of the flow being too short because the dropping height is too low. In this case both gravity and inertial forces are negligible. Although it does not coil well, it does still spiral. Basically put, this spiraling is due to the fluid attempting to get out of the way of itself. As the dropping height increases, the radius of the liquid rope decreases. The next regime is called the gravitational regime[2], which is seen in the photograph. In this regime, steady coiling occurs because the viscous forces in the fluid that resist bending in the coil are balanced by gravitational forces[2]. This balance allows the fluid to coil and stack on itself. The frequency of the coiling can be numerically modeled in this stable regime (Equation 1[3]).

$$\Omega \sim \left(\frac{gQ^3}{\nu a_1^8}\right)^{\frac{1}{4}} \tag{1}$$

Where Q is the drop rate, g is acceleration of gravity, ν is the kinematic viscosity, and a_1 is the radius of the rope at the top of the coil

Without successive pictures or video of the honey, the drop rate could not be determined and thus, the coiling frequency could not be computed in this project. The final two regimes are the inertio-gravitational and inertial regimes. In the inertio-gravitational regime, inertia, gravity, and viscosity all play a significant role in the behavior of the fluid. Due to this modeling the frequency has become extremely difficult, with up to seven possible simultaneous frequencies at that drop height[2]. As the drop height increases further, the radius of the coil decreases and viscous forces in the fluid are balanced entirely by inertia[2], and thus the coiling occurs rapidly and does not stack to a significant height (<1 cm).

III. Photographic Technique

A. Image Capture

In order to capture this image a Nikon D5200 camera was placed 2-3 inches away from the honey dripping area with a focal length on the lens of 55 mm (lens is 18-55 mm). The size of the field of view was roughly 4 x 4 inches (the image was cropped). The camera settings were set to an ISO of 250, exposure time of 1/200 seconds, and aperture of F 5.66. In order to increase the shutter speed, more light was needed, so a compulsory flash was used in taking the photograph.

B. Post Processing

Post processing of the image included cropping the image. Using the rule of thirds, the image was placed on the left third of the image. Improving image quality came from increasing the saturation to improve the colors. Contrast was also increased in order to accentuate the shape of the coils. Finally, the image colors were inverted, which created the blue neon appearance of the image. The color inversion was done because it made the image look like it was lit by a black light, which added created a cold and mysterious quality to the image. The final size of the image was 3076 x 3324 pixels.

IV. Conclusion

This flow visualization project was a success with a nice looking image that captured the desired fluid dynamics phenomena. The fluid dynamics were captured with the honey coiling up onto itself. This was done by using a liquid with the correct viscosity (honey), in the correct environment (72° F), and correct drop height (6 inches). On the artistic side of the photo, the rope coil is personified, almost looking like a living organism of sort. With the color inversion, the honey is given a science-fiction like quality and perhaps even a psychedelic feel. By utilizing the rule of thirds in cropping the image, the coil stack is framed nicely and is in a point of interest. This flow visualization project was a success with a nice looking image that captured the desired fluid dynamics phenomena.

V. References

[1] "Viscosity." *The Physics Hypertextbook*. N.p., n.d. Web. 03 Apr. 2014. <http://physics.info/viscosity/>.

[2] Ribe, N. M., M. Habibi, and Daniel Bonn. "Stability of Liquid Rope Coiling." *Physics of Fluids* 18 (2006): 268-279.

[3] N. M. Ribe, "Coiling of viscous jets", Proc. R. Soc. Lond. A 460, 3223 (2004).

VI. Acknowledgments

I would like to acknowledge my team members for their assistance in the experimental set-up for this image capture and the use of some of their equipment.

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Thank you

VII. Appendix

Figure 2: Original photograph