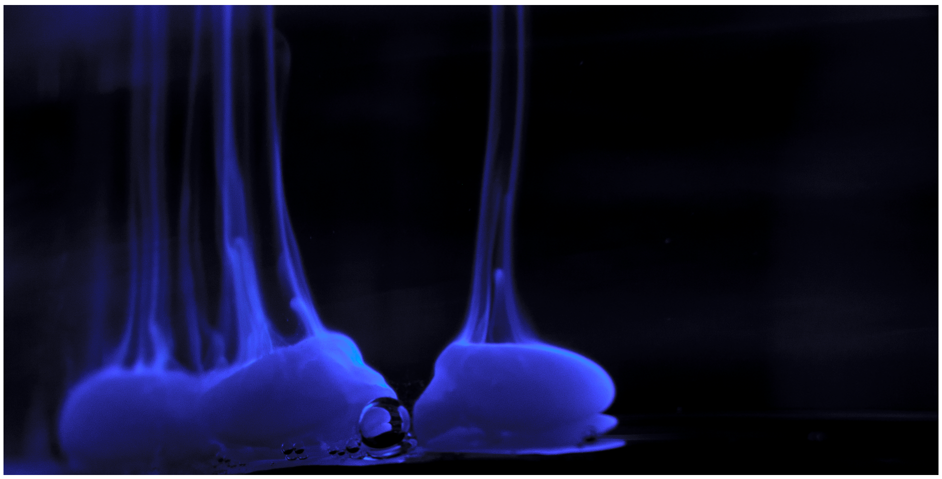
Bluish

Team 3 Image Report



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This report lists and describes the techniques performed to capture the photo *Bluish* as part of the third team image assignment. It also details the fluid phenomena captured in the photo and the relevant physics that explain such phenomena. The photo was one of several photographs captured during the project period, and it was found to be the most aesthetically-pleasing. It is successful in illustrating several flow phenomena. The image intends to display the dynamics of surfactants on fluid interfaces of high surface tension.

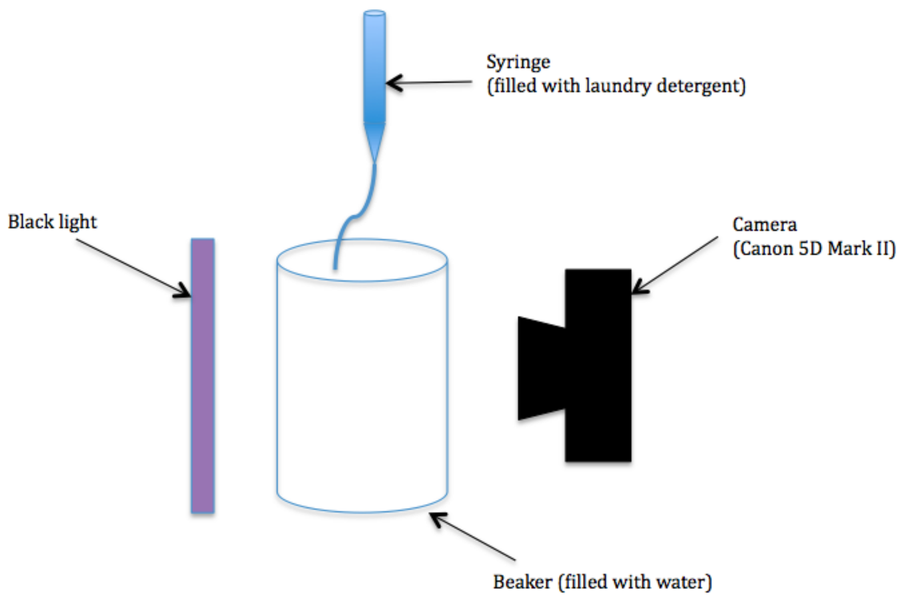

Figure 1: Schematic of Experimental Setup

The experimental setup is shown above in Figure 1. The photo was captured in a dark room under UV light. A 1-liter beaker was filled to the top with tap water and small droplets of a soap and laundry detergent mixture were distributed from a 10 mL syringe onto the surface. Photos were taken when the droplets hit the water surface and began to dissolve.

Surface tension is defined as the surface free energy per unit area, or more simply, the energy required to break through a liquid surface. For liquids such as water, which are characterized by strong molecular interactions, generally have high surface tensions. Detergent is a surfactant, meaning it can lower the isurface tension of a liquid. Surfactants are amphiphilic compounds; they contain both a polar and non-polar parts. Therefore, they are partly water-soluble and partly water-insoluble. At the interface between air and water, a surfactant's hydrophilic heads are forced downward into the water, while its insoluble hydrophobic tails extend out into the air. Thus, surfactants diffuse in water, and adsorb at interfaces between air and water.

The dynamics of adsorption depends on the surfactant's diffusion coefficient. The gradient surface diffusion coefficient at a liquid interface, D_s, is derived from calculations of the thermodynamic flux, or in this case, the surface diffusion flux, $\mathbf{J}_s$.

$$\mathbf{J}_s = -L\nabla_s\left(\frac{\mu_s}{T}\right) = -\frac{L}{T}\frac{\partial\mu_s}{\partial\Gamma}\nabla_s\Gamma \tag{1}$$

where μ_s is the surface chemical potential, T is the temperature (assumed to be constant), Γ is the adsorption, ∇_s is the surface gradient operator and L is known as the Onsager coefficient. By defining the gradient surface diffusion coefficient, D_s, as the coefcient of proportionality between the surface diffusion ux and the surface, we can derive its formulation from equation 1.

$$D_s = \frac{kL\Gamma_\infty}{\Gamma - \Gamma^2} \tag{2}$$

where k is the Boltzmann constant and Γ_∞ is the maximum possible adsorption. These calculations are very involved and beyond the scope of this class; however, they do provide a brief explanation of the theoretical considerations behind this flow phenomenon. For further explanation, see [1]. Simply put, the surfactant molecules in the detergent, align at the air-water interface based upon their polarity. The droplets do not immediately disperse due to the water's high surface tension. However, as time goes on, diffusion and absorption increase and subsequently decrease the surface tension of the water. This causes an increse in the rate of diffusion into the water.

The image was rotated 180° for aesthetic purposes. Thus the traces of detergent appearing to rise from the droplets in the image were actually diffusing downward into the water. This also explains the presence of bubbles on the bottom; they formed on the air-water interface after the droplets were dispersed on the surface. It should be noted that while it is a surfactant, detergent was also chosen because of it contains fluorescein, which causes it to glow under UV light. This allowed for strong contrast in the image and a clear focus on the behavior of the detergent.

The specifications for the final image are shown in Table 1. Based on the focal length and image dimensions, the field of view of the image was estimated to be 118° 33' 0" in the x-axis and 96° 33' 43" in the y-axis. While not directly measured, the angle at which the image was taken can be estimated to be approximately 0°.

Camera	Canon EOS 5D Mark II DSLR
Dimensions	4000 x 3000 pixels
ISO Speed Rating	80
Focal Length	10.7 mm
Exposure Time	1/30 s
F-stop	f/3.2

Table 1: Photo specifications

The image underwent several post-processing techniques. First, the image was cropped down from its original size to achieve a more artistic style. The image was then enhanced by adjusting the curves to rid it of any distracting elements. The contrast was adjusted in an attempt to make a seamless black background. Saturation was adusted to make the blues more vibrant. The original and final images are shown in Figure 2 below.

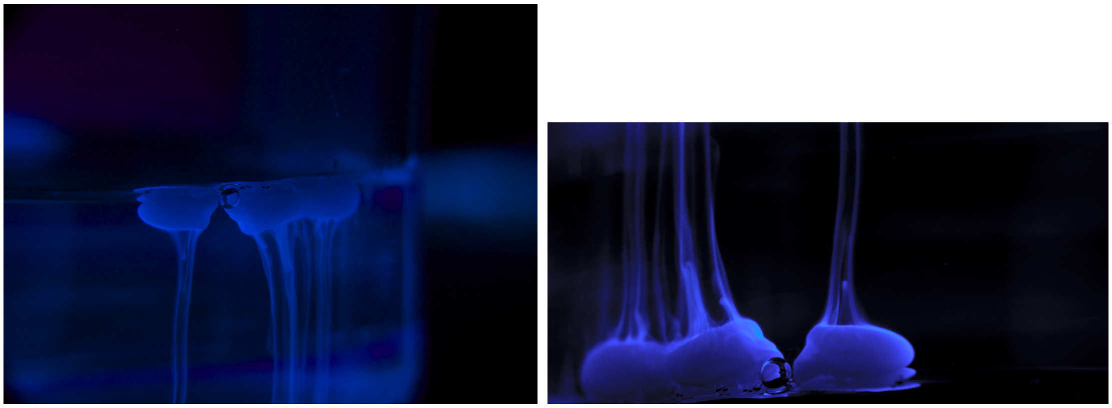

Figure 2: Original and Final Image

The image is titled *Bluish* as an homage to the song of the same name by the Baltimore rock band Animal Collective. The image clearly displays fluid flow phenomena that is both aesthetically-pleasing and creative. Overall, I am extremely satisfied with my final image. I believe it is effective in conveying both the beauty and physics of fluid flow.

References

[1] Danov, Krassimir. Determination of Bulk and Surface Diffusion Coefcients from Experimental Data for Thin Liquid Film Drainage. Journal of Colloid and Interface Science 223, 314316 (2000)