Alexander Hernacki
ATLAS 4151
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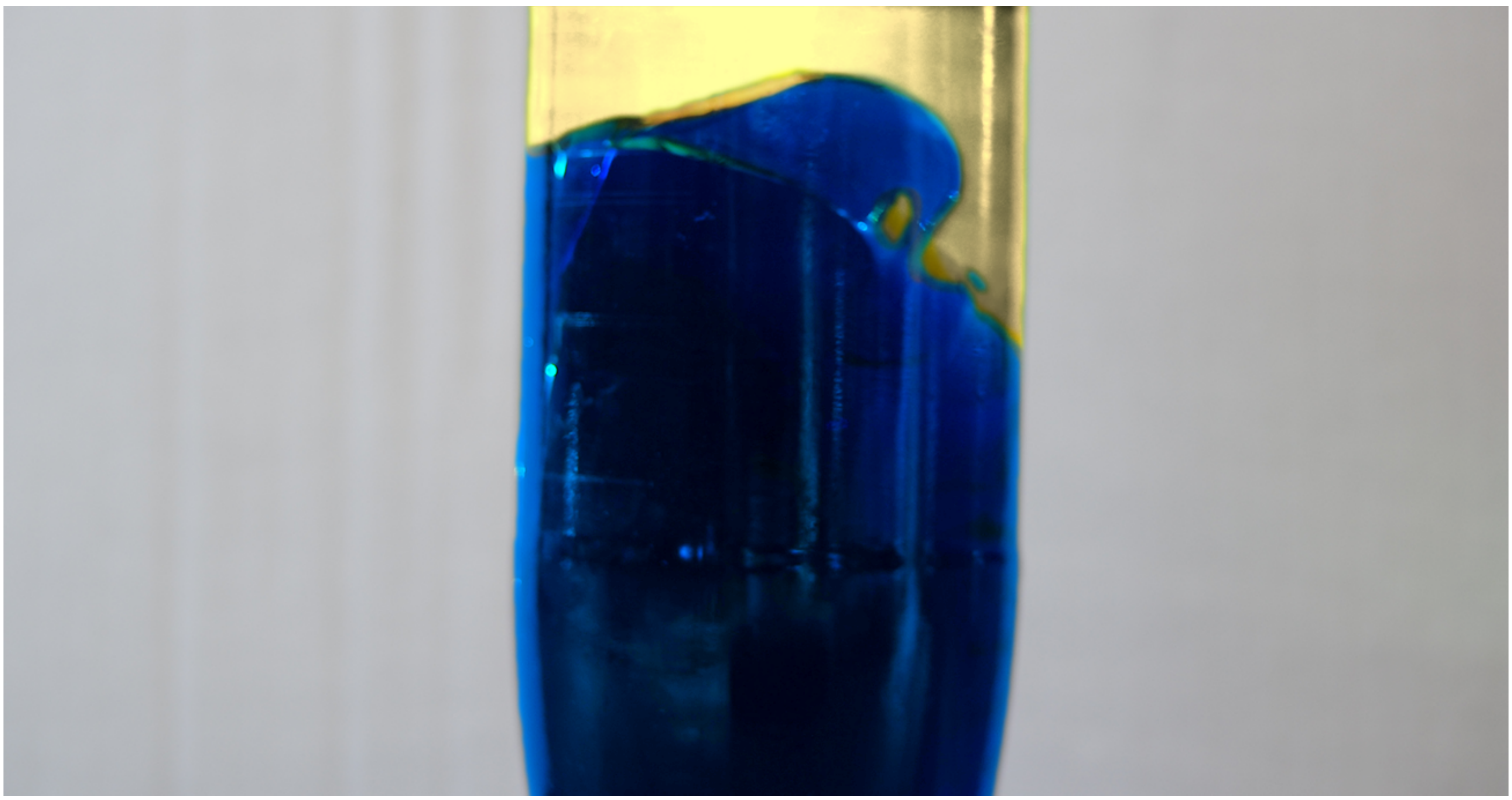
Image 2 Report



Introduction

This project's original goal was to capture the effects of the Kelvin-Helmholtz instability. This was my second flow visualization photo, which continues the use of water and oil to generate instabilities that occur between a set of varying density fluids. In order to highlight the fluid dynamics behind the instability the image was surrealized, to force the viewer to comprehend the effects of the Kelvin-Helmholtz instability.

Set Up

In order to create this image an empty, 1L, glass, Tejava bottle was filled with .5 L of water dyed with Mccormick blue food dye, and .5 L of Kroger's brand Vegetable oil. This bottle was sealed and laid flat with its cap placed above a blue tape marker representing the focal point of the camera. Once any bubbles of vegetable oil that formed in the dyed water returned to the larger section of oil, the bottle was flipped to the upside down position, with its cap resting on the blue tape marker. While the bottle was being flipped, the camera was taking rapid bursts of photos, resulting in the final image.

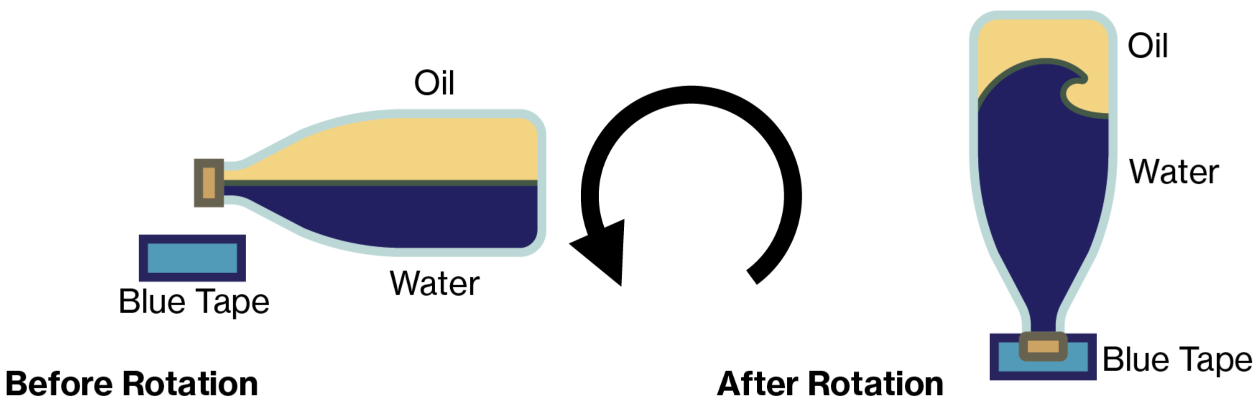


Figure 1: Photo setup diagram

Fluid Dynamics

The Kelvin-Helmholtz Instability forms when 2 fluids at their interface have different velocities[1]. In this case, the vegetable oil is accelerating upward and the water is accelerating downwards due to the density difference between the two and the force of gravity. This means that there are two opposing velocities at the fluid's interface. As a result, the Kelvin-Helmholtz instability occurs. In some instances, the surface tension is strong enough to prevent the occurrence of this instability[1]. The potential occurrence of an unstable interface can be predicted by the Richardson number, for $Ri < 0.25$ it is common for the interface layer to be unstable[1]. This number is given by the following equation.

$$Ri = \frac{g}{\rho}\frac{\partial\rho/\partial z}{(\partial u/\partial z)^2}$$

Figure 2: Richardson number equation g is the gravitational constant, rho is the density of the fluid, z is the height of the fluid, and u is the velocity of the fluid.

This equation compares the buoyancy to the shear flow of a liquid in non dimensional terms[2]. For the experimental setup, the density with respect to height for both liquids is approximately constant, so the only way this number could be changed was by more rapidly moving the bottle upright to ensure maximum increases in velocity due to the acceleration of gravity. This was witnessed in many of the early attempts to capture this phenomena as the bottle was moved more slowly at first in an attempt to maintain clarity. The instability also could have been made more prominent by choosing a set of more dense liquids, but a set of liquids that were more dense and visually distinct was not accessible at the time.

Visualization

The only visualization technique used in this setup is the seeded boundary between the vegetable oil and the dyed water. The water was dyed with Mcormick blue food dye, and the vegetable oil was left its natural color. Most of the visual, clarity enhancements, for the vegetable oil, were done via post processing. In order to avoid excess glare in the water or the glass of the bottle, this picture was taken outside. No Flash or external lights were used to light the image, simply the well dispersed light of the sun.

Photographic Technique

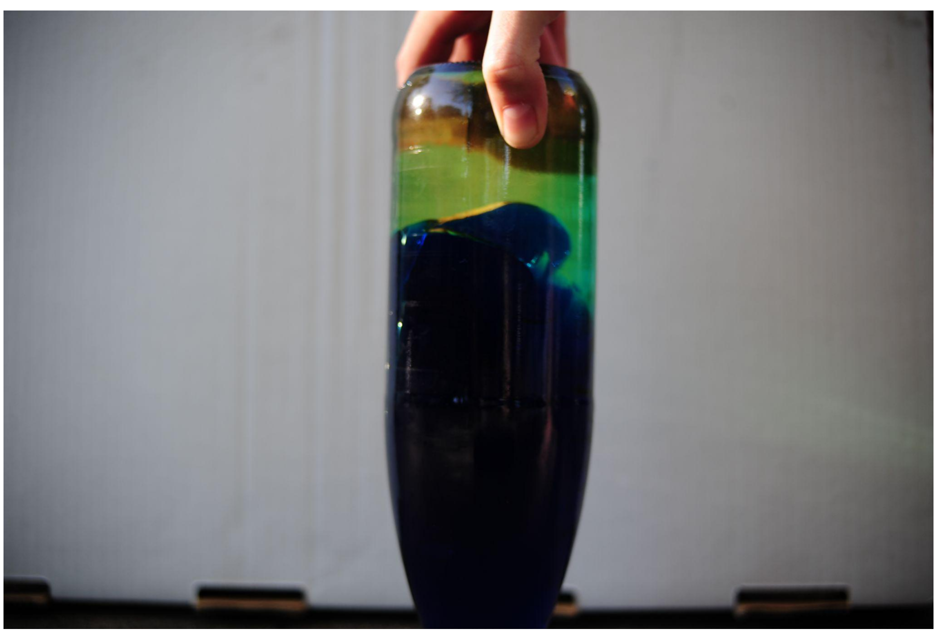


Figure 3: Raw image before post processing.

This image was taken from 1m away with a similar focal length of 1m, an aperture of F4, a shutter speed of 1/200th of a second, and an ISO of 200. The intention of this setup was to balance between a high shutter speed and the corresponding high ISO required to take in sufficient light. Since the last time I imaged water and oil using sunlight, with this camera at a shutter speed of 1/800th of a second required a ISO of 2500, notable noise occured, the above settings were used instead. This resulted in an image without notable noise at a minor loss to clarity. An aperture of F4 was used due to the fact that my control of the instabilities location was precise, and I did not want to include any unnecessary background details. This photo was taken from 1 m with a focal length of 1 m because this was as close as it could focus and maximum detail was desired, especially since cropping would still have to be done. The first edit made to this image in post, was a reduction to its field of view. The image was cropped from 4256 x 2832 to 2850 x 1500 in order to remove my hand, as well as the region of notable necking in the bottle. From there the vegetable oil, background, and dyed water were each individually masked and their brightness', color balances', and contrasts' were individually adjusted. For all three the brightnesses were marginally increased. For the oil, the color balance and vibrance were shifted such that it gave off the light golden appearance seen in the final Image. For the dyed water, the contrast was slightly increased and the color curves were adjusted such that the darker blues were brought closer to the color of the highlight blues. Ultimately these changes sought to highlight the clarity of the seeded boundary to emphasize the instability.

Conclusion

The thorough contrast between the vegetable oil and dyed water in the final image, clearly shows the form of the Kelvin-Helmholtz instability. However, the still nature of the image leaves the formation conditions relatively uncertain for the viewer. The image's clear portrayal of the form of the instability is its highlight and fulfills the initial intention, but the slight lack of focus and detail does subtract from the visual appeal of the image. If this image were to be redone, in order to obtain more detail and clarity, a larger container would be used, a more dense liquid would be used in place of water, a lesser quantity of dye would be implemented, and the shutter speed would be increased. In the future this idea and set up could be scaled up to try and generate a set of instabilities instead of just one. Furthermore, the use of video could be explored in order to demonstrate both the form of the instability and its formation conditions.

Bibliography

[1]Salih, A. (2010, November). Kelvin–Helmholtz Instability. Indian Institute of Space Science and Technology. Retrieved October 10, 2021, from https://www.iist.ac.in/sites/default/files/people/KelvinHelmholtz.pdf.

[2]Encyclopædia Britannica, inc. (n.d.). Richardson number. Encyclopædia Britannica. Retrieved October 10, 2021, from https://www.britannica.com/science/Richardson-number.