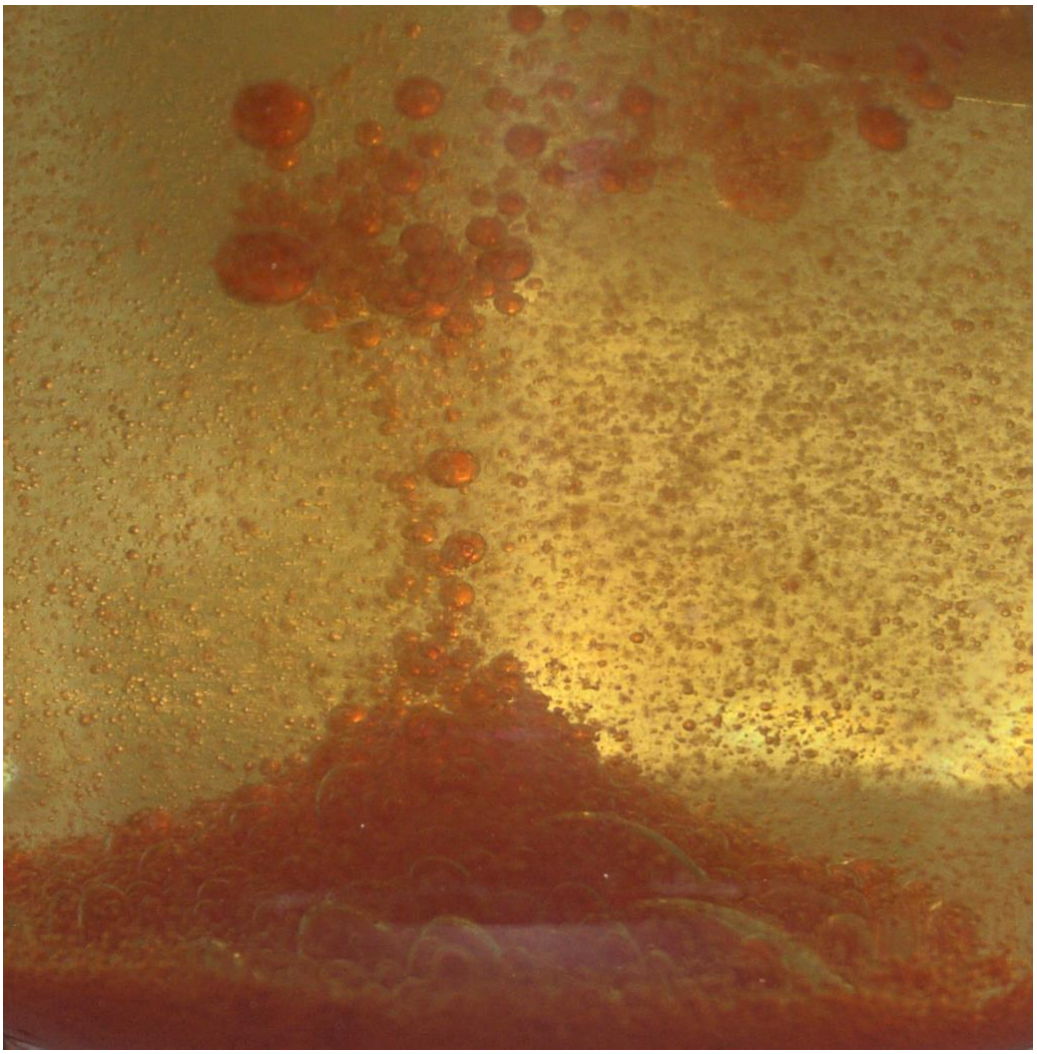
Tristan Martinez
MCEN 5151
11/3/2022
IV 4
Contributors:
Anders Hamburgen,
Sander Leondaridis,
Abdullah Bin Boodai Alkhaldi

Tea Leaf Paradox



Introduction

The objective of this image is to capture the tea leaf paradox in action. This effect is often seen with loose leaf tea, as the tea leaves tend to gather at the bottom of the cup when stirred, hence the “tea leaf paradox”. In this experiment, we attempted to visualize this effect with two different densities of fluids instead. The denser fluid acts as the “tea leaves”, producing a very interesting effect when stirred. I would like to thank Anders, Sander, and Abdullah for assisting with this visualization.

Apparatus

A sketch of the experimental apparatus is provided below.

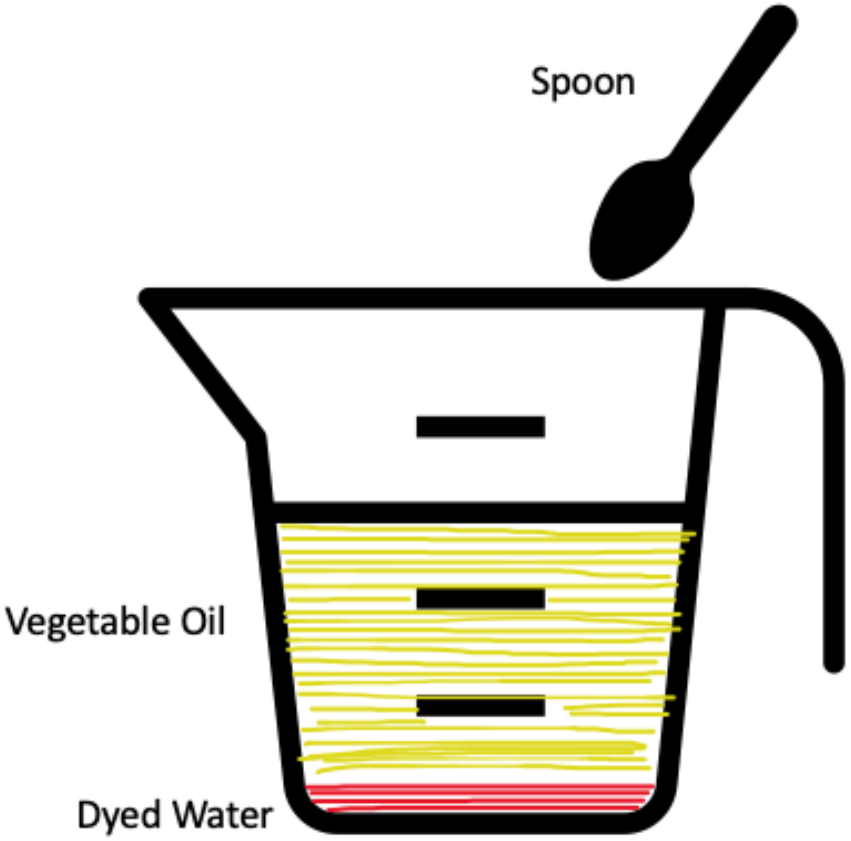


Figure 1: Apparatus

For this experiment, dyed water is put at the bottom of a container, with vegetable oil slowly poured on top of it to avoid disturbing the water as much as possible. The oil is then stirred in a circle until the dyed water rises in the center of the glass.

Flow Physics

The primary fluid phenomenon seen in this image is what is known as a “secondary flow”. The primary flow in this image is a simple vortex, created by stirring the fluid in the container. Vortices in real life can be approximated by a rotational core combined with an irrotational vortex outside of it. This irrotational vortex is characterized by increasing velocity as you move out from the vortex center. However, the so-called “no slip condition” must also be met at the contact point of the liquid and container. This means the fluid velocity must equal zero at the contact point. This slows the flow down at the outermost part of the vortex, but this is the part of the vortex that must be traveling the fastest. This slowing of the vortex leads to the fluid falling toward the center, producing the flow effect seen in the image.

Additionally, the bottom of the container also contributes to this slowing of the flow. This leads the flow at the bottom of the container to more prominently fall toward the center than the flow elsewhere, so the fluid rises in the center of the glass to compensate. This effect can be seen with the column of oil bubbles rising in the captured image.

Visualization Technique

The technique for this image is very simplistic and easily repeatable. As described previously, the water was put into a glass and dyed in order to differentiate it from the vegetable oil used.

The lighting of this shot was done with a couple sources of light. First, there was ambient light in the room from the overhead lighting. Second, the camera flash was used in order to freeze the flow as much as possible.

Photographic Technique

This video was taken using a Canon EOS DIGITAL REBEL XS with an 18-55mm lens. The properties for my final image are tabulated below.

Image Property	**Value**
Shutter Speed	1/200 sec
Focal Length	27 mm
ISO	200
Aperture	f/4

Pixels	1167 x 1184

Table 1: Photograph Specifications

The lens itself was 8 inches from the fluid in the glass in order to capture the entirety of the fluid flow. The field of view of the original video is 2 feet horizontally and 1.5 feet vertically.

The ISO setting was set to auto so the selection of 200 is theoretically the optimal setting for the light in the image. A shutter speed of 1/200 was used in order to freeze the flow in the image, while an aperture of f/4 was automatically selected because shutter priority mode was used.

Finally, Dark Table was used to make a few adjustments to the original image. First, the image was cropped to feature the actual fluid flow rather than the distracting parts of the image. Second, the RGB curve was adjusted to increase contrast within the mid tones.

Figure 2: Original Image

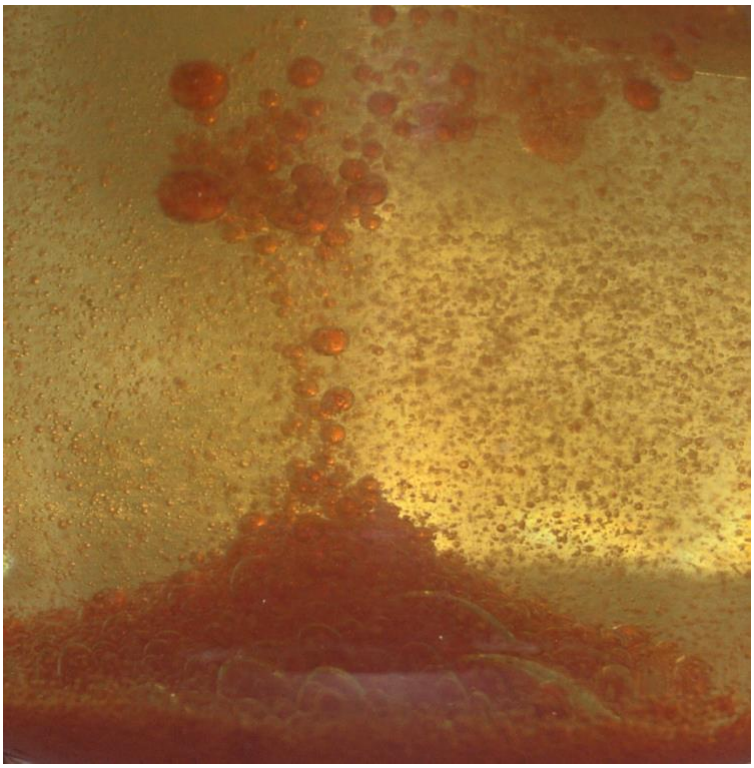


Figure 3: Final, edited image

Conclusion

This picture shows an interesting phenomenon, one that is a bit counterintuitive. It's fascinating how the denser fluid plumes up in the center instead of being pushed to the outside of the container. I like how this image turned out in terms of framing; it really feels like you are immersed in this fluid. The one thing I would change, however, is the color of the vegetable oil. It is a little bit unsavory in my opinion, but I couldn't adjust this in the edited photo without changing other aspects of the image that I did like. Overall, though, I am happy with how this image turned out.

References

1. Schlichting, H. *Boundary-Layer Theory*, 6th ed.; McGraw- Hill: New York, 1968; pp 213–214.
2. Long, David F., et al. "Einstein's Tea Leaf Paradox and Its Relevance to Dissolution Testing." *Daissolution Tech*, http://dissolutiontech.com/DTresour/201408Articles/DT201408_A03.pdf.
3. Kundu, Pijush K., et al. *Fluid Mechanics*. Elsevier/AP, 2016.