IV 1 Report
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Flow Visualization Fall 2022
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IV 1 was the first individual project assigned to get us to 'get wet' with photography and fluid physics, where we were instructed to take an image or video of a fluid phenomenon being observed. I chose to photograph a tea bag diffusing in a glass of hot water. As I drink tea daily, I was curious to see what a well thought out image of the diffusion process would reveal.

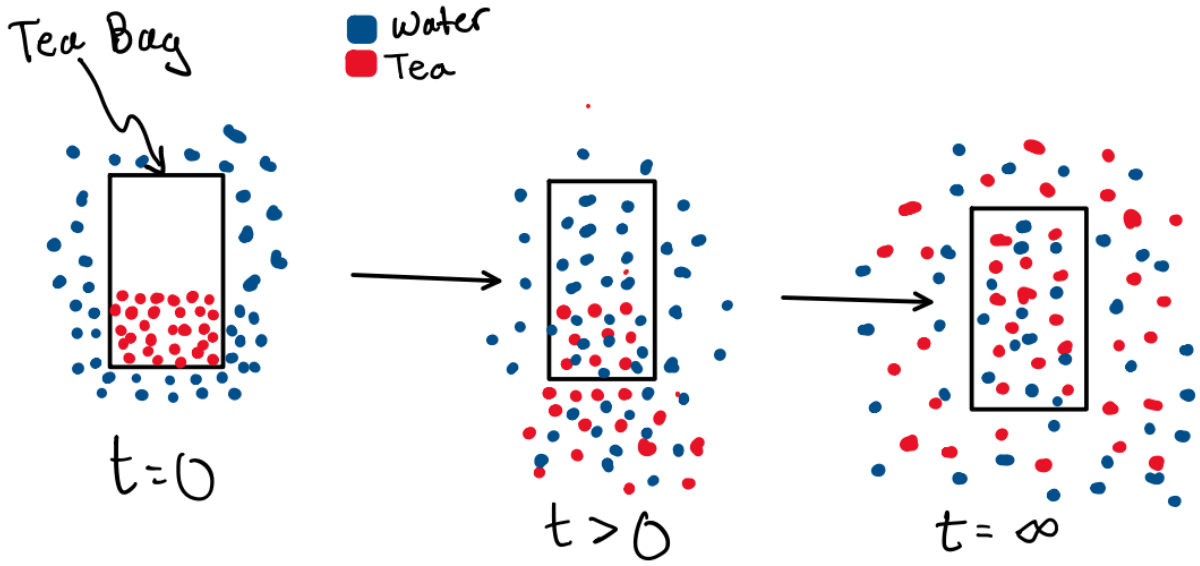

Figure 1. Simplified sketch of tea bag diffusion over time.

The governing process that is happening in the image is the diffusion of tea molecules into the water. As depicted in the sketch above, initially there is a very high concentration of tea within the bag and none outside, causing the tea molecules to go through the perforated tea bag into the water. Particularly, the tea molecules have a higher density than the water molecules which causes them to fall downward creating the pattern seen in the final image. This phenomenon is known as a Rayleigh-Taylor instability, which occurs when a boundary of higher density, and lower density substances interact. The surface tension and buoyancy forces are competing on the tea molecule, but in this case, the surface tension is not enough to prevent the denser fluid from penetrating into the less dense fluid, leading to the instability[1]. Eventually, if the tea bag is agitated enough the tea and water will reach equilibrium and you are left with a nice cup of tea. The temperature of the water also plays a role in the speed of diffusion: the molecules are moving faster so they're more readily diffused.

No dye or other methods of visualization were used to capture the fluid phenomenon occurring in the experiment. The image was taken in the short time frame where the first initial tea particles diffusing were visually distinct from the clear water. A white background helped to clarify the process. Two lamps were used to illuminate the glass jar and background for the image.

The image was taken at an angle below surface level to reduce glare on the jar, and to highlight the physics occurring at the bottom of the tea bag. The focus distance was 0.31m, with the distance from the lens to the subject approximately equal, which had the entirety of the jar in the frame. A digital DSLR camera was used to capture a 5280 x 3462 pixel image that was shrunk to 1300 x 900 pixels for publication. The available camera and lens was a Canon EOS Rebel T5i with a Canon EF-S 18-55mm f/3.5 - 5.6. An ISO of 3200 was used to increase the apparent brightness of the image, but increased graininess of the final image. Other exposure specs were an aperture of f/4.5 and 1/400 exposure. These were the default settings and not altered for this experiment. In terms of post processing, the limited color range made it difficult to adjust the RGB curve without unwanted consequences. Thus, color saturation was increased to create a warmer feel, contrast increased to highlight the flow, and the image was cropped to center the subject.

Overall I am not 100% satisfied with the final image due to several factors. The lighting of the background was not sufficient, leading to a dull looking image. The choice to use a circular glass jar made it challenging to get a shorter focal length and an image without glare. Also, the choice to use a black tea bag led to poor color contrast with the background and foreground, which made it harder to isolate the physical phenomenon being observed. Besides these points, the image successfully visualizes a Rayleigh-Taylor instability well enough. In the future, a fish tank apparatus with improved lighting and a bright red tea would make for a more effective visualization.

References

[1]G. Bar-Meir, “4.7: Rayleigh-Taylor Instability,” LibreTexts (2022)