Figure 1: Depiction of food coloring suspension drops in an oil and water mixture

Ari Matrajt
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Introduction

The image presented in Figure 1 corresponds to the Team Second assignment for the course MCEN 5151, Flow Visualization. The picture shows suspension drops in an oil and water mixture. These suspension drops consisted of food coloring and water. Suspension drops occur when a large amount of small particles are suspended at rest [1]. These droplets then settle due to gravity, with the center attaining a greater velocity, forming mushroom-type shapes [1]. A deeper analysis of the fluid dynamics will be performed in the following section. The experiment, as well as capturing the images was made possible by the help and support of Sierra Greeley and Jonathan Gruener.

Fluid Dynamics

Suspension droplets consist of numerous groups of small particles that are at rest. These particles are within a fully mixed mixture [2], meaning that this phenomenon can only occur within homogeneous liquids. The Reynolds number is used to predict the flow regime of a fluid. It is affected by viscosity and the diameter of the pipe or area through which a fluid moves. However, the Reynolds number differs when it is used to analyze a single drop compared to a group of drops. When a high number of droplets are present, they behave differently.

As surface tension increases, the trajectory of these droplets is altered, resulting in a greater accumulation of particles in the bottom. These then curve upwards seeking a lower surface tension, resulting in a mushroom-like shape. This shape can be seen in the central part of Figure 1. Furthermore, this shape is the result of a swarm of particles moving in the same direction simultaneously, generating a vortex. Such a phenomenon then creates a force outwards, pushing some of the particles, which also leads to a mushroom-like shape [2].

Visualization Method

The visualization techniques used in this experiment to take the photograph in Figure 1 were the following. First, a piece of glass cup was filled 75% with lukewarm water. In a separate glass container, olive oil was poured and mixed with food coloring. The colors used were purple and pink. The amount of oil used was around 20 ml. Once the oil and food coloring were mixed, the mixture was poured into the glass containing water. Since oil and water do not mix, a layer was

formed at the top of the glass. As soon as this happened, a knife was used to push the oil downwards, dragging the coloring with it. The suspension droplets formed instantly and were photographed. The whole mixing process between the oil and water lasted around 2 minutes, while the image in Figure 1 was taken 30 seconds after the initial mixing.

Photographic Method

The image was taken using a Canon EOS 5D camera with a Canon EF 28-200mm lens. This lens has an aperture range of f/3.5-5.6, a focal length of 28-200mm, and a filter thread diameter of 72 mm. The distance from the object to the lens was around 6 inches with a field of view of around 3 inches. The digital camera had the following settings when the image was taken: f/5.6 aperture, 1/60 exposure, ISO 3200, and a focal length of 100 mm. The original image had a pixel size of 5616px width x 3744px height, which was then cropped to 1700px width x 2200px height. The reason for this crop was to reduce some unnecessary background. Other post-processing procedures were to increase contrast, increase color saturation, slightly change the RGB curve, and increase the sharpness of the image. All of these steps were done to make the main suspended droplet stand out from the background, as well as to highlight small details in the background and other small “mushrooms”. The original image can be seen in Figure 2.

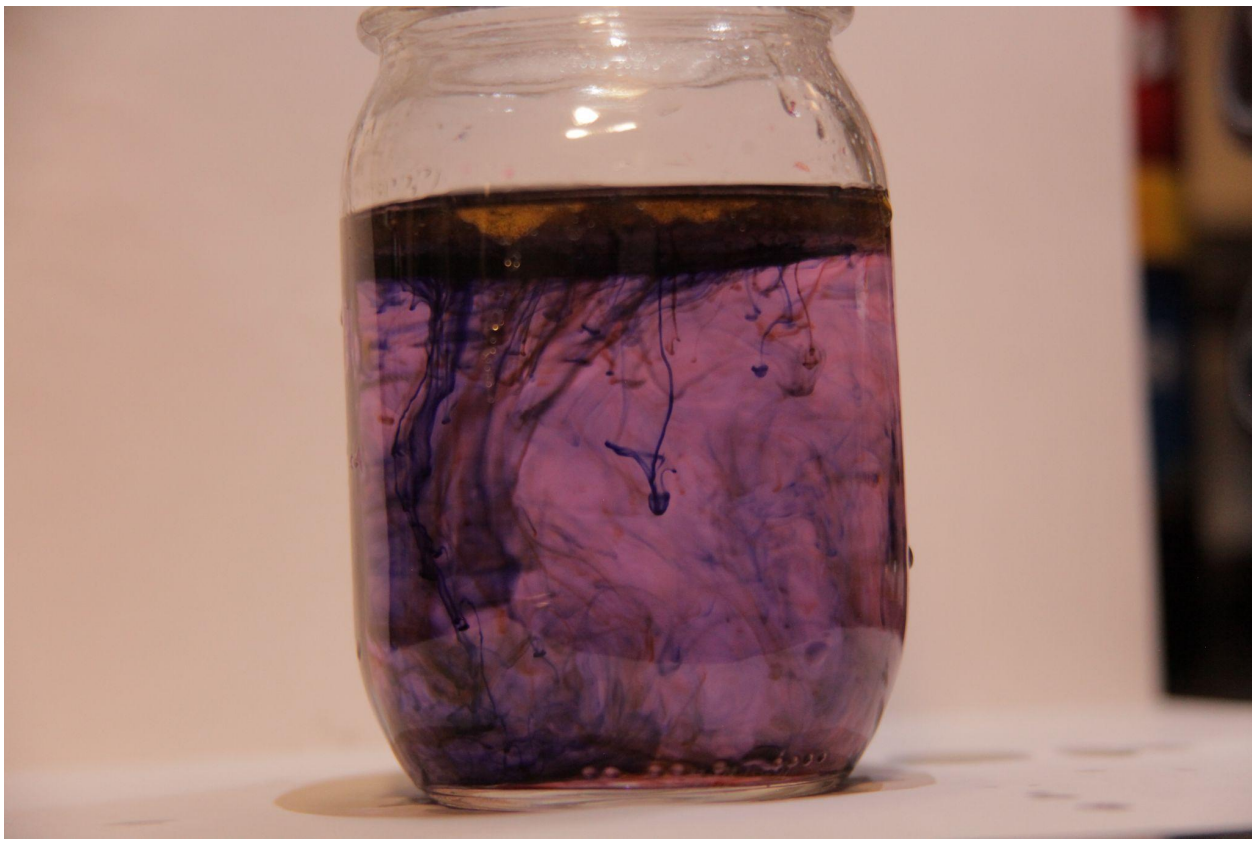

Figure 2: Original image before post-processing depicting suspended droplets

Conclusion

The image taken in this experiment, shown in Figure 1, is a dynamic representation of the physical reactions of different density fluids, resulting in suspension particles forming mushroom-like patterns. The setup was straightforward and fast. Several things could be improved if the experiment was reproduced. Firstly, using a tripod would enable the photographer to produce by reducing unnecessary blurriness induced by shakiness. Another possible improvement could be using more vibrant colors to create a better contrast between the mushrooms and the background. Overall, the experiment was a success and the identified fluid physics were captured as intended.

References

[1] Bosse, T., et al. “Settling and breakup of Suspension Drops.” Physics of Fluids, vol. 17, no. 9, 2005, https://doi.org/10.1063/1.1942520.

[2] MACHU, GUNTHER, et al. “Coalescence, torus formation and breakup of sedimenting drops: Experiments and computer simulations.” Journal of Fluid Mechanics, vol. 447, 2001, pp. 299–336, https://doi.org/10.1017/s0022112001005882.