Get Wet Report 1:

Flow Visualization of Olive Oil Droplets in Water

Caidan Caswell
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Figure 1: Post Processed Image of Olive Oil Droplets in Water

1 Context and Purpose

This project visualizes the behavior of olive oil droplets in water, with a specific focus on the attractive interactions and clustering of droplets during swirling motion. The experiment aimed to capture how droplets move and coalesce when subjected to vortex-like motion within the water. This interaction is typical when immiscible fluids are stirred or swirled, leading to complex patterns of droplet aggregation. The image showcases these interactions and provides insight into how droplets combine under certain fluid dynamics conditions. The project was completed and set up individually.

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2 Flow Apparatus and Phenomenon

The apparatus used consisted of a glass container, approximately 10 cm high and 5 cm wide, filled with ~8oz of tap water at room temperature. Olive oil was introduced into the water using a measuring cup ~1Tbsp, and after allowing the oil interface to settle at the top, the container was gently and in a controlled manner swirled with a spoon in the clockwise direction to create a vortex. The swirling motion created a rotating flow field, drawing the droplets into the vortex and causing them to move towards the center. The observed behavior involved droplets attracting each other, clumping together as they spiraled within the vortex.

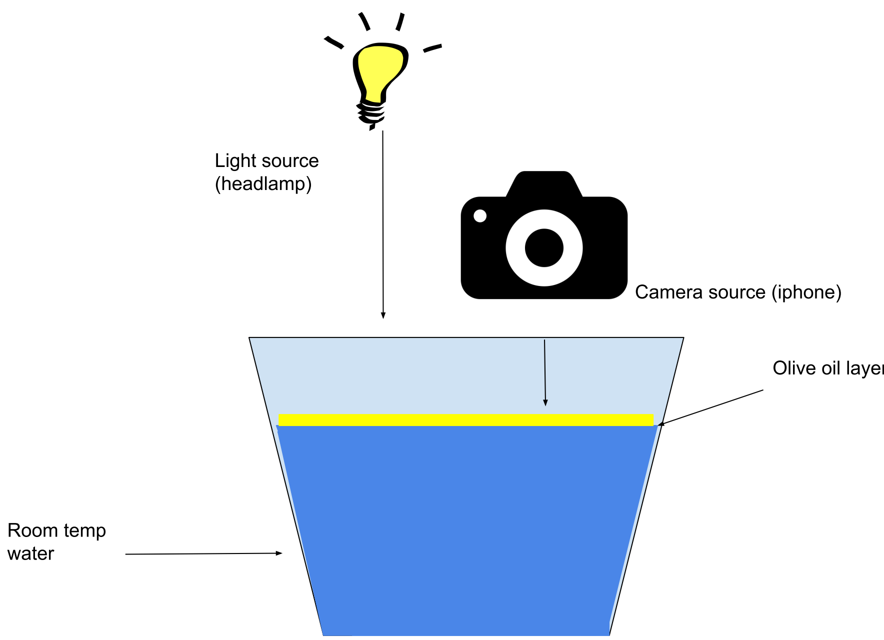

Figure 2: Digram of Experimental Setup and Execution

The primary physical phenomenon here is the attractive interaction between the oil droplets due to surface tension, which causes them to coalesce[1]. Additionally, the flow can be characterized by a low Reynolds number because the movement is slow and laminar. Assuming the droplet speed is around 0.02 m/s, their diameter is about 0.005 m, and the average kinematic viscosity of water is $1.002 \times 10^{-6} m^2/s$, the Reynolds number can be calculated as:

$$Re = \frac{UD}{\upsilon} = \frac{(0.02m/s)(0.005m)}{1.002X10^{-6}m^2/s} \approx 100$$

This value suggests the flow is still laminar, though slightly faster than in static conditions. The droplet coalescence is driven by both fluid inertia and surface tension forces.

3 Visualization and Lighting Techniques

To visualize the droplets clearly, extra virgin olive oil was used, Due to the differences in color. I felt it was unnecessary but possibly something to improve upon when discussing using dye with food coloring for contrast. Once the oil settled at the surface of the water, the glass was gently rotated to create a vortex. As the droplets moved within the flow, their behavior was captured using controlled lighting. A headlamp was positioned perpendicular to the glass, providing strong illumination of the droplet clusters without causing excessive glare. The experiment was conducted at room temperature (~22°C) and the lighting helped to reveal the attractive interactions between the oil droplets, especially as they clumped together.

4 Photographic Techniques

The image was captured using an iPhone 15 Pro with an ultra-wide angle lens. The camera settings were ISO 32, 24mm focal length, 0 EV, f/2.2 aperture, and a shutter speed of 1/932s. The camera was rested directly on top of the glass, shooting perpendicularly to the oil-water interface. This overhead view allowed for capturing the swirling motion of the droplets and their subsequent clustering. The camera’s high shutter speed was essential for freezing the motion of the droplets as they swirled. Post-processing involved slight adjustments to contrast and sharpness to enhance the visibility of the droplets' movement and interactions. It is important to note that the focusing and lighting characteristics of an iphone camera were subbar which limited my post processing, and photo selection based on unclear and messy image samples.

5 Image Analysis and Conclusion

The final image successfully captures the attractive interactions between oil droplets as they move in a vortex, highlighting their tendency to coalesce into larger clusters. The lighting and photographic setup effectively display the flow’s dynamics and the fluid physics involved. The spherical droplets and their gradual clumping are indicative of the surface tension forces at play, while the laminar flow field ensures smooth, predictable motion. One improvement could be to increase the illumination intensity or use a diffused light source to further reduce glare on the droplets. In the future, I would explore how changing the swirl intensity or altering the fluid properties (such as using a different oil) could affect the clustering behavior. This experiment opens avenues for studying immiscible fluid dynamics under rotational motion[2], which can have applications in industrial mixing and emulsification processes.

References

[1]Eggers, J., & Villermaux, E. (2008). "Physics of liquid jets." *Reports on Progress in Physics*, 71(3), 036601.

[2]Lugt, H. J. (1979). "The dilemma of defining a vortex." *Science*, 204(4399), 143-145.