Turmeric Powder Blooms in Water

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MCEN 5151: Flow Visualization, Get Wet Assignment Report

Introduction

The aim of this experiment was to capture a fluid flow phenomenon that is both scientifically interesting and visually beautiful. I chose to visualize how turmeric powder moves through a cup of water and to observe negative buoyancy and Rayleigh-Taylor instability. I was also interested in the strong color contrast between the bright yellow powder and the water. No teammates assisted with this experiment. In my first attempt, the room was not fully dark, and the lighting was insufficient, so I repeated the experiment in a completely dark room with an iPhone flashlight underneath the glass. I also repeated the experiment until I found the right amount of turmeric powder to visualize the flow.

Flow & physics

In this experiment, I used a clear glass cup with a diameter of approximately 6.5 cm and a height of 12.5 cm, filled with warm water. I placed approximately one teaspoon of turmeric powder on the water's surface.

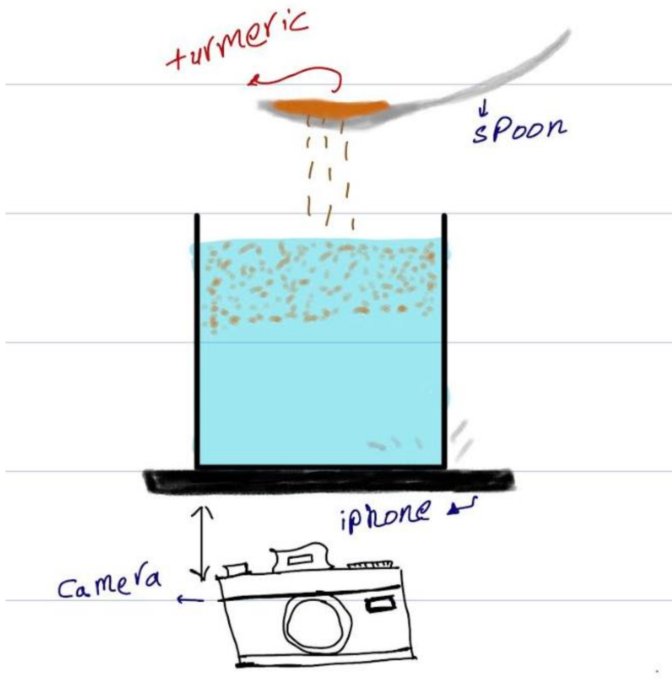

Figure 1: Shows a schematic of the experimental setup.

Because turmeric powder is denser than water, it initially rests on the surface due to surface tension before sinking. Individual particles settle at their Stokes fall velocity, that depends on the particle size and the density difference with the surrounding fluid (Lippert & Woods, 2020). After the turmeric powder sinks into the lighter water below, the interface becomes unstable. This is Rayleigh-Taylor instability, which occurs when a heavier fluid sits above a lighter one, causing the lighter fluid to spread as mushroom-shaped bubbles while the dense, turmeric-laden fluid sinks as spikes (Banerjee, 2020). These plumes are visible in the video, demonstrating particles settling toward the bottom of the cup.

Now we can find the Stokes settling velocity using the equation from (Lippert & Woods, 2020), which determines the velocity at which a small dense particle sinks through a viscous fluid:

$$U = \frac{2}{9}\frac{g(p_T - p_W)}{\mu}\left(\frac{d_p}{2}\right)^2$$

$$U = \frac{2}{9}\frac{(9.81\, m/\, s^2)\;\;((1350 - 1000)kg/m^3)}{(1.002\; x\; 10^{-3}\; Pa.s)}\left(\frac{50\; \mu m}{2}\right)^2 = 0.0005\, m/s$$

Where:

- g= 9.81 $m\,/s^2$ is the gravitational acceleration.
- $\rho_T = 1350\; kg\;/\;m^3$ is the density of turmeric powder ("Bulk Material Density Guide," n.d.).
- $\rho_W\; = 1000\; kg\;/\;m^3$ is the density of water (*Water Density | U.S. Geological Survey*, 2019).
- $d_p = 50\;\mu m$ is the turmeric particle diameter (Chao et al., 2020) ,
- $\mu = 1.002\; x10^{-3}\;\; Pa.s$ is the dynamic viscosity of water (*Viscosity of Water – Martests Instrument*, n.d.).

Next, to describe the flow regime, the Reynolds number for an individual settling turmeric particle is estimated as:

$$R_e = \frac{Up_W d_p}{\mu} = \frac{(1000\; kg/m^3)\;(0.0005 m/s)(50\; x10^{-6} m)}{(1.002 x10^{-3}\; Pa.s)} = 0.025$$

Where:

- U= 0.0005 m/s is the particle settling velocity from the calculation above.
- $d_p\; = 50\; x10^{-6} m$ is the turmeric particle diameter (Chao et al., 2020) ,
- $\mu = 1.002\; x10^{-3}\;\; Pa.s$ is the dynamic viscosity of water (*Viscosity of Water – Martests Instrument*, n.d.).
- $\rho_W\; = 1000\; kg\;/\;m^3$ is the density of water (*Water Density | U.S. Geological Survey*, 2019).

The $R_e = 0.025$ and U= 0.0005 m/s confirms that viscous forces dominate over inertial forces, and it indicates that turmeric particles sink slowly and smoothly through the water without any turbulent mixing, consistent with the Stokes settling velocity framework mentioned in (Lippert & Woods, 2020).

Finally, to estimate the spatial resolution of the video, the distance traveled by a settling particle during one frame exposure can be estimated as:

$$d = Ut = (0.0005 m/s)\left(\frac{1}{125} s\right) = 4\; x\; 10^{-6} = 4\mu m$$

Where t = (1/125 s) is the shutter speed used to capture the video. The result is smaller than the particle diameter of $d_p\; = 50\;\mu m$, meaning individual particles travel less than their own diameter during a single frame exposure.

Visualization Technique:

The visualization technique used to record the turmeric powder flow in the water was direct particle imaging, using one teaspoon of Turmeric powder placed on the surface of warm water. No dyes or additional chemicals were added to the water. The room was completely dark during the video recording, except for the iPhone flashlight (LED) underneath the glass container. This bottom-lighting technique illuminated the turmeric particles from below, creating a bright yellow glow visible against the dark background and making the flow structure clearly visible.

Photographic techniques:

The digital camera used for capturing the video is a Nikon D5200 with the following settings:

- Aperture: f/8
- Shutter speed: 1/125 seconds
- ISO:200
- Distance from camera to glass: 32cm
- Camera resolution: 6000 x 4000 pixels 24.1 MP
- Field of view approximately: 7 cm x 13 cm
- Post-processing resolution: 6000 x 4000 pixels (no editing performed)
- Lens: Nikon AF-S NIKKOR 50 mm f/1.8G
- Frame rate: 30 fps

I chose an f/8 aperture to keep the water cup in sharp focus, and a 1/125s shutter speed was fast enough to capture the slow falling of the turmeric particles without motion blur. The low ISO of 200 minimized the noise. I did not perform any post-processing on the video, so the final resolution remained the same. As a beginner in photography, I chose these settings through trial and error and am still learning how to choose the correct camera settings.

Reflection:

The intent of this video was to capture the beauty of particles sinking in water while showing the physics of negative buoyancy and Rayleigh-Taylor instability. What I like most about this video is the yellow color against the dark background, which makes the flow phenomena clearly visible and beautiful. I also appreciate how simple the experimental setup was while still demonstrating a fundamental physical principle. The critique session was also valuable to me because feedback from classmates and Professor Hertzberg helped me better understand the scientific background of the flow. What I dislike about the video is the video quality, which becomes slightly blurry toward the end. I am still learning how to optimize the camera settings, and I am not sure what caused this issue. It could be my camera settings, and for next assignments, I plan to improve the video and image quality to show the flow more clearly.

References:

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