Fireworks in a Jar

Tandralee Chetia, Get Wet 1, MCEN 5151 Flow Visualisation

September 24, 2023

Abstract

Fireworks in a Jar is an aesthetic fluid dynamic phenomenon that occurs due to varying densities of fluids in a vessel. The underlying flow phenomena can be complex as they include stagnant and moving drops of fluid, the formation of vortex rings, and the effects of gravity and buoyancy. The work tries to capture these details in a still image while appreciating the beauty of fluid dynamics.

1 Introduction

The goal of the study was to capture the Rayleigh-Taylor instability occurring at the interface between two fluids of different densities. In this case, the lighter fluid is the oil which is placed over a heavier fluid, water. The oil is mixed with food coloring which is heavier than the oil. The interplay of these three fluids of different densities leads to complex fluid dynamic phenomena.

Figure 1: Fireworks in a jar final image

2 Flow Phenomenon

The setup of the oil infused with dye over water gives rise to several interesting fluid dynamic phenomena which are described below.

2.1 Rayleigh Taylor Instability

It occurs when the lighter fluid pushes against the heavier one[3]. In this case, a lighter oil mixed with food coloring dye is poured over the water. As a result of this instability, the colored drops begin to sink because they are heavier than the oil, creating a mesmerizing, firework-like pattern. This phenomenon is aptly named "Fireworks in a Jar."

2.2 Suspension Drop

The colored drop forms a suspension drop that tries to settle at the bottom of the vessel due to gravity. As the drop travels through the flow, it breaks up with the increase in velocity forming ring vortices [1]. Some of these vortices are carried upward by the force of buoyancy. In a controlled environment, the formation of a vortex ring is governed by the stroke ratio which can be defined as follows [2]:

$$\frac{L}{D} = \frac{1}{D} \int u_z(t) dt \tag{1}$$

where $u_z(t)$ is the instantaneous discharge velocity in the axial flow direction which is assumed to be uniform across the usually circular discharge plane of diameter D. L is the equivalent stroke length

3 Methods

The materials used in the experiment are as follows:

- A 8.5 x 8.5 x 8.5 (cm) transparent plastic cuboid vessel
- Canon EOS Rebel T3i camera
- Regular 18-55 mm lens
- Two LED lightbulbs
- Tripods to hold the bulbs
- White Posterboard
- Vegetable Oil used in cooking
- Tap Water
- Signature Kitchen Assorted Food Dyes: Blue, Red and Yellow

3.1 Procedure

The vessel that was chosen had a slight increase in its width at the top as shown in Figure 1. This geometry was chosen to make the image look more aesthetically pleasing. The water was first poured into the vessel. The oil mixed with the food dyes is then poured on top of the water. The camera is adjusted to get the right focus and then the image is captured almost instantaneously as soon as the dye begins to drop down.

3.2 Camera and Lighting

The camera used was a Canon EOS Rebel T3i which is a DSLR camera. The 18-55 mm regular lens was put at maximum zoom and focused directly the the jar from the front. The focal length was chosen as 45 mm and the aperture f-number was 5.0. The distance to the subject was 0.53. The camera was placed on the top of a stool for a stabilized image. The lighting used was two LED bulbs that lit the setup from the two sides as shown in Fig 2.

3.3 Post-Processing

The original image was post-processed using the Darktable image processing app ((https://www.darktable.org/) to enhance brightness and adjust the jar's positioning. The settings used in Darktable are the rgb curve and crop image. The image was rotated about 2 deg clockwise. The unedited and edited versions of the image are shown as follows:

Figure 2: The setup used for imaging

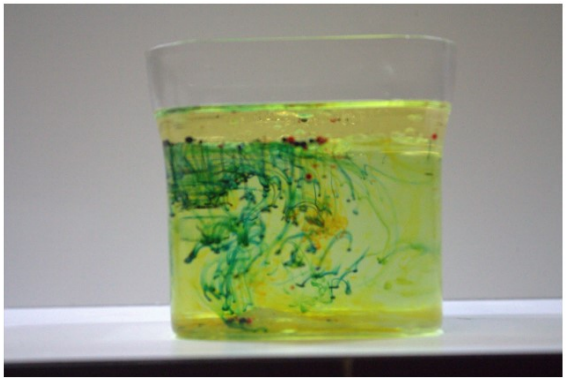

Figure 3: a) Unedited Image b) Edited Image

4 Observations

Even though I initially set out to observe the rayleigh-Taylor instability, I observed various interesting fluid dynamic phenomena such as the ring vortices, and suspension drop. What I like about the image is how a single still can capture so many details about the flow as we see the stagnant dye drops floating on the top of the oil, the dye drops in the process of moving downward, and the ones that have broken down into ring vortices. In the future, more work can be done on observing phenomena with a macro lens that can enhance the quality of images. The detailed process of the fireworks in the jar can also be captured using a high-speed camera.

References

[1] Yuan Lin, Jian Hao Tan, Nhan Phan-Thien, and Boo Cheong Khoo. Settling of particle-suspension drops at low to moderate reynolds numbers. *European Journal of Mechanics B/Fluids*, 61:72–76, 2017.

[2] YRigoberto Ortega-Chavez, Lian Gan, and Philip H. Gaskell. Formation and evolution of vortex rings with weak to moderate swirl. *Journal of Fluid Mechanics*, 967(A16):1–35, 2023.

[3] D.H. Sharp. An overview of rayleigh-taylor instability. *Physica D: Nonlinear Phenomena*, 12(1–3):3–10, 1984.