Visualization of a Vortex in Water Using Food Dye

Purpose and Intent

The purpose of this image was to visualize a vortex using food dye in water. Initially, the project started off as an attempt to visualize the Rayleigh instability using food dye but evolved into a vortex as a phenomenon caused by the spreading of the dye on the water. There was minimal shaking of the shelf that the apparatus was sitting on.

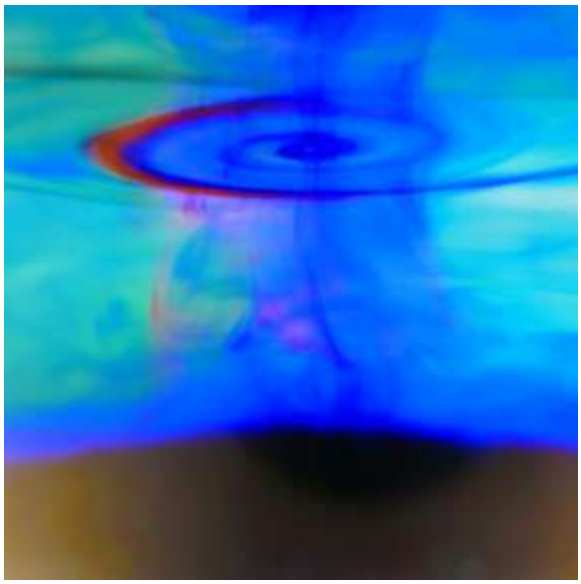

Figure 1: Original Image

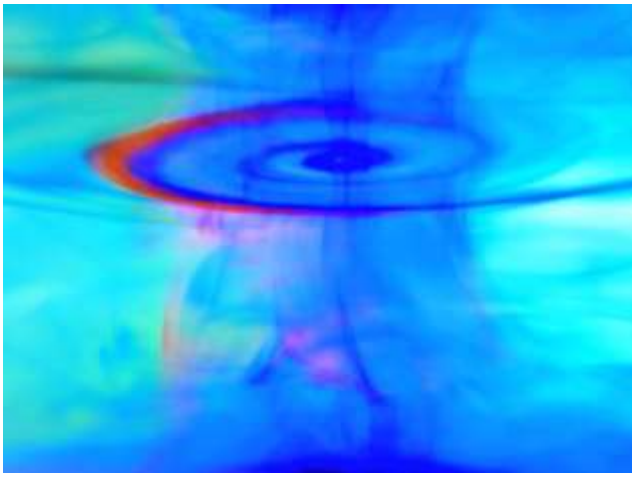

Figure 2: Photoshopped Dye Vortex

Concepts and Theory

The image was taken by dropping a drop of blue and then red dye into a shallow pyrex bowl that was about five inches in diameter. The dye used was of the typical Kroger brand.

The weber number can be thought of as a way to compare the surface tension to a fluid's inertia. The dynamics at play in this experiment are between the kinetic energy of being dropped and the surface tension of the dye droplets. This creates a spreading and the vortex shape shown.

The weber number for this flow was estimated at approximately 9-10, using a drop characteristic dimension of about 1mm. These values are taken for drops of 5cm

above the apparatus, using approximations adapted from Comeau's paper, which relates Weber number and spread factor.

$$We = \frac{\rho v^2 l}{\sigma}$$

A Worthington jet forms when there is rebound and the drop comes back up. For this case, a Worthington Jet does not form and would for higher weber numbers or higher drops, which would yield higher velocities.

Experimental Set Up

Visualization was performed using simple food dye that can be found at a grocery store. Lighting was provided using an indirect halogen light source. The pyrex bowl was placed on a shelf and the drops were dropped approximately 5cm above the water surface. Tap water was used.

Camera specifications

The image was taken using a Panasonic DMC-LX5, with an aperture of f/2.2. To capture the effects of the color, an exposure time of 6 seconds was used. The focal length was 5.1 mm and the ISO used was 400. Photoshop was used to crop the image and to bring out the contrast between the red and the blue in the image. The macro feature on the camera was used as well.

Further Work

The image highlights the effects of dropping water dye in water. Since taking this image, the experiment has been replicated with similar results. The image presents a clear view of the vortex, not just of the swirl at the surface of the water but also of the vortex lines coming down towards the bottom of the pyrex bowl. It would be interesting relating height of the drops to the shape and diameter of the vortex or spread formed. It would help to map out the relationship between height and the formation of a Worthington jet as well.

Vortices could also be explored through the addition of a rotational component. A clearer vortex could be formed by rotating the bowl on a record and then placing drops of dye in the flow and exploring differences between free and irrotational vortices could further develop the idea.

A vortex is described as a spiral motion caused by spinning, turbulent flow around a center. It is important to note that in a vortex, pressure is lowest in center and increases moving away from the center. From Bernoulli's theorem, vortices increase speed as you move away from the center. Common examples of vortices in daily life can be seen off of wingtips in airplanes, dust-devils, tornados, and drains in tubs. Energy is contained in the rotational component of a vortex and ideally, this energy

would not dissipate. Since viscous effects cause shear and slowing of the fluid, energy dissipates moving from the core of the vortex.

References

Bergeron, V., Quere, D. Water droplets make an impact. IOP (2006)

Comeau, David, Kevin LaTourette, and John Pate. "The Effect of Weber Number and Spread Factor of a Water Droplet Impinging on a Super-hydrophobic Substrate." *Program in Applied Math, University of Arizona* (2007). Print.

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