

Flow Visualization – Team Third Paint and Water



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Introduction

For the team third image my team and I were inspired by beautiful work that has been produced using paint and water. Our goal was to capture a beautiful image that demonstrates interesting physics. Initially I was interested in using latex paint to create interesting shapes as the paint flows through water. As a team we decided to work with acrylic paint and create turbulent jets instead. I worked with several team members in order to create my image Daniel Bateman, Jeremiah Chen, and Jason Savath. Daniel deserves special acknowledgement for providing his house and camera. My team was a great asset in creating this image. The final product was the result of teamwork and several tests and trials.

Setup and Physics

The setup for this image was much simpler than other work that I have produced for this class. A pint glass with no labels was used as our vessel for this experiment. It was placed on a counter 4 inches in front of a white sheet of paper used as the backdrop. A desk lamp was placed behind the paper and used as a defused light source. The back lighting that the lamp provided helped to highlight the interesting physics of the fluid flow. The overhead lamps also provided more lighting. The camera was placed about 6 inches away from the glass. The glass was filled with water and a spoon was used to stir the water to and create a vortex rotation prior to injection of paint. Acrylic paint was used for this image. If the paint was not diluted before injection into the water the surface tension and density of the paint would cause it to not clump together and sink to the bottom of the glass quickly. In this case the paint would not dissolve into the water. By mixing the paint and water with different ratios, the resulting solution would create a Rayleigh–Taylor instability when the solution was injected into the glass of water. Below is a diagram of the setup used to create this image.

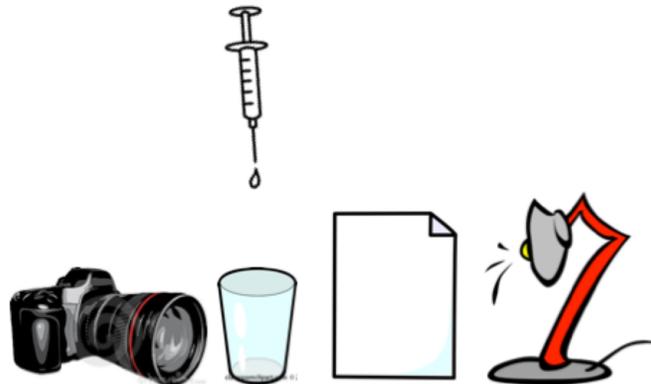


Image 1 - Setup

The first mixture of water to paint tested was a 10 to 1 ratio. This ratio created a nice example of the Rayleigh–Taylor instability but the paint dissolved faster than I liked. After experimenting with several ratios I chose a ratio of 2 to 1

water to paint. This ratio increased the density of the solution and decreased the rate of diffusion. The thicker solution also created a richly colored jet. The Rayleigh–Taylor instability occurs when two fluids interact and a destabilizing acceleration occurs such that the pressure and density gradients are in opposite directions. (Dalziel, 1993) The image that I created looks similar to other classic examples of the Rayleigh–Taylor instability, like an atomic bomb explosion plume or smoke from a volcano.

To really understand what is happening several equations can be examined. To understand if the flow is unstable or stable you must solve for the Eigen value n .

$$n = \sqrt{gk \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}}$$

The relation $(\rho_2 - \rho_1)/(\rho_2 + \rho_1)$ is also known as the Atwood number and can be written as A . The simplified equation becomes.

$$n = \sqrt{gkA}$$

For this image the Eigenvalue is negative and the Atwood number is positive due to the unstable nature of the flow. At the peak of perturbation, the amplitude grows proportionally to the quantity. (Oakley, 2004)

$$\exp(t\sqrt{gkA})$$

So for this case the growth rate is exponential in time and not nonlinear. This is why the turbulent jet expands at a fairly constant angle creating the beautiful example of the Rayleigh–Taylor instability.

Photography Technique

For this image a tripod was used to hold the camera level and to stabilize it. The field of view of the edited image was about 3 inches wide and 5 inches high. The focal length was 21mm. The lens I was using is called The Cannon EF-S 17-55mm f/2.8 IS USM. The camera I used is a Cannon ESO 70D. The original raw image was 3,648 pixels high and 5,472 pixels wide. The final image after cropping and editing was 480 pixels high and 276 pixels wide. The ISO setting was ISO 1,600. The aperture was set at F7.1 with a shutter speed of 1/165. These settings made for a bright image with great depth of field. After taking the photo I made adjustments using GIMP photo editor. First I cropped the image to remove distracting elements. I was interested in keeping the stream of blue paint pouring into the glass but I decided the top of the glass was too distracting. I then used the contrast maps to slightly adjust the brightness and help to make the background look whiter. I then rotated the image in order to make the image look like a rising plume from a volcano. The paint that was trapped on the surface of the surface of the water made a nice base for the image. Below is before editing and after editing pictures side by side.

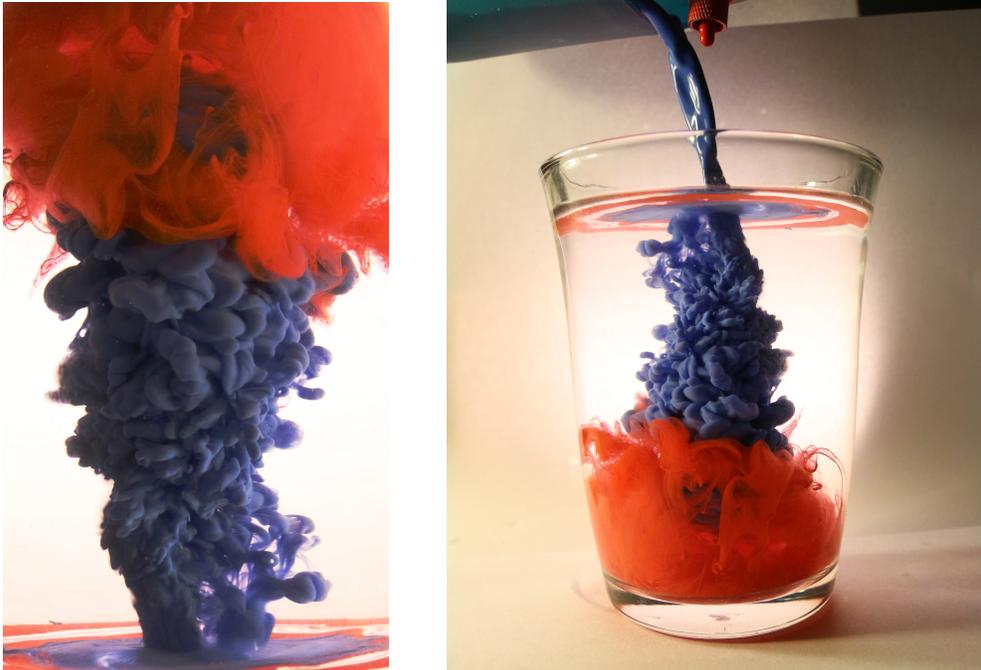


Image 2 – Original vs. Edited Image

Conclusion

In conclusion my team three image was a success. Working with my team this semester resulted in the creation of beautiful images. I also learned a lot about photography from my team. I feel that this image really demonstrates everything that I have learned. I am proud of the clarity, depth of field and beauty of the image. The image clearly displays the Rayleigh–Taylor instability. I don't think I would change anything about this image if I were to do it again. I am still interested in creating images with latex and water. This course has given me the confidence to create images on my own and has inspired me to create more flow visualization images!

References

- Dalziel, S. B. (1993). *Rayleigh-Taylor instability: experiments with image analysis*. Cambridge: Elsevier Science Publishers B.V. .
- Oakley, J. (2004). *Rayleigh-Taylor Instability Notes* .