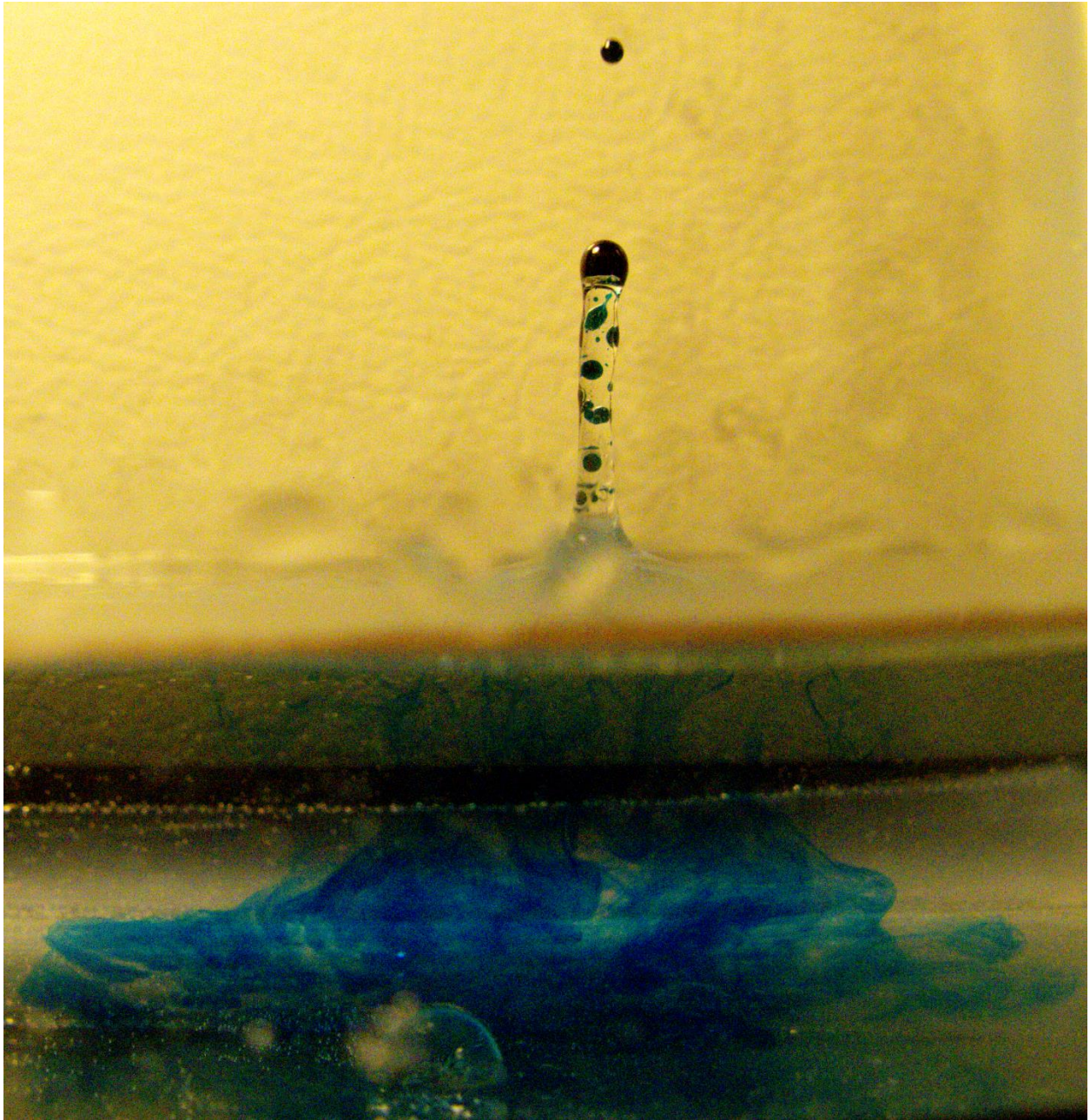


**Second Team Assignment:  
Worthington Jet with Dye Fluid Flow in Water**



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Flow Visualization  
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## Background

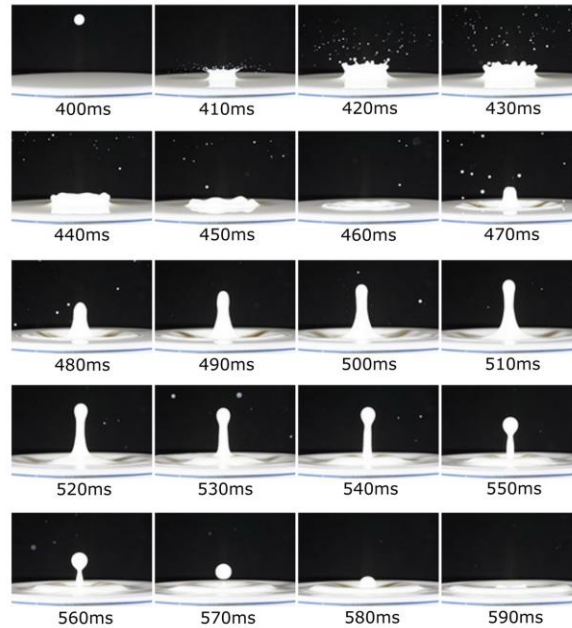
Believe it or not, but the Worthington jet was not part of the plan. The original idea for my team was to get some fluid flow in submerged water and I tried using acrylic paint and dyes. The acrylic paint did not work whatsoever, it immediately sank to the bottom as a “blob.” Putting the acrylic paint to the side I started using dyes, which started giving me a much better result however, I was not pleased with just the dyes in water. I then moved the camera to water level to get an underwater and above view. This is when I started dropping dyes from heights to see how the fluid flow changes in the water and possibly capturing an above water splash. Many trials later, I captured the Worthington jet phenomenon.

## Technique

For the experiment, a small two gallon plastic fish tank was purchased. Using the fish tank, I was able to fill the tank to various heights to capture the underwater flow. After scrapping my initial ideas, I only filled the tank to roughly one and a half inches high, or the height of the center of the camera lens to get both views. The background is my white fridge. I used two different dyes, a green dye and a blue dye. The blue dye mixed very well with water and for some reason the green acted abnormally and was “patchy.” After filling the fish tank to the desired height, I placed some vegetable oil to act as a boundary layer so the dye did not immediately fall through the water once placed. The oil acted okay, the blue dye fell directly through while the green dye was getting caught. The green dye did not fall through and that is why in the image you only see blue dye in the water. With the green dye getting caught in the vegetable oil I started dropping droplets of green dye from roughly two feet above the oil circle. I thought I could capture a visually appealing image and thus I placed the camera so both underwater and above water were in my frame. I dropped the dye with one hand while my other hand took photos.

## Behind the Scenes: The Worthington Jet

To get a better understanding of the phenomenon taking place, I did a little digging and some research. First of all, a Worthington jet is caused by a drop into a liquid (preferably a less viscous fluid) and the drop impact causes a “launch” upward from the conservation of energy law. The Worthington jet happens very quickly and is difficult to capture unless you are specifically trying to capture the phenomenon.



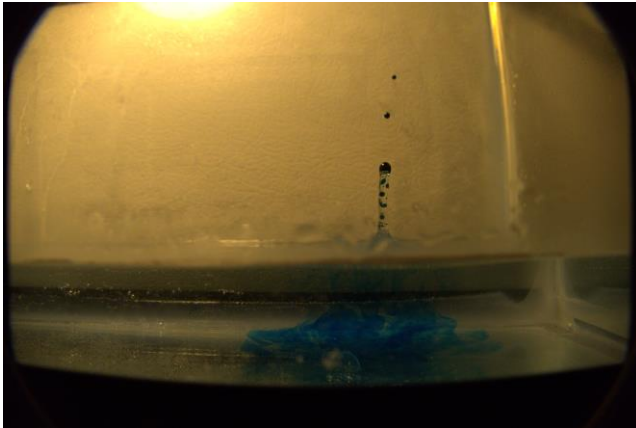
**Figure 1:** Worthington Jet Time Sequence

For a Worthington jet to be present, the droplet must puncture the thin film boundary layer of the liquid below (Rein). According to Rein and his research, a liquid cavity is formed in a cylindrical shape. This cavity expands and “the drop deforms and lines the walls of the crater.” This causes the crown you can see in the first couple time segments. Once the “crown” crater starts to collapse and the energy from the circular pattern causes the jet.

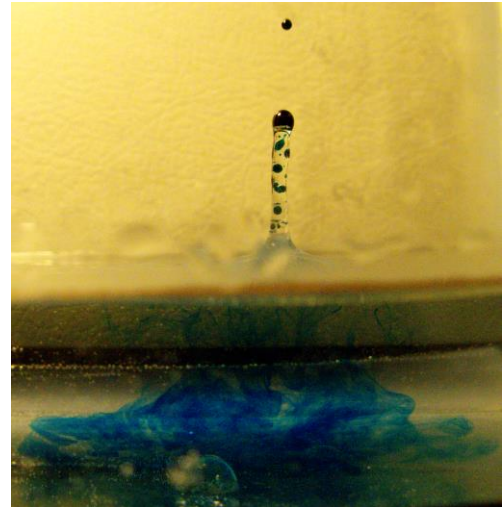
## Image and Post Processing

A Nikon D3300 camera was used for this experiment. The original pixel size was 5488 x 3664 with a resolution of 72 pixels/inch. The shutter speed was 1/200 with an f stop value of f/5.6. I did not alter too much in the post processing. Some of the post processing features was enhancing the brightness and slightly changing the curves so the white would come out more. After post processing on gimp the final pixel size is 2302 x 2376. You can see below the original and edited versions of the image. I liked leaving in the blue dye below because I thought it added a different perspective to the image and kept the theme of the project for my group.





**Figure 2a:** Original Image



**Figure 2b:** Edited image via Gimp

I am not sure why the original photo has a “fish-eye” effect, but I like it because it symbolizes the fish tank I had to use. I also like how you can clearly see the vegetable oil layer and how high the Worthington jet looks. Overall, I tried to focus on both sides of the water and make the image look “clean.” If I had more skill with post processing, I could have made the entire background white to increase the overall images aesthetic.

## Conclusion

I am pleased with the results of my experiment although it ultimately did not really keep the theme of my groups intentions. The Worthington jet totally dominates the image and you don’t even see the blue dye flow in the water until after a couple seconds later. In the future I would have liked to have a white poster board background and to mechanically drop the dye. Because I was frantically dropping the droplets there were splash effects, which you can see in the image and it would be nice to not have those block the image. The overall feedback on the comments seem to be leaning towards cutting out the bottom portion of the flow and strictly focusing on the Worthington jet.

## References

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- Rein, Martin. "Phenomena of a Liquid Drop Impact on Solid and Liquid Surfaces." *Fluid Dynamics Research* 93rd ser. 12.61 (1993): 81-88. Web. 18 Nov. 2016.  
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