Household Magic

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Purpose:

This image was created for the Get Wet assignment of the class MCEN 4151 Flow Visualization. The intent of this image was to show that a beautiful and artistic image could be created with simple household items and an amateur camera. The phenomenon to be seen in this image is known as a Worthington Jet. This jet is created by an object falling a certain distance and impeding a still bed of water. In this case, the object traveling the distance is a saline solution from an eyedropper. The image was realized with the help of Clarisa Czekajlo, a student in the school of Integrative Physiology at the University of Colorado at Boulder.

Sketch/Flow:

The apparatus for capturing this image can be seen in Figure 1. Essentially it consisted of a light source, water bed, dropping point and two different colored backgrounds. The dimensions of the whole apparatus are shown in the figure. The width of the actual picture is 2 inches.

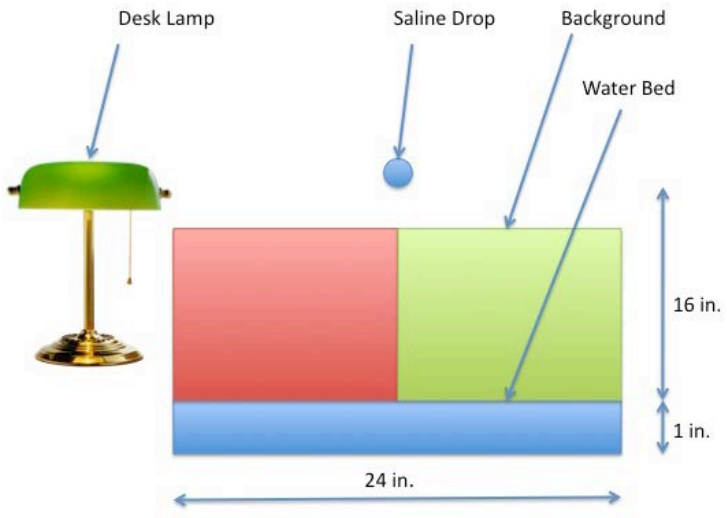

Figure 1: Sketch of Apparatus

The saline drop was realeased 16 inches above the surface of the 1 inch water bed. The water retains a certain amount of surface tension until the drop impinges upon its surface (Figure 2a). The drop then pulls down on the surface of the water, opposing the direction of the surface tension (Figure 2b). Eventually the drop reaches a point where the surface tension cannot withstand the force exerted by the gravity on the drop and the surface breaks [1]. This causes the water to rebound back to the surface, creating a column of water about 10 mm high (Figure 2c). Once the column has reached its maximum height, the tension between the top and bottom of the column is released and a spherical drop of 3 mm is formed (Figure 2d). The picture was achieved at this instant in time when the column is receding into the water and this newly formed droplet is refracting the background and acting as a lense. The entire process of the Worthington Jet occurs in under a second from drop to settling. Refer to Figure 2 for a visual reperesentation of what was just explained.

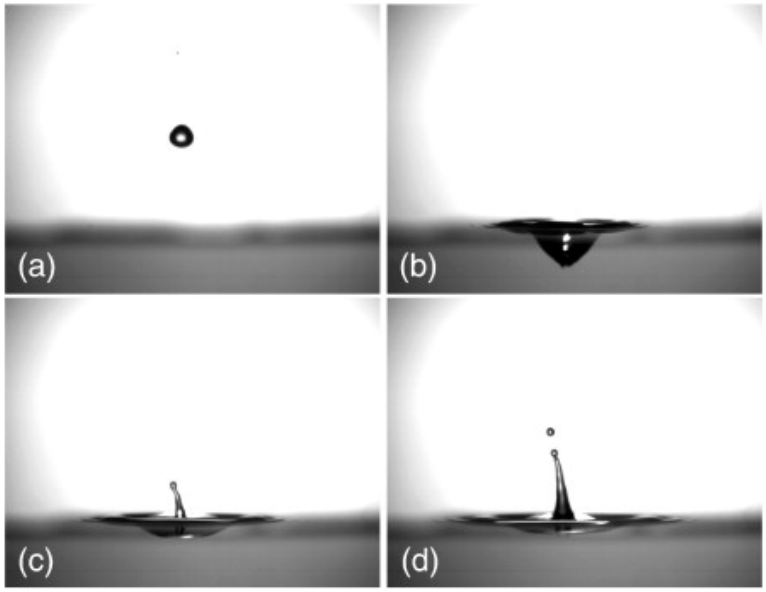

Figure 2: Cycle of a Worthington Jet [2]

It is important to determine the Reynold's number of this experiment as it will tell whether the flow of the image is that of turbulent or laminar flow. It is an appropriate guess that the flow in this situation is turbulent due to the distrubance of the water bed upon impingement by the saline drop. To test this theory, it becomes evident that the velocity of the drop must be calculated by first using Newton's Constant Acceleration equations. This equation is shown below:

$$V = \sqrt{{V_o}^2 + 2as}$$

$$V = \sqrt{0^2 + 2\left(-19.6\ \frac{m}{s^2}\right)(.406\ m)} = 2.82\ \frac{m}{s}$$

Having calculated the velocity of the drop to be 2.82 m/s and knowing the kinematic viscosity of water at room temperature to be 1.00E-6 m^2/s and the distance that the drop falls to be .406 meters, it becomes possible to calculate the Reynold's number of the fluid once impinged by the saline drop [3]. The cacluation for Re is shown below:

$$Re = \frac{vL}{\nu}$$

$$Re = \frac{\left(2.82\ \frac{m}{s}\right)(.406\ m)}{1.006\ x\ 10^{-6}\ \frac{m^2}{s}} = 1.15\ x\ 10^6$$

Obtaining a value of 1.15E6 for the Reynold's number means that the water bed experiences turbulent flow once the saline drop hits and breaks the surface of the bed of water. This turbulent flow can be seen in the picture in the ripples that are seen distorting the bubble at the bottom of the water bed. It is important to note the occurrence of turbulence in order to

recreate a similar event. If the droplet is dropped from a fraction of the height, the turbulency will either be non-existent or not noticeable at all.

Visualization Technique:

The main technique in this picture was to ensure that there was a noticeable image to be refracted by the image. In this case, that image was two houshold notebooks of different colors. This gave a specific reference to the size of the image as well as two distinct colors to be refracted by the lenslike drop. A concscious choice to use semi-settled tap water was made in order to add texture around the focal point of the image. The bubbles help lead the viewers eyes towards the center of the piece where the real phenomenon is occuring. The only light source came from a standard desk lamp pointed directly at the notebooks in the background. This was in order to light the bed of water with as much of the color of the background as possible. The water bed was also placed over a black surface so that the bed of water could be lit up as much as possible.

Photographic Technique:

The field of view of this image was mentioned before to be 2 inches from edge to edge. The distance from the object to the lens was 1 inch and the lens had a focal length setting of 6.2 mm, this meaning that there was no optical zoom set during the capture of this image. The picture was taken with a digital camera. The original size of the image was 3648 x 2736 but was eventually cropped to a size of 3622 x 2264 to eliminate unwanted elements of the picture and to create a more capturing focal point. The image was captured with a Canon PowerShot SD1200 IS with an f stop of 2.8, a shutter speed of 1/25 seconds and and ISO setting of 400. The image was altered in iPhoto by enhancing the contrast, the definition of certain parts of the image and slightly increasing the values of the green pixels in the image. Refer to Figure 3 for original image.

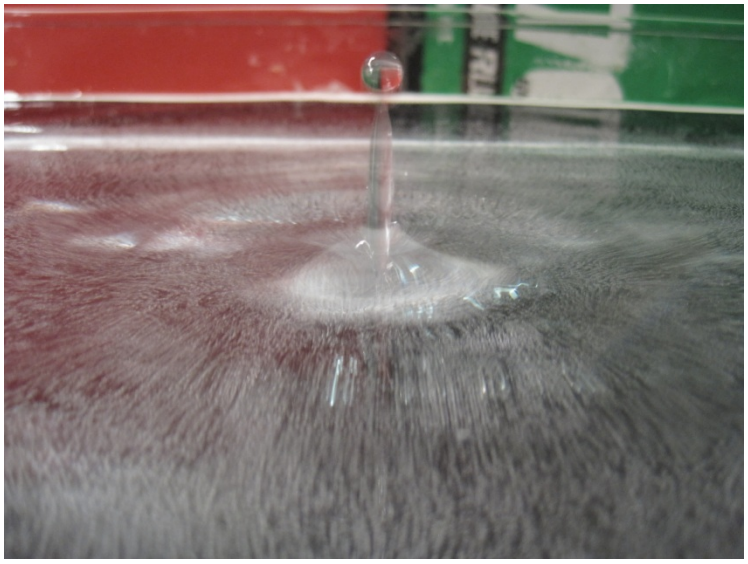

Figure 3: Original Image

Concluding Remarks:

This image reveals that there are beautiful fluid phenomena found in everyday life. The Worthington Jet is a testament to the fact that often times people overlook things that can contain beauty at microscopic levels. Just because you can't see something, doesn't mean it's not there. Taking the time to look closely can often reveal beautiful and powerful things.

I like the fact that I was able to capture this image with a camera that was not meant for situations like this. The shutter speed on the camera would suggest that it is nearly impossible to capture something happening so quickly. Being able to capture this image was a feat in and of itself. At the same time, I also dislike the fact that I had a camera with such a slow shutter speed. If I was able to capture the picture faster, things would have looked smoother and more polished. The physics of a Worthington Jet show the dynamics of surface tension and gravitational effects quite well. It is a very interesting thing to look at closely and to understand what is going on behind the scenes of these water droplet pictures that can be seen all over the internet. As for questions, I can explain how the droplet forms at the top of the column as shown in the image but I do wonder why the droplet forms here and why the top of the column doesn't recede into the water like the bottom of the column does.

I do feel that I fulfilled the intent I set forth in that I set out to make a piece of art by using household items and a camera that was very simplistic. I believe my image is very captivating and unique in its use of long exposure in a swiftly occuring phenomenon. The main aspect that I would improve is to capture a more professional image by using a more professional camera. Though the use of the longer shutter time creates a unique blur in the picture, it would be nicer to have a little bit clearer image by using a nicer camera.

It would be nice to expand this image into a high speed, high resolution movie that illustrates the different phenomena happening to create the Worthington Jet shown in my image. You could see the water surface being pulled down by the droplet and the rebounding surface forming the water droplet as seen in the image. This would require a very nice camera but would be a very neat experiment to perform using different water bed depths, different heights and different fluids in the water bed. These are all things to think about for future exploration.

References:

[1] Jenna McKown, Experimental Study of Worthington Jet. Pg 1-2. 2011
[2] http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html
[3] Firat Y. Testik, Atmospheric Research, Volume 98. Pg. 538