Team Report #3

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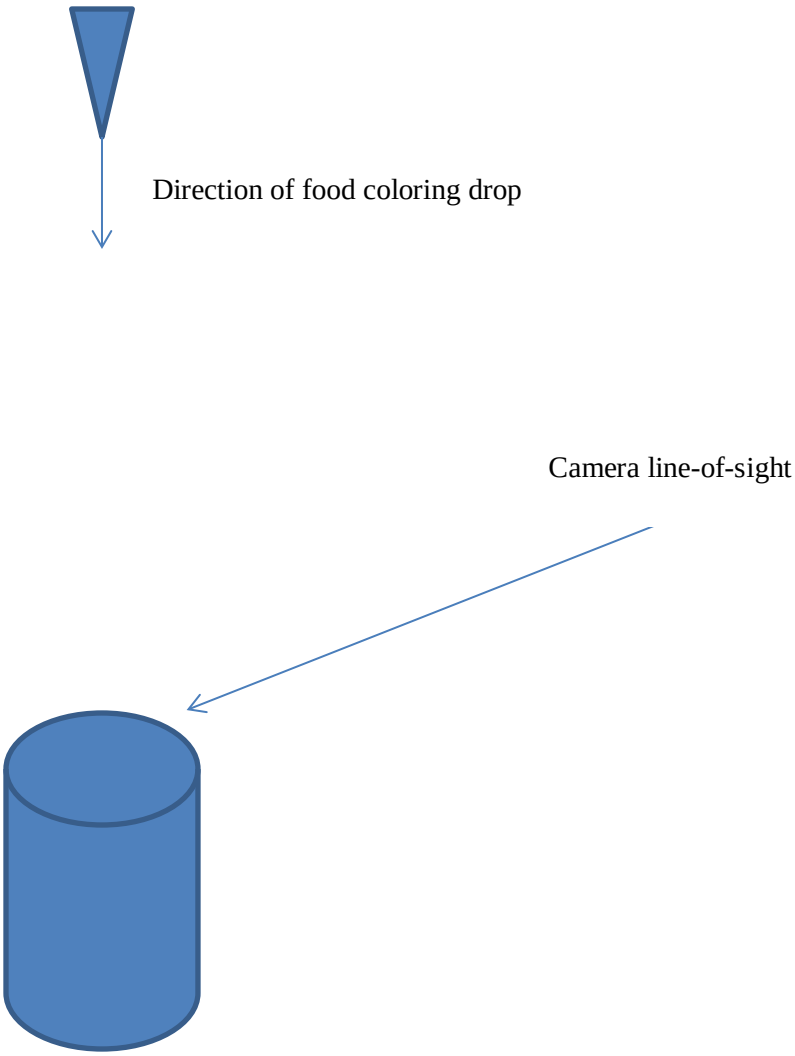
Team Project #3 Report

The purpose of this project was to capture the effect known as a “crown splash” formed when an object impacts the surface of a body of fluid at rest. This was a team project, and I worked with Jeff Byrne in the capturing of this image. The intent of the image was to capture a drop of food coloring dropped into a glass of milk at just the right moment so that the viewer could observe a unique effect created by the impacting droplet. My image captured a crown splash, while Jeff captured a different phenomenon which is described in his report. The image submitted can be seen below.

The setup and experimental design used to capture this image was relatively simple. A glass full of milk was placed on the ground while a camera was held at a slight angle above the surface of the milk to try and look down into the crater formed by the crown splash. The camera angle can be seen above to be approximately 30 degrees from the horizontal, and approximately 12 inches away from the glass. The glass contained milk that was roughly 6 inches deep and 4 inches across. The food coloring was dropped from a height of approximately 6 feet above the surface of the milk at a steady flow. As individual drops impacted the surface, images were taken at as fast of a pace as the camera would allow until the desired effect was captured. It was found that a higher dropping point for the food coloring produced more dynamic results, and thus the height was raised to the 6 ft. height from an original height of approximately 3 feet. The setup for the experiment can be seen in the image below.



A simple series of calculations can be done to approximate the Reynolds number of the droplet entering the milk, which provides for a better understanding of the fluid effects at work. The equation to calculate the Reynolds number is given as $Re = \frac{VL}{v}$. Dynamic viscosity of the food coloring is approximated to be the same was water, 1.002 kg/m*s. The same is done for the density of the fluid. The velocity of the food coloring at impact is calculated to be 6 m/s. The diameter of the droplet is approximated to be 1 mm. These approximations show the Reynolds number to fall around a value of 6 (with high rounding and approximation error). This number is so low that it is very clear that viscous forces account for the majority of the effect seen in this image.

The main fluid effect that causes a formation like this comes from the Rayleigh-Plateau instability, which is a phenomenon created when surface tension effects cause a single body of fluid (such as the drop of food coloring) to break into multiple droplets. In this case, the impact of the drop on the surface of the milk causes surface tension to pull apart the jet shooting out of the surface of the fluid into multiple smaller droplets in a symmetric formation. This symmetry creates a circular formation, and the effects at the leading edge of this circle form the clearly defined drops that appear to form the “crown” shape, giving the crown splash its name. This

effect can be controlled and manipulated fairly well, and altering the fluids in action and depth of the surface fluid can greatly increase the clarity and formation of the crown shape.

The visualization techniques used for this image were relatively simple. The camera was mounted on a tripod at first, but it was found that with the dropping of the food coloring adjustments needed to be made quickly, so the final image seen was taken with the camera in hand. Multiple images were taken in rapid succession, so a flash was not used and lighting came from lamps in the room and the ambient lighting of the room. The food coloring was McCormicks Food Color and the milk was Safeway brand fat-free milk.

The final image seen was cropped quite a bit from the original image, so the pixel dimensions of the shot are 972 and 1037 in the X and Y directions, respectively. The distance from camera to surface is approximately 12 inches, and the zoom on the camera was used to try and fill the shot with the surface of the milk. A Nikon D50 DSLR camera was used to take this photo, with an F-stop of f/5.6, and ISO of 1600, Shutter Speed of 1/640 sec, and Focal Length of 50.0 mm. The shutter speed and ISO were forced into high settings due to the fact that this effect was so quick in action and difficult to capture, and therefore a small amount of clarity was lost in the final image. Photoshop work was very minimal, with cropping being the major change and minor adjustments to increase color clarity and sharpness of the final shot.

Overall, I am pleased with how this image captured the crown splash effect. It was not easy to capture such a fast effect, or to do so with any clarity in the image. If I were to do this experiment again I would likely alter the depth of the fluid I was using as a surface fluid and possibly look into using different fluids than milk and food coloring (results of my research after the image was captured). However, for the given circumstances I think that Jeff and I did a great job in showing the effect we set out to photograph, and I think the image is very visually appealing and a great example of a common, but difficult to capture fluid phenomenon.

References:

"Rayleigh-Plateau instability causes the crown splash" by Robert D. Deegan, Philippe Brunet, and Jens Eggers. http://arxiv.org/pdf/0806.3050v2.pdf

"Nonlinear dynamics and breakup of free-surface flows" by Jens Eggers.
http://rmp.aps.org/pdf/RMP/v69/i3/p865_1