Flow Visualization Essay – Second Group Assignment

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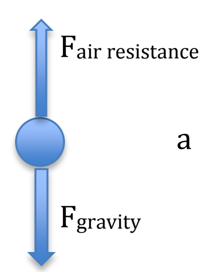
The image that was taken depicts a single water droplet falling into still water. This is a simple concept that was difficult to capture but interesting to learn about. Every day we see water droplets fall into still water and think nothing of it. It is just something that everyone has seen a million times. Although when you see a water droplet impact the surface it is very difficult to determine what the 'splash' looks like. With the use of high-speed cameras, viewing this phenomenon has become easier. This essay will describe both the physics of water droplets and the artistic qualities of the image.

In this experiment a fish tank, a small-tipped bottle, a highlighter, and water were used. The original idea was to put water into the fish tank and create constructive and destructive interference with waves and slits. The first attempt didn't work well and was very difficult to photograph. The second attempt involved soaking the inside portion of the highlighter in the water until the water was completely saturated and we were able to use black lights to further illuminate the surface of the water. As it was still difficult to photograph the waves, the team decided to try to use the small-tipped bottle to drop the liquid into the still water. The result was a simple but interesting experiment. It was difficult to photograph the drops actually landing, but the team was able to get some interesting photos; including the photograph used for this submission.

When a water droplet impacts the surface of still water a few interesting things happen. First, the surface tension of the water surface is disturbed. Next, the liquid creates a void, creating a change in the pressure of the surface. A normal force is then created; causing water to move in from the outer edges of the 'hole' created and collides at the center. These steps can be referred to as the 'crown', the 'column', 'propel', and 'collapse'.

In this experiment the droplet strikes the water it falls into the surface at a high speed, a column is formed that extends upward at a higher velocity than the actual drop had fallen into the water. This is the 'propel' stage where a column has risen up and the top of the column is moving so fast that it creates a new droplet that can be seen in the motion blur in the submitted image.



Since the initial droplet was dropped from a height of about a foot, it is expected that it reached its terminal velocity, or the velocity at which the force of gravity is equal to the force of air below the drop. A simple free body diagram showing the force balance on a single droplet is shown at the right. In this case, the forces can be described by the simple equations below.

$$F_{gravity} = mg$$

$$F_{air\ resistance} = \frac{1}{2}\rho S C v^2$$

In these equations m is mass, g is gravitational acceleration (9.81 m/s^2), ρ is the density of air (1.2 kg/m^3), A is the cross sectional area of the water droplet (approximate average of 0.0015 m), C is the drag coefficient, and v is the velocity. To calculate the terminal velocity, these two equations are set equal and the v is solved for. The result is a terminal velocity of approximately 20 m/s. This is the velocity of the droplet as it strikes the surface of the water. Therefore, the velocity of the droplet that has risen above the column is moving faster than 20 m/s.

The camera used was a Canon PowerShot. This was not the most ideal camera to use for capturing such fast-moving phenomena, but it was able to capture a great image. The ISO was set to 100, this helped keep the image from being noisy since the shutter had to be so high. The shutter was set to 1/80. This was necessary for getting some motion blur but making the column appear to be sitting still. However, the higher shutter meant that the camera didn't take in as much light as it needed to. The f/stop was set to F2.8. This gives a stop number of 3, meaning that the light exposure was fairly high and the effective aperture diameter of the lens was 2.8. To get a little more focus, the macro setting was turned on.

The editing that went into this image was primarily altering the RBG balance so that the water, which was originally a neon yellow/green became a nice soft teal color. The contrast was also increased so that the outlines of the column and the motion blur were easier to distinguish.

In the future a setup similar to those created by Martin Waugh (reference) would be ideal for taking interesting droplet photographs. It would also be interesting to increase the shutter speed so that the motion of the droplet could be slowed down even further. Ultimately, I am happy with this image because it shows a simple concept that has proven to be more complex and interesting than anticipated. The image also looks great and shows this phenomenon well.

Resources:

http://www.imaging-resource.com/news/2012/04/26/how-martin-waugh-makes-his-astonishing-liquid-sculpture-photographs

http://www.wired.com/wiredscience/2011/08/how-fast-is-falling-rain/