Fall 2015

Flow Visualization

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[TEAM IMAGE #3]

For this team image, our group wanted to capture fluid phenomena in slow motion again. The inspiration for this specific video came from the Slow Mo Guys. In this video, these artists, Free and Gruchy, captured water spirals at a frame rate of 1600fps. We liked this video because it truly looked like a galaxy forming. There was great symmetry in the spiral pattern with interesting physics too! As an adaption to this inspiring video, our group used a rectangular sponge instead. I provided the sponge and water for the team to experiment with. Joanna rented the high speed camera and gave the group access to different backgrounds. Luke operated the camera and Rob helped focus the camera.

This video was shot in the middle of the day when the sun was very bright. The video was captured outside of a building where the camera still had access to a power supply outlet. Focusing the camera was a difficult process but it led to a well-focused video. To do this, we took a video of a piece of paper with text on it while it moved various lengths away from the camera. We watched this video to determine where the best focus was and performed the experiments at this distance away. To capture the spiral effect, I started with a completely damp sponge and held a single corner. Once the camera started recording, I tossed the sponge upward while applying a torque. This moment on the sponge caused it to spin in the air. In the video, it can be observed that the corner I initially held did not create a water stream. This is because water was draining where my hand applied force. Figure 1, below, shows how the experiment was set up. A white cloth was set up against the building and the camera pointed in this direction. The experiment was set up about 6 feet from the camera. To avoid any shadows in the frame of view, the person tossing the sponge had to be on the right side of the camera.

Figure 1: Actual experimental setup. Photo taken by Joanna Bugajska

The table below shows important information regarding the how the video was captured. Windows movie maker was used in post processing to convert the image to black and white and then trip both ends of the original video. The camera used has a problem with white balance so the majority of the videos turned out extremely dark or with a yellow tint. To avoid this unnatural color, the final video is in black and white. The table below contains information about the specific camera setting and specifications.

Camera	Olympus I Speed
Lens	Prime 50 mm
ISO	Unreported fixed ISO setting
Shutter Speed	½ the frame time
F-Stop	1.4
Contrast Setting	Normal
Original Size	800x600 px (WVGA)
Flash	No flash
Lighting	Natural Sunlight
Distance from object to lens	5-6 feet

Sponges are unique because of their porous material. Sponges are made by combining cellulose fibers, hemp fibers and sodium sulphate crystals. This mixture is baked and during the heating process the sulphate crystals break down leaving an intricate hole pattern. The end product has more empty space than fibrous sections. Sponges retain water by soaking up the liquid and storing it these empty spaces which causes the fibers to swell. This expansion prevents the water from flowing right back out. It isn't until the sponge experiences the necessary forces that the water is squeezed out [2].

The physics behind how water will break away from a surface is especially interesting in this video. At any instant, it may appear that the water is moving in the opposite direction from the sponge. This is not the case and is only an illusion. For a single point on the surface of the sponge, there are different velocity vectors: tangential and radial. These can be seen in Figure 2. These vectors add together to obtain the total velocity vector.

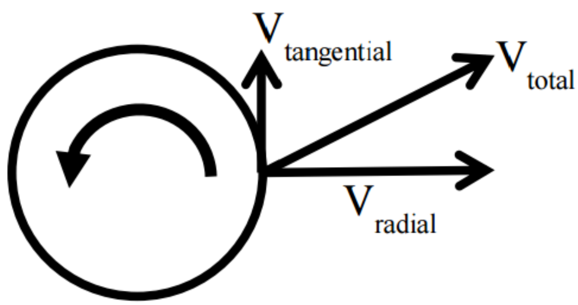

Figure 2: Diagram of the different velocities at the surface of a spinning object

Once the droplet of water breaks free from the surface, the Fibonacci ratio takes effect to create the spiral shape. The Fibonacci ratio is very common in the natural world. The pattern can be in in pine cones, sea shells and flower petals. The ratio is obtained by taking a number and adding it to the previous number. For instance, if the pattern starts with the number 1 then the sequence would be 1, 1, 2, 3, 5, 8, 13, 21 and so on. The golden ratio is when the two numbers are added and the ratio of their sum is the same as the ratio of this sum and the largest number [3]. This says that a golden ratio spiral would grow approximately 1.6 per revolution. This ideal spiral can be seen in Figure 3 overlaid with an image from the video. Both spirals almost perfectly overlap each other.

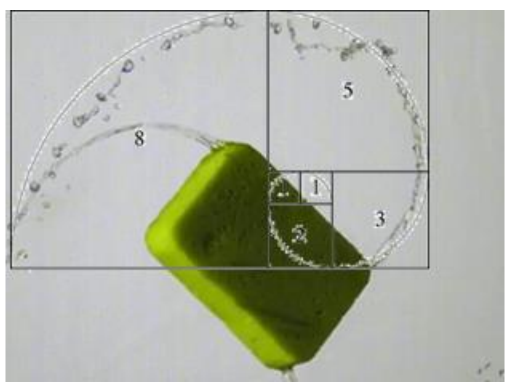

Figure 3: An ideal golden spiral

This video was frustrating to produce because the camera had many issues. It was difficult to set the focus, white balance and it took a very long time to render and download the video. Despite these annoyances, I am very happy with how the video turned out. I think it is a good balance between art and science. In the future, I would try using different colors of water or different fluids. The density of a different fluid might change how the spirals are produced.

References

[1] Gnarly Water Spirals at 1600fps - The Slow Mo Guys. (n.d.). Retrieved December 14, 2015, from https://www.youtube.com/watch?v=FVo2qdXxQ7o

[2] How Do Sponges Absorb Water?. (n.d.). Retrieved December 14, 2015, from http://www.ehow.com/how-does_4661324_do-sponges-absorb-water.html

[3] Golden Ratio. (n.d.). Retrieved December 14, 2015, from https://en.wikipedia.org/wiki/Golden_ratio