Team Image #3 Report

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This image is a product of the third team image assignment for the Flow Visualization course at the University of Colorado at Boulder. This idea was inspired by my teammate, Danielle Metzner, who has seen the effect of water droplets on flowers in many works of art. Danielle and I worked together to photograph these images, with the intent to capture water condensation droplets on flowers. It was inspired by images seen online and by the flowers that have begun blooming with the spring season! The phenomenon demonstrated in the final image displays the surface tension of water on the surface of a flower petal. We were able to capture the final image and original intent without too much difficulty.

The flow apparatus used in this image consisted of an orchid plant, a white foam poster board, a spray bottle, a yellow orchid plant and a camera. A schematic of the flow is demonstrated in Figure 1. Water droplets are best captured when the lighting is soft, therefore the overcast day allowed for the light to reflect off the water droplets enough to be visible through the lens of the camera. The basic flow demonstrates the surface tension of water and how it holds onto different surfaces. This phenomenon is created by the hydrophobic surface of the orchid flower. The opposite of hydrophobic, otherwise known as hydrophilic, is demonstrated by surfaces that cause water to spread out when it hits a surface. Hydrophobic is the opposite phenomenon, which is demonstrated by water droplets forming on a surface. Different flowers have different tendencies of attracting and repelling water droplets[1]. When Danielle and I first experimented, we used 3 different types of daisies along with the orchid plant displayed in my image submission. It was interesting because each flower had a different inclination to let the water droplets stick onto the pedals. For example, a red daisy (Figure 2) was very difficult to photograph because the water droplets did not stay on the flower pedals long and when they did, they were not large enough to allow the camera to focus. This is an example of a plant with a more hydrophilic disposition because the water had a higher tendency to form

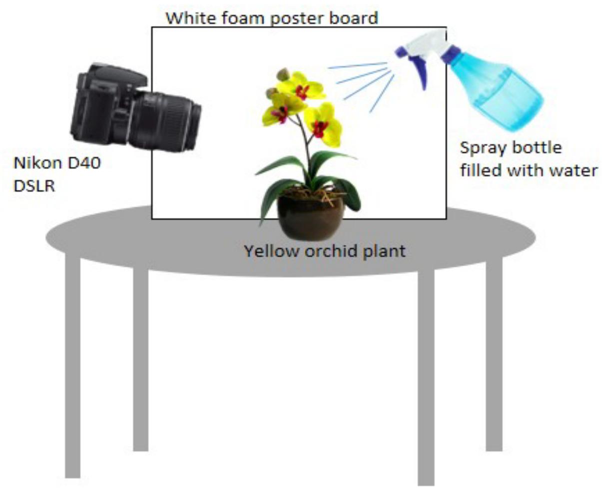

Figure 1. Schematic of flow imaging set-up.

Figure 2. Red daisy with a more hydrophilic surface.

[1] Chandler, David L. "Explained: Hydrophobic and Hydrophilic." *MIT News*[Boston] 16 July 2013: n. pag. Web. 28 Apr. 2014.

pools on the surface of the flower pedals than to form droplets. The purpose of hydrophilic plants is for water and nutrient absorption. However, if water remains on the surface for too long, it can hinder the gas exchange that occurs on the pedal, which can reduce photosynthesis and create biofilms which negatively impact the flowers' growth[2]. Since orchids are a plant with a hydrophobic surface, it is an ideal environment for the condensation of water droplets. Therefore, the orchid is an ideal flower if one would like their pedals to last longer because the hydrophobia of the surface does not cause as many negative effects on the surface.

The water droplets that appear on the flower pedals form due to surface tension, which pulls the drop into a spherical shape due to the cohesive forces[3]. These droplets form into spherical shapes because of the fine microstructure that composes the surface of the orchid pedal. Therefore, the liquid-solid contact area and the water droplet adhesion is reduced[4]. Additionally, surface tension accounts for the equilibrium pressure difference between the two fluids of the droplet – water and air[5]. The force-balance of this type of water droplet can be modeled by the Young-Laplace equation:

$$\Delta P = \frac{2\gamma}{r}$$

In this equation, ΔP is the difference between internal pressure and external pressure, r is the radius of the droplet, and γ, gamma, is the surface energy, which is 0.072 N/m for water. Therefore, by assuming a variety of different radii of the droplets on the orchid pedals in my image, I calculated the pressure differences that could be possible for the droplets in my image. These pressures are shown in Table 1. From this table, it can be seen that as the droplets increase in size, the pressure difference decreases, meaning that the droplets are more likely to break open. Overall, the physics of the fluid flow displayed in my image are a combination of the hydrophobic surface of the orchid and the surface tension that keeps water droplets help together.

Radius (mm)	Radius (m)	Pressure Difference (Pa)
0.5	0.0005	288
1	0.001	144
1.5	0.0015	96
3	0.003	48
5	0.005	28.8

Table 1. Table of water droplet radii and corresponding pressures

The materials used to create this image consist of various types of flowers and a spray bottle. These were both obtained from the local super market, King Soopers. The orchid, featured in this image, is a Westerlay Orchid from Carpinteria, California. In addition to the flower and spray bottle, a white foam poster board was used for the background of the images.

[2] Koch, Kerstin, and Willhelm Barthlott. "Superhydrophobic and Superhydrophilic Plant Surfaces: An Inspiration for Biomimetic Materials." *Philosophical Transactions of The Royal Society* 367.1893 (2009): 1487-509. *CrossMark*. Web. 22 Apr. 2014.

[3] Nave, R. "Surface Tension and Bubbles." *Surface Tension*. Hyper Physics, n.d. Web. 27 Apr. 2014. <http://hyperphysics.phy-astr.gsu.edu/hbase/surten2.html>.

[4] Teisala, Hannu, Mikko Tuominen, and Jurkka Kuusipalo. "Adhesion Mechanism of Water Droplets on Hierarchically Rough Superhydrophobic Rose Petal Surface." *Journal of Nanomaterials* 2011 (2011): 1-6. *Hindawi Publishing Corporation*. Web. 28 Apr. 2014.

[5] Zang, Ling. "Lecture 8: Surface Tension, Internal Pressure and Energy of a Spherical Particle or Droplet." *The University of Utah*. Web. 28 Apr. 2014.

There was no flash used to take this image since the image was captured on an overcast day at about 4:00 pm so that the lighting was diffuse. The image was photographed using a Nikon D40 DSLR camera and the distance from the lens to the object was about 1.5 feet. The image was shot with a shutter speed of 1/80 of a second, F6.3 exposure and ISO 200. The size of the field of view was about 4 inches, since the single orchid flower shown in the image is 2 inches in diameter. The final image was post-processed using iPhoto where I chose to make minor adjustments to enhance the quality of the droplets shown in the image. To do this, I increased the definition, highlights and sharpness of the image. I also adjusted the exposure and contrast by moving the notches to the left to decrease these settings. Making these adjustments allowed for the background of the image to become a clearer white and the droplets to stand out slightly more. The final image is the same size as the original, at 2000x3008 pixels. The two images can be seen side-by-side in Figure 3 to see the differences in editing.

For future work, I would have liked to edit the final image so that the background is an even starker white. Furthermore, I think the editing of the image could be improved upon even more with a further zoom and definition of the droplets. Overall, photographing the flowers was a very fun and interesting process. The entire set-up was uncomplicated, yet it really helped me understand the art of finding the correct settings to use on a camera. Although simple, the physics of the water droplet in this image are appealing and very telling of the surface tension of water on a flower pedal surface. I would like to continue this idea further with even more images of water condensation on flower pedals, or other parts of the flower. I would also like to be able to show the reflection of something in the droplets, such as the one droplet that is hanging off the orchid pedal in my image.

Figure 3. Side-by-side of original (left) and edited (right) final orchid images.