Get Wet: Wax and Water Hydrophobia

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Flow Visualization: The Physics and Art of Fluid Flow

The goal of this flow visualization project was to explore some type of fluid phenomena. I had multiple ideas going into the project but I ended up landing on the hydrophobic properties of wax which would display surface tension through drops of water that were placed on the wax. My inspiration for this project was drawn from wax and other types of coating that are used on rain jackets to repel water droplets.

The main phenomena that can be seen in this experiment is surface tension in the individual buble with the help of a hydrophobic surface such as wax. The wax surface being hydrophobic allows us to witness this phenomena because the wax is repelling the water at a relatively high contact angle. Normal surfaces have a lower contact angle and we are not able to see the water droplets as well, instead they end up flattening out and looking more like a puddle rather than a droplet. The diagram below shows a droplet shape that was in the raw picture and the angle of contact, which is greater than 90 degrees and allows for the droplet shape to form.

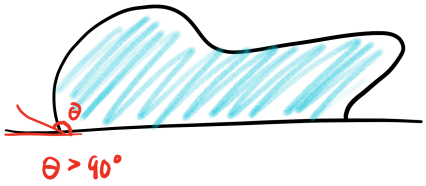

Fig. 1: Contact Angle

The force of surface tension is pushing outwards in all directions of the water droplet and therefore the shape of a sphere is the most ideal shape for a water droplet. This perfect sphere shape for ideal surface tension and surface area is relatively hard to achieve because either the droplet needs to occur in very low to zero gravity situations or occur on an extremely hydrophobic surface. Below is a diagram of both the force of surface tension and how it acts in all directions outwards as well as the difference between an ideal and realistic gravitational force.

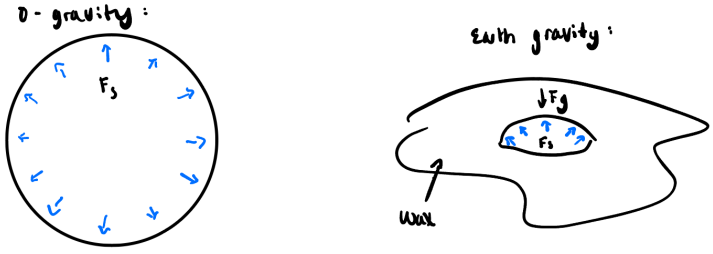

Fig. 2: Surface Tension - Ideal vs Non Ideal

For analysis purposes there are a multitude of fluid dynamic based equations that you can relate to this experiment but the Young-Laplace equation is particularly interesting. This equation is what can be used to calculate the surface tension “γ” in terms of a pressure differential “ΔP” and the radius of the droplet “r”. The equation below shows how these terms relate to one another and how to solve for surface tension.

$$\gamma = (\Delta P * r)/2$$

Eqn. 1: Young-Laplace equation

The set up for an experiment includes proper lighting, a dark backdrop, a dark surface, and a dark room. The idea is that there needs to be one soft light source on the droplet of water to really define the phenomena. If there is too much light then the droplets will appear more washed out and lose that “pop” look that is desired in this experiment. Below is a picture of the set up that I had used for this experiment. It shows the dark surface that I melted the wax on, that being an old calculus textbook as the dark backdrop that I used which was two towels. The lighting that I decided to use was a phone camera flash light covered with tissue paper to try and soften the light and make it cover a wider path. Then I would turn all the lights off so that the only source of light is the phone. The second picture below shows the process in which I set up the wax portion of the experiment. This was done by simply scraping candle wax with a spoon then melting the wax with a lighter to try and get a flat surface to put the droplets on.

Fig. 3: Camera Shooting Setup

Fig. 4: Wax Melting Setup

The camera settings that I chose to use were an automatic setup on my Nikon D3200 DSLR. This picture required a very close image so that you could see the dime size droplets in detail. The lens for the final picture was roughly 2 inches away from the droplets. The lens that I was using was a AF-S Nikkor with a 18-55mm focal length. The D3200 took a 6016x4000 pixel raw image and then after processing and color correction the image was at 1300x867 pixels. The settings for the exposure are as follows, 1/30 shutter speed, f/5.3, and 3200 ISO. The raw image originally already had a lot of detail and captured the phenomena pretty well, but to make it pop more I increased the whites and made the darks darker as well as adding a sharpening filter to the image. In general these settings were not intentional because I had never used a DSLR camera before but the results ended up making a very good picture. I attempted to get more of the droplets in the picture but I was having trouble with the focus. I tried adjusting the shutter speed but this made the image insanely dark, so I stuck to my original settings.

For my first flow visualization project and photographs, I think that these pictures turned out well. I don’t think the focus is at its fullest potential but the loss of focus on the edges of the wax also adds some emotion to the picture and draws your eyes to the largest droplet. Going forward I think I need to ask more questions and do more research on camera settings in order to get the best picture possible.

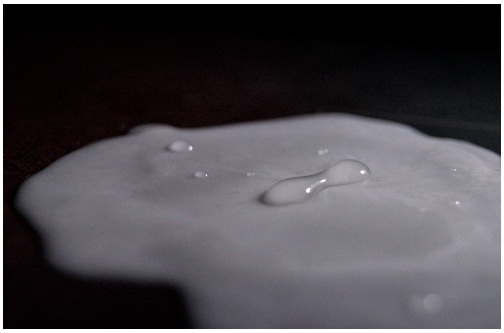

Fig. 5: Final Image (Edited)