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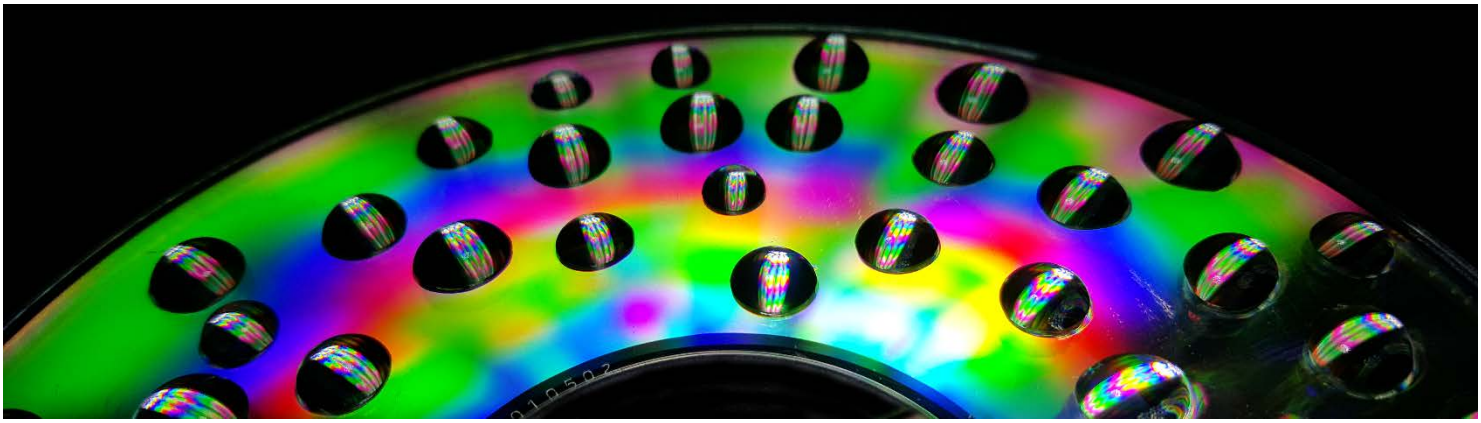
Flow Visualization

Team Project 2: Surface Tension on a CD



The purpose of this image was to explore the properties of surface tension on the relatively hydrophobic surface of a CD. We were trying to highlight the shape and surface of the water droplets by utilizing the reflective properties of the CD. The series of images this specific image was selected from was created with the assistance of both Danny Maguire and Erick Pena.

To produce this image, droplets of plain tap water were placed on the surface of the CD by a common eye dropper. Each drop was approximately 0.5 cm in diameter when on the CD. These droplets were places all across the surface of the CD in a semi-uniform pattern, all radiating out from the center and placed at similar distances around the circumference of the CD. The CD in this situation was resting on a black stool to act as the background for the image. No other steps were taken in the setup for this image. All of the color was generated from the lighting.

Here, the main fluid property being captured is surface tension. Surface tension is caused by a small internal pressure in the droplets of water. This is generated because, in a body of liquid, each molecule is pulled on equally in every direction by the neighboring water molecules, resulting in a zero net force. However, at the surface-air interface, molecules are not pulled on by the same neighboring molecules on all sides and are pulled inward. This results in some internal pressure which then forces the liquid surface to contract to a minimum area. Surface tension itself is described by the equation:

$$\gamma = \frac{F}{2L}$$

Where gamma is the surface tension and is described by the force per unit length to keep a movable face of water still. The units of surface tension are (N/m). Surface tension result in other properties as well including surface curvature and a contact angle. The surface curvature as a result of surface tension is described by the Young-Laplace equation:

$$\Delta p = \gamma(\frac{1}{R_x} + \frac{1}{R_y})$$

Where delta p is a pressure difference described by the Laplace pressure. For a water droplet at 1mm, delta p is equal to 0.0014 atm. R_x and R_y are the radii of curvature in the respective axis. The contact angle, where the droplet meets the surface of the CD is described by the equation:

$$\gamma_{ls} - \gamma_{sa} = -\gamma_{la}\cos(\theta)$$

Where gamma ls is the surface tension of the liquid solid interface, gamma sa is the surface tension at the solid air interface and gamma la is the surface tension at the liquid air interface. The angle theta describes the contact angle of the fluid with the solid surface. This is a very difficult property to calculate directly. Instead there are many experimental methods that have been developed to measure the contact angle.

This image was taken in a dark classroom with a black stool acting as a platform to hold the CD. No dye or coloring was used to achieve the effects visible in the image. The only lighting used in these images was a small LED flashlight aimed at the CD surface at a variety of angles depending on the image. Some images were long exposures with the camera set on a tripod as the flashlight was swept across and around the surface of the CD. For this specific image, the flashlight was held still at an angle of approximately 30 degrees at about 8 inches above to CD's surface. The flashlight was held on the side of the CD directly opposite the camera setup aiming toward the photographer.

This image was shot using a Nikon D90 DSLR camera with a standard lens with a focal length of 55 mm. This image is about four and a half inches across the back face of a standard CD. It was take approximately 6 in above the surface of the CD as this was where the coloring seemed to show the largest coverage of the CD face. The original image was 5312x2988 pixels in size. The original is shown here:

Since we were shooting in low light a high ISO of 2400 was used. An aperture of F 5.6 was used to allow for more light and a shutter speed of 1/200 was utilized. Post processing was done in adobe Photoshop. The image was cropped to eliminate the black space above the CD as well as some of the unfocused droplets on the bottom half of the image. The final image is 5312x1492 pixels. An unsharp mask was then applied to sharpen the edges of the droplets and the clone stamping tool was used to eliminate the stool texture in the center of the CD.

I really like the simple nature of this image. Dynamically there is very little going on which made it a very easy image to capture. The colors from the CD really add the layer of interest which makes this a pleasing image. Not only does the LED create a vivid colorful landscape on which to display the water droplets, but it also does a nice job of highlighting the surface curvature of the individual drops shown. I

think that this image could be potentially improved through the addition of a more uniform, denser surface of droplets. The trouble with this would be spacing, making sure to keep the drops from connecting with each other. However, this may upset the balance of the colorful droplets with the vivid background.