Flow Visualization Report #2

MCEN 4151

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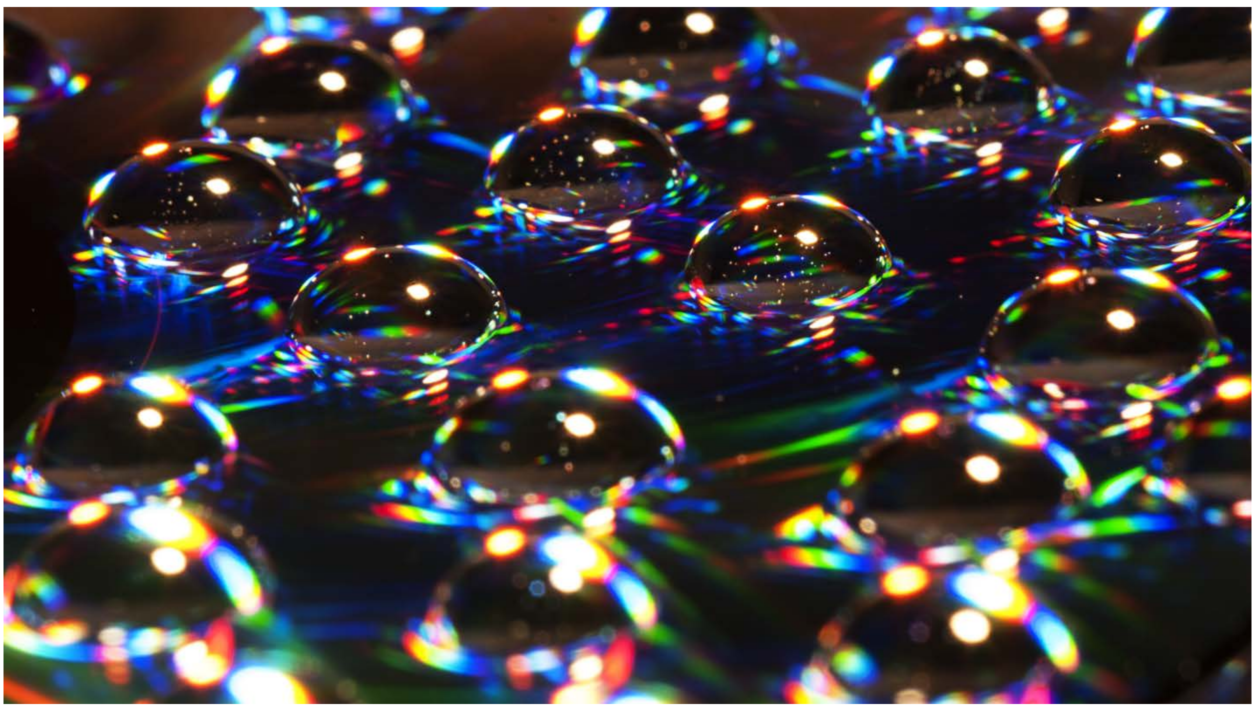

This is the second flow visualization submittal for the MCEN 4151 class. The image was taken individually, however a group was assigned to help with the brainstorming ideas for the photo, the setup, and the lighting of the image. The phenomenon that was intended to be observed was the diffraction of light when it encounters a DVD, how light bends through droplets of liquid, and surface tension of the liquid in contact with the DVD. Team members that helped to make this photo possible include; Coulter Pohlman, Hans Loewenheath, James Shefchik, and Spencer Aguilar.

The flow apparatus that was used to achieve the image was simply a new DVD, glycerin, a halogen work lamp and an ITLL lab cart. A lab cart was moved into the media shack in the ITLL so that the lighting would be easily controlled. A simple sketch of the apparatus used to capture the photo can be seen in Figure 1.

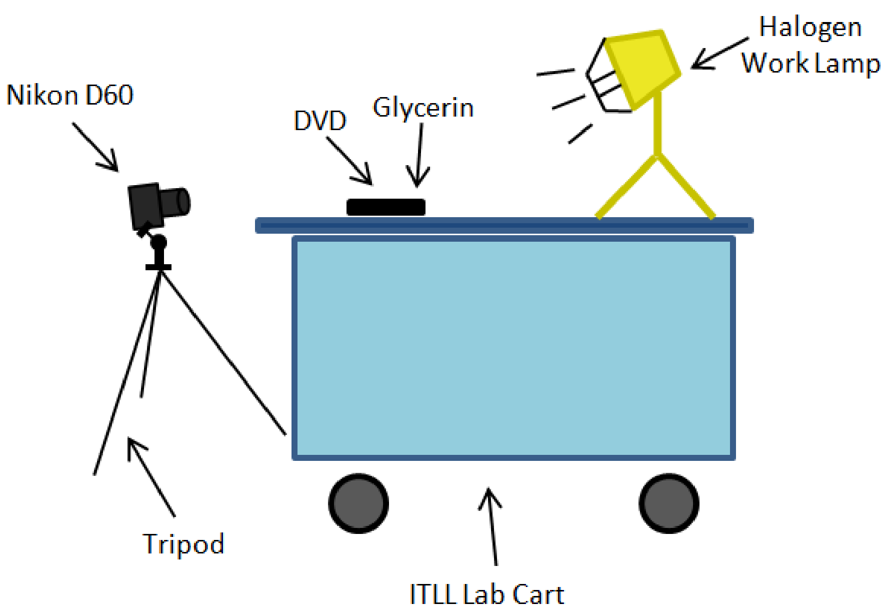

Figure 1. Photo Apparatus

Within the final photo there are two main physical phenomena that are occurring; diffraction of light and surface tension of the glycerin. Within the droplets of glycerin there are two different types of surface tension occurring. The first type is cohesion, the force holding one glycerin molecule to the next. Second is adhesion, the force between the glycerin and the DVD. The cohesive surface tension of any homogeneous liquid is constant throughout the fluid, 0.063 N/m for glycerin. However, the adhesive force that the fluid exerts on the object it is in contact with, in this case the DVD, is dependent on the length the fluid is in contact with the object for. This force can be determined using Equation 1. [1]

$$F = \gamma L \tag{1}$$

Within Equation 1 γ is the coefficient of surface tension, equal to 0.063 N/m for glycerin, L is the length of line of contact, and F is the force. A single drop of glycerin was approximately 0.005 meters in diameter. Using that value as the line of contact it is found that the resulting force of the glycerin drop on the DVD is 0.000315 Newtons.

The next phenomenon that is displayed in the photo is the diffraction of the white light into its spectral components. This separation of the spectrum happens due to something called diffraction grating. A diffraction grating is an object with periodic structure that occurs very close together to split the light into its components. The grating of the object acts as a dispersive element and the directions of the beams depend on the spacing of the grating and the wavelength of the light. In the case of the DVD, the tracks or memory storage on the disk are separated evenly (about 1.6 micrometers apart) and act as the diffraction grating for the light. Since the spacing of the grating is held constant and each color of the spectrum has a different wavelength, the various colors are each sent in different directions allowing the viewing of the separated colors. To determine what angles the various colors are reflected at Equation 2 can be solved [2].

$$\theta_r = \arcsin\left(\frac{m\lambda}{d} - sin\theta_i\right) \tag{2}$$

Within Equation 2, θ_r is the angle at which the light is reflected off of the DVD, λ in this case is the wavelength of the light, and θ_i is the incident angle of the light onto the DVD. If calculated, it can be seen that each color is reflected in a different direction, this explains why each color can be seen across the DVD. Each droplet of glycerin also acts as a lens and bends the light in different directions. This accounts for the different lines of color around each of the droplets.

The visualization technique that was employed, as described above, was simply glycerin on a DVD. The glycerin that was used was acquired from a local grocery store and the DVD was purchased from the vending machine on the top floor of the ITLL. Lastly, the halogen work lamp that was used was already in the ITLL Media Shack when the group arrived. The glycerin was not diluted in any way when dropped onto the DVD. The only lighting that was used was the halogen work lamp placed on the lab cart. The windows were covered and the door was shut so that the halogen lamp was the only source of light as to see the separation of the spectrum more defined.

The photographic technique that was used was different that many other projects. A Micro-Nikkor 105mm macro lens was used with an f stop of 5.6. This f stop was chosen specifically to shorten the depth of field and only make the single droplet in the top right third of the image in focus while the other droplets are not as crisp. In this case the field of view is approximately 6 centimeters and the lens was approximately 40 centimeters away from the DVD. A Nikon D60 in RAW format was used to capture the image. The shutter speed was two seconds and the ISO was 100. This allowed to let as much light as necessary into the sensor while keeping the image free of noise. The original image size was 3900x2613 pixels and the final image turned out to be 2000x1500 pixels. Photoshop was used to crop the image and increase the contrast slightly. Also, the high-pass filter was used in separate layers to sharpen the edges. In Figure 2 below, a before and after photo can be seen side by side for comparison.

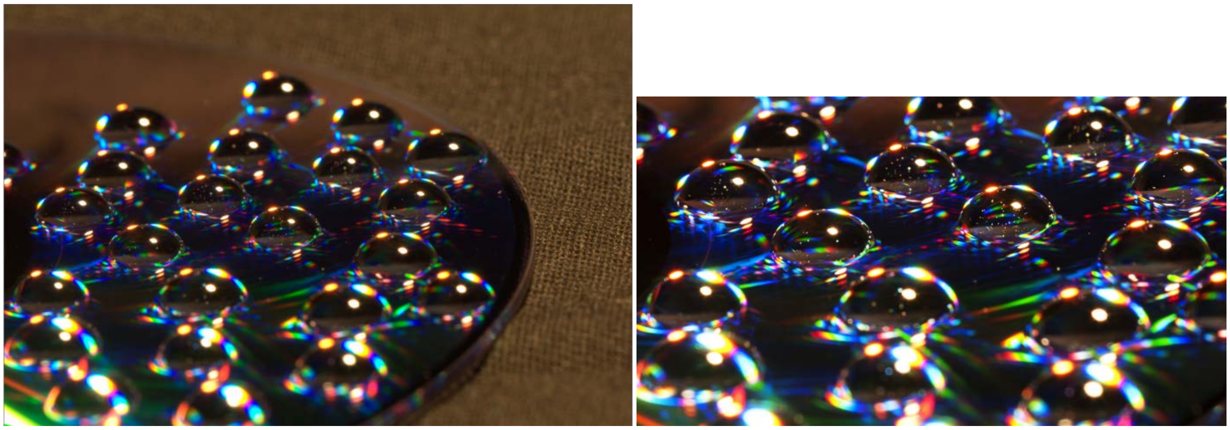

Figure 2. Before (Left) and After (Right) Photos

The final image reveals various physical phenomena including surface tension and the diffraction of light across a DVD. I personally like how crisp the single droplet looks as I intended. I also like the amounts of color throughout the image. Something that I dislike and could improve is the droplets at the very bottom of the image; I think that they maybe should have been cropped out. In developing the image further various light sources such as lasers could be used to see the different spectrums that they break into.

Bibliography

[1] "Surface Tension." *Visual Physics School of Physics*. University of Sydney, n.d. Web. 14 Mar. 2013. <http://www.physics.usyd.edu.au/teach_res/jp/fluids/surface.pdf>.

[2] I.C. Botten , M.S. Craig , R.C. McPhedran , J.L. Adams & J.R. Andrewartha (1981): The Dielectric Lamellar Diffraction Grating, Optica Acta: International Journal of Optics, 28:3, 413-428