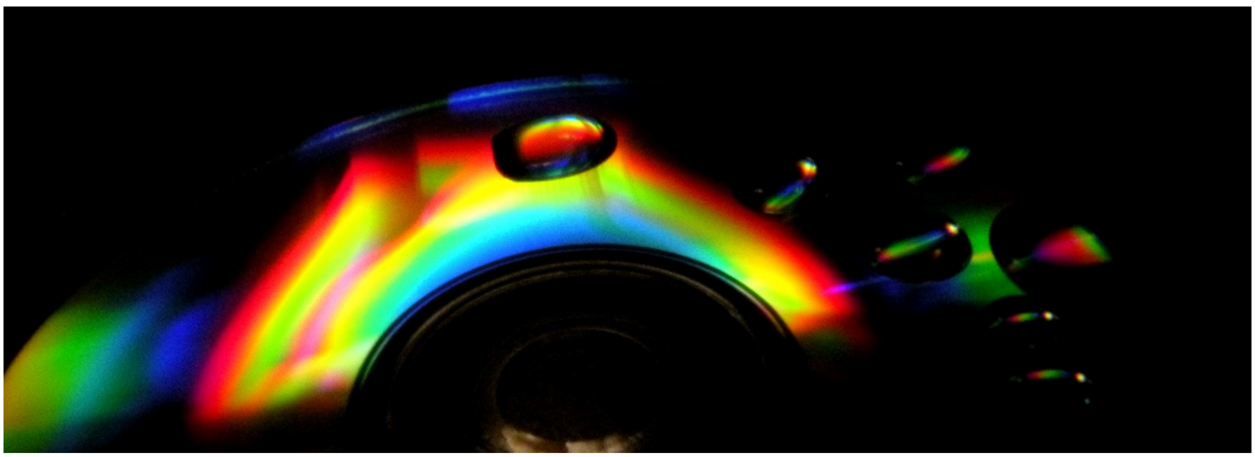
Light reflected from a CD in Water Droplets



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INTRODUCTION AND PURPOSE

This photograph and paper was created for the third Group assignment in the Flow Visualization course at CU Boulder. The instructions for this assignment were to simply capture an image of any flow that displays physical phenomenon. I decided to interpret physical phenomenon related to the changing index of refraction in different materials. For the initial "Get Wet" image in this class I worked with CDs submerged in water, and had been intrigued by the water droplets effect as well. In order to display this effect, I decided to use droplets of water on a CD.

FLOW GENERATION

The apparatus used to capture this image consisted of several components: a CD, turtle shell wax, eye dropper, and water, a flashlight, and the camera. Figure 1 displays the arrangement of the components to capture the image. The lighting was a dark room, with a flashlight being used to reflect the light. The CD was covered in the turtle shell wax and allowed to dry. Once the wax was dry, an eyedropper was used to drop several droplets to one side of the CD. I thought it would make an interesting image if only half had the drops, and the rest was just the pure reflection from the CD.

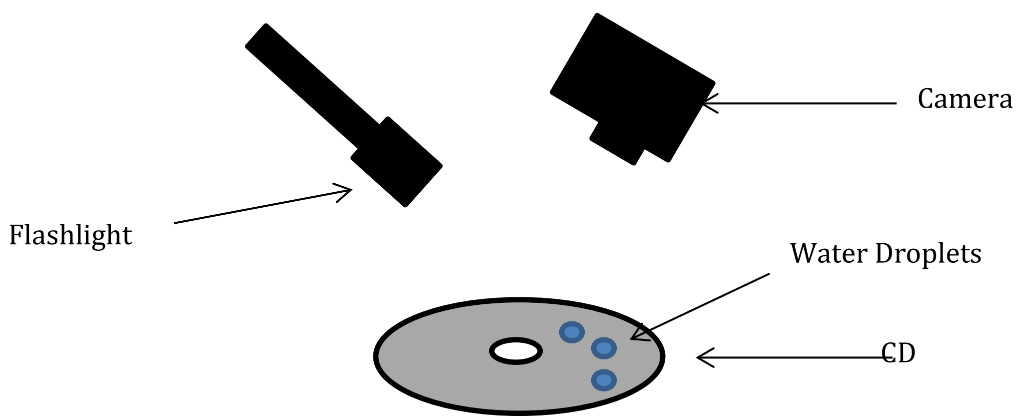

Figure 1: Schematic of Setup

FLUID PHYSICS

To create the rainbow display seen in the photo, a point light source must be used. The flashlight I used had a wide and narrow function, I noticed that the rainbow colors were more intense with the focused light ray. To avoid getting a large white reflection spot in the image, the flashlight light was diffused somewhat by my hand. I aimed it at the center of the center of the CD to avoid the bright spot. When the light hits a CD, it is completely reflected back up in every direction. Some of the light is going to hit the droplets on the surface of the water. Water has a different index of refraction than air so the light that is not reflected upwards is refracted down through the water, this follows Snell's law, seen below in Equation 1. The amount of bending in light depends on the change of density in the medium.

$$\frac{\eta_1}{\eta_2} = \frac{sin\theta_2}{\sin\theta_1} \qquad \text{Equation 1}$$

Water and air have a slightly different index of refraction, creating an angle change in the refracted light. The angle of refraction in the water can be calculated to be:

$$\eta_{air} = 1.00029, \qquad \eta_{water} = 1.3$$

$$\theta_{water} = \sin^{-1}\left(\frac{(sin\theta_{air})(\eta_{air})}{\eta_{water}}\right) = \sin^{-1}\left(\frac{(\sin(60))(1.00029)}{1.3}\right) = 41.79\ degrees$$

When light hits the aluminum all of it is reflected upward (except the melted parts), through the plastic and water. The grooves on the aluminum film are so close to the wavelength of light that they disrupt the angle of reflection of the light, essentially splitting the light into colors. This causes some of the wavelengths of light to cancel out, and the rest to add together, creating an intense rainbow spectrum. A depiction of this effect can be seen in Figure 2. The rainbow light beams reflect from the aluminum and then reflect again off of the side of the water container and eventually into your eye. The reflection of the side of the container can be seen in the final image, where the reflection occurs again and the lines from the melted aluminum can also be seen reflected.

PHOTOGRAPHIC TECHNIQUE

The camera used to capture this shot was a Nikon CoolPix P80 held directly over the apparatus setup, see diagram in Figure 1. As can be seen in the data in Figure 3, a fairly large aperture was used f/3.5, giving the image a greater depth of field. This allowed for the tunnel effect of the reflection up the sides of the water column in the image. The light source from the flashlight created an intensely bright spot, so I was able to use a fast shutter speed of 1/70th of a second, in order to prevent motion blur in the image.

DSCN0934
JPEG image

Date taken:	1/24/2014 8:09 AM
Tags:	Add a tag
Rating:	☆☆☆☆☆
Dimensions:	1024 x 768
Size:	272 KB
Title:	Add a title
Authors:	Add an author
Comments:	Add comments
Camera maker:	NIKON
Camera model:	COOLPIX P80
Subject:	Specify the subject
F-stop:	f/3.5
Exposure time:	1/70 sec.
ISO speed:	ISO-64
Exposure bias:	0 step
Focal length:	5 mm
Max aperture:	3
Metering mode:	Pattern
Flash mode:	No flash, compulsory
35mm focal length:	27
Date created:	1/29/2014 11:18 AM
Date modified:	1/29/2014 11:18 AM

Figure 2: Photo data

IMAGE POST PROCESSING

In the final stages of this image creation, I did minimal edits using Adobe Photoshop. Using the Curves function, I essentially made the blacks blacker in the image, I wanted to remove the background so the image was also cropped slightly. I also slightly increased the contrast of the image in order to make the rainbow more intense, and to remove the "shine" from the image.

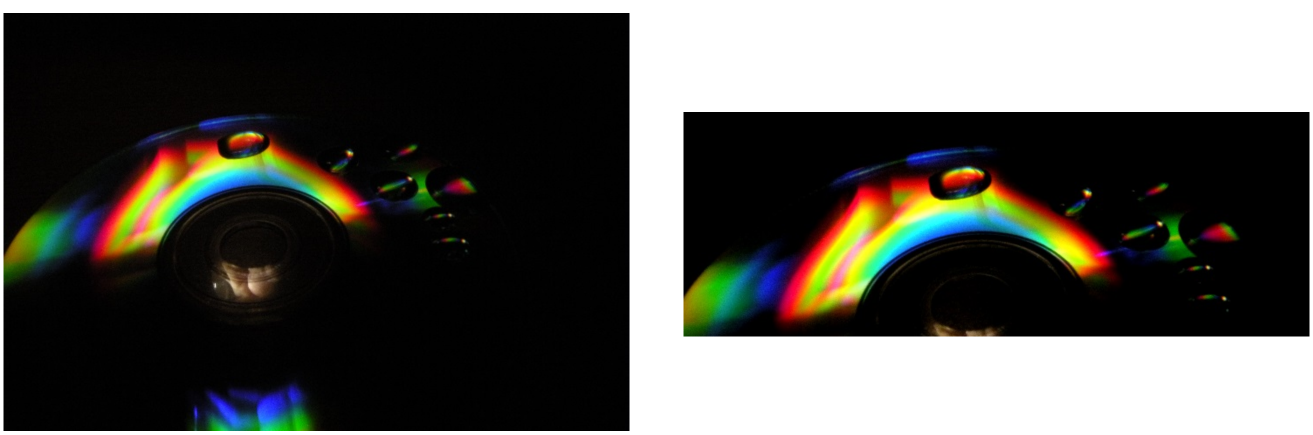

Figure 3: Left: Original image, Right: Final image

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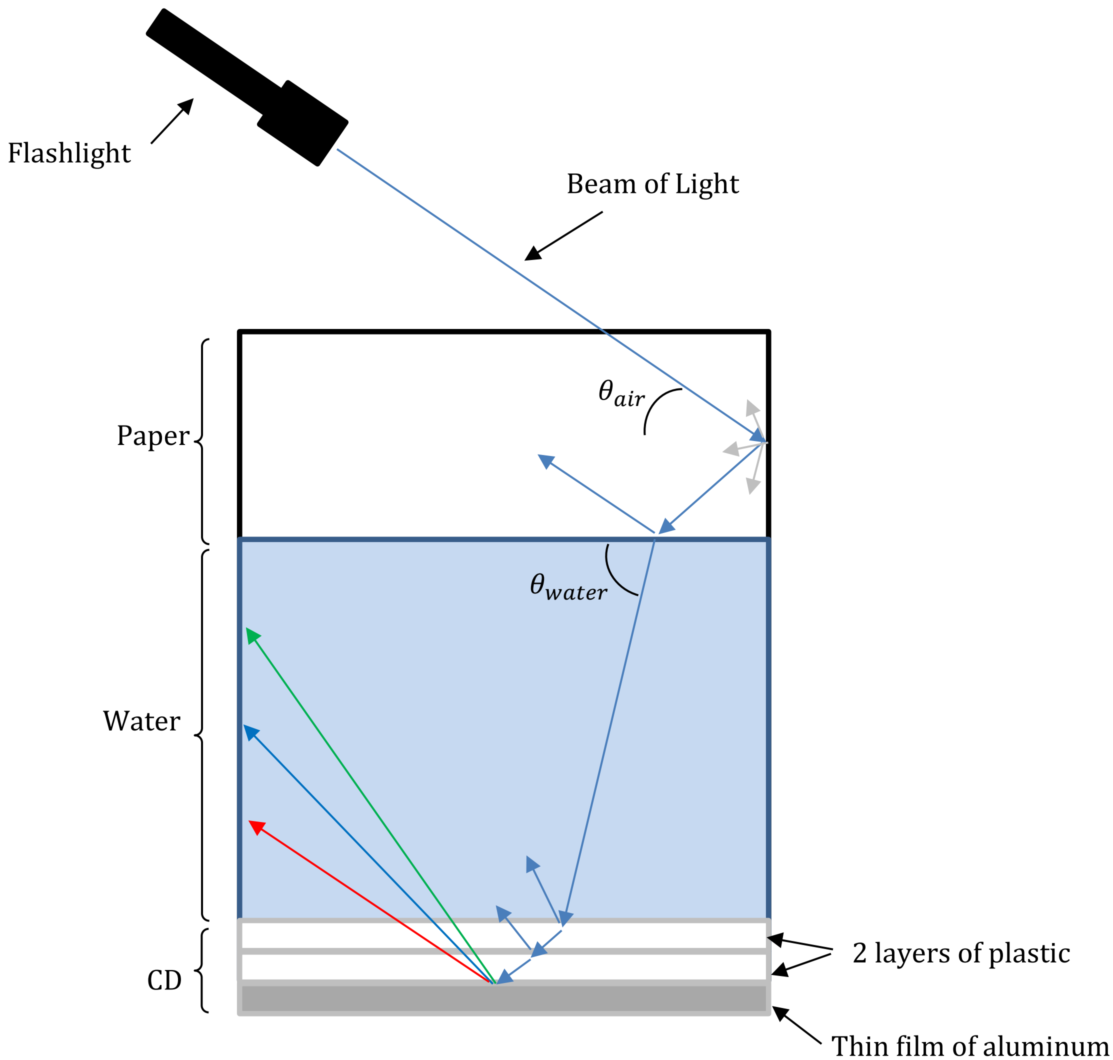
Flashlight
Beam of Light
θ_{air}
Paper
θ_{water}
Water
CD
2 layers of plastic
Thin film of aluminum