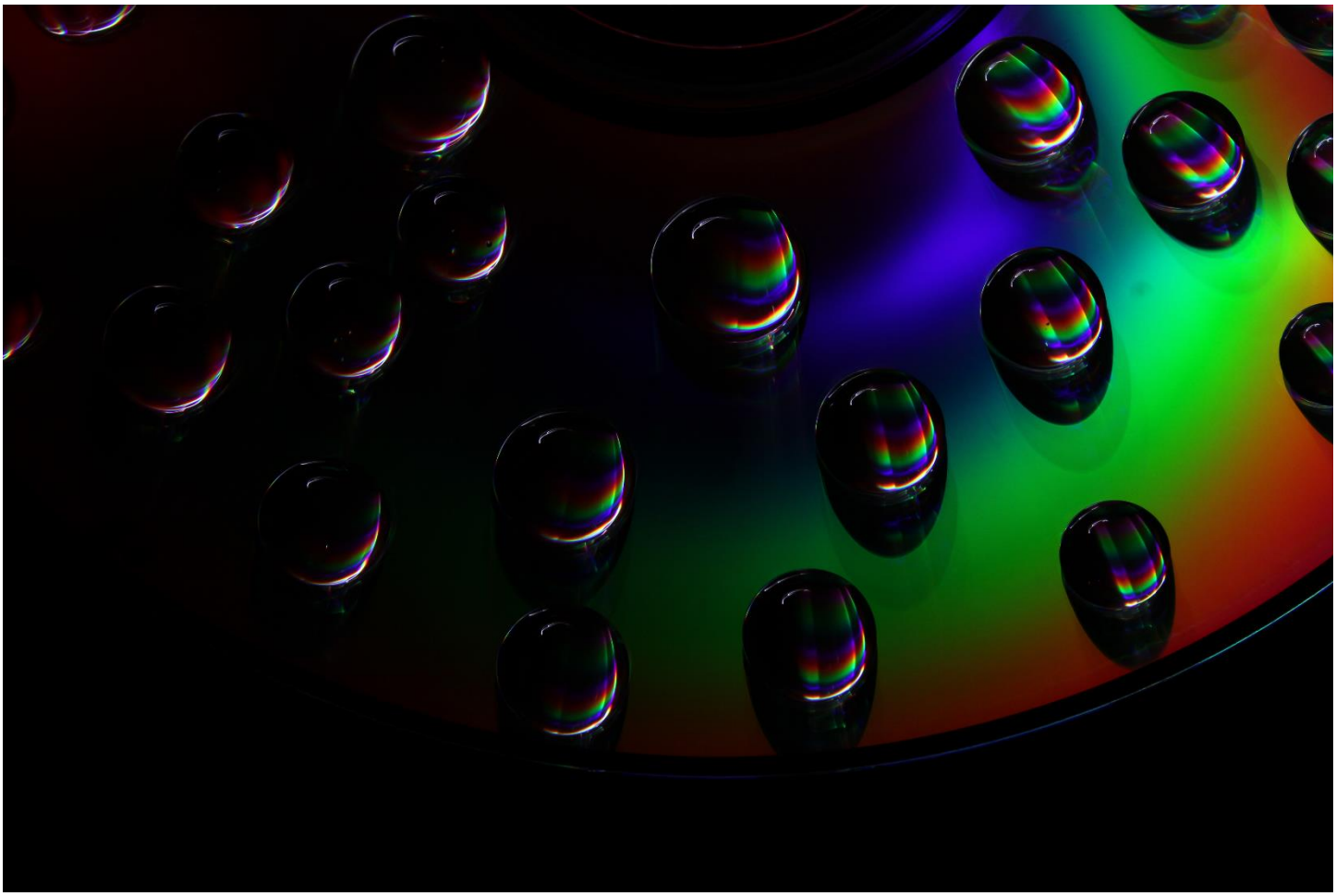
Surface Tension Water Droplets in a CD

TEAM SECOND IMAGE



Erick S Pena | Flow Visualization | November 16, 2015

Goal

The purpose of the group image was to do research of flow visualization and as a group decide on a fluid phenomenon. The goal of this flow visualization image is to capture the fluid's surface tension by adding a different feel to the overall picture. By using a CD we wanted to capture the brilliant colors reflected by the disk and showing the spherical water droplets due to surface tension. The surface tension characteristic has been seen in nature such as grass and leafs which caused the team's interest. This Idea came from looking at pictures on the Flow Visualization[1] web galleries.

In Figure 1 we see three different images with red arrows, the red arrows indicate the defects that was in the photograph. The only editing that was done to the original image was going through the entire image and using the clone tool in gimp to get rid of the defects. The size of the edited image remained the same as well as the colors did not change from the original photograph.

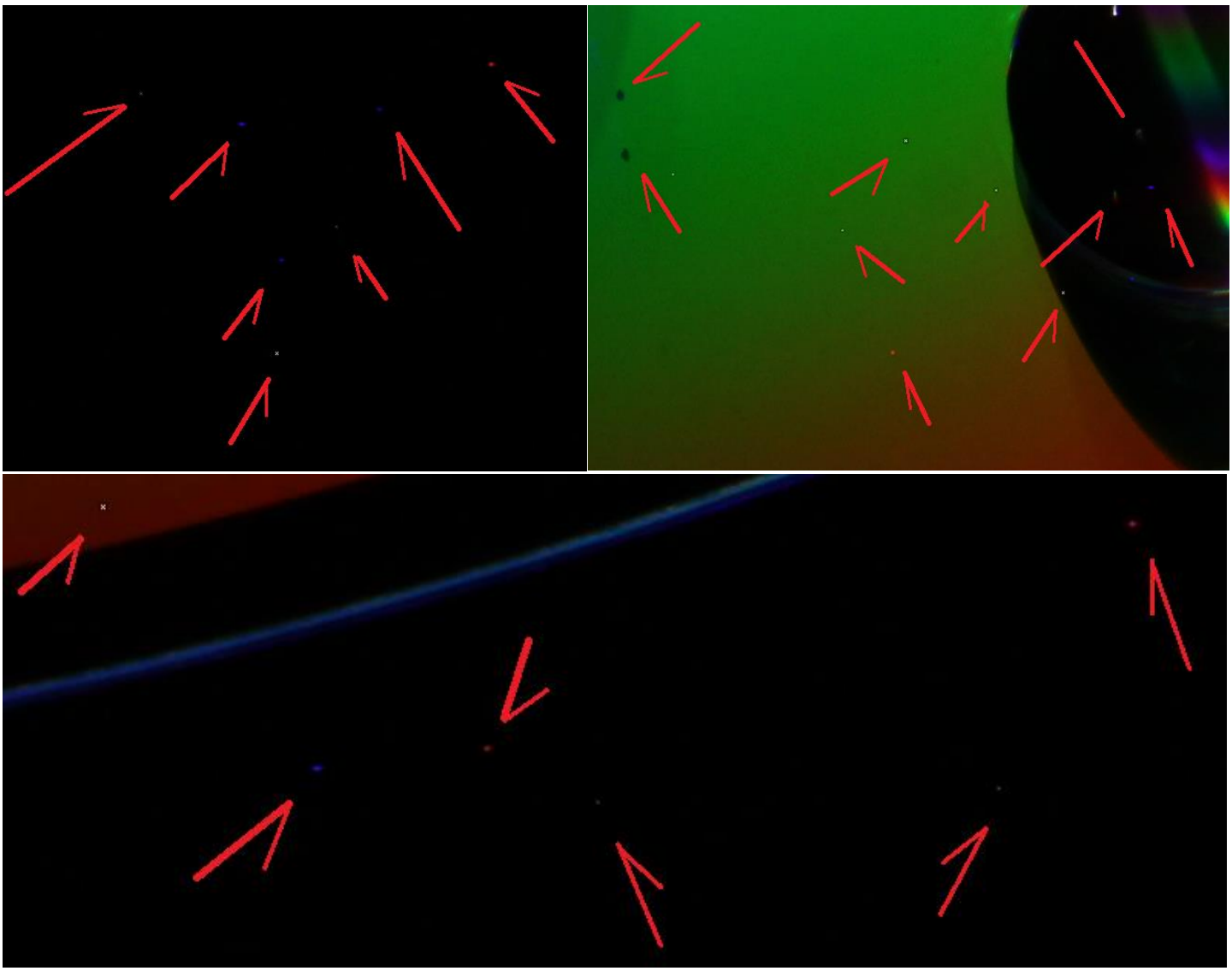


Figure 1: This are the defects that were found in the raw image. This are only but a few sections of the original picture.

[1] Course Flow Visualization Website

Team

For this assignment, I was assigned to a group of two other members, consisting of the following members

1. Erick Pena
2. Daniel Patrick Maguire
3. Stefan Schultz

Materials

This is a list of materials that will be needed to produce a similar photograph as seen on the cover.

1. Blank CD
2. Water dropper
3. LED light lamp
4. Water
5. 2'length x 1'height black velvet background
6. ND 8 filter (Polarizer)
7. Canon EOS REBEL T2i

All of the photos that were shown are taken inside, with the blinds down, directly above from circular objects. A black cloth was placed on the background to direct the focus to the flow. To get a similar photo as seen in Figure A, the settings for the camera were as fallows.

- No flash
- Distance from lens to object: about 60 mm to 90 mm
- Manual (M)
- Exposure Compensation: 0
- Focal length 55 mm
- Aperture f/14
- Exposure 15 sec
- ISO: 320
- Original Dimensions: 5184 X 3456
- Cropped Dimensions: 5184 X 3456

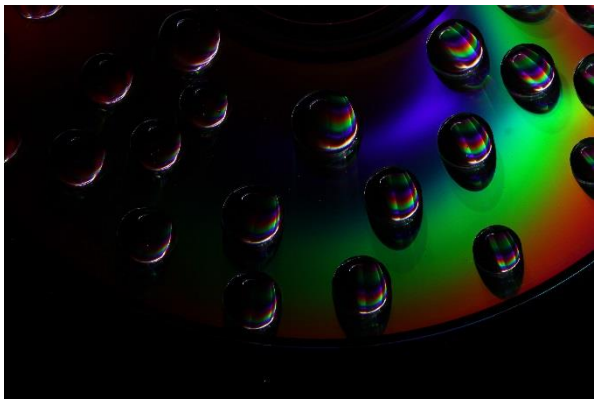


Figure A; this is the original photograph with dimensions of 5184 X 3456

Procedure and set up

To produce a similar image as seen above we used the materials seen above. In Figure 2 we can see the setup, we set the exposure time to 15 seconds and then I swung the LED lamp side to side as seen in Figure 2. This created the shadows that you see in the image. We noticed that we got some extra reflection that made the image over exposed, to fix this we used a Polarizer to get rid of the extra light in the image. The colors on the CD were made by the reflection of the disk and the three LED colors in the white light LED Blue, Red, Green.

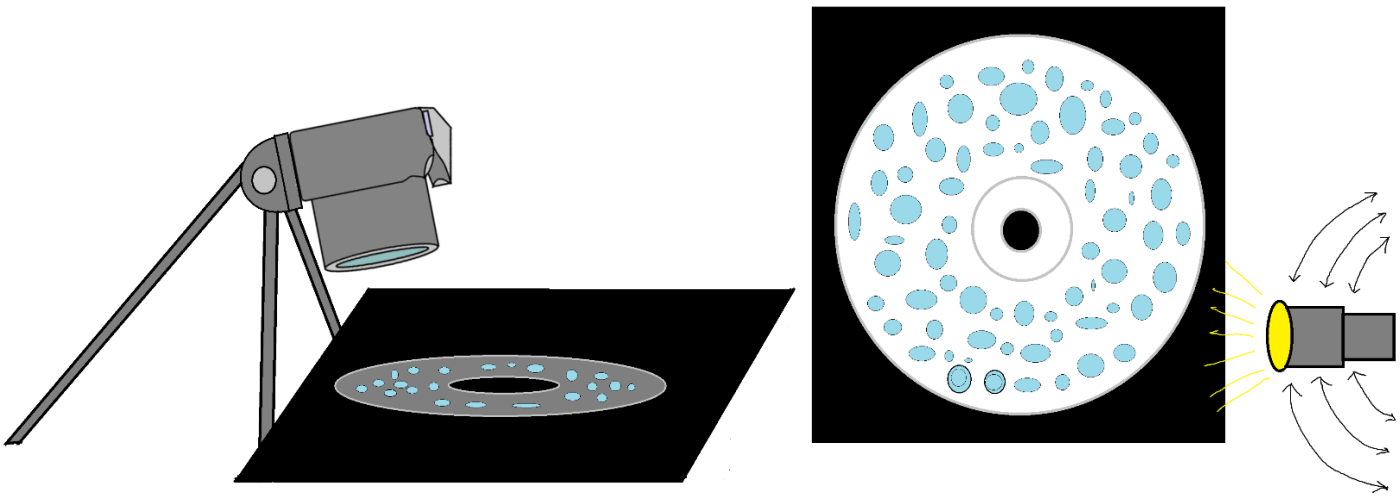


Figure 2: this is the setup of how we got the image seen above. The one in he left is a side view of the set up, and the one on the right is a top view of the set up.

Fluid Physics

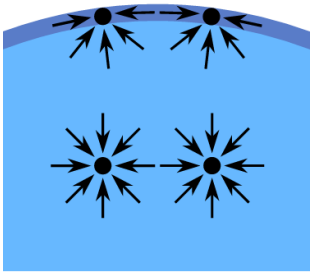


Figure 3: Diagram of the force on molecules of a liquid

The Cohesive Forces between the liquid molecules is what makes the surface tension phenomenon possible seen in Figure 3. Each molecule is pulled likewise in every direction by neighboring liquid molecules, results in a net force of zero[2]. Because the molecules at the surface do not have the same molecules meaning that they don't have a neighbor and are attracted to the center or inward. Surface tension is also responsible for the spherical shape of the droplets, reason being is because a sphere has the smallest surface area to volume ratio. In the following paragraphs we will talk about the math on the contact angle on my experiment using Engineering Equation Solver (EES) to calculate the angles describe in the fallowing paragraphs.

Figure 4: Coexistence of three fluid phases in mutual contact: α, β, and θ represent both the labels of the phases

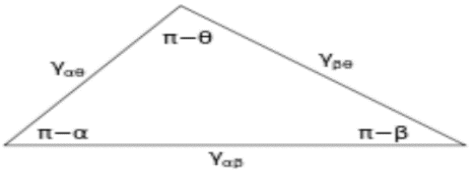


Figure 5: Neumann's triangle relating the surface energies and contact angles of three fluid phases coexisting in static equilibrium, as depicted in Figure 4

In Figure 5 describes Neumann's triangle, this relates the contact angle of three fluid phases that coincide in static equilibrium. This energies and phases as called in Figure 5 are then derived to get Equation 1 through Equation 3. In Figure 4 and Figure 5 we see how all of the phases and Surface energies are related to one another.

To get the contact angles, the phases and their surface energy I use EES by plugging in Equation 1 through Equation 4. I made some assumptions, I replaced the β phase by a flat rigid surface that made it equal to 180 degrees. I also had to plug in one more value so I estimated *h* to equal 0.4 cm. EES was then able to solve for the angle of contact through linear algebra to get a Θ equal to 95.19 degrees. Finally the other assumption made was α + β + Θ = 360. The Results to the EES code are seen in Figure 6.

[2] https://en.wikipedia.org/wiki/Surface_tension

All of the information was obtained in Wikipedia in the fallowing Surface Tension[3] and Wetting[4]

Equation 1 $$\lambda_{Alph} + \lambda_{Bata} \cdot \cos[\theta] + \lambda_{AB} \cdot \cos[\alpha] = 0$$

Equation 2 $$\lambda_{Alph} \cdot \cos[\theta] + \lambda_{Bata} + \lambda_{AB} \cdot \cos[Bata] = 0$$

Equation 3 $$\lambda_{Alph} \cdot \cos[\alpha] + \lambda_{Bata} \cdot \cos[Bata] + \lambda_{AB} = 0$$

Equation 4 $$h = \sqrt{\frac{2 \cdot \lambda_{LA} \cdot [1 - \cos(\theta)]}{g \cdot p}}$$

Figure 6 shows the solutions with units to the equations seen above. EES is capable of completing various tasks and linear algebra is one that comes very handy when working with multiple equations. EES can also recognize when a solution does not coincide with the units that where imputed and allows to correct this unit mistakes easy.

Unit Settings: SI C kPa J mass deg

α = 84.81 [degrees]

Bata = 180 [Degrees]

g = 981 [cm/s^2]

h = 0.4 [cm]

λ_{AB} = 0.8641 [Dyne/cm]

λ_{Alph} = -7.497E-08 [Dyne/cm]

λ_{Bata} = 0.8641 [Dyne/cm]

λ_{LA} = 71.97 [Dyne/cm]

p = 1 [g/cm^3]

θ = 95.19 [degrees]

No unit problems were detected.

Figure 6: This are the solutions that were abstain in Engineering Equation Solver (EES)

Conclusion

This Experiment was one of my favorite this semester in the Flow Visualization class at CU Boulder. I had a lot of fun setting this experiment and obtaining all of the different colors that were displayed through the reflection of the CD. The Fluid physics that this team wanted to show was the surface tension that is seen in multiple places in nature. We wanted to go a step further than just showing the viewer a droplet that seems suspended on the top of the CD by surface tension and add some visual stimulation and mystery. I would recommend this experiment to others, the images that you obtain are great and the hardest thing about it is showing what image you want because they all turn out amazing. As to what I would change if I did this experiment again is perhaps do an image of the entire CD and do a different movement. Also we only used white LEDs that did gave us wonderful colors but maybe by using other colors besides white light we could create very interesting color reflection and patterns on the CD.

[3] Surface tension; https://en.wikipedia.org/wiki/Surface_tension

[4] Wetting; https://en.wikipedia.org/wiki/Wetting

Image Assessment Form
Flow Visualization
Spring 2015

Name(Erick Pena)

Assignment: Date:

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Comments
Intent was realized	!	The intent was to show the physics of surface tension by also making the image visually appealing
Effective	!	You can clearly see the almost spherical shape of the water droplets. There was hardly any wetting
Impact	!	This is one of my favorite images that I have done so far. The impact that this image had on me was astonishment. You know when an image is impactful when there is very little or no image processing
Interesting	!	This type of method is not used very frequently in this class I only found one that used similar method which makes this image unique and therefore interesting.
Beautiful	!	I love this image. I would say that it is beautiful and unique. The colors on the image are the actual colors, not image processing.
Dramatic	!	I would say that this image is very expressive and bold of dark brilliant colors.
Feel/texture	!	I would say that the feel and texture is 3 Dimensional with smooth surface.
No distracting elements	!	The image only includes the object and the fluid

		physics with a dark background to minimize the distraction and focus the viewer to the water droplets.
Framing/cropping enhances image	!	For framing I decided to do half of the CD to get a closer view to the water droplets.

Flow	Your assessment	Comments
Clearly illustrates phenomena	!	The water droplets are seen clearly and almost spherical.
Flow is understandable	!	I think that it takes the viewer a few seconds to realize that this is a CD and the spherical objects are water droplets, but when seen closely the flow is clear.
Physics revealed	!	Because there is no moving parts or fluid flow the viewer can understand that surface tension is cussing the shape of the spherical droplets
Details visible	!	One of the reasons that I choose this image was because it gave very interesting shadows that I did not see in the other ones that we took. So I would say that the details are clearly seen.
Flow is reproducible	!	This is a simple but affective experiment and can be reproduced plenty of times.
Flow is controlled	!	We used a dropper to place the droplets this experiment it reproducible and very controlled
Creative flow or technique	!	As I said above going through the flow visualization website not a lot of people do this experiment and makes this image unique

Publishable quality	√	I would say so. The image is clear and attractive

Photographic/video technique	Your assessment	Comments
Exposure: highlights detailed	!	We used a polarized filter to control the exposure to light and the time exposed
Exposure: shadows detailed	!	The shadows are one of the things that I like the most about this image.
Full contrast range	!	
Focus	!	The focus is clearly highlighted
Depth of field	√	The entire image is in focus and both the droplets add to the depth of field
Time resolved	!	Flow is stationary so this is time and spatially resolved
Spatially resolved	!	Flow is stationary so this is time and spatially resolved
Photoshop/ post-processing enhances intent	!	This was not much just adjusting dead pixels
Photoshop/ post-processing does not decrease important information	!	Unless you zoom in you can't even tell where there was dead pixels

Report		Your assessment	Comments
Collaborators acknowledged		!	
Describes intent	Artistic	!	
	Scientific	√	
Describes fluid phenomena		!	
Estimates appropriate scales	Reynolds number etc.	√	
Calculation of time resolution etc.	How far did flow move during exposure?	NA	
References:	Web level	√	
	Refereed journal level	√	
Clearly written		~	
Information is organized		!	
Good spelling and grammar		√	English is my second langue and so I sometimes struggle with grammar
Professional language (publishable)		~	
Provides information needed for reproducing flow	Fluid data, flow rates	√	
	geometry	!	
	timing	!	
Provides information needed for reproducing vis technique	Method	!	
	dilution	!	
	injection speed	NA	
	settings	√	
lighting type	(strobe/tungsten, watts, number)	~	
	light position, distance	~	
Provides information for reproducing image	Camera type and model	!	
	Camera-subject distance	√	
	Field of view	√	
	Focal length	!	
	aperture	!	
	shutter speed	!	
	Frame rate, playback rate	NA	
	ISO setting	!	
	# pixels (width X ht)	!	
	Photoshop and post-processing techniques	!	
	"before" Photoshop image	!	