Kolby Koeck

MCEN 5151

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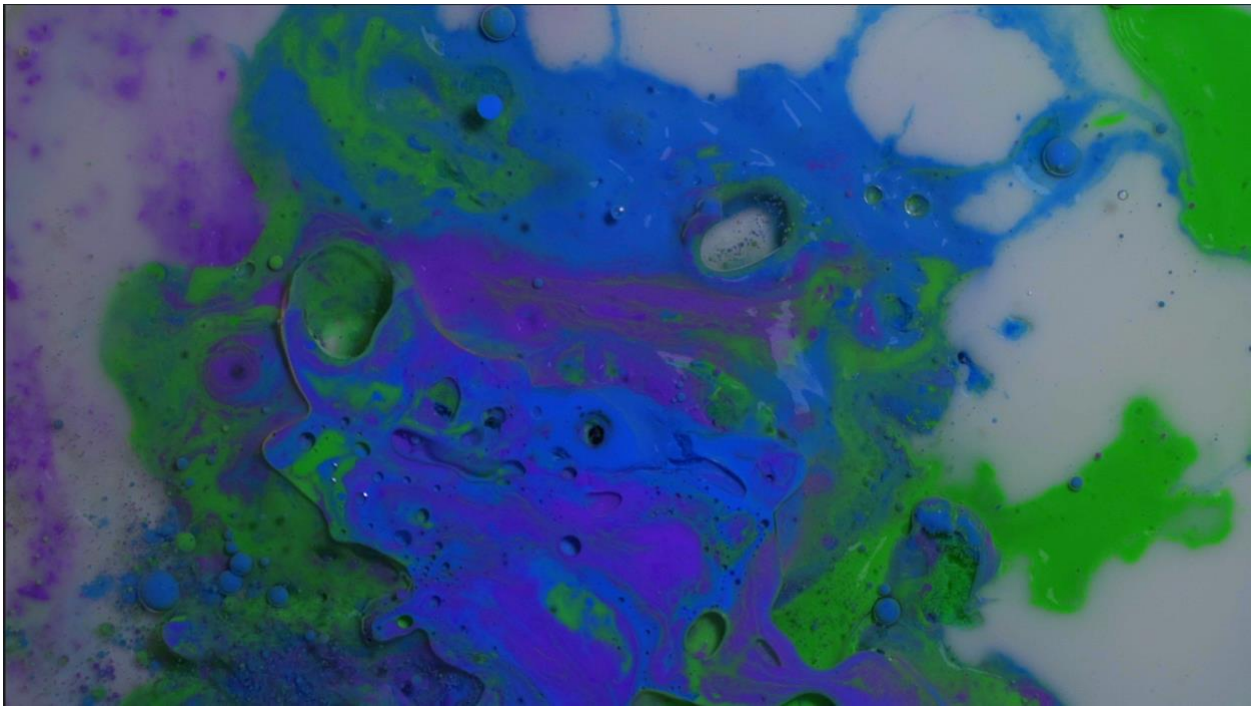
Image-Vid 2



Milk, Paint, Oil, and Soap Surface Tension Demonstration

1. **Purpose**: For my second investigation into fluid phenomenon, I wanted to capture the interactions between several different liquids in high-speed video. Specifically, I wanted to create a video showing milk, acrylic paint, oil, and soap mixing together and how the different properties of each can affect the surface tension and create visually interesting designs. This was much more difficult than anticipated, as the ratio of each was an effort in trial and error and creating a beautiful, defined color scheme was hard get right from an artistic standpoint. Eventually, a good mix of milk and acrylic paint was found to create a medium viscosity fluid that retained its vibrant color, then a gentle mixing of oil to create well defined pockets of color. Finally, the right amount of soap was needed to alter the surface tension, per the Marangoni effect, and create a bright, colorful display of moving color throughout the video.

2. **Flow Apparatus and Discussion:** For this experiment, the flow setup is fairly simple. A small white plate measuring 7.5” by 7.5” is placed in the center of the table. Then the tripod is set up over top this plate and the camera is then attached and centered as demonstrated in Figure 2 and 3. The milk is then poured onto the plate in a thin layer and a few drops of each color paint are added. Then a separate mixture of paint, oil, milk, and soap is prepared in a Pyrex measuring cup. The flow is then created by pouring this mixture from the measuring cup onto the plate with milk and paint and the camera then begins recording with a tight and close perspective. This captures the flow of this mixture onto the plate as well as the unique reaction that occurs when the soap interacts with the milk on the plate. The soap alters the surface tension of the system and one can capture the Marangoni effect.

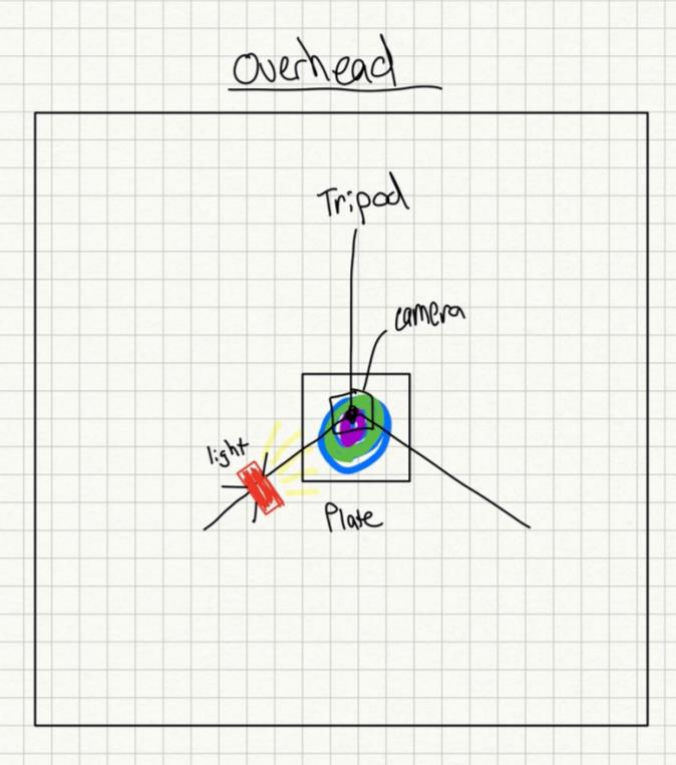


Figure 2: Overhead layout of subject and lighting

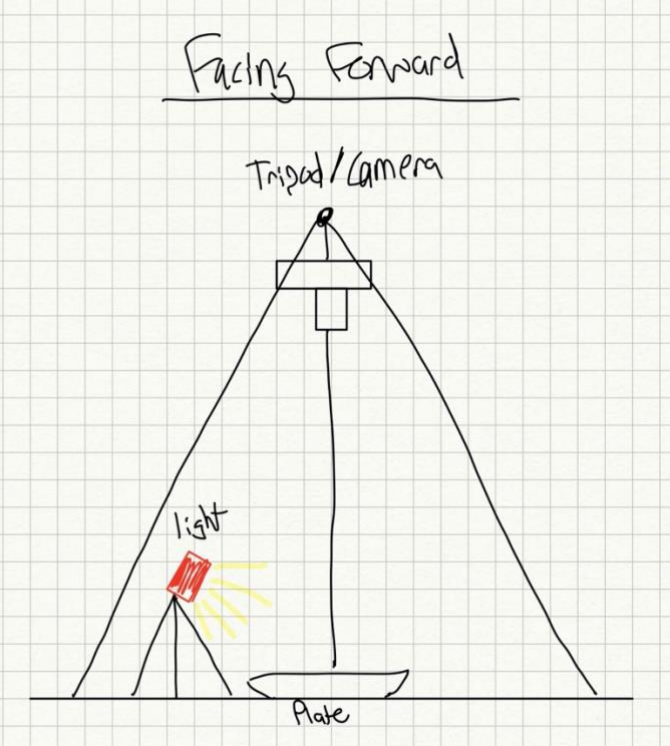


Figure 3: Forward facing perspective of subject and lighting

In this investigation the two main fluid flow phenomena captured are surface tension and the Marangoni effect. To understand the Marangoni effect, surface tension must first be discussed. Surface tension is a general trait for liquids where the cohesive design of its molecular structure allows them to resist a force at the surface (3). What this means is that there is a stronger cohesion of the liquid molecules at the surface compared to the air above it, which makes it more difficult for an object to break through the surface. This characteristic can be calculated for almost all liquids using Equation 1 below and is expressed as N/m For this experiment whole milk at about 55 degrees Fahrenheit can be assumed to be 45.5 mN/m, olive oil is 33 mN/m, and soap can be assumed to be 25 mN/m (4, 5, 6). By combining several liquids of varying surface tension values and properties together, interesting interactions can occur, most notably the Marangoni effect. The Marangoni effect is "the macroscopic manifestation of a liquid flow as a result of local differences (gradients) in interfacial tension" (1). This means that due to a varying surface tension across the top of a liquid, fluid flow is induced. This experiment aimed to use paint and oil to capture this flow and movement in a more colorful and defined way. The milk in the plate would act as my starting fluid with an even surface tension, then the mixture of milk, paint, oil, and soap in the measuring cup is the catalyst. This is due to the soap acting as a surfactant that will lower the surface tension in the area it is poured into, causing the surface tension to taper away from this area and create the flow (2). By adding the colorful paint, it is much easier to see this movement, and with some skill can become quite the artistic and mesmerizing effect.

$$\gamma = \frac{1}{2} * \frac{F}{L}$$

Equation 1: Definition of surface tension. F is defined as force and L is defined as length

3. **Visualization:** This video was a demonstration of multiple different liquids with different properties interacting together in an abstract and artistic manner. The main liquid was Kroger whole milk, which was mixed with Artist's Loft acrylic paint, then mixed with

Trader Joe's olive oil, and finally a small drop of Dawn dish soap. The measurements of each were about 10ml of paint and 10ml of milk mixed together, then I added a few drops of oil and one drop of soap. For the milk on the plate, it was just enough to cover it, about 70ml. For the lighting, only one light source was used, the Aputure AL-MX on-camera LED light set to its highest brightness setting and daylight white balance. This small light was placed on a small flexible tripod that pointed at about a 45-degree angle toward the plate that the mixture would be poured onto.

4. **Photographic Technique:** In an attempt to capture more of the fluid movement and accentuate all the small details, like the oil bubbles and changing surface tension, I decided to capture this experiment in high-speed video, 120 frames per second, in full HD 1920 x 1080. This video would also be recorded in Hybrid Log Gamma, a video setting that would allow for a lot of light and color detail to be captured but be fairly easy to edit. For this, I used my Sony A7iii and the Tamron 28-75mm f2.8 lens. I set the camera up on a tripod above the scene and had the lens set to 75mm and its closest focus distance to capture a close up, detailed, and abstract perspective of the fluids interacting. In addition to this, this camera has a special feature called "Super 35mm" mode where the video is cropped in camera to 1.5x crop factor equivalent for full frame cameras but retains the full detail and abilities of the sensor. This allowed for the video to get even closer to the scene technically and had a 35mm equivalent focal length of 112.5mm. For the 120 FPS video settings, the shutter speed was set to 1/250 of a second to adhere to the 180-degree shutter rule, which states the shutter speed should be double the frame rate to capture motion that is most similar to what the human eye would perceive. The aperture was then set to f4.5 to ensure sharp focus was achieved but enough light was allowed in the get proper exposure. Lastly, the ISO was set to 400 to compensate for the high shutter speed and smaller aperture so the video was well exposed. With the raw video files recorded, I then imported them into Davinci Resolve to be cut together and color graded. I clipped two scenes that showed the fluid motion best, the initial pour that shows the layers of each liquid and how they spread out, and the interaction of the changing surface tension that caused the bubbles and colors to move. For this, I was able to slow down the initial pour by 5 times, from 120 FPS to 24 FPS, and the fluid interaction was then sped up by 20%. With the structure set, I then color graded the clips, adjusting the white

balance to be slightly cooler and whiter, increasing the exposure and increasing contrast, and finally added saturation to certain colors to make them stand out more. Lastly, music was added to create a more ethereal sense to the abstract color movement ("Arcade" by Generation Lost via Artlist – See attachment 1).

Photographic Details Overview

- **Object Distance:** 39cm
- **Lens:** Tamron 28-75mm f2.8 set at 75mm
- **Camera:** Sony A7iii
- **Resolution:** 1920 x 1080 HD Video
- **Frame Rate:** 120 FPS
- **Aperture:** f4.5
- **Shutter Speed:** 1/250
- **ISO:** 400
- **White Balance:** 5500k

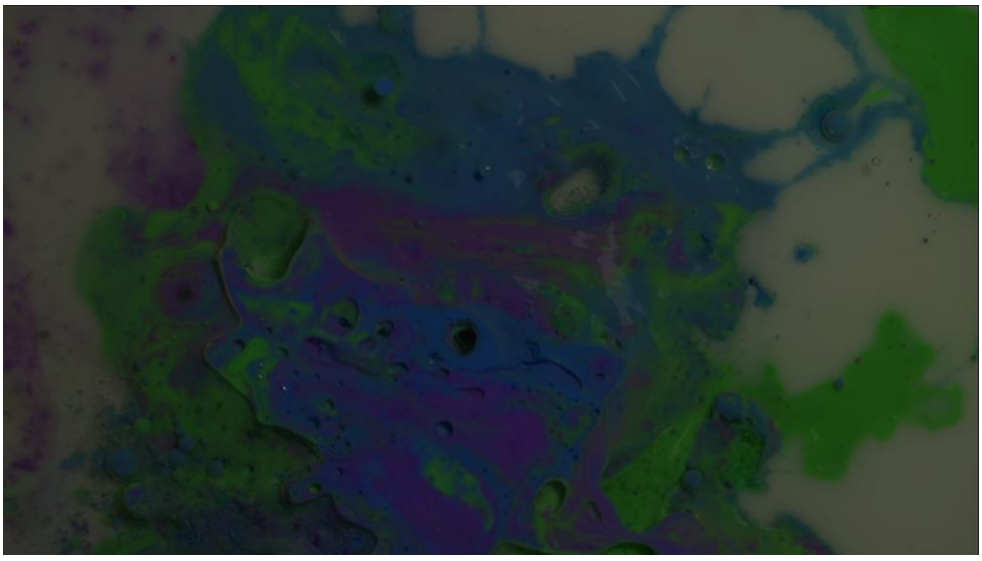


Figure 4: RAW Image

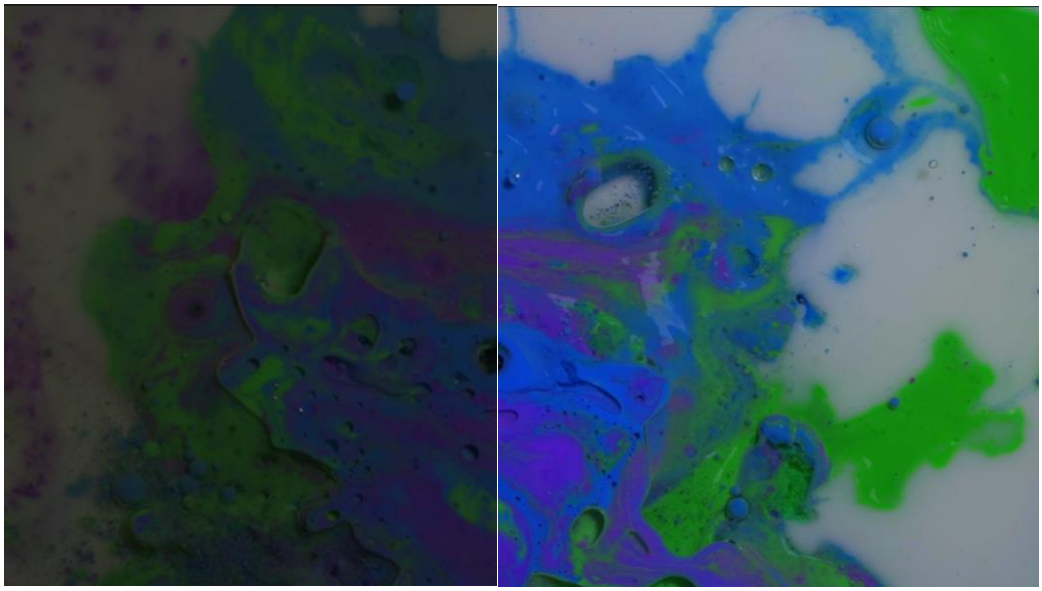


Figure 5: Raw Image vs Final Image

5. **Self-Assessment:** This image reveals the delicate balance between surface tension and the interaction between several different fluids of different properties. This chaotic reaction can be hard to control and predict but when done well can be an artistic display of physics in motion. What I like about this video is how well the vibrancy of the colors came out and that I was able to get the oil mixture right as the bubbles and defined lines between colors and fluids are sharp and clear. The main disappointment I have with this video is not being able to produce a more chaotic reaction as well as not having a macro lens to closely focus on some of the more erratic sections of the fluid as a whole. With a macro lens and possibly a more accurate tool to inject soap or oil into the mixture I may have had a better video to demonstrate the dynamic interaction on display. Still, this experiment does a good job at showing in near macro detail the sporadic changes that occur at the surface of the liquid mixture and the added colors and oil only add to the vibrant and abstract nature of this effect.

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Arcade
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