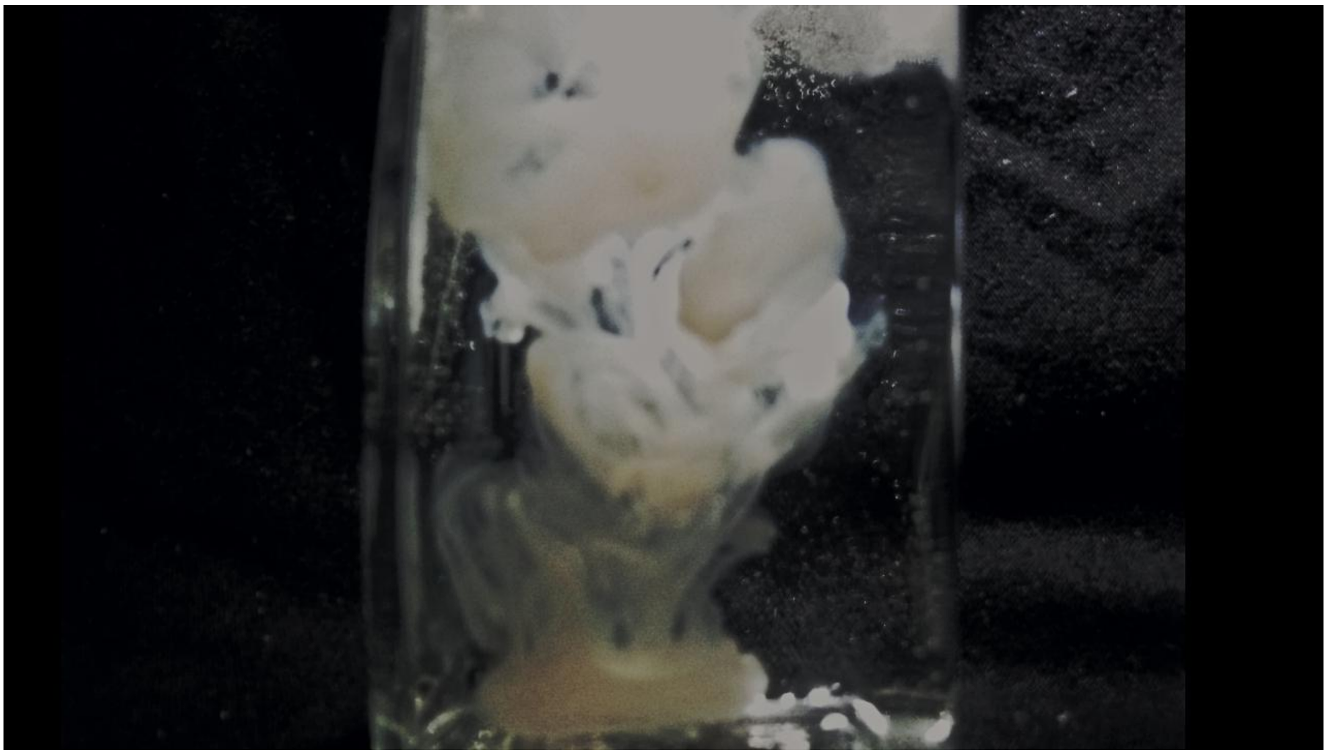
Bryce Gallo

Second Image/Video Assignment

MCEN 4151

10/11/21

Milk Drop Experiment



For the second image assignment, I decided to run the milk drop experiment to photograph the transition in the milk from laminar to turbulent flow. The goal of this experiment was to see the way the milk behaved when poured into water, photograph it, and then use physics to loosely determine why the milk behaves the way it does. I also wanted to experiment with different lighting techniques during post processing, and this picture was an excellent test subject.

The supplies for this experiment consisted of about a tablespoon of milk and a glass container of water. The procedure for this demonstration would be to first set up the camera and container of water. I used an empty salt shaker since I wanted a small enough container to get the entire milk-water system in the shot. To take the picture, the milk was poured into the water from about a half an inch above the container. I set the camera to take a burst of pictures close to the moment when the milk hits the water, and then repeated the experiment several times with slightly different lighting settings. The procedure is very simple for this particular phenomenon, but the pictures come out with extremely dynamic and interesting shapes from the milk.

The physics of the experiment are defined by the Reynolds numbers of the water and of the milk. Generally, the higher the Reynolds number, the more turbulent a flow is. However, when two fluids are mixed very suddenly, like the milk being poured into the water, the fluid with the higher Reynolds number will temporarily affect the flow of the other fluid. In this case, the Reynolds number for the milk and water can be approximated using the equation:

$$Re = \frac{VL\rho}{\mu} = \frac{VL}{\nu}$$

where V is the velocity, L is the length, and the density ρ is combined with the dynamic viscosity μ to form the final equation with the kinematic viscosity variable, ν. The kinematic viscosity is $1.130E^{-6}$ Pa·s for milk, and $1.002E^{-6}$ Pa·s for water. [1] V can be found from the length because of the equation:

$$V = \sqrt{2gL}$$

where g is gravity and L is the pour height, which is 12.7mm (half an inch). This means the Reynolds numbers for the milk and water come out to be roughly:

$$Re_{Milk} = \frac{\sqrt{2gL}*L}{\nu_{Milk}} = \frac{\sqrt{2*9.8\frac{m}{s^2}*(.0127m)}*(.0127m)}{1.130E^{-6}Pa*s} = 5607$$

$$Re_{Water} = \frac{\sqrt{2gL}*L}{\nu_{Water}} = \frac{\sqrt{2*9.8\frac{m}{s^2}*(.0127m)}*(.0127m)}{1.002E^{-6}Pa*s} = 6323$$

Since water has a bigger Reynolds number, it interferes with the milk as it is being mixed into the water. This is the reason why there is more laminar flow near the surface, where the water hasn't mixed as much, and turbulent flow towards the bottom, where the water has thoroughly changed the flow.

The camera used was the Insta360 One R with a 4K wide angle lens. The camera is usually used for 360 degree videos and more action shots with motion, however it is also modularized to be capable of taking good pictures with the 4K lens attached. I used two flashlights as the light sources, one pointing almost directly down where the milk was poured, and one behind the black cloth pointing up. The camera was placed on the table at a slight upward angle with the ability to capture the whole water container in the shot. The container was placed at a slight angle to the camera to show a bit of depth and to give the picture a more 3-dimensional feeling. I can control the camera with my phone, so I was able to take burst photos close to the moment the milk hit the water. The settings of the camera are below:

Camera	
Camera Maker	Insta 360
Camera Model	One R
F-stop	f/2.8
Exposure Time	1/60
ISO Speed	ISO-400
Exposure bias	0 step
Focal Length	16.4mm
Dimensions	4000 x 3000
Width	4000 pixels
Height	3000 pixels

Figure 1: Camera Settings

For the post processing, I knew I was going to have to fix the blowout from the overhead light before I did any color changing. I brought the darkness levels up as can be seen in the background cloth in **Figure 2**. I also decided that the top half of the photo was not usable because of the overexposure, so I cropped it out and zoomed into the bottom half of the container. The 4K lens preserved a surprising amount of detail, so there weren't any problems with artifacts. The transition from laminar flow to turbulent can still be seen, but it happens right at the top of the picture. The only color correcting I did was adding a slight bit of saturation, and making the whites more creamy. The comparison can be seen below.

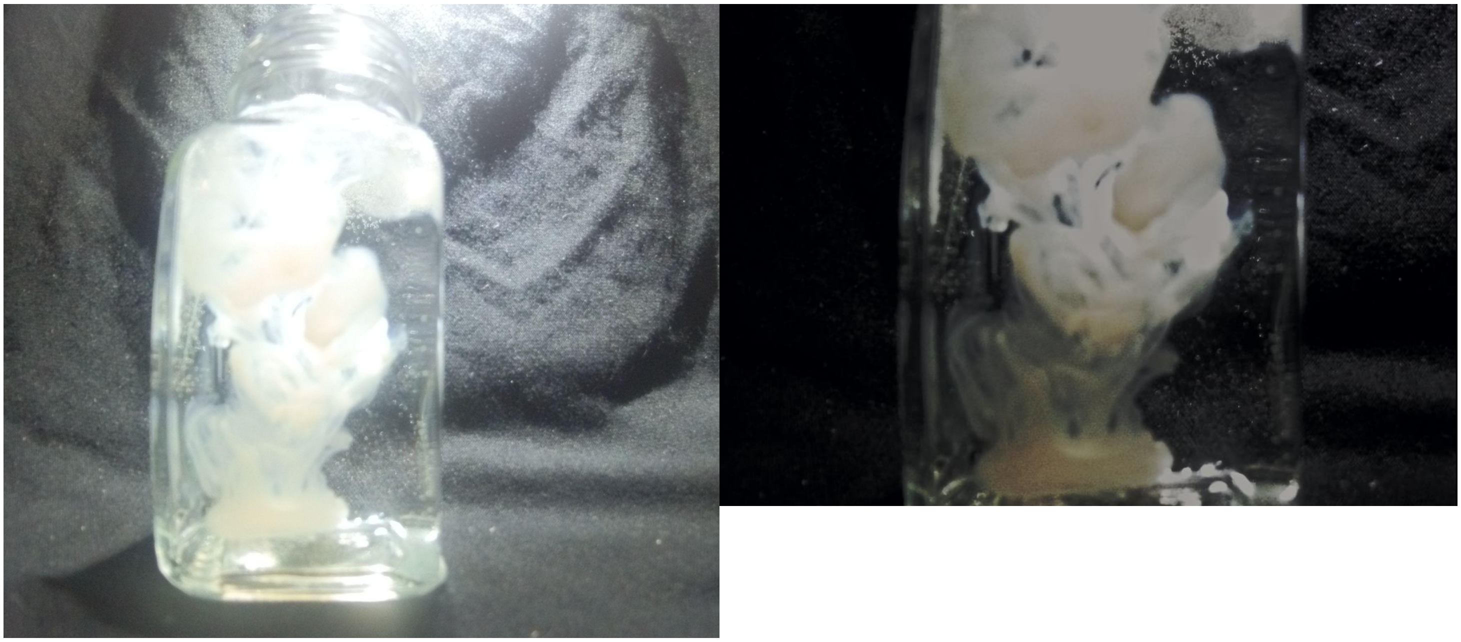


Figure 2: Post processed image on right, Original on left

After reviewing the picture, it does accomplish what I set out to do, and captures the different types of flow of the milk at different positions in the water. I am disappointed with the lighting of this picture because of the blow out at the top. If I were to do this again, I would find a way to light the container from the bottom, so that the light is less concentrated on the pouring of the milk, and instead is concentrated where the milk settles. To develop this experiment further, I wonder what would happen if the milk was poured into less viscous fluid like ethanol. Would the plume of laminar flow be longer?

References

[1] Engineering ToolBox, (2003). *Liquids - Kinematic Viscosities*. [online] Available at: https://www.engineeringtoolbox.com/kinematic-viscosity-d_397.html