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Flow Visualizations
MCEN 4228-010

Assignment 6: Group Project 3

Very few flow phenomena are seen as frequently in day to day life as surface tension. No matter what fluids are involved, at any boundary between two different fluids there is a very unique interaction between the fluid molecules. To further visualize this phenomenon, this experiment will attempt to visualize the concept, but will be described using known characteristics of the flow. Several different setups will be used to fully understand what is being observed.

The setup used to create the flow was very simple. The objective was to create holes in a container that would cause fluid to emerge with enough velocity to fulfill the image intent. The apparatus used was a large water jug and fruit punch as the liquid. To create a large outlet velocity, a large enough pressure was needed at the location of the outlet (See Figures 1 and 2). The pressure could easily be increased by increasing the depth of the fluid as described by the hydrostatic equation below:

$$\Delta P = \rho g \Delta h$$
Eqn. 1 – Hydrostatic Equation (1)

where the change in pressure from the surface is a function of the density of the liquid, gravity, and the depth of the fluid.
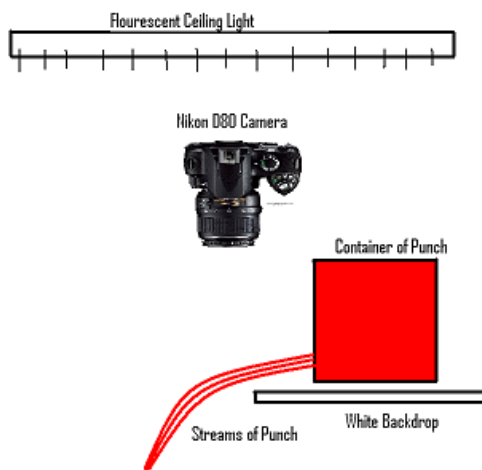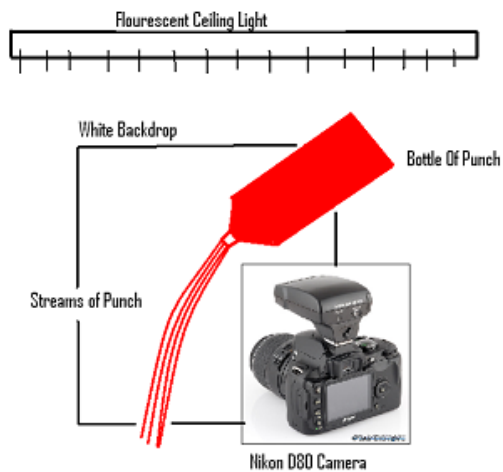

Figure 1 – Setup 1

Figure 2 – Setup 2

For our experiment, the water depth was approximately 13 cm (.13m) with a liquid density close to water of 1000 kg/m^3 (1). Using these values, the pressure of the exiting fluid was approximated to be 1569.6 Pa higher than that of the atmospheric pressure. The exit holes were created to be approximately 2mm using a nail. In the process of creating the holes, the nails indented the container in a way that caused the exiting liquid to spiral at high velocities. This effect is seen in the unmerged fluid paths of Figure 5. Due to conservation of mass, a relationship exists between the velocity of the exiting liquid and the velocity of the level of fluid in the container that is a function of density and area of the flow. Though the velocity of the level of the fluid is not needed, the exit velocity of the fluid can be calculated using the following equation:

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

Eqn. 2 – Exit Velocity (1)

This equation gives an exit velocity of 1.59 m/s. Using the velocity, it was then necessary to calculate what shutter speed would be necessary to keep the image time resolved. The initial velocity of 1.59 m/s will only describe the instantaneous velocity at the exit and there for a smaller velocity will used to calculate the shutter speed. This velocity is estimated to be around .3 m/s. To keep the image from having too much motion blur, a change in position of no more than 1 cm is desired. The minimum shutter speed to accomplish this was then Dist/Velocity or 1 cm divided by 30 cm/s giving a shutter speed of 30. The velocity also had an effect on the fluid phenomenon and the ability to visualize the surface tension. As the fluid exited the holes, they traveled outward in separate streams at approximately the same velocity. However, once their path was interrupted and intersected with a neighboring path, the surface tension between the liquid and the surrounded air caused their paths to merge (2) (See Figure 7 in Appendix)
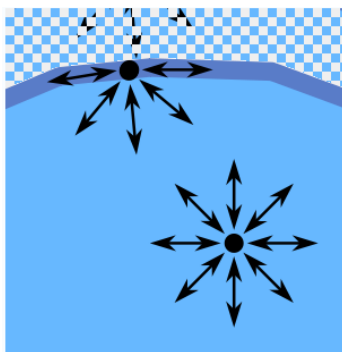

Figure 3 – Surface Tension (3)

$$Re = \frac{\rho V D}{\mu}$$

Eqn. 3 – Reynolds Number

The larger the liquid velocity, however, the less likely the fluid would be to merge together due to its ability to overcome the surface tension. Therefore a large enough velocity was needed to allow for the desired exit motion, but not too much to prevent the surface tension effect to be visible. Finally, it can be useful to calculate the Reynolds number of the exiting fluid which dictates the behavior of the fluid after exiting. This value was calculated from Equation 3 above to be 3180 (approximating the density and viscosity to be that of water at 20^oC).

To better visualize the fluid behavior, a colored fluid was necessary and was chosen to be fruit punch. This liquid was purchased at a local grocery store and no dilution was necessary. In order to capture the relatively quick motion of the fluid, a significantly large shutter speed was needed. In using a quick shutter speed, a sufficient amount of light was needed to give the desired image. To get the right amount of light, the ambient light was used along with the camera flash. This allowed for either a slower shutter speed to capture the general motion of the fluid or a quick shutter speed that would capture the fluid at one instant in time.

Unmerged Paths – Matthew Blessinger

Table 1: Matt Image Specs

Size of the field of view	5 in. x 6 in./ 30 in^2
Distance from object to lens	7 inches
Lens focal length	135mm
Lens specifications	18.0-135.0 mm f/3.5-3.6
Type of camera	Nikon D80 Digital SLR
Original Image Size	3872 X 2592
Final Image size	926 X 1648
Aperture	F/5.6
Shutter Speed	1/80 second
ISO Setting	100

Table 1 gives all of the image and camera settings used to capture the flow of the punch. The focal length was set at its max to get the best close-up picture possible. The distance from the stream was then varied to get the correct focus. I then set the Nikon's shutter speed to a 1/80 sec. because it allowed me to capture the fluctuations in the streams without having any motion blur. After the initial

image was captured, several Photoshop techniques were performed to further highlight the fluid flow. In Photoshop I cropped the image, leaving a close-up of the streams.

This particular photo was taken when the height of the punch was 5 in. When we were experimenting with "tying" the streams together, we noticed that the individual streams were interesting themselves. This is because the streams exit the bottle in a spiral. This can be seen with the varying cross section of the streams. What I really liked about this photo is the spiral/helix pattern of the streams, and the individual drops at the bottom of the picture. The individual drop was caused because the velocity of the stream increased as that point and the surface tension could no longer hold the stream together anymore, and thus it started breaking apart. I believe the photo captured a unique part of the experiment and how surface tension affects fluid flow. To improve the experiment, I would have extended the white bottom sheet so that the black spot was at the bottom of the picture. In addition I would have pointed a light directly at the bottle to eliminate the shadow.

Merged Paths – Jason Ortmann

Table 2: Jason Image Specs

Size of the field of view	5" X 4"	5" X 4"
Distance from object to lens	6 Inches	6 Inches
Lens focal length	95mm	95mm
Lens specifications	18.0-135.0 mm f/3.5-5.6	18.0-135.0 mm f/3.5-5.6
Type of camera	Nikon D80 Digital SLR	Nikon D80 Digital SLR
Original Image Size	3872 X 2592	3872 X 2592
Final Image size	2614 X 1524	
Aperture	F/5.6	F/5.6
Shutter Speed	1/30 second	1/60 second
ISO Setting	100	100

To create the final image using the two original image files, the original files were first cropped. They were then placed together into one image and the blur tool was used on the seam between the images.

I am very satisfied with my final image because I was able to show what I was intending to show as well as some other fluid characteristics that were not expected. The ability of surface tension to "bunch" different jets together was shown incredibly well, and how they combined was very extraordinary. The only thing I did not like about the image was that the side view was blurry in order to show the entire stream. Increasing the shutter speed resulted in capturing only one frame of the

motion which did not demonstrate the overall behavior of the fluid. My only question is why the fluid appeared to twist after they combined. I would like to see if this effect was due to the surface tension, or just in the orientation of the jets coming out of the container. However, I believe I completely fulfilled my image intent and am satisfied with the overall quality of the image(s).

Combination – Kevin McCoy

Table 3: Kevin Image Specs

Size of the field of view	6" X 5"
Distance from object to lens	8 Inches
Lens focal length	135mm
Lens specifications	18.0-135.0 mm f/3.5-3.6
Type of camera	Nikon D80 Digital SLR
Original Image Size	3872 X 2592
Final Image size	3872 X 2592
Aperture	F/5.6
Shutter Speed	1/30 second
ISO Setting	100

The image was not photoshopped or cropped. Care was taken during the original image to frame the image as shown to ensure everything necessary was included in the frame and nothing else, this way the final image is as large and of the best quality possible.

This image reveals the surface tension phenomena. There are six total holes in the cap of the bottle. The lower three streams have merged due to surface tension as well as the two above those. The upper stream did not contact the lower stream and thus took its own path. Eventually the bottom two merged streams collect due to surface tension and travel together and even farther down the stream the upper droplets tend to rejoin with the group stream. The upper stream shows how surface tension is lost within the stream and the droplets separate, where surface tension still holds them together as droplets, but no longer as a solid stream. I believe the physics are shown quite well. I like the image and the inclusion of the bottle really helps to describe what is going on. The flow tends to spiral after streams have come together and I still do not quite understand why that is happening. I assume it is because of the momentum of the flow and the flows are not hitting exactly tangentially in one plane so as the grab together due to the surface tension the momentum of each stream causes them to rotate about each-other. I believe the intent of capturing the phenomenon of surface tension quite well and

am happy with the result. In order to develop this idea further I would love to play with large variations in hold diameter, distance between holes, and head pressure to monitor which variables have which effects on the surface tension phenomenon.

Works Cited

(1)
Smits, Alexander. <u>A Physical Introduction to Fluid Mechanics.</u> New York: John Wiley and Sons, Inc.,
        2000.

(2)
Walpole, Brenda. <u>175 Science Experiments to Amuse and Amaze Your Friends</u>. New York: Random
        House, 1987. Pg 28

(3)
2006-05-18 11:07 Roland.chem 300×304×8 (14982 bytes) *Bildbeschreibung: Wasser in Tropfen und an
        der Phasengrenze * Quelle: own made * Fotograf/Zeichner:
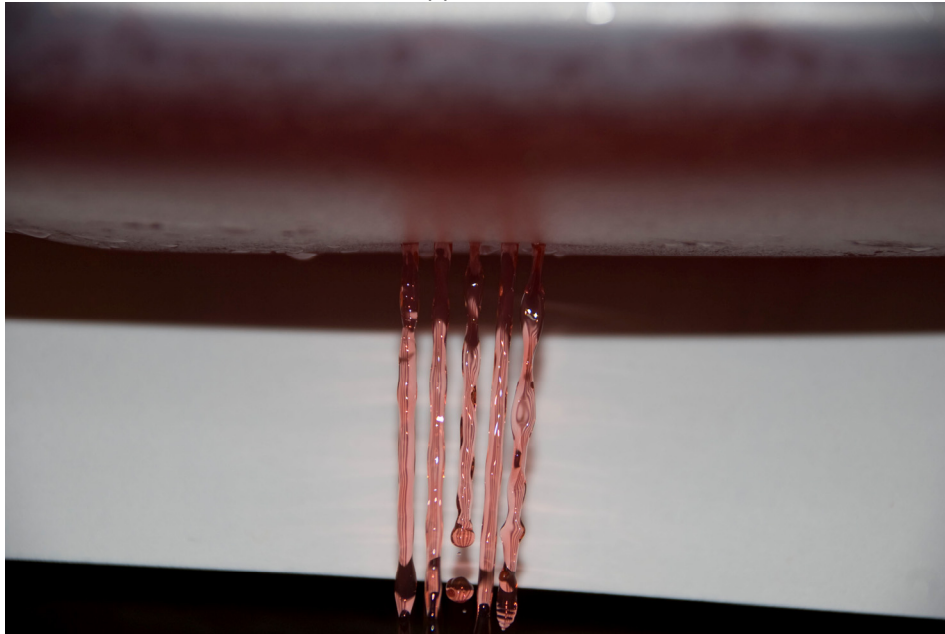   [[Benutzer:Roland.chem|Roland.chem]] * Datum: 18.4.06 * Sonstiges*

Figure 4 – Unmerged Paths Original

Figure 5 – Unmerged Paths Final

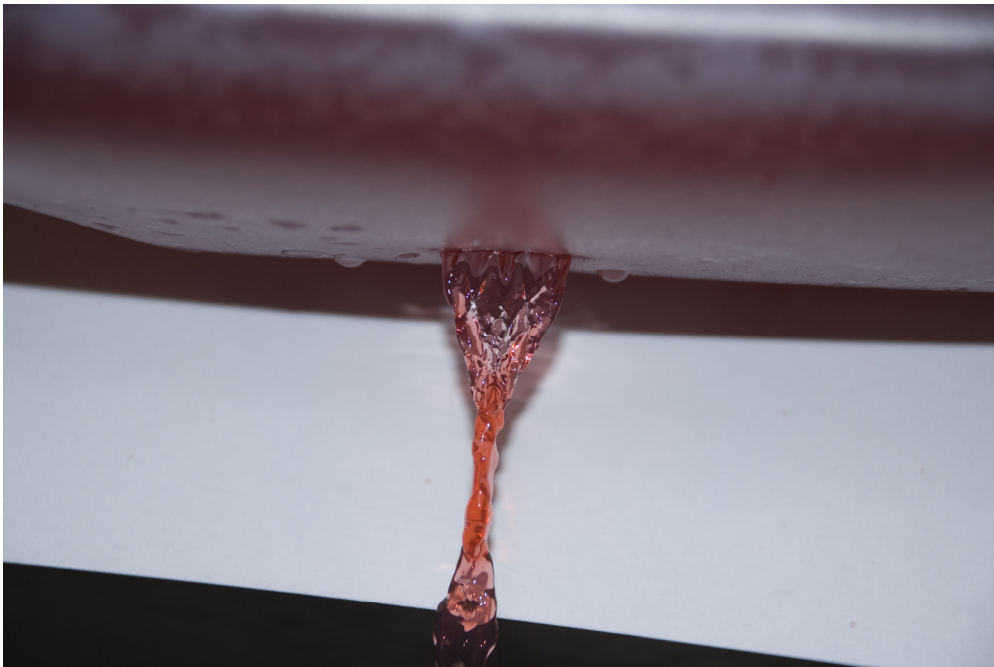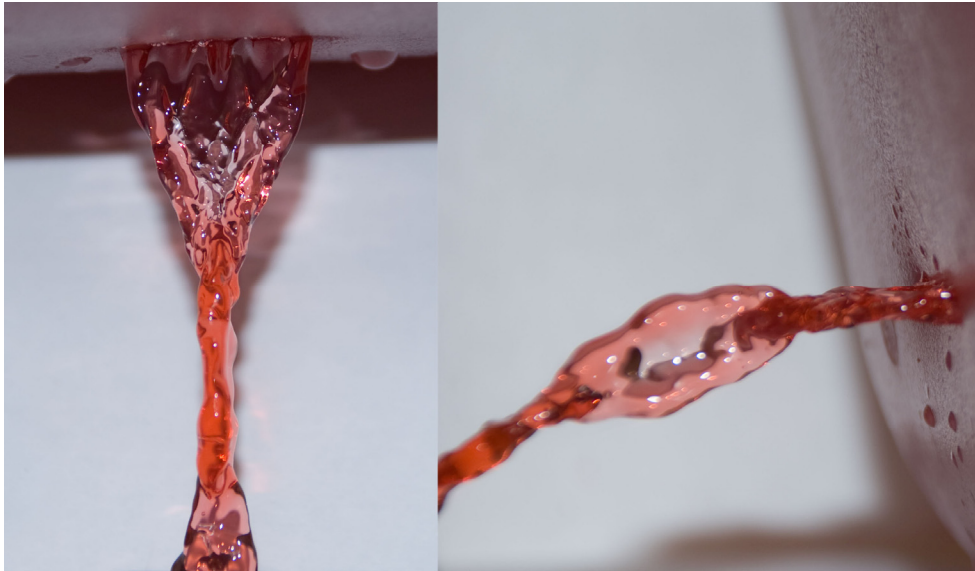Figure 6 – Merged Side View Original

Figure 7 – Merged Top View Original

Figure 8 – Merged Final

Figure 9 – Combination Original/Final Image