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# Team Third – Whirlpool

This image was taken for submission as the third team assignment for the course. It aims to capture the motion of swirled water exiting a small opening and the development of the motion as it is pulled downward by gravity. The effects of surface tension and laminar flow can be seen in the upper portion of the image, and the overcoming of said surface tension in the lower portion. Capture of the image was accomplished with assistance from a colleague, Karinne Bratkowsky, who has a casual background in photography and took the photo.

The apparatus used to create this flow, as shown in Figure 1, was simply a two-liter soda bottle with a hole punched into the bottom to allow airflow as the water drained from the bottle opening. The bottle was filled approximately two thirds with the hole in the base plugged, then the bottle was inverted and revolved to develop a whirlpool within. The water then drained from the bottle as pictures were taken. The process was repeated numerous times until a set of images were available to choose from. The portion of the flow shown in the image measures roughly 1 inch wide at the top, 2.5 inches wide at the bottom, and 7 inches vertically.

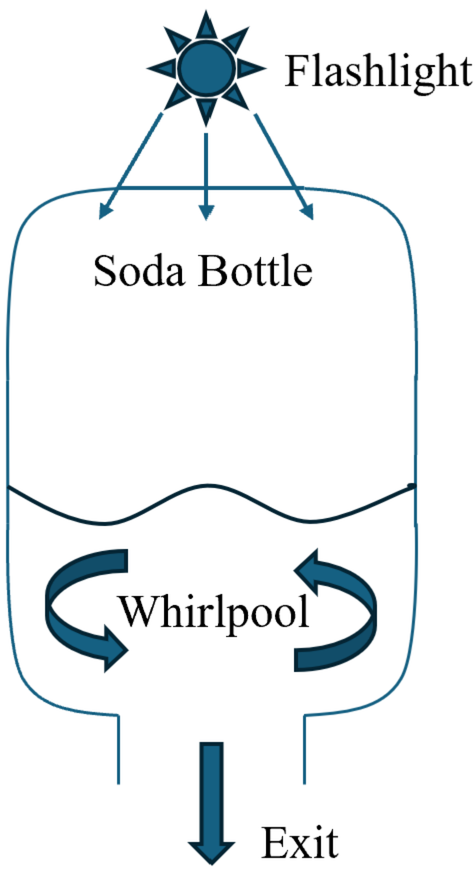

*Figure 1: Diagram for Flow Apparatus*

Beginning in the whirlpool generated within the bottle, the flow carries that angular velocity through the opening and continues to revolve about a central axis. As seen in the upper portion of the image, the surface tension of the water maintains a semi-cylindrical shape until the combined gravitational and centrifugal forces overcome it. The general form of the flow does not vary greatly with time, though the length of the laminar portion becomes shorter as the bottle empties due to the decrease in total fluid momentum within the source whirlpool. To further describe this flow, the Weber number, which relates surface tensile forces to inertial forces, provides a scale for quantifying the flow[1]. This value is defined by:

$$We = \frac{\rho v^2 l}{\sigma} = \frac{\left(1000\,\frac{kg}{m^3}\right)\left(0.08\,\frac{m}{s}\right)^2 (0.025\,m)}{\left(1.28e-4\,\frac{N}{m}\right)} = 1250$$

where $\rho$ is the density, $v$ is the velocity, $l$ is a characteristic length, and $\sigma$ is the surface tension of the fluid. These values were chosen based on estimates of fluid rotational speed and mass flow rates as the flow occurred.

The flow in this image is purely visualized by the light that was shown into the water as seen in Figure 1. Due to the almost perpendicular motion of the circulating water to the light source, ripples within the water became quite visible due to the reflection and refraction of the light. This proved to be much more effective than initially thought and made the need for alternate visualization methods unnecessary.

The image was captured with a Canon EOS Rebel T3i digital camera. To capture a higher quality image in low-light conditions, the settings were adjusted to ISO-1600, f/6.3, and 1/125 second exposure at a 29 mm focal length. This allowed for a relatively instantaneous capture of the flow that held focus while avoiding too much graining and motion blur. The image was taken from approximately one foot away at a slight upward angle to avoid capturing objects behind the flow. The original image, seen in Figure 2, was taken at a full 18-megapixel resolution of 3464x5202 pixel and was edited to 1659x2390 pixels to crop out the bottle outlet and lower portion of the scattering flow. The only other edit made to this image was increased sharpness to accent the ripples within the flow.

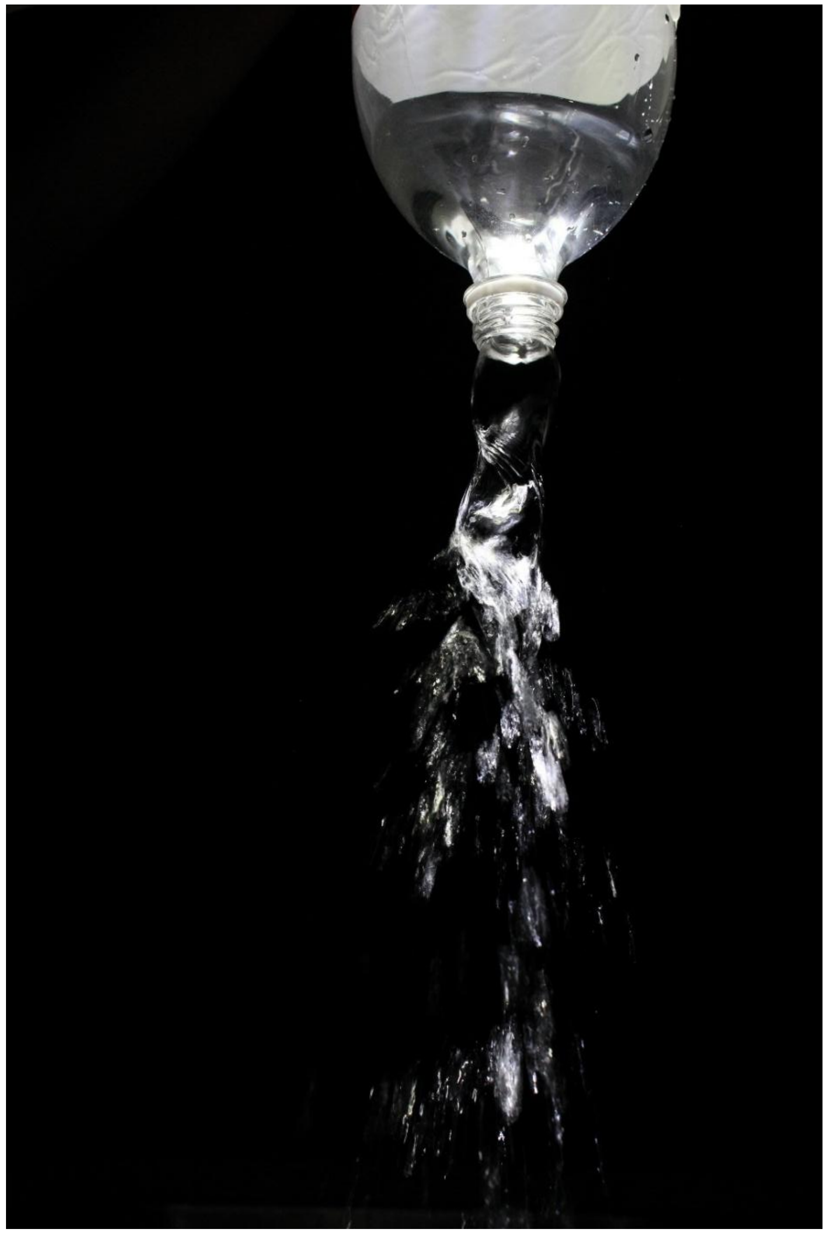

*Figure 2: Original, Un-Edited Image of Flow*

Ultimately this image reveals a sort of balance between the forms water can take on, ranging from the smoothly connected to random scattered flow. Capturing this image went significantly better than anticipated, and the results are pleasing. As mentioned previously, the image could be improved by increasing the shutter speed to capture more detail in the quickly moving droplets, but aside from that, I am quite content with the results.

# References:


[1] “Weber number,” *Wikipedia*, May 21, 2021. https://en.wikipedia.org/wiki/Weber_number