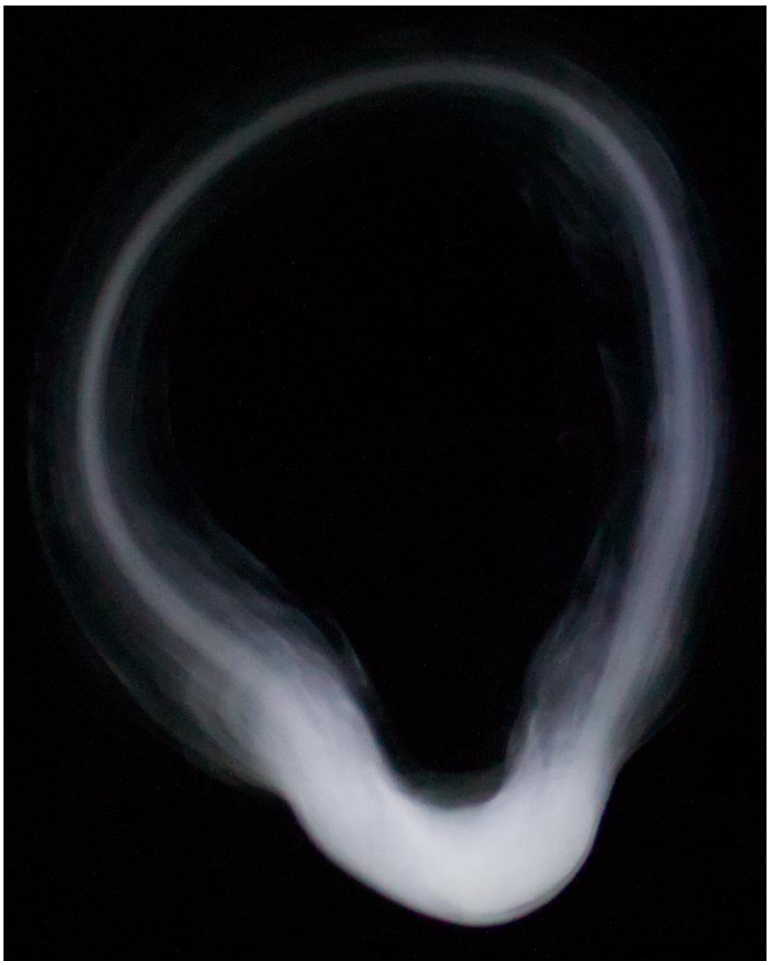
Friderik McMahan

MCEN4151-001

10/03/2025

Team First – Warped Vortex



This image was taken with the intention of capturing the dynamics of stage fog within a vortex. Though the Team First assignment called for team effort in capturing images, this image was taken as a solo effort after previous attempts at collaboratively gathering images. This was due to the need for a dark room with well-controlled lighting, which was achieved by taking the image late at night. Regardless, the efforts of the team, Nathaniel Wheaton and Kanon Page, provided much needed information through initial experimentation that assisted with later photographing efforts.

The vortex was generated using a Zero Blaster toy vortex gun, a rough sketch of which is shown in Figure 1. This device utilizes electrical resistance to vaporize stage fog fluid inside of a chamber which is then ejected through the circular opening by striking the flexible membrane at the rear of the chamber. When the fog passes through the circular opening, frictional forces cause the fluid to begin circulating, eventually developing into a vortex ring[1]. This flow occurs in open air, travelling outward from the 2-inch diameter opening, slowly growing to roughly a diameter of 6 inches, eventually dissipating into the surroundings.

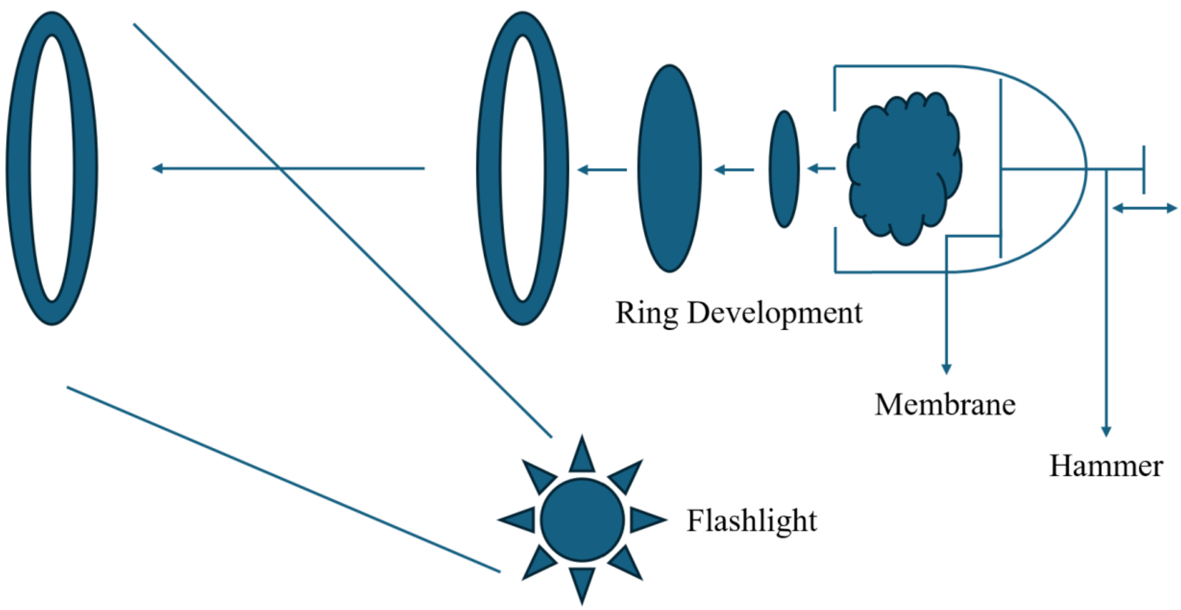


Figure 1: Diagram of Apparatus Setup and Ring Development

The Taylor number serves to describe the flow as a ratio of angular velocity of the fluid to the viscous forces acting on the fluid. It is often used in reference to Couette flow, which can be related to the formation of these vortex rings. The number is defined by the equation:

$$Ta = \frac{4\Omega^2 R^4}{\nu^2} = \frac{4\left(6\frac{rad}{s}\right)^2 (0.0127\ m)^4}{\left(1.46e-5\frac{m^2}{s}\right)^2} = 1.93e4$$

Where Ω is a characteristic angular velocity, R is a characteristic radius, and ν is the kinematic viscosity of the fluid. The values for angular velocity and radius are rough estimates loosely based on observations of a variety of rings produced throughout the process of capturing the final image. The calculated Ta value is significantly greater than the accepted critical value of 1700 signifying the generation of vortices[2].

As previously mentioned, the flow is visualized using stage fog. This is integrated into the toy via the trigger system, requiring no additional markers for flow visualization. There is a blue LED included within the chamber, but it only dimly lit the vortex ring for short distances. Thus, a white LED flashlight was aimed diagonally across the room such that the vortex ring would pass through the light beam as it travelled. The light was positioned facing a dark surface so that the light would not scatter around the room, which was proven to be an issue with previous setups. The positioning of this arrangement is also portrayed in Figure 1.

The image was taken from approximately four feet away with the vortex itself occupying roughly 1/20th of the total frame. This was accomplished with a Canon EOS Rebel T3i digital camera with settings of ISO-3200, f/4, and a shutter speed of 1/60 seconds at a focal length of 27 mm. These settings were chosen due to the low-light environment in which the image was taken. Post-processing of the image included cropping, sharpness, and contrast modifications to enhance the visibility of smoke details within the vortex. The original un-edited photograph is shown in Figure 2 below.

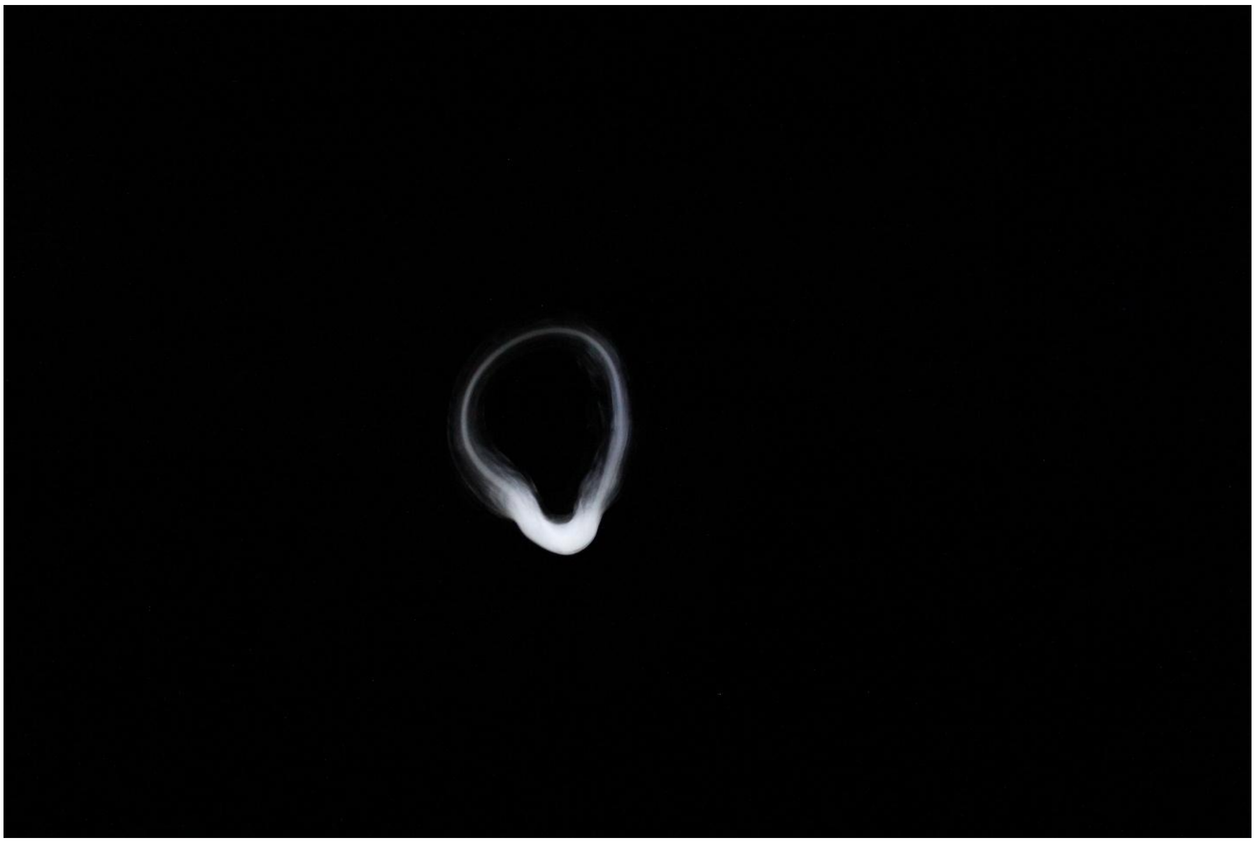


Figure 2: Original Un-Edited Photo of Vortex Ring

Revealed by this image are the effects of density and angular velocity on fluids. This is clearly shown by the stage fog which, while largely being sustained by the rotation of the vortex, tends to gather in the lower section of the ring. Potential improvements to the process of taking this image include achieving higher resolution of the vortex itself by getting closer or improving the consistency of the motion of the vortex ring after formation. Either of these could more easily be achieved with the assistance of another person.

References:

[1] The Royal Institution, “The Science of Vortex Rings,” *YouTube*, Mar. 14, 2018. https://www.youtube.com/watch?v=yjgACB7urOo

[2] Wikipedia Contributors, “Taylor number,” *Wikipedia*, Dec. 31, 2024. https://en.wikipedia.org/wiki/Taylor_number