Vis 2 Report
Flow Visualization
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I. **Introduction**

The goal of this image was to capture a vortex ring generated by a Zero Blaster smoke ring gun. This was challenging due to the motion of the smoke ring causing the image to come in and out of focus, but we were ultimately able to capture a solid image of a smoke ring developing through the air.

II. **Testing Setup and Materials**

The test apparatus consisted of the camera sitting on a tripod facing where the smoke ring gun would fire at an angle. This allowed the smoke ring to develop forwards and be captured while not capturing the gun itself. Figure 1 shows the experimental setup below.

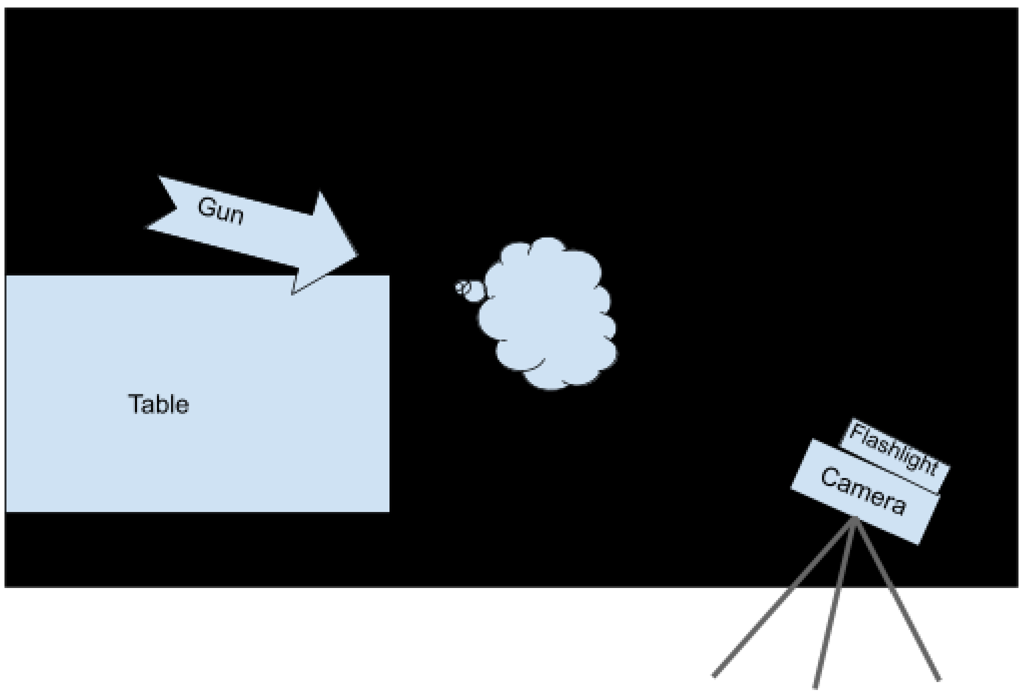

Figure 1: Experimental Setup

III. **Physics Analysis**

The primary physics concept illustrated in this image is that of a vortex ring and its vorticity.

A. **Vortex Rings**

A vortex ring is defined as a core of fluid with vorticity, around which additional fluid moves in a circular orbit (Hertzberg). This vorticity is defined as the rotation of a fluid around its own middle (Hertzberg). As the fluid moves away from the core of the vortex, its radial velocity decreases exponentially as the structure of the vortex decays (Hertzberg). As shown in figure 2, the fluid around the ring itself is moving in the aforementioned circular orbit. This orbit is what drives the vortex ring across the room. The arrows in figure 2 represent the direction that the outermost layer of the ring is moving, and we can see that each section of the fluid is moving "into" the screen. When all of these velocities are added up, it causes a net motion into the screen. The process by which each section of the vortex ring causes the adjacent sections to move is called self-induction, as the vortex ring itself is inducing the motion that it is experiencing (Hertzberg). It can also be seen that the velocity of the fluid is changing sign around the center of the vortex ring.

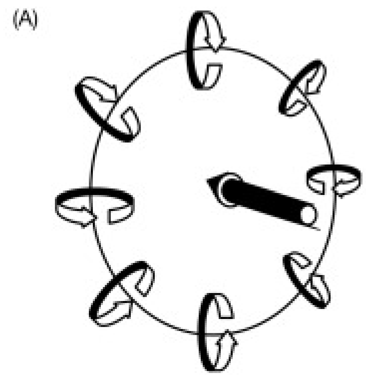

Figure 2: A diagram of a vortex ring (Friedlander et al.)

We can see in the image that this is not a stable phenomenon. The wake of fluid being left behind by the ring indicates that the ring itself will eventually dissolve and cease to exist. This is because other forces, such as air friction and temperature differences, are also action on the ring. An idealized vortex ring would not lose any fluid into the wake (Hertzberg).

IV. Photographic Technique and Post-Processing

This image was taken by a Nikon D3500 in a room in the basement of the Fleming building. The camera specifications are shown in Table 2 below.

Table 2: Camera Specifications

Specification	Value
Focal Length	155 mm
ISO	12800
f-stop	f/5.0
Shutter Speed	1/50

The camera was about 6 feet away from the smoke ring. The image was lit using a bright flashlight, with the black cloth background sitting about 5 feet away from the subject. The image was finalized in Darktable. Figure 4 shows the raw image before any edits were made.

Figure 4: Raw image

Once the image was brought into Darktable, a few adjustments were made to enhance the sharpness and coldness of the image. While the exact adjustments made are currently unknown due to a file corruption issue, I believe that they were likely a combination of adjusting saturation, contrast, and the rgb curve of the image. The image was also cropped to more closely follow the developing vortex ring. This resulted in the following final image:

Figure 5: Final image

V. Conclusion

I am overall very satisfied with this image. Capturing the movement of the vortex ring was a difficult challenge, but I believe that the clarity achieved in the final image is something to be admired. If I were to repeat this experiment I think it would be interesting to play with multiple Zero Blasters to see if I could cause multiple rings to interact with one another, potentially using different colored smoke.

VI. References

Friedlander, S., et al., editors. *Handbook of Mathematical Fluid Dynamics*. Elsevier Science, 2002. Accessed 10 October 2022.

Hertzberg, Jean. *Oral Description*. 23 September 2022.