

Smoke Vortex Rings

MCEN 5151: Flow Visualization | Team First Assignment | Oct. 2 2026

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Introduction

This assignment focuses on utilizing a team to create more complex setups to capture flow phenomena. With the help of Tegan and Joshua, we were able to formulate bubbles filled with fog and capture a variety of flows. After experimentation, I decided to capture the moment right after a smoke bubble hits the ground and a vortex ring forms. My intention was to photograph the curling motion of the smoke to visualize the vortex ring formation.

Test Setup

The test setup was conducted on an outside patio facing west. Figure 1 depicts the test setup consisting of a plastic tube, soap solution and fog machine. All items are listed in Table 1 with their descriptions. Two people were required to conduct the test with Person A holding the fog machine at waist height and Person B holding the tube. In order to produce the image, Person B first dipped the end of the tube into the soap solution. Person A then turned on the fog machine and slowly moved the machine's nozzle to the other end of the tube, filling the tube with smoke. When the smoke bubble grew to adequate size, Person A flicked the tube so the bubble came loose from the end of the tube and fell to the ground.



Figure 1: Test setup

Equipment Number	Description
1	Plastic tube, diameter 4 mm
2	Soap solution
3	Bubble drop zone
4	Fog machine

Table 1: Test equipment descriptions

Fluid Dynamics

A. Vortex Formations

Vortex rings occur when fluid circulates in circular paths around a “core” perpendicular to those paths. A visualisation of the fluid movement in a vortex ring is shown in Figure 2. Many different apparatuses have been used to create vortex rings in lab environments but they all involve quickly pushing an amount of fluid (a “slug”) out of an orifice into relatively stagnant air. The fluid on the edges touching the orifice creates friction, slowing down the outer edges and rotating the flow (Moreau, 1995). Meanwhile the center moves faster and collides with the stagnant open air, also creating friction, slowing down the flow, pulling the flow to rotate as well (Moreau, 1995).

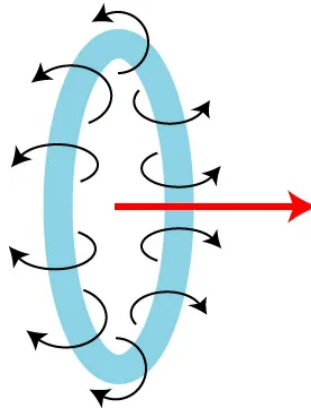


Figure 2: Fluid movement in a vortex ring

All/most academic literature involves creating vortex rings with pipes, so why do vortex rings form when a fog bubble hits the ground? When the bubble hits the ground the smoke has to continue moving to satisfy the no slip boundary condition (Simpson, 2008), pushing the fog radially outward. The fog then experiences friction from the ground and from the stagnant air. Then just like a pipe vortex ring, the fast moving center curls over the slower layers of fog due to the fog's viscosity.

To estimate the circulation and vorticity we will use the following equations used by Gharib (1998) and Kundu (2015).

$$\Gamma = \frac{1}{2}UL ; \omega = \frac{\Gamma}{A_{core}}$$

Where U is the impact velocity, L is the length of a fluid “slug” and A_{core} is the area of the core. Estimating the impact velocity to be 1 m/s and L as the diameter of the original bubble, circulation and vorticity become:

$$\begin{aligned}\Gamma &= \frac{1}{2} \left(1 \frac{m}{s}\right)(0.0635 m) = 0.03175 \frac{m^2}{s} \\ \omega &= \frac{0.03175}{\pi(0.015)^2} \approx 45 \frac{1}{s}\end{aligned}$$

Using these results we can estimate the Reynolds number of the flow. Where ν is the kinematic viscosity.

$$Re = \frac{\Gamma}{\nu} = \frac{0.03175}{1.48e-5} = 2145$$

This Reynolds number tells us the flow is technically laminar, but the estimations made to calculate may set it in the transitional range.

Visualization Technique

Fog Worx's high density stage fog was used to fill the bubbles. The soapy solution was created with about ~200 ml of store bought bubbles and ~1 tablespoon of liquid hand soap. The bubbles and liquid hand soap were mixed together until the liquid hand soap dissolved.

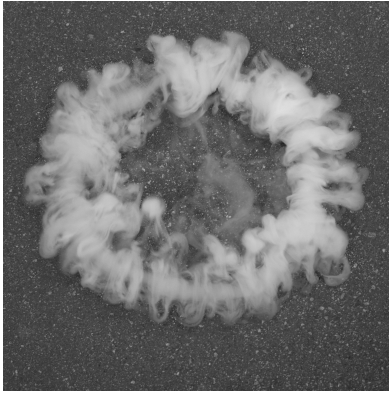
Only natural lighting was used to create the image. At the time of the image the sun was positioned west about 30° above the horizontal with no cloud obstruction. The image itself was taken on the ground (refer to Figure 1) behind a 4ft balcony wall that blocked the direct sunlight.

Photographic Technique

The motivation behind the chosen camera settings was to capture the moving vortex ring in focus. Small aperture and ISO were chosen due to the harsh lighting conditions. The focal length allowed me to kneel over the ring with it being in focus.

Camera	Canon EOS Rebel T7
Lens	Canon EFS 18-55mm
Aperture	f/10
Shutter Speed	1/60 sec
ISO	320
Focal Length	46 mm
FOV (Vertical, horizontal)	18°, 27°
Original Dimensions	6020 x 4015
Edited Dimensions	4015 x 4015

A decent amount of post processing was done to make the smoke ring visually pop and to remove dark spots in the background. Black and white color scale was chosen to highlight the rings and swirls in the smoke while trying to minimize the speckled background. Additionally, color balance and heavy contrast editing was done to make the background as plain as possible.

*Before Image**Edited Final Image*

Conclusion

The image reveals the swirling motion air performs to create vortex rings. Overall, I'm moderately satisfied with the image. I believe there are a lot of improvements that could've been made to increase the visual impact of the image.

In terms of setup, this experiment could've been improved by working in a controlled environment. A lot of our difficulties as a team were because of factors such as wind and harsh sun.

In the future I would change the background to a solid color, capture a video instead of a still of the growing vortex ring, and attempt to set a side profile of the effect. In further work I would like to explore the dependence on vortex height on bubble size and drop height.

Sources

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