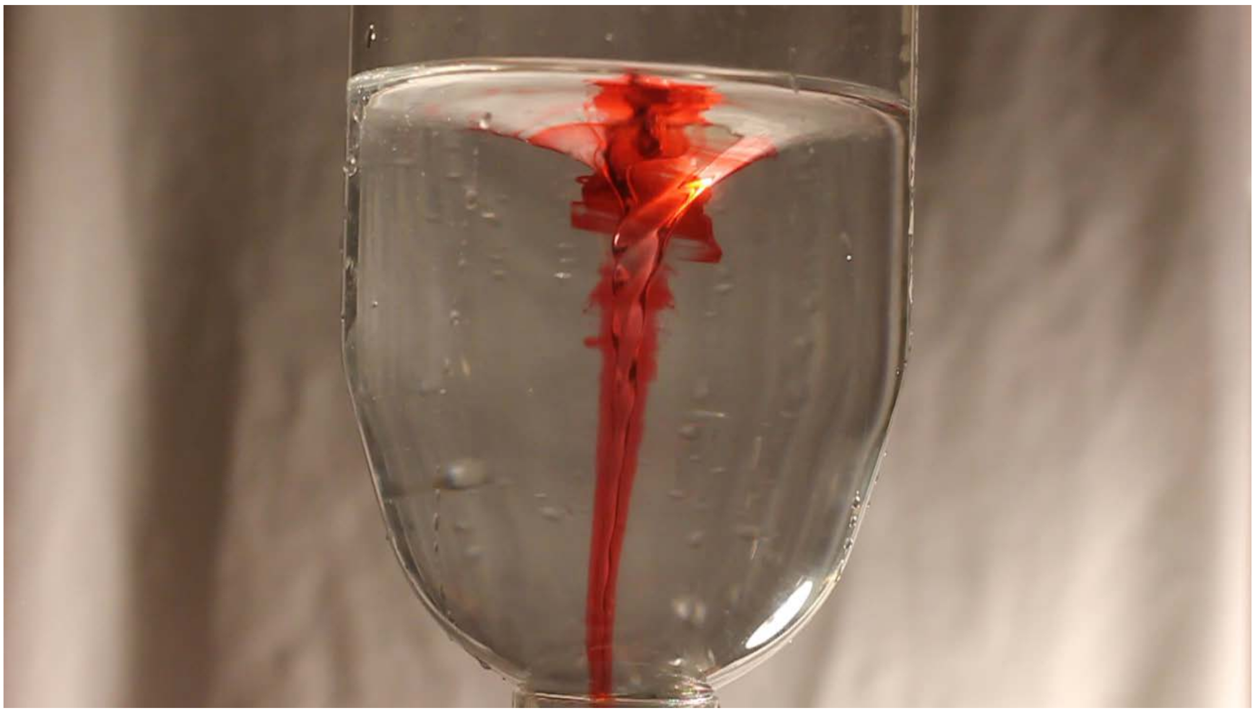
# Vorticity and Shear: Bathtub Vortices



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## Context and Purpose

I got the idea for this video while attempting to take pictures of bathtub vortexes from a top-down view for a course called "Flow Visualization" at CU Boulder. In the course, students are encouraged to find unique ways to visualize fluid flows. While attempting to take the bird's eye bathtub vortex photos, I glanced at my set-up from the side, and I was entranced by how the dye curled around the bottle and was suspended for a period of time before draining through the vortex. When I saw this, I realized that I could capture the shear layers of the vortex from the side better than from the top and better in motion than statically, so I set up my video camera on the side.

## Visualization Technique

To obtain this image, I used a 2-liter bottle, cold water, and a variety of food dyes. During each run, the water eventually reached a dilution of 10 drops per liter. The bottom third was removed from the 2 liter bottle, and a small hole (3mm diameter) was cut in the lid. The bottle was filled with cold water, and then inverted into the neck of another larger water bottle. To reduce back pressure, vent holes were cut lower in the neck of the drain bottle. Once the top vortex bottle was inverted, a butter knife was used to create the initial vortex. After the vortex was formed, varying colors of dye were dropped into the vortex at different radii from the center to experiment with how the distance affected the visualization. Refer to figure 1 for a sketch of the setup.

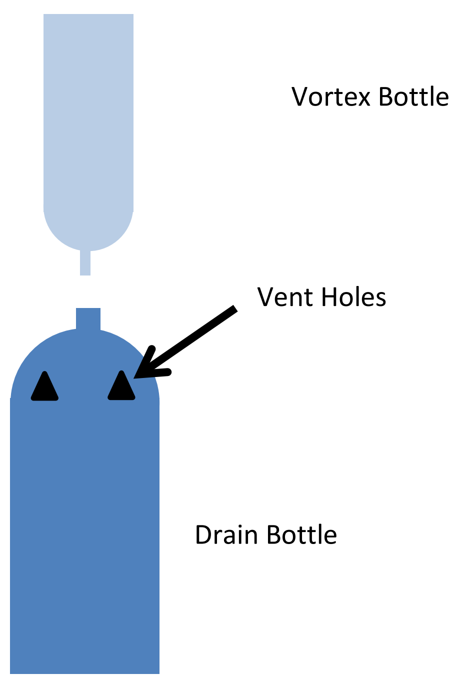



Figure 1
Visualization Set-Up

As mentioned earlier, dye that was injected at different radii from the center of the vortex exhibited extremely different behavior. Dye that was injected far from the center diffused rapidly, dye that was injected within 5cm of the center formed semi-stable “curtains” that lingered, and dyes that were injected at the very center drained almost instantly. The curtains formed at roughly the same diameter as the neck of the vortex bottle. This dye concentration is caused by a balance of forces between the inertia of the more dense dye attempting to move outward and the flow towards the center and down towards the drain. The Reynolds and Froude number calculations are taken from Halasz et al[1].

$$Re = \frac{\Omega a^2}{v}$$

$$Fr = \frac{\Omega d}{gR^{.5}}$$

With $\Omega = 50\ s^{-1}$, R = 20 cm, a = 5 cm, d = 1cm, and v = $10^{-2}$ $cm^2$ $s^{-1}$

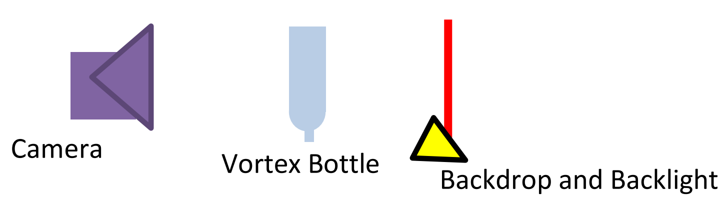
$$Re = \frac{(50)5^2}{.1} = 11{,}000$$

$$Fr = \frac{50(1)}{((980)(20))^{.5}} = .36$$

With these numbers, it is shown that gravity has a large influence on the flow, while viscosity is not as important (expect for in the center of the flow).

<u>Visualization Technique</u>

To create contrast to visualize the flow, backlighting was used. The camera was set on a tripod 1 meter from the vortex bottle, and a white backdrop was set 1 meter behind the vortex bottle. The scene was lit from ambient incandescent light from the kitchen along with a focused incandescent light from in the plane of the backdrop. See Figure 2 for a sketch of the set-up and lighting



## Photographic Technique

To take this photo, I used an 18 MP Canon T2i DSLR. The lens I used was a 50mm 1.8. To get the vortex in focus, I used manual focus to get the wine glass in focus. To hit the sweet spot for sharpness of the lens, I set my aperture to 6.3. To minimize noise, I set the ISO to 200. I used a slightly longer shutter speed to capture more light in order to compensate for the low ISO. The original video was 1920x1080 pixels at 24 frames per second, and the ouput video stayed the same. Contrast was increased very slightly during post processing, and a free soundtrack was used to create a dramatic but peaceful atmosphere.

## Conclusion

Overall, I like this final video. While this image was not what I was aiming for at all initially, I really like the dramatic outcome. I hope to recreate this phenomenon on a bigger scale someday, as I think the flow is particularly beautiful. It might also be good to find a more precise initial stirring mechanism to minimize turbulence and a more precise dropping mechanism to further investigate the effect of the drop radius.

Works Cited


1 Gábor Halász, Balázs Gyüre, Imre M. Jánosi, K. Gábor Szabó, and Tamás Tél. "Vortex flow generated by a magnetic stirrer." *American Journal of Physics 75, 1092 (2007); doi: 10.1119/1.2772287*

Appendix

(Still from Raw Video)