Matt Blessinger
MCEN 4228: Flow Visualization
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Get Wet

The Atomizer: An Application of Bernoulli's Principle

Many consumer products on the market are based upon fluid dynamic principles and phenomena. A perfect example of this is the atomizer mechanism that is used in perfume bottles to spray the perfume. My Get Wet project is intended to recreate an atomizer with household objects, so that anyone can explore the phenomenon on their own.

The experiment involves a simple setup that can be recreated with standard household equipment. Below in Figure 1 the setup is shown with all needed materials. A small drinking glass, such as a 1.8 ounce shot glass, was used so that I could get a close up of the fluid flow without having to worry about part of the experiment not being in the frame. Once I decided upon the glass, I glued a clear straw to the inside of the glass and another one perpendicular to the first straw. I chose clear straws so the fluid can be seen moving up the vertical straw.

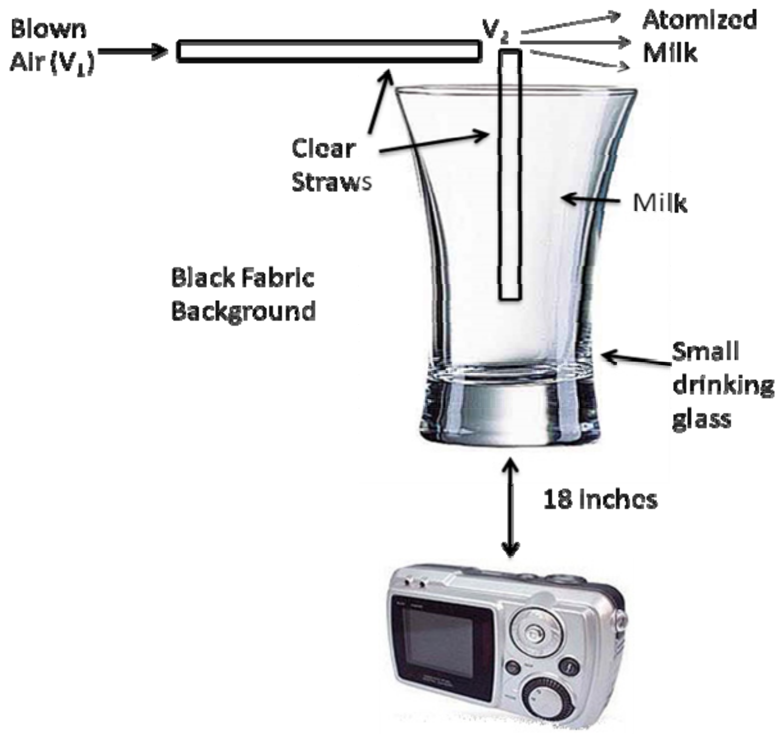

Figure 1 - Experiment Setup

In this case, the fluid flow is modeled by Bernoulli's Principle, which is given as: $p_1 + \frac{1}{2}\rho V_1^2 + \rho g z = p_2 + \frac{1}{2}\rho V_2^2 + \rho g z$ [1]. For the atomizer, Bernoulli states that as a velocity increases, pressure decreases. This results in a low pressure spot above the vertical straw, and in turn atmospheric pressure pushes the milk up the straw, in which the airstream disperses the milk particles. To conduct the experiment, I blew into the horizontal straw, resulting in airflow across the top of the vertical straw. As expected a low pressure spot was created above the vertical straw and the milk was atomized.

To determine the velocity of the milk at the atomization point, the air flow through the horizontal straw is estimated to be fully developed laminar, i.e. a Reynolds number less than 2000. This gives an average velocity of $V = \frac{D^2}{32\mu}\left(-\frac{dp}{dx}\right)$ [1]. I then researched the pressure a human can create with their lungs and found it out to be 1570 Pa [2]. The milk has an absolute viscosity close to water, thus $\mu = 0.0021$ [3]. The length of the straw is 17.9 cm and its diameter is 0.54 cm. The average velocity at the exit of the horizontal straw, and thus the velocity of the atomized milk is 38 m/s. With an average velocity of 38 m/s and a time exposure of 1/10 sec., it can be calculated that the fluid moved 3.8 meters during the exposure.

To be able to take a good picture of a fluid spray, several obstacles had to be overcome. I discovered that a fluid spray is hard to capture because the particles spread out, resulting in less light being directed towards the camera. To help overcome a washed-out fluid, I used a black cloth background and 2% milk, as the fluid, to give the greatest contrast possible. I purchased the cloth at Jo-Ann Fabrics and Crafts, and the 2% milk at King Soopers. In addition to the materials involved, I used light to my advantage to help highlight the fluid as much as possible. I directed four 40 watt fluorescent spiral bulbs at the shot glass and away from the background. I didn't use the flash on the camera because it would wash-out the background, minimizing the contrast of the picture.

Table 1 - Image Settings

Photographic Technique	Value
Field of view	4.5 in. x 3.5 in./ 16 in^2
Distance from object to lens	18 in.
Lens focal length	135mm
Type of camera	Nikon D80 w/ AF-S Nikkor 18-135mm, 1:3.5-5.6G ED lens
Original picture size	3872 x 2592
Final picture size	2664 x 1532
Aperture	F/5.6
Shutter speed	1/10 sec.
ISO setting	100

Table 1 gives all of the image and camera setting used to capture the atomization of the milk. I set the lens focal length at its max to get a close up of the fluid leaving the straw. I set the Nikon's shutter speed to a 1/10 sec. because it allowed a long enough exposure so the fluid spray would be visible. The other settings were automatically set by the camera. After the initial image was captured, several Photoshop techniques were performed to further highlight the fluid flow. In Photoshop I increased the overall contrast of the photo to better highlight the milk spray. I then cropped the photo to emphasize the actually fluid flow and remove the unnecessary parts of the setup.

The picture shows exactly what I was going for: a simple display of Bernoulli's equation. It shows how a fluid can be “sucked” out of a reservoir with a fluid flow across the top. It displays a great application of Bernoulli’s Principle and how it can be used with consumer products. One area I would like to improve is the setup itself. I would like it to be cleaner, i.e. not have glue showing. To fix this, other glasses or reservoirs would be experimented with.

Sources:

1. Smits, Alexander J. A Physical Introduction to Fluid Mechanics. New York. 2000

2. “Anatomy.” 1997. MadSci Network. 31 Jan. 2009. <http://www.madsci.org/posts/archives/1997-08/865350639.An.r.html>

3. “General Physical Properties of Milk.” Newer Knowledge of Dairy Foods. 31 Jan. 2009. <http://www.nationaldairycouncil.org/NR/rdonlyres/52BEEEB2-9DF5-4555-B5F2-D01C12F27ED2/0/TABLE14.pdf>