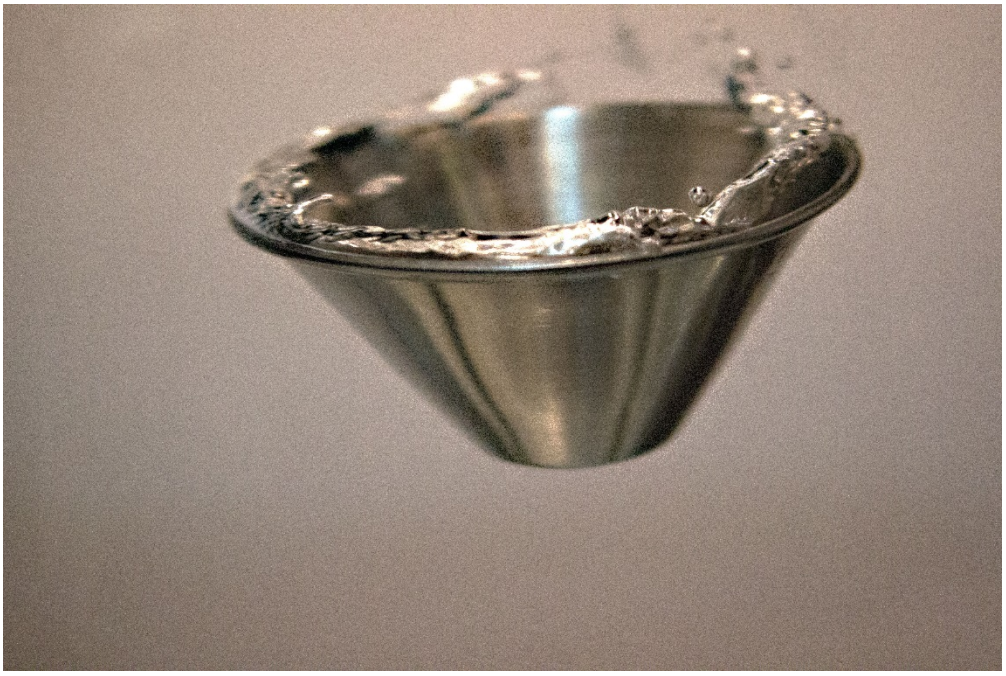
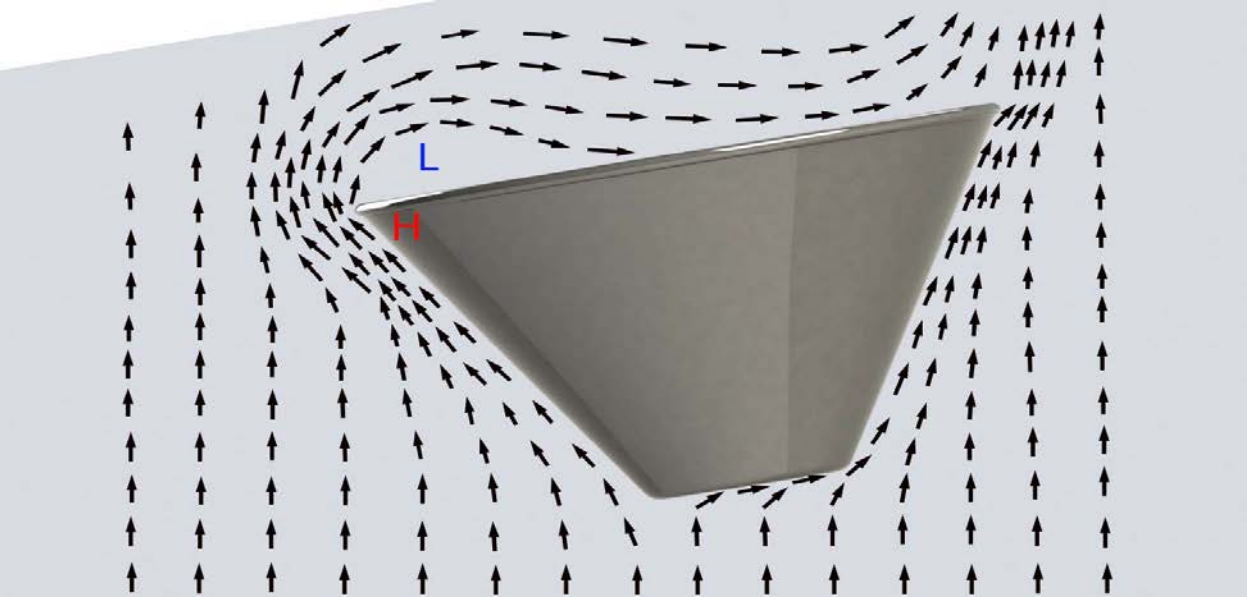
Get Wet: Ring Focus



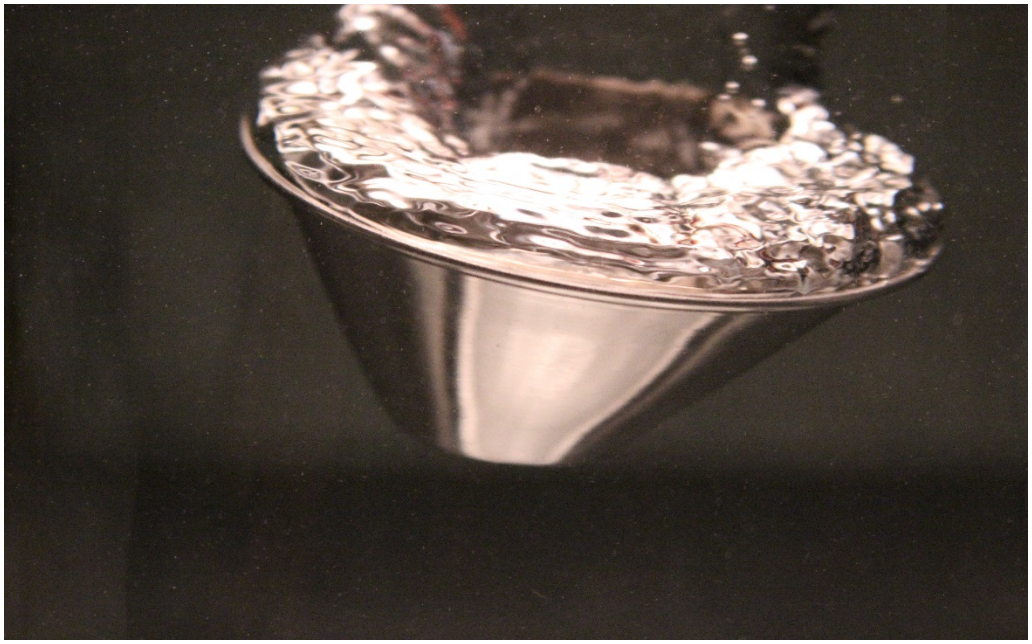
Kenny Wine

My image of a pocket of air escaping a vessel as it is submerged into water is a very interesting image visually and physically. The initial idea that lead to this image was to freeze a shot glass in liquid nitrogen then drop it into water with the intent to see different phase changes occurring. First, I hoped the water would freeze on the glass while the nitrogen would evaporate creating a visually gripping image. These images ended up being a little too busy and extremely difficult to focus because of the lack of light and the speed of the motion. So what I began to notice that the flow of the air bubble out of the glass was very interesting and there was lots of physics at play while also capturing a fascinating image.

In order to capture this image it required lots of setup and repetition. To get a crisp image I cleaned and filled a 2000 mL beaker with deionized water. Then I took a conical stainless steel shot glass and filled it with a stainless steel ring to give it enough weight to overcome the buoyancy force in order to get the glass to sink. Once this was set up I place the camera on a tripod and attached a trigger to the camera to insure the camera was still. As I began focusing on the glass the need for more light was obvious. So, I set up a light box with white poster board and got every light I could get near the set up as well as a desk lamp that was sitting directly above the beaker, giving the image a very direct top light. Once this was in order I began shooting! In this particular image I placed the weight in a position to get the glass to drop with the opening slightly facing the lens. To begin the discussion of the physics involved in this image I want to discuss the pressure and the flow of water around the glass.



In order to create this image I modeled the glass in Solid Works and sent the image to Photoshop to show a visual of the flow around the glass (vector field of water with respect to a shot glass.). As you can see above, the flow field creates a high pressure packet of water below the lip at the front of the glass. The shape of this lip also affects the flow of the water and in turn it creates a low pressure pocket of air right behind the high pressure of water. As many people are aware fluids flow from high to low pressure. This pressure difference (gradient) is what drives the flow up and over the glass. The force from this pressure also contributes to holding the pocket of air in place at least temporarily until the buoyancy of air over comes this force. This next image is a beautiful representation of this flow field where you see the low and high pressure areas of the air.



While looking at this image you see the high pressure air in the front of the glass and the low pressure air in the back trapped due to this gradient. In both images there are other flow phenomena occurring, if

you look closely to the final image or more obvious in the image above there are capillary waves that are propagating through the boundary of the air and the water that's created from the water flowing over the air and this flow is what initiates the wave. The other thing that is occurring that contributes to the metallic beauty of the image is the effect of refraction through the boundary layer. Because light is traveling through both fluids there is a difference in the index of refraction which essentially means light is bending as it travels through the boundary layer of the fluids because it is slowing down. When thinking about known dimensionless quantities it seems important to determine whether the flow over the cup is turbulent or laminar. To execute this calculation I assumed some things and determined the values of density and viscosity of water at 70 F. I also timed the drop and it is falling at approximately 0.5 ft/s. and the cross sectional diameter of the cup through the fluid is about 2 inches

$$Re = \frac{\rho * V * D}{\mu}$$

$$\rho_{H2O} = 62.30 \frac{lb}{ft^3}$$

$$\mu_{H2O} = 2.03 \frac{lb_f * s}{ft^2}$$

$$V = 0.5 \frac{ft}{s}$$

$$D = 2\ inch = 0.167\ ft$$

With these parameters known or assumed the Reynolds number is $Re = 7500$. Since the Reynolds number is low you can assume that there is a laminar flow over the cup.

The visualization technique I used for this was simply letting the air in the glass do the talking! As far as lighting goes I used lots of fluorescent lights with a light box around the beaker with exactly 4 fluorescent lights. Then I had a tungsten lamp right above the beaker to add more light and add some warmth to the picture. Lastly, I put up white poster board around the beaker to create a light box in order to reflect as much light as possible to the beaker. For capturing the image lighting seemed to be the most difficult part of the project.

The photography to capture this image was very tricky especially for the fact that everything was moving so quickly. With this in mind I first determined what speed I needed the shutter to run at to avoid image blur. To determine the shutter speed necessary to avoid image blur I decided on a few simple assumptions. That 4 mega pixels was acceptable for motion blur. While also knowing the image is moving roughly $v = 0.5 \frac{m}{s}$ and a field of view of about 4 inches I was able to calculate the shutter speed. To avoid confusion I used an online calculator *vision-doctor* and determined the speed should be anything above 1/2000 of a second. After some trial and error I decided to catch the image of the air bubble I need to speed up the exposure so I decreased the time to 1/3200 sec to get the best clarity of the image. After I determined the speed I had to play with the aperture and the ISO because the light was very low with the short exposure. To counter this I set the aperture to F4.5 and ISO 3200 This gave me a bright enough image without giving me too much noise. The distance of the object from the lens was about 1 foot. I made this choose because I didn't want the beakers edge in frame. The focal length was 18 mm because I wanted the aperture to be as wide as possible. The camera I used was a DSLR

Rebel T3i which is an 18 mega pixel camera. When I put the image in final cut I adjusted the image with curves, played with edges slightly, while also healing the background with the stamp tool.

The image reveals something that is rarely seen with the naked eye. The effect of the water flowing around the air that creates a pressure gradient while also showing the capillary waves on the surface layer. Another cool feature is that the boundary reflects the stainless steel making the water look extremely metallic. I would really like to see more color in this image and higher contrast with the background. I could really improve on lighting and just all around camera skills but am fairly pleased with the way my first attempt went. I really want to experiment with attempting to get natural streamlines with ink over the falling object.

Citation

"Flow Over Immersed Bodies." *Fundamentals of Fluid Mechanics, 6th Edition Student Value Edition*. Ed. Wiley. N.p.: n.p., n.d. N. pag. Print.

http://en.wikipedia.org/wiki/Capillary_wave

I also used Google images just to make sense of the physics nothing in particular though.