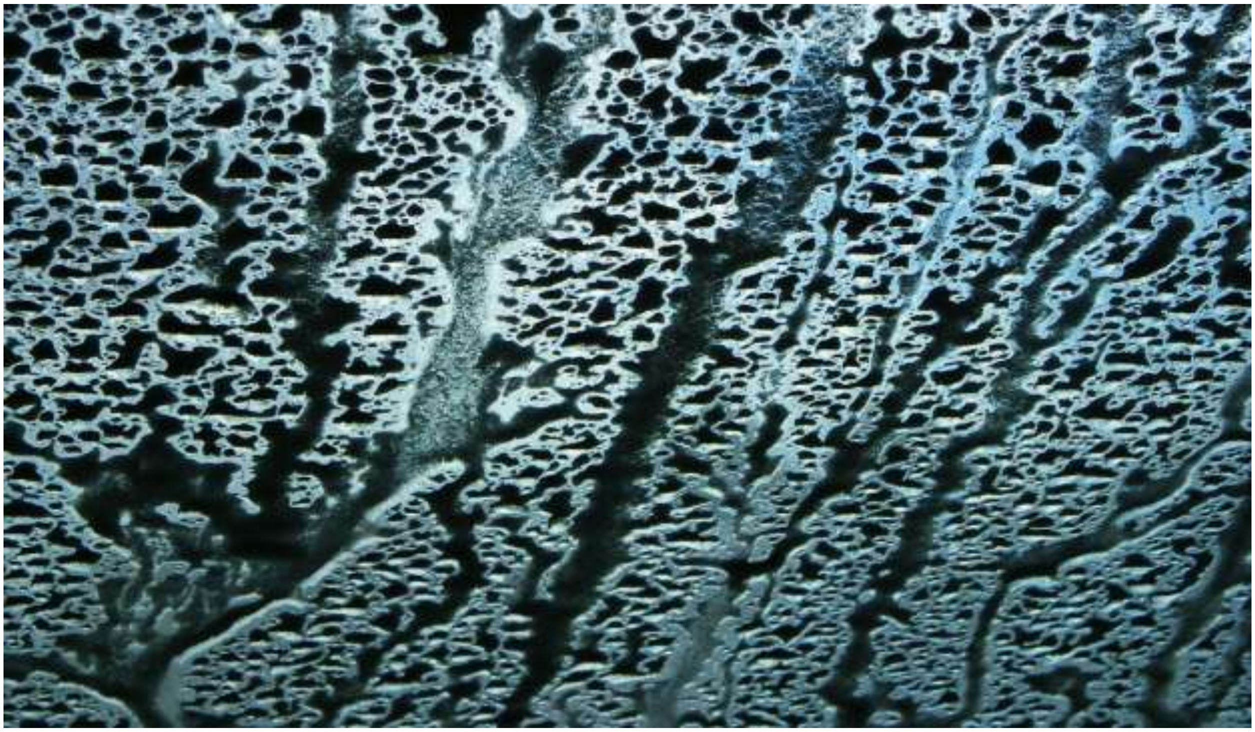
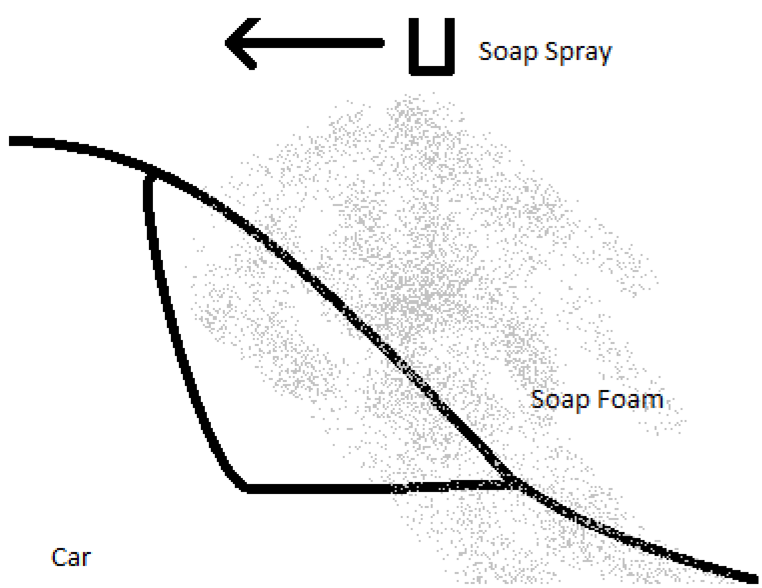


Due to the timing of this project, most of my group was out of town and unable to work together, so we opted to split up and do individual things this time. In that way, I treated this as sort of a “Get Wet version 2”. The Get Wet project showed me just how hard it is to do specific things with fluids, so for this project I decided to let fluids do whatever they wanted and capture images of whatever phenomena the fluids exhibited. For this image, I chose to go through an automatic car wash, pick the most expensive one and take pictures of what happened, without knowing if I would even get anything good. Although most of the pictures focused on the colored foam used during the wash, the photo I ended up using was one of a “regular” white soap foam/water combination. I like this image because it shows stability in the non-moving parts as well as full streams of the fluid between those stable portions. In the streams you can see dispersion of the suspended foam within the water, and I thought these factors coupled together produced a fascinating image.

A basic schematic of the process is shown in the figure to the right. Foam was sprayed on to the whole car evenly. The picture above shows the result after the spraying has stopped on the windshield, from the inside. The picture is about 30 inches across, and about 12 inches in the vertical direction. The parts of the fluid which are stationary are dominated by the effects of surface tension at the fluid-air-glass interface.



That surface tension balances gravity and these parts of the fluid remain stationary as a result. There is an upper limit on the size of these “globules” of fluid, because after a certain size the effects of gravity are such that the surface tension can no longer retain the fluid, and it flows down the incline of the windshield in large streams. These streams, as seen in the picture, disperse the suspended soap foam. The foam pools at the leading edge of the stream which leaves behind dispersed remnants of the foam in the wake of the stream. I would estimate the velocity of the flowing sections of the fluid to be about 0.5 m/s. The viscosity of this fluid is probably very close to the viscosity of water, about 1.004×10^{-6} m^2/s at 20^o C. The characteristic length can be estimated to be about 0.2 m, the estimated length of the main stream in the picture. This produces a Reynolds number of about 99,600, indicating a very turbulent flow. It’s worth noting that this estimate is probably higher than the actual number, considering a large portion of the fluid in the image has no velocity and therefore a Reynolds number of 0. That said, it’s clear from the picture that the flow in the stream is probably turbulent considering the somewhat random looking paths from top of the windshield to bottom.

The shape that the fluid takes on the windshield is dominated by boundary effects. Water by itself, air by itself, and glass by itself all behave rather intuitively, but throwing water into the air-glass boundary produces unintuitive geometries. Although most of the literature I found on this subject pertains to water in an open glass container surrounded by air, a basic understanding of the phenomenon can be explained in simple terms. The interaction of the water and the glass produces a “no-slip” condition, in which the layer of water directly above the glass sticks to it and doesn’t want to move. This condition is commonly assumed in basic fluid analysis. The air is not as sticky as the water, although it produces a weaker no-slip condition in the areas which the water has not collected due to the difference in the fluid viscosities. For water flow from where it is to an area in which air contacts the surface of the glass, the gravitational force on the water must exceed the energy associated with the strong no-slip condition of the water-glass interface as well as the weaker no-slip condition of the air-glass interface. After an area on the surface of the glass becomes water-dominated, air will be unable to “push” it out of the way alone. For air to contact the glass again, a collection of water must flow down the glass after it’s reached its maximum mass to be stable at rest on the glass. This leaves a void where the water used to be in which the air can freely flow. Of course, as the water flows away some droplets will stick to the glass, which means the voids which air can fill remain tiny. This is how I understand the flow pictured above.

The visualization technique utilizes suspended soap foam particles within water. Without these soap particles scattering the light from the back, the window, water and air would all be transparent and the picture would consist mainly of cars and trees and sky. Unfortunately I do not know the exact composition of the fluid or chemical properties of the soap. The image was entirely backlit from natural sunlight, and no flash was used on the camera in the car. The car wash was attached to a Conoco gas station and, again, the most expensive wash was chosen in order to get enough opportunities to take a good picture.

The camera used to take this picture was my Pentax X90 DSLR. The aperture was set to 7.1, the exposure time was set to 1/60 second and the ISO used was 80. The focal length was 15 mm. The field of view was about 3 feet wide, 2 feet tall. The original image was 4000 pixels wide and 3000 pixels tall. The height of the picture was cropped down to 2319 pixels, removing the bottom quarter of the image. The reason was because the bottom part of the picture was out of focus. That part of the image was the farthest away from the lens due to the tilt of the windshield. The camera was about 2 feet away from the center of the image. The contrast was changed slightly, using Curves in the RGB channel in Photoshop, to make the edges of the water more defined. The ISO, exposure time and aperture was chosen automatically using the Program function in my camera. This was because I was limited by time due to the automatic aspect of the car wash, and could have contributed to the fact that the bottom quarter of the image was originally out of focus.

This image reveals the details of the water-air-glass interaction on the surface of an inclined plane of glass. I like the detail shown in the boundary and the contrast with the bright background the best. I wish I would have done this in a controlled environment in an attempt to get at a more interesting phenomenon, but I hadn't even thought about it until after I turned this image in. I also wish I could have found some detailed articles on exactly this phenomenon instead of just articles detailing the meniscus of water in an open glass container. My intent for this project was to capture a pretty image detailing an interesting fluid phenomenon, and in that respect I feel I was successful. During the next project my team plans to work together to get interesting, unique images in controlled environment.