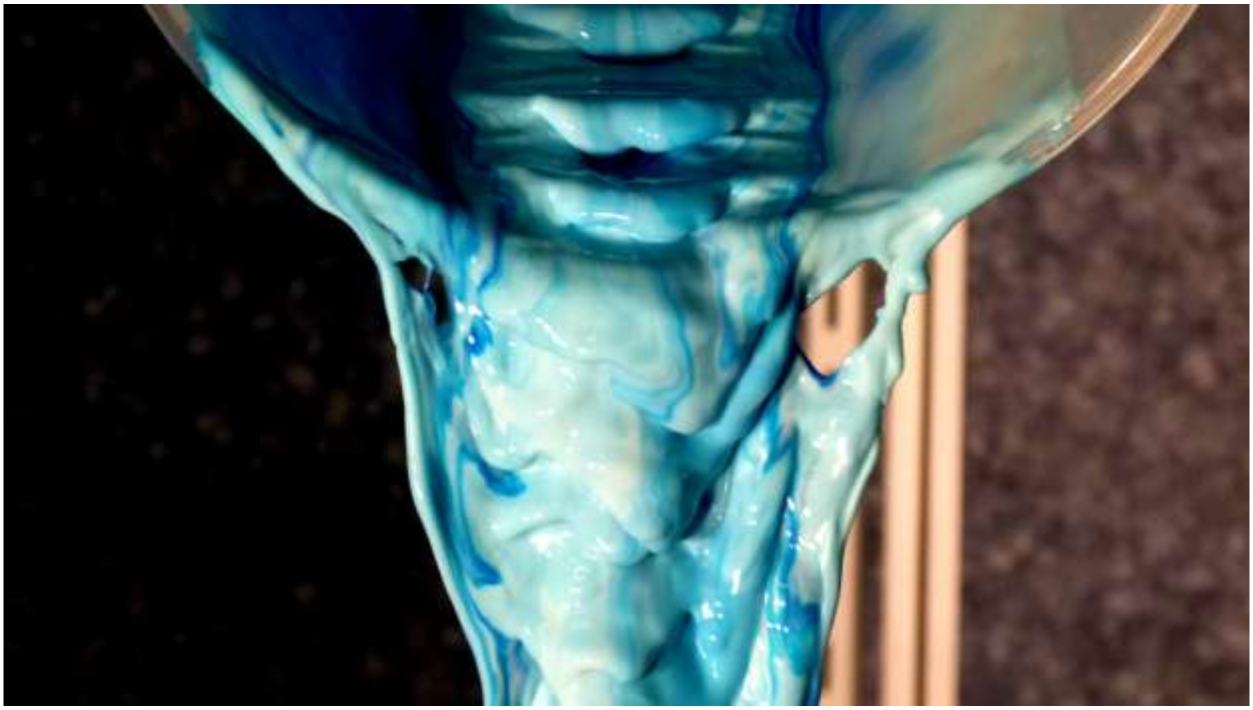

The fluid consisting of two-parts cornstarch, one-part water known as “oobleck” has fascinated me since I first found out about it during the Get Wet assignment for this class. My group decided to attempt to visualize its shear-thickening properties in a number of original ways. My official submission for this assignment is a picture a large quantity of the substance, died with blue food coloring that has not been thoroughly mixed in, being poured out of a bucket through air. As simple as this setup is, it was a result of many failed small-scale attempts to properly visualize the fluid properties. Originally, we thought it would be best to show the fluid’s properties by forcibly throwing small objects into a relatively small volume of the substance. The result was shockingly dull, and prompted my suggestion to us a much larger quantity of the substance during future trials.

The results were striking. As the oobleck accelerates due to a body force such as gravity, it develops a complex shear profile which results in layers of the fluid thickening while its surroundings remain liquid. The body force in the case of my image was gravity. Although it pulls evenly on each fluid parcel, an uneven velocity distribution due to friction against the walls of the vessel leads to a very strange flow. As can be seen in the picture above, the upper layers of the fluid are moving faster than those underneath. In a few moments, those layers thicken and the slower moving layers behind it start to flow above them, cause new layers. Presumably, the thick fluid underneath those layers lowers its viscosity as a result of slowing down, but becomes trapped in the newly thickened layers on top, which stresses it further. This explains a phenomenon we viewed that is apparent in the video[1], which is that the upstream fluid grows on itself, forming a much wider stream than the downstream parts, which looks roughly like a cone pointing downward. This effect is visualized in the group video, submitted by Daniel Anson.[1] This is quite different from Newtonian flow, where the faster fluid parcels would continue to accelerate past the slower moving parcels under a constant body force. Due to the very low velocities and high average viscosity inherent in using this fluid, it is reasonable to assume the Reynolds number to be low enough to consider the flow to be laminar. Almost all perceived motion is large-scale and macroscopic, with no eddies or vortices occurring at all. Describing the motion of this type of fluid in mathematical terms is exceedingly difficult due to the interdependency of viscosity with shear stress, as well as their time dependency (rendering a steady-state assumption false). The Naviers-Stokes equations[2] could be sufficient to solve the problem given the necessary boundary conditions, however, once the viscosity-stress relationship is solved. The other main problem is the fact that that very relationship depends entirely on the proportion of water to starch, and minute differences in the levels yield very different properties, and those proportions were not measured for these various tests.

The visualization technique used to make the bland beige mixture a bit more exciting to look at was food coloring. To achieve the effect shown in the picture above, the food coloring was simply dropped on top of the oobleck mixture in the bucket before pouring. The layering effect caused the interesting smear shown, whereas a fully-mixed, died oobleck (like that shown in the video) is a bit less spectacular to look at. This technique is fairly volatile as the dye fully mixes in after one or two pours, leading to a stale, homogeneous mixture of dye and oobleck. A schematic of the setup is shown in Figure 1 below. Lighting was simple indoor florescent with appropriate white balancing from our digital camera with no flash. The setup is extremely simple to repeat, using the mixture described in the first paragraph with food coloring dripped on top.

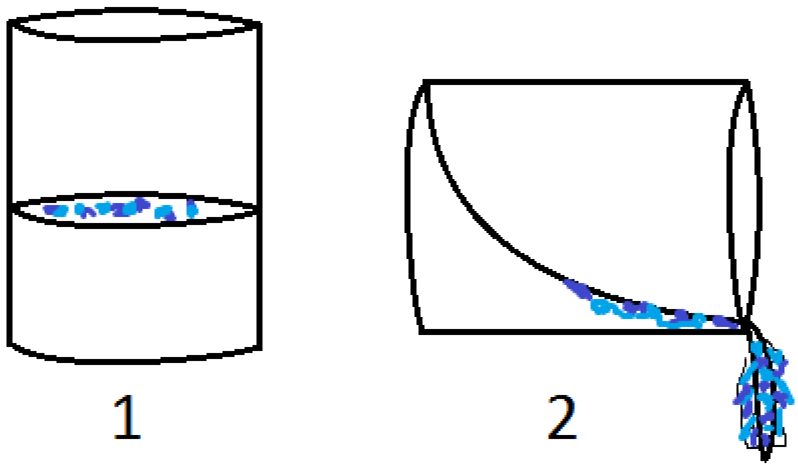

Figure 1: Setup for Group Project 1

The field of view is about ten inches from one side of the image to the other. The distance from the object to the lens was about two feet. The lens focal length was 31 mm. A digital camera was used, and the original image size was 4320 pixels by 2432 pixels, the final image was not cropped. The camera used for this picture was a Panasonic DMC-FZ100. An F-stop of f/4.5 was used with an exposure time of 1/60 sec and an ISO speed of 200. The camera was set to an automatic aperture based on shutter speed, and the shutter speed of 1/60 second was chosen based on lighting conditions such that the picture was detailed enough. Photoshop processing included changing the contrast to make the dark parts of the image much darker, keeping the light parts of the image roughly the same.

The image reveals the nature of a shear thickening non-Newtonian fluid under a uniform body force flowing through air. The physics are shown quite well in the image; although I wish I used an image of when we rolled the bucket in circles with the oobleck inside. Imagining a mathematical model of this fluid is beyond me as far as complexity goes. I've never analyzed a fluid without a constant density, and the density of this fluid is based on both the velocity of the fluid and time. These complex interdependencies really discouraged me from pursuing a more complete analysis in the context of this picture. I would be very interested in how a fluid which is shear thinning or has some other property which makes it non-Newtonian would flow given these same conditions.

[1] http://vimeo.com/20743439

[2] http://en.wikipedia.org/wiki/Navier%E2%80%93Stokes_equations