Scott Legg
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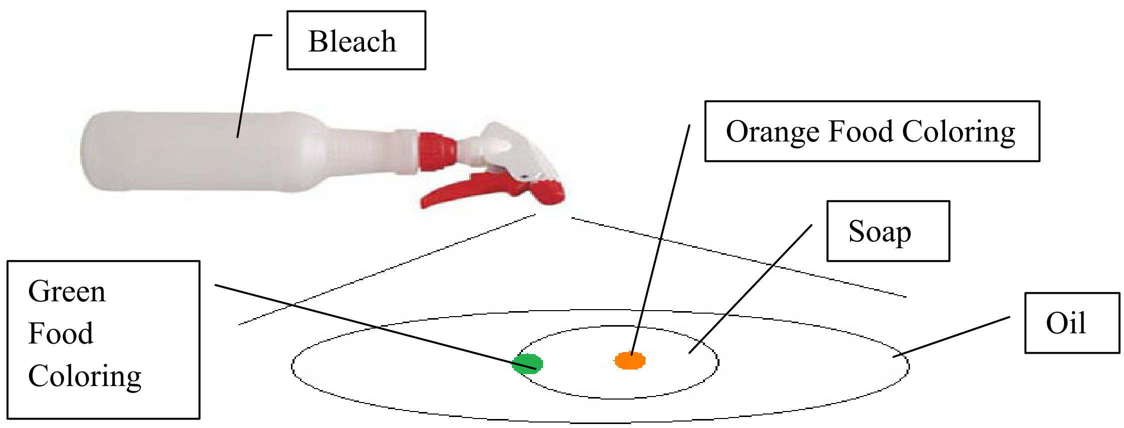
Get Wet

This image was created to show the diffusion of food coloring through ordinary dish soap as well as boundary layers created between the soap and oil. The oil did not pick up the food coloring, which is why clear circles appear. Originally, I thought there would be immediate and rapid diffusion because the soap is water soluble and the oil is not. The first few trials were just food coloring sitting on top of soap – the food coloring didn't diffuse as dramatically as I desired so I used bleach to break the surface tensions and induce diffusion.

A base layer of vegetable oil and soap are poured over a glossy white plate and because they are both oil based, they do not mix well. The boundary layers are easily visible. About half an ounce are both poured, and they spread to approximately 2 inches in diameter. Two drops of food coloring are now applied to the soap surface, which has been surrounded by the vegetable oil, having a higher surface tension. The veggie oils density is about 0.894 g/mL compared against the 1.059 g/mL of Dawn Dish Soap (http://www.science-house.org/student/bw/chaos /heleshaw/sld019.htm). Bleach (viscosity ~1000cP from Chlorox Company material safety sheet) was then misted over the entire system, in order to break down the boundary layers and spark rapid diffusion. The food coloring quickly spread throughout the soap, however the oil tended not to mix, rather to form small beads not penetrated by the food coloring soap combination. When everything was completed, the final diameter was 4 inches, however the photograph captures approximately 2 inches in width of this diameter. The maximum expansion occurred in approximately 3 seconds. In calculating the Renolds number, the viscosity of the working fluid must be known. Because food coloring is the major working fluid, the Reynolds calculated using its viscosity of 980 cP (Science-House.org). The formula for Reynolds number: $\mathrm{Re} = \frac{\rho V D}{\mu} = \frac{V D}{\nu} = \frac{Q D}{\nu A}$ yields a R= 2630 assuming that fluid density is 1000 kg/L, stream velocity V= 1 inch/sec, diameter is 4 inches and dynamic fluid viscosity is 980 cP.

Figure 1:



*Notice the orange coloring on the soap while the green is on the boundary layer.

The visualization technique was relatively simple and was realized using dye and common household chemicals, most of which are used for cooking. Once giving ample time to allow the base layer of soap and oil to settle, the food coloring drops are added, and a slow diffusion occurs. The misting of bleach should be applied before significant diffusion occurs, which happens in a matter of minutes. All materials were acquired from a grocery store, and the testing room was ambient pressure and temperature, approximately 20 degrees Celsius. Lighting was supplied by an overhead bank of color corrected fluorescent bulbs, with no flash from the camera itself.

Camera Information:

Mark: PENTAX Corporation
Model: PENTAX Optio S
F Stop: f/3.5
ISO: 200
Exposure Time: 1/20 sec.
Focal Length: 10 mm
Dimensions: 1024x768
Distance from Lens to Specimen: 3 inches

A small amount of Photoshop was used. The curves function was used to increase contrast and maximize the color differentials as well as to brighten the image overall.

The image reveals how food coloring mixes well with itself, I was excited to see a lot of blues because I only used orange and green food coloring, the blue must come from the red in the orange coloring and the lighter shades of blue. By noting the colors, we can see the interaction between the 2 types of food coloring. Some other cool interactions I notices were that the soap helped to hold the food coloring, even when the bleach hit it, centrally located you can see the orange took over because it was completely contained by the soap originally. The vegetable oil never broke down, which was disappointing. I didn't expect its surface tension to hold as strongly as it did. Fluid physics between different densities and viscosities interacting to create shear zones and boundary levels is readily apparent, which was my intent. In developing this idea further, I would try to use some other fluids to disperse the food coloring. The bleach was effective, and I tried isopropyl alcohol, which caused everything to move too quickly to effectively analyze. I would also try to vary the temperatures of all the fluids, to see if would disperse more readily as I would guess.