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Flow Visualization
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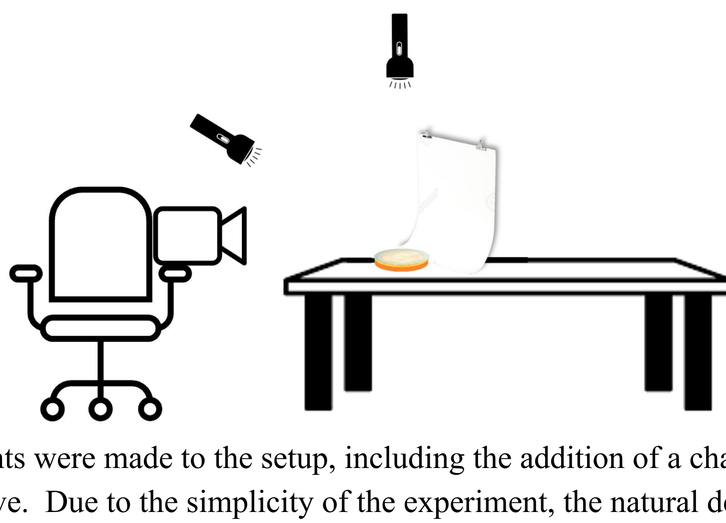
Image-Video Report #1

This image was supposed to be an introduction to some of the different aspections of flow visualization including, setup, camera, different shooting modes, and editing. A simple experiment was chosen to keep the repeatability high, as it would require many takes due to inexperience. The initial experiment was just dropping water onto the penny to explore how much it could hold, and to see if it would produce an interesting picture. Once proven, a slightly more elaborate setup was used to create a better picture.

This experiment was very straightforward. All that it required was a penny and a dropper. The dropper was used to drop water onto the penny. This method can be used to find the upper limit in which the surface tension breaks. Then, run the experiment again with just a few less drops. This ensures that the liquid on the penny's surface is as much as possible. The room had to be kept extremely still, no fans or large vibrations that could break the surface tension were allowed.



Improvements were made to the setup, including the addition of a chair to stabilize the camera, shown above. Due to the simplicity of the experiment, the natural desk background was distracting, so a piece of white A4 paper was put down to remove any distractions. It was determined that a slight angle (looking down on to the penny) created the desired image.

The physics involved with this experiment included cohesion, which is the attraction between the water molecules. This cohesive force creates a “skin” which is known as surface tension. Surface tension is often thought of in a body of water where the forces are strong enough that the surface can support insects. Surface tension can be measured in force per unit length.

$$\gamma = 1\frac{dyn}{cm} = 0.001\frac{J}{m^2}$$

In terms of energy, surface tension is the ratio of the change in energy of a particular liquid to that of the change in surface area of the liquid. Different liquids have different cohesive forces. For example, liquids such as oil and syrup do not have as strong of cohesive forces as water. The polar water molecules are much stronger than those of the oil and syrup because they produce hydrogen bonds. This experiment shows off the adhesive force between the water molecules and the penny. It is this force between the water and the penny that keeps the water from falling off. There is also refraction in the water. This refraction allows us to see the surface of the penny because the light is traveling at a different speed through the water when compared to the air. Given Maxwell’s Formula:

$$n = \sqrt{\varepsilon\mu}$$

Since water is a nonmagnetic substance, the μ is effectively 1. This means that the refractive index of water (n) is equal to the square root of the dielectric constant (ε). That makes the refractive index of water 1.33.[1] There is also a non dimensional number called the Bond Number (Bo) which measures the ratio of gravitational forces compared to surface tension forces.

$$Bo = \frac{\Delta\rho\, g\, L^2}{\gamma}$$

Here gamma is surface tension, g is gravity, L is the length scale and delta rho is the change in density between the two fluids.[2] Unfortunately, this dimensionless number cannot be calculated because there is no way to calculate the surface tension.

This experiment did not require any special visualization technique. The setup also used two main light sources. First, the overhead lighting in the room, and secondly a strong LED flashlight that would change the lighting on the penny depending on the angle. Placed at different angles there could be a large white spot on the water or reflections off of the penny.

For this photo of the penny, the goal was to zoom in as much as possible because of how small the penny is. The lens used during this experiment was a 55-250mm stabilized lens with 250mm zoom used. The submitted image to the flow visualization website was 1300x798 pixels. This lens allowed for a better closeup than the typical 18-55mm. The DSLR Canon EOS Rebel SL1 Camera was placed as close to the penny as possible while still being able to focus, which was about two feet. A shutter speed of 1/100 second was used, which in retrospect seems like it could have been decreased because of how steady the environment of this experiment was by design. An f-stop of 10 and iso of 1600 were also extrapolated from the image. Due to inexperience editing photos, and the new program darktable, the image was taken to require little editing. Just a simple crop and rotate was used to zoom further in on the image.

This image reveals some of the static fluid physics on an object. Mainly the cohesive and adhesive forces between the water and itself as well as the water and the surface of the penny respectively. Overall the image taken is simple, but being able to see the large bubble above the surface of the penny as well as the refraction was the goal of the experiment. This image is not perfect, in terms of image quality, as there is much a notable amount of noise in the background which created a grainy effect. Some of the suggestions from class included lowering the f-stop, as well as using the denoise tool in darktable.

References

[1] Born, M., Wolf, E., Bhatia, A., Clemmow, P., Gabor, D., Stokes, A., Wilcock, W. (1999). <i>Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light</i> (7th ed.). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139644181

[2] Clift, R. (Roland) & Grace, John R, (joint author.) & Weber, Martin E, (joint author.) (1978). *Bubbles, drops, and particles*. Academic Press, New York ; London