Get Wet Report

MCEN 4151 - Flow Visualization

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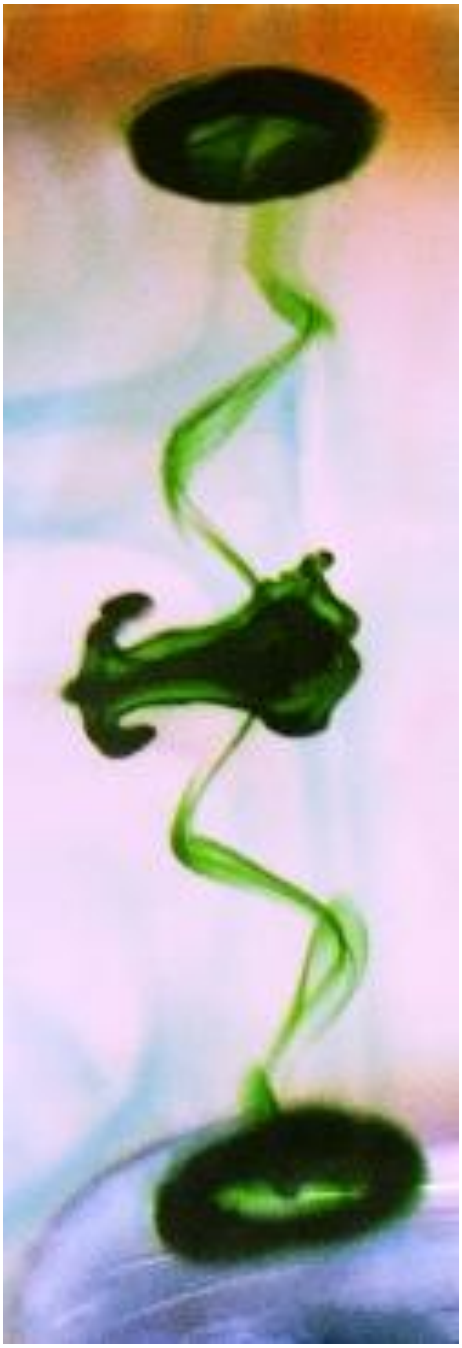

The Get Wet image is the first individual project for the MCEN 4151 Flow Visualization class. The instructions were simply to capture an image of some sort of flow that displays physical phenomenon. Initially, I started mixing fluids and seeing not only what the reaction was but also if I would be able to capture an artistic image from the flow. The intention of the image was to capture multiple physical phenomenon within one single shot. The first phenomenon that was desired to be displayed in the image was to show a reflection of the image in the surface of the water, thus capturing the same action symmetric about the center of the photo. The next phenomenon attempted to be displayed was the creation of a vortex ring using a colored fluid for visibility.

The apparatus used to capture this image consisted of 6 components; a martini glass, tap water, food coloring, a desk lamp, tripod, and a camera. To capture the reflection in the water it was required that the camera faced upwards towards the surface of the water. Figure 1 displays the arrangement of the components to capture the image.

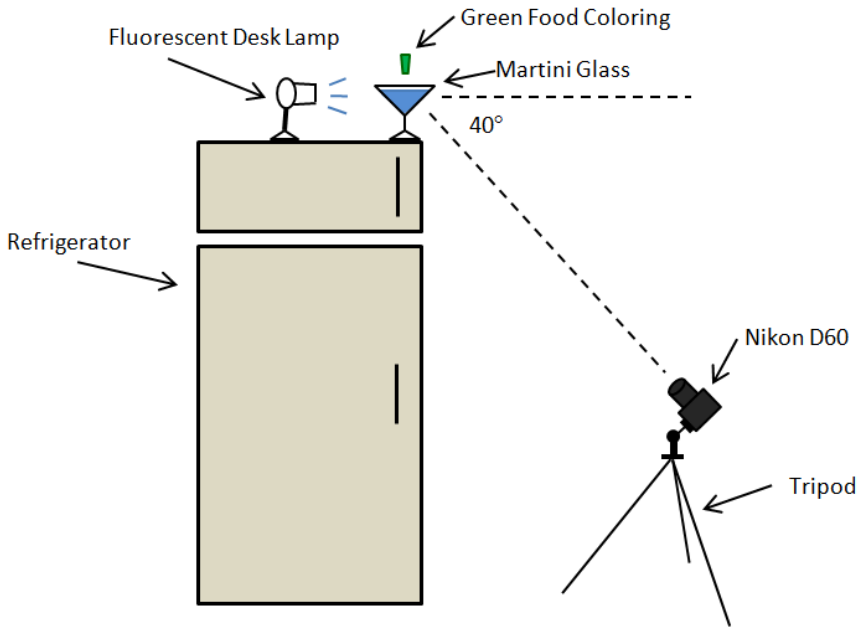

Figure 1. Get Wet Image Apparatus

The fluid to create the flow is simply store-bought food coloring dripped into the martini glass containing tap water. Regarding the procedure, the martini glass was elevated five feet above the floor and the camera was two feet above the floor atop a tripod. The angle that the bore of the lens made with the surface of the water was approximately forty degrees so that the surface reflected without being transparent. The Nikon D60 was operated using its remote function to release the shutter. With this capability, I was allowed to run multiple trials of dripping the food coloring into the center of the glass while simultaneously releasing the shutter to ultimately focus the camera.

To capture the reflection of the dye in the surface of the water a necessary angle that the camera must be within can be calculated. This angle is called the critical angle; the angle at which light is no longer refracted through the surface but is instead reflected. To calculate this value, Snell's Law is used and can be seen in Equation 1[5].

$$n_i sin\theta_c = n_t sin90° \tag{1}$$

Where n_i is equal to the index of refraction of the water, n_t is equal to the index of refraction of the air, and θ_c is equal to the critical angle. Thus, using a table of refractive indices it is found that the refractive index value of water is 1.333 and the refractive index of air is 1.000. Plugging these values into the Snell's Law Equation it is found that the critical angle that the camera must be at with respect to the vertical plane, orthogonal to the surface of the water is 48.624°. Thus, making sure that the angle was greater than the critical angle ensured that the reflection of the dye would be captured.

As the food coloring that was used is more dense than water, the dye sinks when added to the glass due to the force of gravity. Since the flow is moving a parameter that helps to describe the motion is the Reynolds number. The equation to solve the Reynolds number can be seen below in Equation 2[3].

$$Re = \frac{u * d_h}{\nu} \tag{2}$$

With regards to Equation 2, calculation of the Reynolds number, u represents the velocity in which the vortex ring is falling, d_h is the hydraulic diameter, and ν is the kinematic viscosity of the fluid. For the case in which the final image was taken from, photos were taken in a 3 shot per second burst mode. From the picture before the final image to the final image the vortex ring had traveled an estimated .05 meters. This allowed for the derivation that the vortex ring was moving at approximately .15 meters per second. The kinematic viscosity of the water at 60 degrees Fahrenheit was found to be 1.210×10^{-5} ft^2/s[4]. For simplicity, the vortex ring is assumed to be circular. Thus, the hydraulic diameter is approximately .025 meters. Using these values it was determined that the Reynolds number for the vortex ring seen in the final image is 357.14. This value is valid as a vortex ring can be expected to become unstable and dissipate at Reynolds numbers greater than 1100[1].

The visualization technique that used employed minimal materials. The main materials consisted of the martini glass and green food coloring that were purchased at the Dollar Tree and King Soopers respectively, both located on Table Mesa Drive. There were no significant environmental components that affected the outcome of the image. The lighting that was used to create the image was a simple fluorescent desk lamp placed six inches away from the martini glass orthogonal to the bore line of the lens on top of the refrigerator. Opposite the lamp was a window with the shades drawn, minimal light was coming through the window. Also, the room in which the photo was taken had an overhead fluorescent light that was turned on. The overhead light was used to illuminate the scene while the desk lamp was chosen to define the details within the flow.

For this image, there were various different decisions made to capture the desired result. The chosen photographic technique chosen was color photography. Figure 2 shows the image before and after post-processing in PhotoShop.

Figure 2. Image Before (Left) and After (Right)

The size of the field of view of the original image is about 6 inches by 4 inches. For this photograph a Nikon D60 DSLR was used. Taken in RAW format, the original image dimensions in pixels are 3872 x 2592 and the dimensions of the final image are 1356 x 520. Unlike many of the other images that were taken in the class, this image was not taken in a macro mode. In fact, the Nikkor 50-200mm lens was employed to capture this shot and the lens was about three feet from the object. At this distance a focal length of 90mm was used so that the flow was clearly in the frame as well as the glass containing it. For this exposure an aperture of f/6.3 was used to increase the depth of field in an attempt to capture all of the detail within the flow. The ISO of the camera was set to 400 to increase the lighting of the image while still keeping the noise to a minimum. The shutter speed that was used was 1/25 of a second as determined by the camera with the available light since the photo was taken in aperture priority mode.

To get from the original image to the final a number of post-processing steps were taken. First of all, the image was cropped down to the final size to show the most detail. Next, the martini glass contained fresh tap water which left small bubbles on the sides which the photo was shot through. These bubbles were then removed using the content aware feature in PhotoShop. Then the color curves were analyzed to increase the contrast throughout the image a little more. Finally, a layer was made with the hard light filter used to make the edges of the image stand out more. These layers were combined to create the final image.

The final image reveals the complexities that flow can take on even though it originated from a simple drop of food coloring into water. I like that the image revealed the reflection on the surface that I was hoping to capture from the beginning and that I fulfilled my intent of the image. Also, I like the gradient of colors from the top to the bottom. At the top of the image there is a warm red background and towards

the bottom that shifts to a cool blue background. Something I dislike about the image is that the vortex rings are out of focus. I attempted to increase the depth of field by increasing the f-stop however I did not have enough light to compensate for the smaller aperture. An aspect that I would like to improve is to be more creative with my lighting as well as taking an overall sharper image. To develop this idea further, one could attempt to recreate this shot with a more dense fluid instead of water. Using a more dense fluid would allow the food coloring to fall at a slower rate and making the image easier to capture. Also one could run with the reflection of the water surface idea and experiment with capturing multiple different types of flows showing symmetry on the surface.

References

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