Interactive Visual Report 1 - MCEN 5151

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1 Background

To be frank, this image is the result of a fluke. While originally experimenting with a dispersion of oil in water, there was a lack of any quality photographs. During the clean-up of the failed experiment, vegetable oil was filtered through layers of paper towels in order to rid it of the glitter seeded within it. The paper towel did not act as a perfect filter, letting a fraction of the glitter remain in the oil as it ran down the sink into the drain. The intricate streaks of oil were exceedingly interesting as they carried the glitter down the course of the sink at different rates. The photograph was taken at a nearly isometric viewing angle. The lighting conditions were poor, thus a high exposure time was used. This produced a blurring effect on the faster moving points of the fluid.

2 Physics of the Flow

The flow phenomena in this image is relatively simple. Beads of oil are flowing over a surface doused with water. The Reynolds number of the oil will be calculated based on estimated fluid velocity. The glitter will be used in velocity estimations. Knowing the distance the glitter has traveled, based on the known diameter of the glitter itself, the velocity can be determined by this Δx divided by Δt which is the exposure time. The outer diameter of the glitter used measures to nearly .875mm. The shutter speed of the camera was $\frac{1}{30}$ of a second, or $\approx .034$ seconds. By analyzing the greatest distance any singular piece of glitter travels in the image, a net displacement of $\Delta x \approx 1.094\text{mm} = 1.0994 * 10^{-3}\text{m}$. Thus, the greatest measurable velocity in the image can be calculated below:

$$v = \frac{\Delta x}{\Delta t} = 0.032\,\mathrm{m\,s^{-1}} \tag{1}$$

Now that velocity has been determined for the flow, and adequate length scale must be determined to calculate the Reynolds number. Via *Fundamentals of Fluid Mechanics, 7th Edition* by Munson, Okiishi, Huebsh, and Rothmeyer, an appropriate choice in length scale would be the diameter, or width of a strand of oil. The width of the stream that gave the velocity value is 39 pixels, or $d = 4.27 \times 10^{-3}\,\mathrm{m}$. *Encyclopedia of Food Sciences and Nutrition (Second Edition)* by N.A.M. Eskin, and R. Przybylski gives material properties of vegetable oil: $\rho = 914\,\mathrm{kg/m^3}$ and $\mu = 71.5\,\mathrm{Pa\,s}$ at 20° Celsius. Thus the Reynolds number of that particular stream of fluid can be calculated:

$$\mathrm{Re} = \frac{\rho v d}{\mu} = 1.75 \times 10^{-3} \tag{2}$$

Calculating the Reynolds number shows that the flow of this oil is certainly laminar, as it does not have nearly enough velocity to become turbulent. To be frank, I am unsure of what other flow phenomena I should analyze in this image. Suggestions would be greatly appreciated.

3 Experiment Setup

This experiment could be set up with relative ease. There materials required consist of a camera, vegetable oil, water, Extra Fine glitter by Recollections$^{\text{TM}}$ (purchased at Michaels Crafts Store), paper towels, and a glass to contain it all. A black, inclined surface is also necessary to carry out the experiment. The incline should be at an angle of $\theta \leq 5°$. Once each component is sourced, mix 1 cup of water, a quarter cup of oil, and a tablespoon of the Extra fine glitter, and let settle. From top to bottom, there should be a layer of oil, then glitter, then water in the cup. Place 4 paper towels over the top of the cup, and then invert it onto your wet, inclined surface. A mixture of water, oil, and glitter will seep through the paper towel, forming tendrils which can be photographed. The lighting in this experiment could have been improved, though, though the settings used on the camera let enough light in in order to make a pleasing image. This subject is best captured from a nearly isometric viewing angle, though with variations in lighting a top-down approach could also be used.

4 Photographic Technique

The basic specifications and camera settings are listed in the table below. The exposure time was large due to the lack of light, creating the motion blur effect seen in the bottom left side of the image. Another notable setting is the high zoom;

this is an effect of finding the best viewing angle relative to the light source.

Camera Setting	Value
Aperture	f/6.3
Exposure Time (s)	1/30 = .034
ISO	400
Resolution (Width x Height, in pixels)	4832 x 3142
Camera/Lens Model	Canon EOS Rebel T1i, Sigma 18-200mm f/3.5-6.3 DC OS Lens
Distance From Object to Lens (m)	.61
Lens Focal Length (mm)	173

Some basic calculation can be done to calculate the field of view of the camera. As previously stated, the diameter of the glitter measures to $d = .875$mm. With this knowledge at hand, the length of one pixel can be calculated:

$$\text{Size of Pixel } = \frac{d}{\text{number of pixels}} = \frac{.875}{8} = .1094\text{mm}$$

From this point, the field of view is easily determined. First, the width of the photo is calculated.

$$\text{Photo Width} = (\text{Pixel Width}) \cdot (\text{Resolution}) = (1.094 \times 10^{-4}\,\text{m}) \cdot (4832) = 0.53\,\text{m}$$

Lastly, The field of view angle can be calculated using right triangles. The width of the photo is divided in two to make a right triangle which is in turn used to calculate half of the Field of View.

$$\frac{\theta}{2} = \arctan\left(\frac{0.264\,\text{m}}{0.61\,\text{m}}\right) \rightarrow \theta = 53^\circ \text{ FOV} \tag{3}$$

In terms of image processing, not much work needed to be done to the image. To account for the lack of illumination, there was high exposure and a high ISO. In post processing, the sharpness of the image was increased in order to reduce the graininess induced by the high sensor sensitivity. The brightness was also increased in tandem with minor adjustments on each RGB Curve. The image was also cropped to more clearly emphasize the subject.

5 Intended Image Ideals, and the Inevitable Shortcomings

As the initial assignment for this class, I am quite proud of the image. I think the subject of the image is interesting, and the general shapes and color palette is enjoyable. There are some issues I would have liked to fix with the image, though. First, the image is not incredibly well focused. It would have been beneficial to focus more towards the center of the frame. For the duration of the image-taking, the light quality made it difficult to inspect the photos on the screen of the camera, thus it was difficult to tell if the focus was in the desired location. For the focus, high accuracy was necessary due to the large zoom. If I were to rerun the experiment, I would work with a tripod and an external light to help remedy some of the flaws with the original photo. For an impromptu shoot, I am quite happy with my image.