MCEN 4151 – Flow Visualisation

Team Second Report

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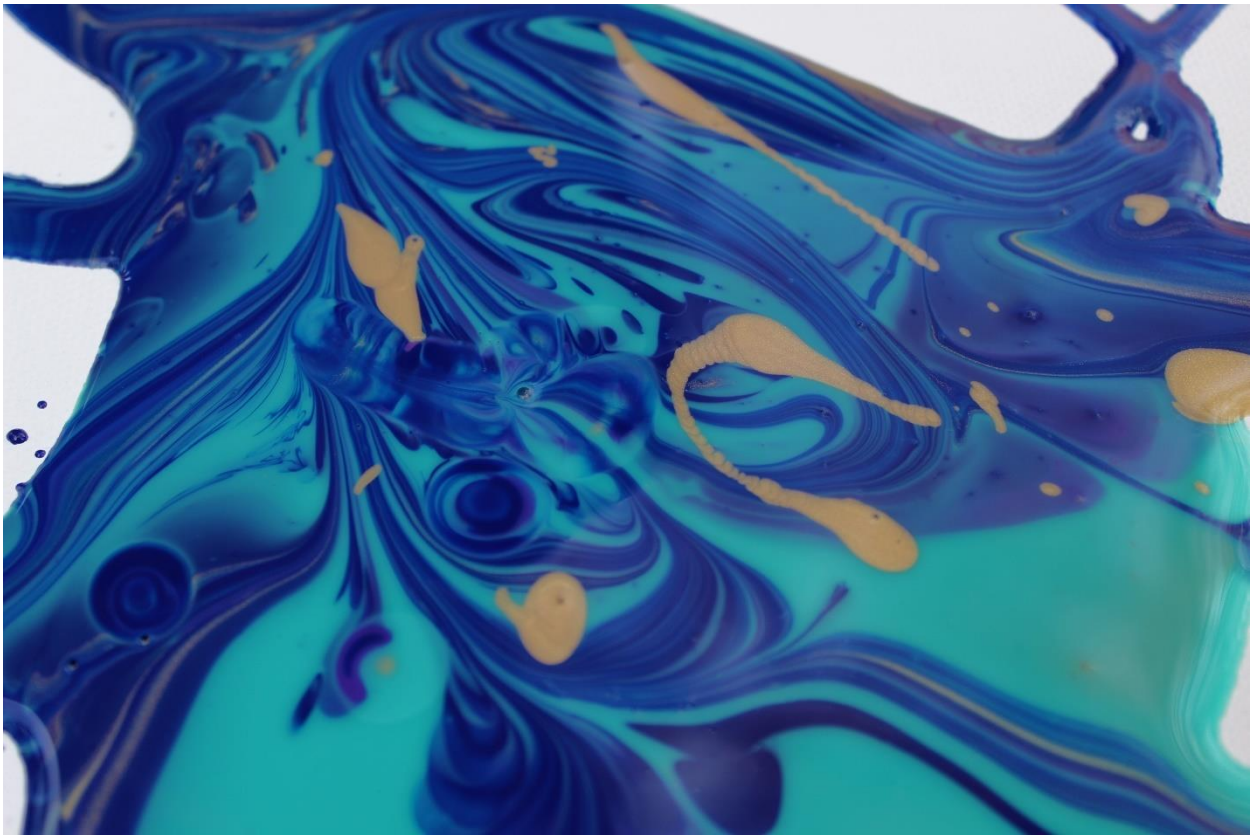

Figure 1: Final, edited photo

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Background

The motivation behind this experiment was to recreate the Rayleigh-Taylor instability via the use of different water-based paints. The reasoning behind this thinking was that different paint colors would have different densities due to the different dyes and pigments used in the paint. By using a variety of different paint colors, an aesthetically pleasing picture can also be attained as the instability develops in the flow regime being observed.

Setup

The experimental set-up was quite simple. It involved the use of the following: A plastic tarp, a shallow cup, a small blank canvas sheet, coconut oil, and a selection of different water-based paints. The paints were then poured into the shallow cup, one layer of color at a time. All colors except white were mixed in a 1:1 ratio. Once filled with the desired amount of paint, the cup was flipped face down onto the canvas, and lifted slowly. The paints then were to slowly spread over the canvas and left to show any interesting flow being developed.

Figure 2: Experimental Setup showing paint, canvas, tarp.

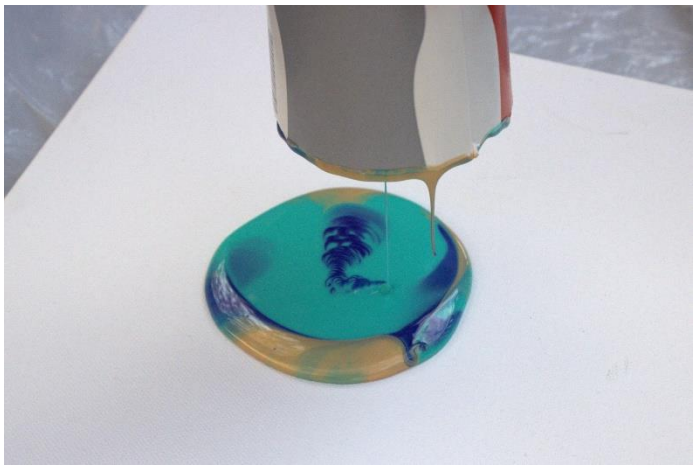

Figure 3: Cup being flipped to start the RT instability.

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Physics Behind the Flow

The flow can be described as laminar fluid flowing over a flat sheet. The canvas sheet was 10in x 10in and can therefore be classified as external flow over a surface. The main forces acting on the fluid are viscosity (intermolecular) and gravity (momentum). The fluid was indeed quite thick and viscous, so it did not flow with relative ease. We estimated the paint to have a density ρ of 1500kg/m^3, a density of 0.1m^2/s and a velocity of 2 cm/s. With this in mind, we can calculate the Reynolds number using the equation below.

$$Re = \frac{\rho VL}{\mu} = \frac{1500 * 0.02 * 0.254}{0.1} = 76.2$$

A Reynolds number of 76 indicates a highly laminar and orderly flow; this makes sense in this case, because the flow velocity was rather low, and the fluid viscosity rather high. As such, the intermolecular forces between the paints govern the behavior of this flow.

As for the Rayleigh Taylor instability, it is important to note that the lighter colors are reported to have a higher density than the darker colors [1], and this is a key factor in the development of the Rayleigh-Taylor instability. Since the cup was filled with lighter colors first, and then flipped, this inversion in density would easily cause the instability to develop – the lighter but more dense colors would exert a force on the darker but less dense colors, causing them to spread and flow until an equilibrium was achieved. The addition of coconut oil further added to the Rayleigh-Taylor instability, as its low relative viscosity forced rather stable paint to begin flowing again. This is visible in the circular instabilities forming in figure 1 above.

Visualization Technique

The visualization technique used was simple light impingement on a variety of different colored dyes. The paints used were water based, and the photographs were taken on a clear day in Boulder, CO. The lighting used was moderate sunshine.

Photographic Techniques

I decided to go with my fellow teammates photo, specifically, ones taken by Peter. I did not realize it at the time, but my ISO was set at the maximum of 6400. As such, all pictures that I took were very noisy, and hard to clean up. The image featured above was taken by Peter, and It has the following information.

Setting	Value
Camera	Canon Rebel T3i

Lens	18-55mm
Aperture	f/4.5
Exposure	1/100
Focal Length	30mm
Focal Distance	0.29m
ISO	100
Dimensions	5184px x 3456px

The photo was left uncropped – I liked the amount of detail that the image shown in its full frame. However, I decided to adjust the image by adjusting the RGB curve. I decided to increase the contrast between the different colors of paint, and hopefully make many of the details "pop-out". I also decided to decrease the overall brightness of the image to make the white colors present not so overwhelming. The original and edited images are displayed below.

Figure 4: Raw, unedited photo

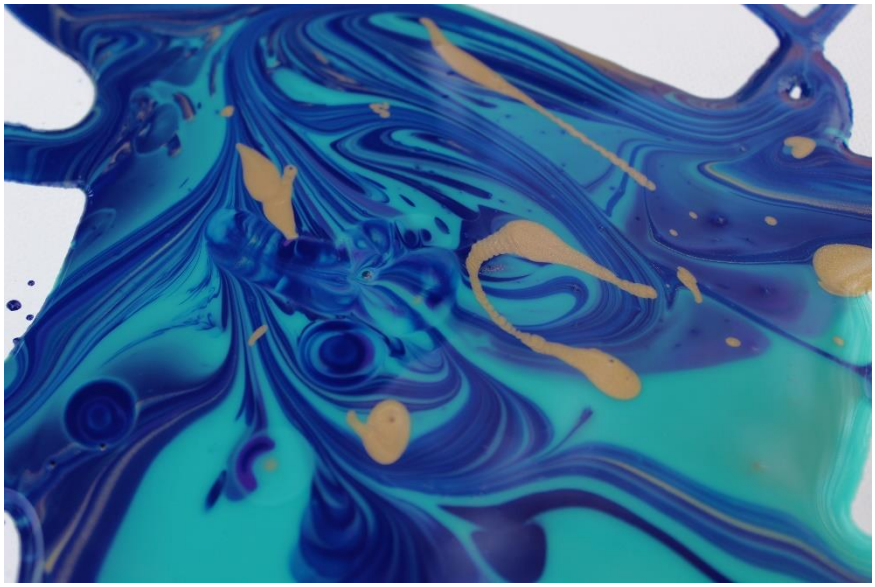

Figure 5: Final edited photo

Conclusion

I find the image above rather aesthetically pleasing – the even color selection of blues and whites is easy on the eye. Clear lamina can be observed between the different colors of paint, further hinting towards perfectly laminar flow. The swirls and distortions formed by the addition of coconut oil also add more interesting, organic shapes and characteristics to the canvas.

References

[1] "The Key to CELLS - Acryic Paint Density Made Easy!" www.youtube.com, 6 Aug. 2022, www.youtube.com/watch?v=Z-fauTeq1Y0. Accessed 8 Nov. 2023.