Get Wet Report

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MCEN 5151-001

23 September, 2025

The image that I produced for my Get Wet assignment was one of exploration. I have a background in photography but have not been very active with it in the last year. My goal was to highlight a phenomenon that I see quite frequently in my lab, the smoke that occurs from the act of tinning a soldering iron. What commonly occurs when doing so is the smoke rolls up into vortices of variable size. My intent was to capture the effects of the buoyant and viscous forces developed by the smoke rising through the air. I had the help of my fellow classmate and lab mate, Alyx Ellington, who assisted me in capturing the image by tinning the soldering iron and helping me with the background and lighting setup.

The setup for the image was much simpler than one would initially expect. It was a simple set up on one of the workbenches in my lab, with a foam scrap background, a soldering iron, two sizes of solder, and two phone flashlights. In figure 1, the entire setup and camera location can be seen. The phenomena being created was that of viscous vortex roll up, in which the friction between the smoke particles and the standing air within the lab would induce rotationality within the flow, thus inducing vortices[2]. The smoke in the flow would move through the frame of the camera in about a second and a half, which would correlate to approximately .5m/s. Using the length scale of the camera frame, which could be estimated as approximately .75 m, the Reynolds number of the flow around 24k. That would place the flow solidly within the turbulent regime, which is reasonable given the physics seen within the photo. Within the photo, there are various sizes of the vortices, which is indicative of turbulent flow by way of the decreasing scales of turbulent structures and the energy cascade. Continuum mechanics states that the energy moves from large scales of motion (large structures) to small scales of motion (small structures) before dissipation occurs[1].

The setup for the image was much simpler than one would initially expect. I had set up one of the workbenches in my lab with a black foam scrap as the background. I had a soldering iron and two sizes of solder as a source for the smoke. I used two cellphone flashlights for edge lighting, with the goal of illuminating the smoke and only the smoke. One of the primary issues that I had was being able to properly illuminate the smoke without also illuminating the background. I got around this by propping the flashlights up and orienting the beams more towards the camera. This allowed the sensor to receive more light while keeping the background relatively dark.

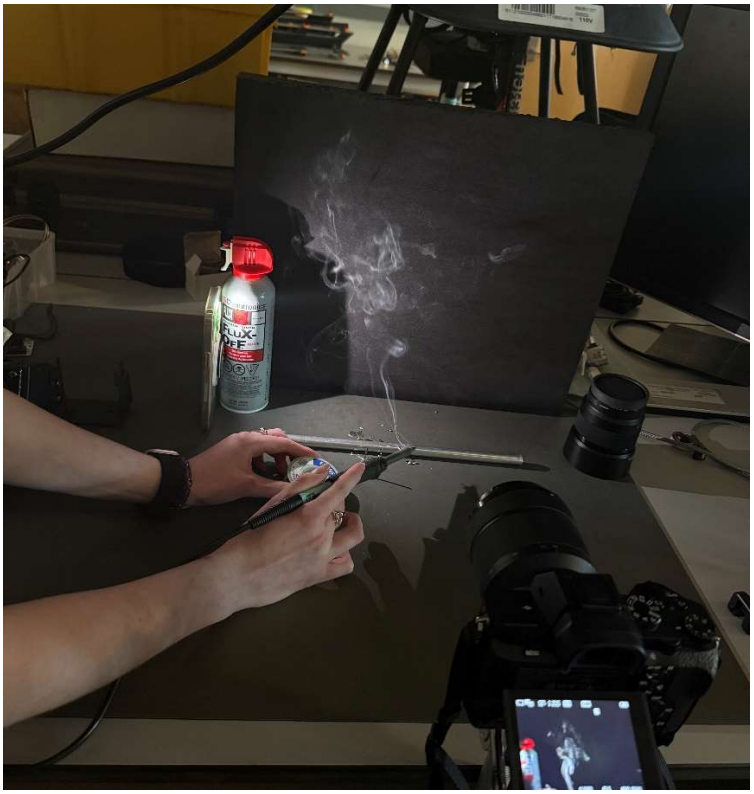

Figure 1: Imaging Setup

It was not particularly easy to capture the physics in this image, between timing and focus there was a fair bit of trial and error. This image was captured on my Sony A7ii using a 28-70mm lens. I had the lens set as wide as possible, at 28mm, with a focus distance of ~0.33m. This focal distance is consistent with the setup seen in figure 1. I chose a shutter speed of 1/4000, because I wanted to capture the instantaneous behavior of the flow, with as little motion blur as possible. By increasing my shutter speed, I also limited the amount of light that was able to make it to the sensor of the camera, which meant I had to offset that darkness with the other components of my exposure. I started with my aperture, which I had all the way open at f/3.5. The downside of having such a low aperture, however, was that the depth of field was quite shallow, which contributed to my focusing woes. For this set of images, I had left my ISO in auto mode, which resulted in an ISO of 25600 being used. This was significantly higher than I would have chosen manually and became something that I had to fix later in post-processing. Figure 2 shows the unedited photo, which required a fair bit of work. First was the crop, I went from the full frame photo (6048x4024) to the cropped photo (2771x3494). Next, I adjusted the contrast to pull out the details and make the smoke more easily visible. Finally, the largest part of the edit was the denoise. I used both a color and brilliance denoise to reduce the amount of noise generated by having such a high ISO. The adjustments to the contrast and denoising did most of the heavy lifting for this image.

Figure 2: Unedited Photo

The photo captures the flow very well, highlighting the numerous scales of vortices. That said, I still feel that there is room for improvement. I would've liked to have had less noise in the raw image, as it would have meant that I would lose less detail in the smoke from using a denoise tool. If I were to take this image again, I would have manually set my ISO lower and increased the amount of light illuminating the smoke. If there had been more light, I could've raised my shutter speed further, close to the camera's limit of 1/8000, which would have allowed me to truly minimize the motion blur captured within the image. From a scientific perspective, I would like to set up a calibration target as the background. That would give me a way to quantify the scales of the vortices, which would theoretically allow for the calculation of the energy contained within the flow.

References:

1. Richardson LF. THE FUNDAMENTAL EQUATIONS. In: *Weather Prediction by Numerical Process*. Cambridge Mathematical Library. Cambridge University Press; 2007:21-114.
2. Moffat, H K. "A Brief Introduction to Vortex Dynamics and Turbulence." University of Cambridge Department of Applied Mathematics and Theoretical Physics, 2011, www.damtp.cam.ac.uk/user/hkm2/PDFs/Moffatt_2011_WorldScientific_Abitvdat_1.pdf.