MCEN 4151

FLOW VISUALIZATION

REPORT- IMAGE 1: BILLOWING SMOKE

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MCEN 4151: Flow Visualization

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1- Introduction

The purpose of this image is to depict the behavior of smoke as it rises naturally from a source. As a first project image, it attempts to capture a physical phenomenon that we see in our daily lives involving smoke. Initially, I was shooting perpendicular to the background and at the same level as the smoke. However, the light source from the flashlight made it difficult to not overexpose the image. To remedy this issue, I positioned the camera lower than the incense stick and shot the smoke from below. From a fluid flow perspective, the burning end of the incense stick heats the air around it. From the incomplete combustion process, smoke particles are emitted and carried upwards by the warmed air below. To limit the amount of smoke coming from the incense stick, the end was only lit for a brief period before the flame was blown out and the smoldering smoke could rise. This resulted in a smaller, more controlled stream of smoke that could be isolated. I also experimented using different sources of smoke (paper, smoldering bread, wood incense) but each resulted in a suboptimal combinations of a high smoke velocity or low smoke output. As a result, a traditional Eastern Tantra incense stick was selected for the final photograph.

2- Experimental Setup

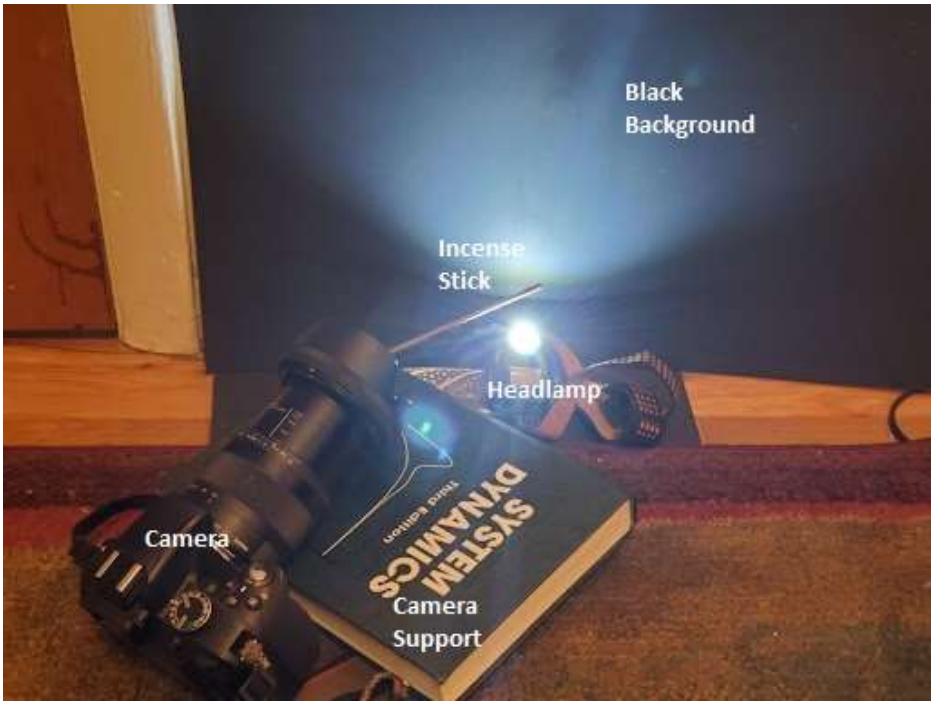

Figure 1: Experimental Setup

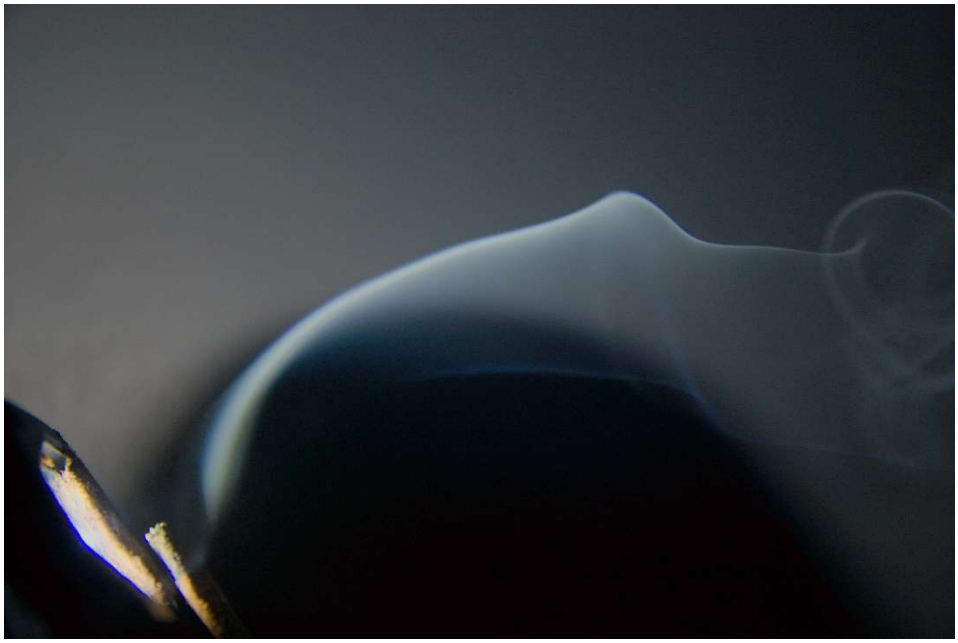

Figure 2: Incense Stick and Light Source

Figure 1 depicts the experimental setup. The incense stick was lit from below using an LED headlamp. The black background was a dark piece of posterboard. The camera was supported with a book initially. However, the final image was taken offhand without the camera being fully supported by the book. As the incense stick burned (as a significant amount of time was spent configuring camera settings) the headlamp was moved below the incense stick. *Figure 2* shows the proximity of the incense stick to the light source near the end of the shoot. The photo was only lit by the flashlight. No other external light was used (as the photo was taken in a dark room, at night).

3- Flow Phenomena

As mentioned previously, the heat from the incense stick changes temperature of the air around it. This air effectively decreases in density, which creates a net flow upwards in the fluid. With the difference in fluid densities, the air around the incense stick becomes more "buoyant" relative to the surrounding air, causing the smoke to rise upwards. Initially, this effect is strong and results in laminar flow from the source (shown in *Figure 2)*. However, once the air (and the smoke particles carried in it) reach a certain height (approximately 6" above the source) transitions to stokes flow. This phenomenon occurs when the Reynolds number transitions from laminar flow ($Re < 2300$) to stokes flow ($Re \ll 1$) Also known as creeping motion, this occurs when inertial forces are relatively small when compared to viscous forces.

4- Visualization Technique

Smoke from the incense contrasted well with the black background when lit from below. To recreate the image, its important to light only the smoke when possible. To accomplish this, a flashlight with a narrow field of lighting (approaching a beam) would be ideal. Flash was not used on the photo, as it would have resulted in sub-par contrast in the end image. The incense sticks used were Satya Brand, Eastern Tantra

5- Photographic Technique

The photo was shot using manual settings on a Nikon D3300 with a Sigma 17-70 mm HSM Macro lens. For a balance between focal length and aperture, this photo was shot at a 28mm focal length and F3.2. These were paired with a relatively fast shutter speed of 1/250 sec (to capture the moving smoke without significant blur), and an ISO of 5600. Additionally, manual focus was used for this image. In the end, these settings were a compromise given my current setup. With either a faster lens, or a larger format sensor, the shutter speed could have been increased or the ISO decreased. There was relatively little post processing done on the image. A hot/dead pixel average was applied, highlights were compressed, and the overall exposure of the image was brought down. A lens correction was applied, and the color curve adjusted slightly to show the slight variations in hue within the smoke. The photo was also cropped down slightly so the smoke would trail from the bottom left of the image, to the top right. All editing was done in an open-source program called RawTherapee. *Figure 3* (below) shows the image before editing. *Figure 4* (below) shows the image after editing.

Figure 3: Before Editing

Figure 4: After Editing

6- Meaning

From a visual standpoint, this image reveals how the smoke gradually disperses within the air. Without a close source of heat, the flow goes from being steady to seemingly folding over itself in time. In a way, it reminds me that the entropy of the universe is always increasing. The fluid physics behinds this are apparent in the image, however they could have been enhanced by viewing the stream of smoke from a distance. This would help make the smoke devolving over time more apparent. One of my main questions is about finding a background without significant glare/reflections. Although the background I used was matte black, there were certainly angles in which the light source was painfully apparent. Additionally, I'd like to learn more about post processing techniques to improve the visual appeal of this image. I am happy with this image, given my relatively rudimentary knowledge of developing RAW files.