Team Second Report
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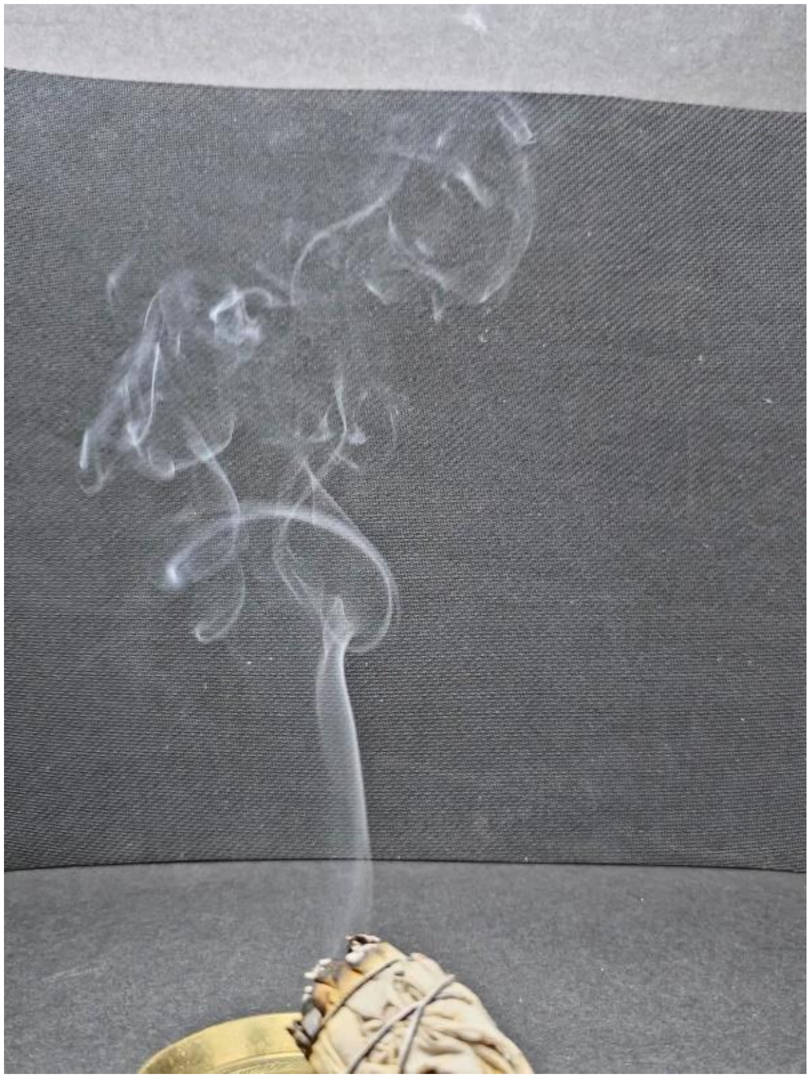

Image 1: Team Second Raw Image

This image was created for the flow visualization project named team second. It focuses on capturing the unique smoke patterns formed by a burning sage bundle against a black backdrop. The intent was to observe the interaction of rising smoke with ambient air, resulting in distinct formations, including a “mushroom” shape. Initial attempts revealed challenges with airflow consistency, requiring adjustments to create a steady burn and maintain the smoke's integrity for better visualization. The project was completed individually, with all setups, adjustments, and photography done independently to achieve the final image that effectively showcases the intricate dynamics of smoke flow.

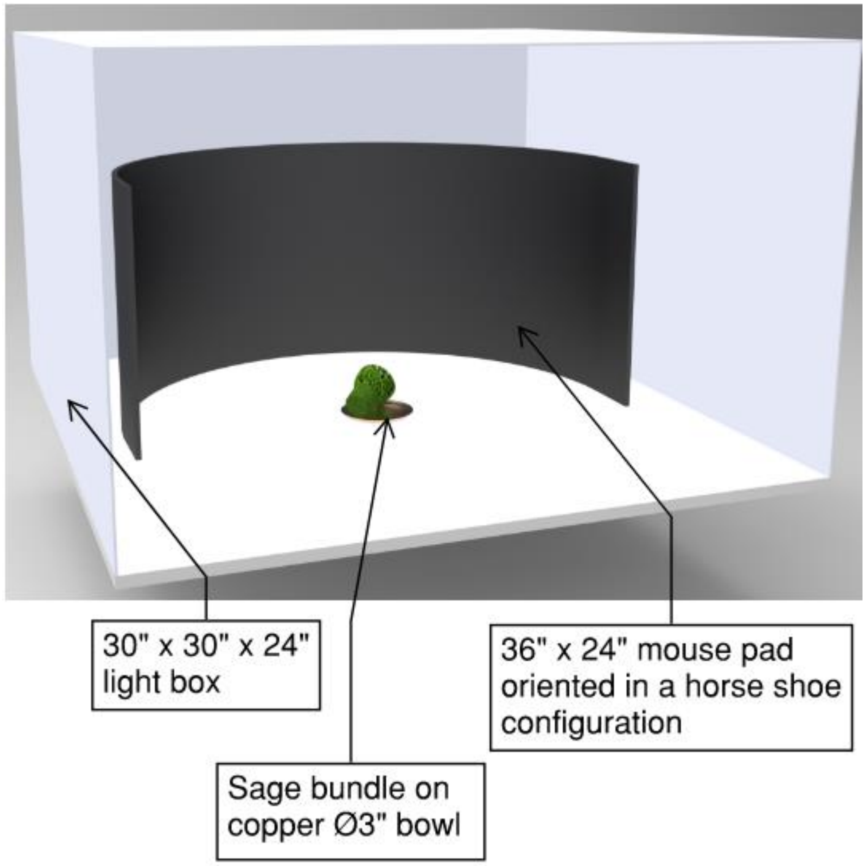

Image 2: Team Second Setup

The flow apparatus constructed for this project can be seen in image 2. The setup began with a white canvas lightbox with the dimensions 30” wide x 30” deep and 24” tall. Using a large 36” x 12” rubber black mouse pad I have, I was able to create a black back drop as well as a decent wind break for the smoke produced by the sage bundle. The sage bundle was placed on a Ø3” copper bowl to protect any plastic from burning sage. The sage and bowl were placed roughly concentrically in the center of the horseshoe mouse pad configuration. The sage was lit with a lighter and was allowed to go out leaving a hot ember that produced smoke. The goal of the setup was to capture the white smoke against the black background. In terms of flow, this setup illustrates the rise of smoke—driven by buoyant forces due to the hot ember—through a relatively quiescent environment, with minimal cross-draft interference. The smoke flow resembles a plume, with visible transitions as it rises and cools, occasionally forming mushroom-shaped vortices. Estimating the Reynolds number (Re) for the smoke, based on a velocity scale chosen around 0.1 m/s and assuming a characteristic dimension of 0.05 m, we get,

$$RE = \frac{UL}{v} = \frac{\left(\frac{0.1m}{s}\right) x(0.5m)}{1.5x10^{-5}m^2/s} = 333$$

suggesting transitional flow.[1] This Re indicates that, while the flow may begin laminar, instabilities can quickly introduce turbulence, forming distinct vortices in the smoke.
Forces acting on the smoke include buoyancy, gravity, and drag. The buoyancy force initiates the upward flow, while drag slows the ascent and disperses the smoke, creating varying shapes. The mushroom shapes form due to the interaction of the rising smoke with cooler air above, creating a Kelvin-Helmholtz instability.[2] Over time, as the smoke cools, it transitions into more dispersed and turbulent patterns, illustrating complex fluid behaviors.

For this project, smoke was used as the visualization medium, generated by a small sage bundle. The sage bundle, a common herb bundle easily sourced from natural stores, was ignited with a lighter and left to smolder, producing a steady stream of smoke. Positioned on a 3-inch copper bowl to contain the embers, the sage burned within a mostly enclosed, white canvas lightbox and large mouse pad to minimize drafts and control airflow. Ambient room temperature was approximately 72°F with no forced ventilation, which helped maintain steady conditions for the smoke's ascent and shape formation. For lighting, the lightbox utilizes a pure white light positioned directly above the sage bundle to illuminate the smoke without casting strong shadows. The lighting setup, combined with the low ambient light in the room, highlighted the white smoke against the dark background, making details such as the mushroom-shaped vortices visible. This setup can be easily recreated by using a black background, a controlled smoke source, and low, even lighting from above to accentuate smoke patterns.

For this image, I used a Samsung Galaxy S24 Ultra, shooting in RAW format to capture high detail and maintain flexibility in post-processing. The original image dimensions were 4284x5712 pixels, and after editing, the final dimensions were 2748x5201 pixels. The image field of view was set to capture only the area surrounding the sage bundle and smoke, approximately 12 inches across, allowing a detailed look at the smoke patterns against the black backdrop. The camera was positioned around 10 inches from the sage bundle to focus closely on the smoke’s structure and patterns. The lens specifications included a focal length of 6mm, with an aperture of f/1.7, allowing for a narrow depth of field to highlight the smoke while keeping the backdrop dark. The exposure settings were 1/60 second shutter speed and ISO 1000, chosen to balance the lighting with minimal noise and achieve a clear capture of the smoke’s delicate details. These settings provided the right balance between capturing the smoke’s motion and preventing blur from slower shutter speeds.
For image processing, I adjusted the contrast and brightness to further enhance the smoke’s visibility against the black background, without altering the natural texture and structure. The image was cropped to focus on the main smoke plume and reduce distractions from the edges, while maintaining the details necessary for studying the flow patterns. The editing process emphasized clarity and detail in the smoke without altering the authenticity of the capture.

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[1] C. G. Heisler, “Aerodynamic Properties of Buoyant Plumes,” *Atmospheric Environment* 9, no. 1 (1975): 71-82.
[2] S. B. Dalziel, “Plume Dynamics,” *Annual Review of Fluid Mechanics* 31, no. 1 (1999): 239-271.

The image reveals intricate details of the smoke rising from the burning sage, including swirling eddies, subtle shifts in density, and the formation of a mushroom-like shape due to buoyant forces and ambient air interactions. I particularly like how the dark background and soft lighting make the smoke stand out, highlighting delicate patterns and vortex formations that wouldn't be visible in a busier environment. One drawback is that some finer smoke textures are lost in certain areas, likely due to the exposure settings and slight overexposure in parts of the plume. The fluid physics are displayed well, capturing the initial laminar flow of the smoke and its transition to turbulent structures as it rises and cools. The mushroom shapes hint at Kelvin-Helmholtz instabilities, revealing how temperature and density gradients interact. However, I'm curious about the specific conditions that lead to the mushroom shapes and whether these could be more consistently replicated with different smoke sources or environmental controls.
Overall, I believe the image met my intent, successfully highlighting the fluid behavior of smoke in a visually compelling way. To improve, I would refine the lighting and exposure settings to capture even more detail in the plume's finer structures. In future explorations, I could introduce airflow or manipulate temperature gradients to observe how these factors influence the smoke's shape and movement. Additionally, exploring various light sources or colors might enhance contrast and reveal additional details in the smoke dynamics, adding another layer of complexity to the flow visualization.

Image 3: Team Second Edited Photo

References

Heisler, C. G. "Aerodynamic Properties of Buoyant Plumes." Atmospheric Environment 9, no. 1 (1975): 71-82.

Dalziel, S. B. "Plume Dynamics." Annual Review of Fluid Mechanics 31, no. 1 (1999): 239-271