Vortex Visualization Using Smoke

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Image/Video 1 Report

1 Introduction

For the first flow visualization assignment, we were tasked with capturing a fluid flow phenomenon of our choosing to the best of our ability. I have always been fascinated by air flows and how to visualize something that is normally invisible to the naked eye. An easy and cheap way of visualizing air flow phenomenon is to simply use smoke or vapor from any number of common household items. These could be candles, incense, or diffusers that emit a pleasant scent. I had a Voluspa brand candle in my house with a decorative aluminum enclosure that, if arranged properly, briefly emits a thin column of smoke when blown out. This assignment was also an opportunity to get my feet wet with photography since its something I haven't deeply explored in the past. Set-up, sensors, camera angles, and settings were all things that took some iteration to capture the video that I submitted.

2 Discussion of Flow Phenomenon

Figure 1: Kelvin-Helmholtz Instability seen in a layer of clouds

After some research, it seemed that the particular flow phenomenon seen in my video is known as Kelvin-Helmholtz Instability (KHI). This kind of instability in the air leads to vortices or roll-ups that can result in some very interesting and mesmerizing formations in clouds or other markers. KHI is something that can be observed everywhere. From Jupiter's red spot, to the perturbations on the surface of a body of water as the air flows across, this phenomenon is truly universal.

Conceptually, KHI is characterized by velocity and/or density differences between two layers of a fluid, or at the interface between two different fluids. The high level idea of what is happening, particularly in air as seen in my video submission, is that a difference in velocity between two layers of the fluid induces vorticity at the interface, resulting in the spiraling of the two layers. With smoke acting as a marker, this can be seen in real time.

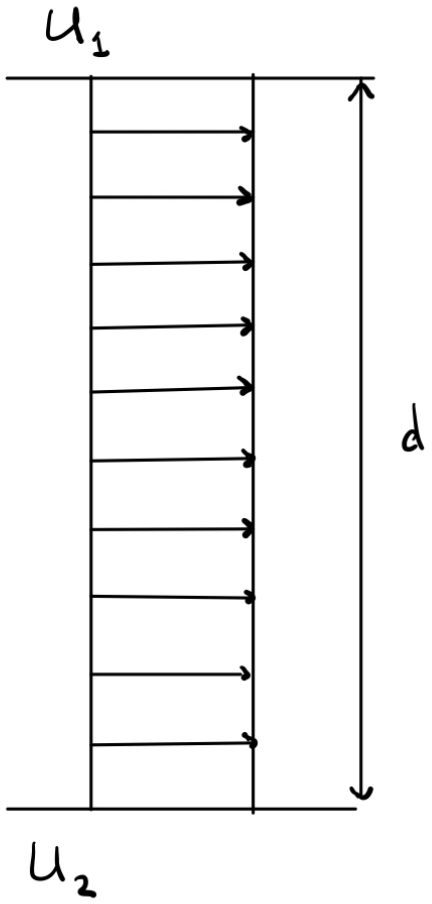

Figure 2: Shear layer between two flows

The theory behind KHI is two dimensional, and the Vortex Sheet Model is the foundation. First we must assume that the distance, d, between the top and bottom boundaries of the shear layer is much less than wavelengths of the disturbances. This layer is called the Vortex Sheet.

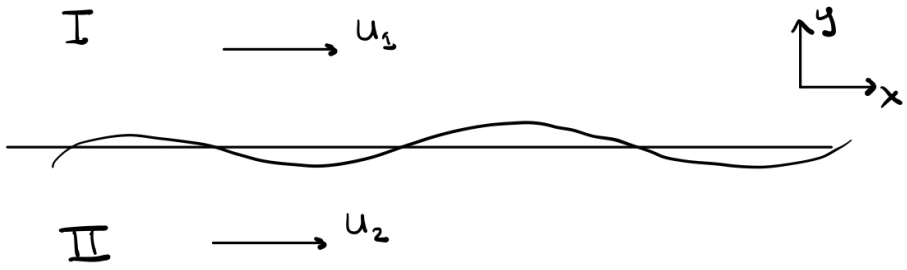

Figure 3: Vortex Sheet Model

The evolution of this kind of flow can be visualized in stages below.

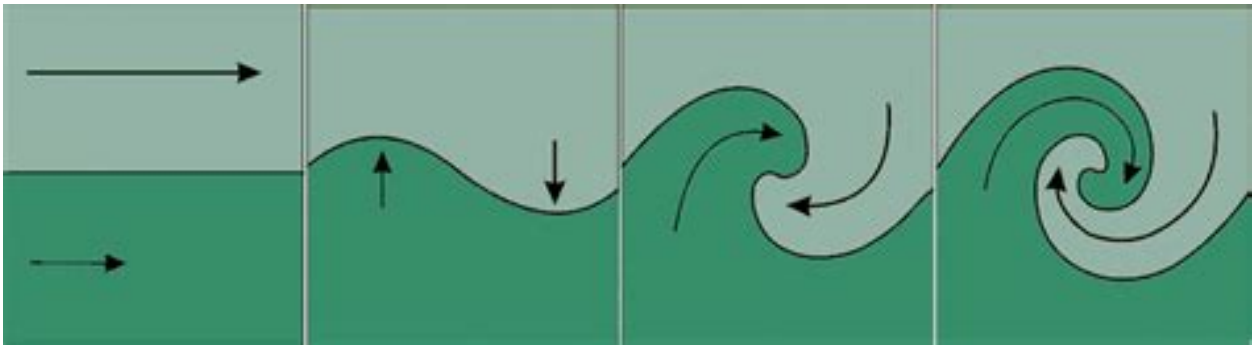

Figure 4: Evolution of flow in Vortex Sheet Model

3 Producing the Phenomenon

The production of this phenomenon was not necessarily done deliberately, however, I did utilize a lot of trial and error to get something that seemed interesting. The conditions that led to the capture of the KHI in my video were very little movement of my self near the camera setup, and turning my ceiling fan completely off. This probably ensured that the airflow around the setup did not become turbulent, which is one of the preconditions for creating KHI. The airflow needs to be laminar in order to get the idealized shear forces in the fluid and thus the picturesque vortices.

4 Visualization Technique & Equipment

To begin with I utilized white construction paper underneath and behind the candle. This may not have been the best choice since smoke is already a light color. However, the light in my room is much more yellow than white so the smoke didn't seem to disappear against the background. Next I utilized my iPhone 12 Pro which luckily has flat sides which it can balance on. This allowed me to hit record on the device itself and not have to hold it, which may have caused undesirable movement in the video. Next, after starting the cameras slow motion capture mode, which operates at 240 frames per second, I blew out the candle and allowed the smoke to rise. The slow motion mode really showed the development of the vortex just as you can see in Figure 4.

References

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