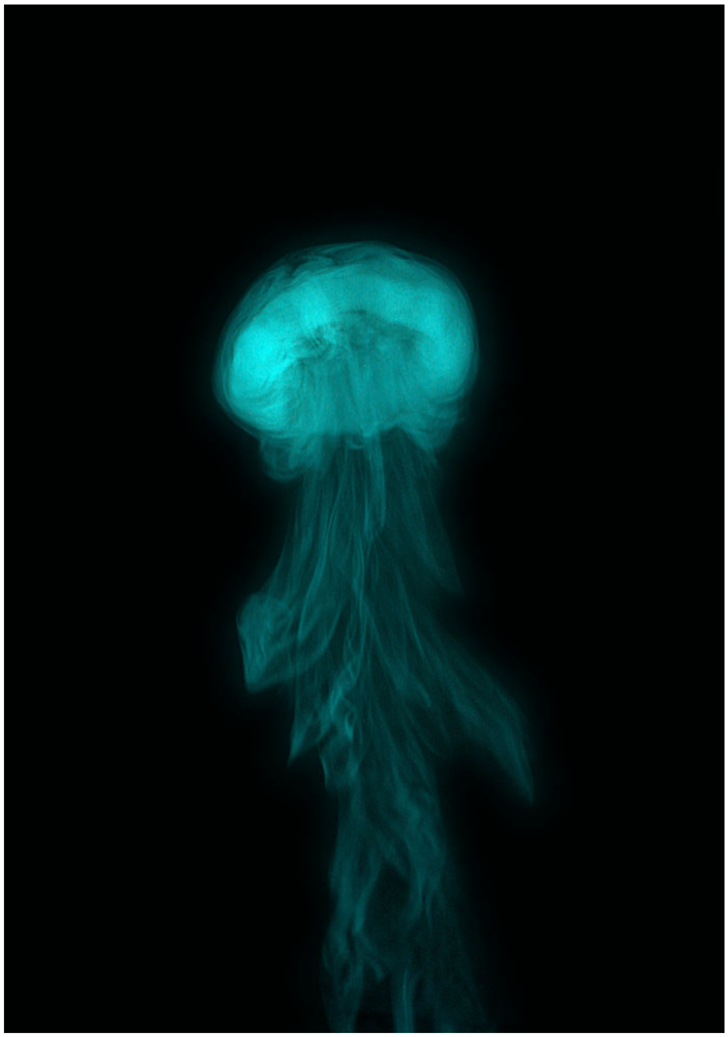
Jellyfish



Kristopher Tierney

MCEN 5151 – Flow Visualization

Group Assignment 1

3/13/2014

University of Colorado, Boulder

Introduction

Jellyfish was created as the initial team project for the Flow Visualization course. This project was not only used to promote students to create and photograph more complex and intriguing fluid phenomena than they would on their own, but also to reinforce the importance of proper group dynamics in a team project setting. The original intent of *Jellyfish* was to create and capture torsional vortices well, which was told to be a far greater challenge than expected. Once the images were captured, however, *Jellyfish* was changed to mimic a living jellyfish, not only due to my passion for creativity, but to distinct my image form those of my group members (William Derryberry, Lael Siler, and Mark Voll). This report will not only elaborate on the physics involved in *Jellyfish*, but will also detail the setup of the experiment and the post processing of the image.

Description of Flow Physics

Jellyfish is a clear example of a fluid dynamic phenomena known as a toroidal vortex, or more simply a vortex ring. This phenomena occurs when a circular disk of fluid is jerked normal to its plane and subsequently moves through a uniform, relatively stationary fluid medium[1]. Once this disk is in motion, shear forces within the disk take over, and begin to form a ring. This is caused by the relative difference in viscous friction between the outer and inner radii of the vortex ring. As the ring progresses through the stationary fluid, viscous friction slows the outer layer of fluid relative to the rest of the ring. As this happens, the inner, faster fluid catches up, and forces the slower fluid out of the way, taking its place. Subsequently, the slower fluid reaches the back of the vortex ring, where there is a low pressure zone caused by the continued velocity of the fast fluid. Once the slow fluid reaches this low pressure zone, it is quickly converted into the new fast fluid, and the process repeats itself.

Toroidal vortexes are largely dependent on the Reynolds number. The Reynolds number is a measure of the ratio of inertia force on an element of fluid to the viscous force on an element, and is defined by the equation below[2]; where "U_d" is the velocity of the vortex ring, "r" is the radius of the ring, and "ν" is the kinematic viscosity of the air. For the purpose of this experiment, both "U_d" and "r" were estimated using videos of the experiment for reference, yielding a velocity of 1 m/s and an outer ring diameter of 10 cm. The viscosity of air was assumed to be $3.82*10^{-7}$ m^2/s at an estimated temperature of 70° F (21.11° C).

$$Re_d = \frac{U_d R}{\nu} = \frac{(1\frac{m}{s})(10 * 10^{-4}\ m)}{3.82 * 10^{-7} m^2/s} = 2617$$

Once calculated, the Reynolds number is shown to be moderate (slightly above 2300) and greater than 1, and thus indicates mostly laminar, inviscid flow[2]. The "mostly" within the previous sentence comes from the Reynolds number being over 2300, which is known as a transitional Reynolds number. These Reynolds numbers indicate that although the Reynolds number for the fluid is too low to be completely turbulent, and too high to be completely laminar, both laminar and turbulent flows are possible within the fluid. This accounts for the smoke “tail” following the smoke ring, resulting from the non-perfect recirculation cycle due to the slight turbulence of the ring itself.

Experimental Setup

To create *Jellyfish* a relatively simple experimental setup was used. First, a large, black sheet was hung from the ceiling behind the table on which the experiment was to be conducted. This was to create a plain, dark background to contrast the light smoke rings. Next, a box cutter was used to cut a hole in one if the skinny sides of a cardboard box, which is was then filled with smoke from a smoke machine. Finally, the smoke-filled box was placed on the box from the smoke machine to give it sufficient elevation from the table. To generate the smoke rings themselves, the smoke-filled box was simply given a slight, but fairly quick squeeze on both of the largest sides. This was done with sufficient time between tests to assure no residual smoke nor air turbulence from the previous test remained. No external lighting was used other than the natural light of the sun, which was conveniently overcast on the day this image was taken, providing ample diffuse, grey light. Due to the large, slow-moving nature of the smoke rings, photographs were taken by hand, without the aid of a tripod.

Figure 1: Animated experimental setup (Left), Realistic experimental setup (right)

Photographic Technique

To take the original JPEG image of *Jellyfish* a 6.5 megapixel Canon EOS Digital Rebel digital camera was used. A Canon EF 50mm f/1.8 II camera lens with a UV filter was also used to compliment this camera, and allowed for greater color balance and reduction of glare. The camera was not placed a specific distance from the smoke rings, but was rather shot by hand in real-time to experiment with various angles and distances to maximize image quality. Thus, rather than manually focusing and adjusting the cameras default shutter speed, aperture, and ISO for every shot, the cameras default sport setting was used. For this image in particular, the camera used a shutter speed of 1/250 seconds, an aperture of f/1.8, and an ISO of 400.

For the post processing of the image, Adobe Photoshop CS5 was used. First, the image was cropped from 2048 x 3072 pixels to 2048 x 2921 pixels. This was to reduce the field of view of the image from about 30 cm x 45 cm to around 30 cm x 40 cm, thus removing a small amount of blank space above the head of the "jellyfish" to better conform to the rule of thirds. Then, the sharpness, highlights and shadows, contrast, and color levels of the image were all adjusted to allow for more visible fluid flow, and a generally more appealing image. Finally, a blue color filter was applied to the image, and the background was set to an off black to make the image feel more natural compared to a pure black background. The glowing effect from the "jellyfish" comes from a fading technique where a thin outline around the "jellyfish" gradually fades into the new darker background.

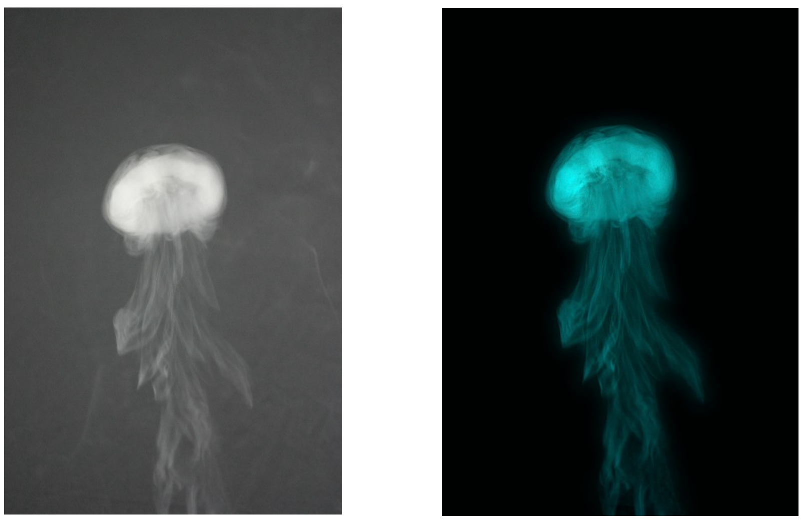


Figure 2: Pre-processed image (Left), Post-processed image (Right)

Conclusion

Jellyfish not only clearly displays a toroidal vortex of smoke moving through air, but also connects nature to fluid flow in a fascinating way. Overall, I am very happy with this image. Not only did our group accomplish the task of photographing a type of fluid flow generally regarded as very difficult, but we did so with relative ease. Moreover, the experiment was extremely fun to play with, even after we took a sufficient amount of images. The one thing I would change about this image is the relative focus of the tail of the ring compared to the ring itself. Although it is extremely difficult to get that sort of depth of field in this type of fluid flow, I feel like it should be possible with sufficient photographical ability.

References

[1] Batchelor, G.K. (1967), *An Introduction to Fluid Dynamics*, Cambridge University Press

[2] D. F. Young, B. R. Munson, T. H. Okiishi, W. W. Huebsch (2007). *A Brief Introduction to Fluid Mechanics, Fourth Edition.* Hoboken, NJ: John Wiley & Sons, Inc.