IV III – Quarter Drop

https://www.youtube.com/watch?v=LJqbieTvGcY

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MCEN 5151

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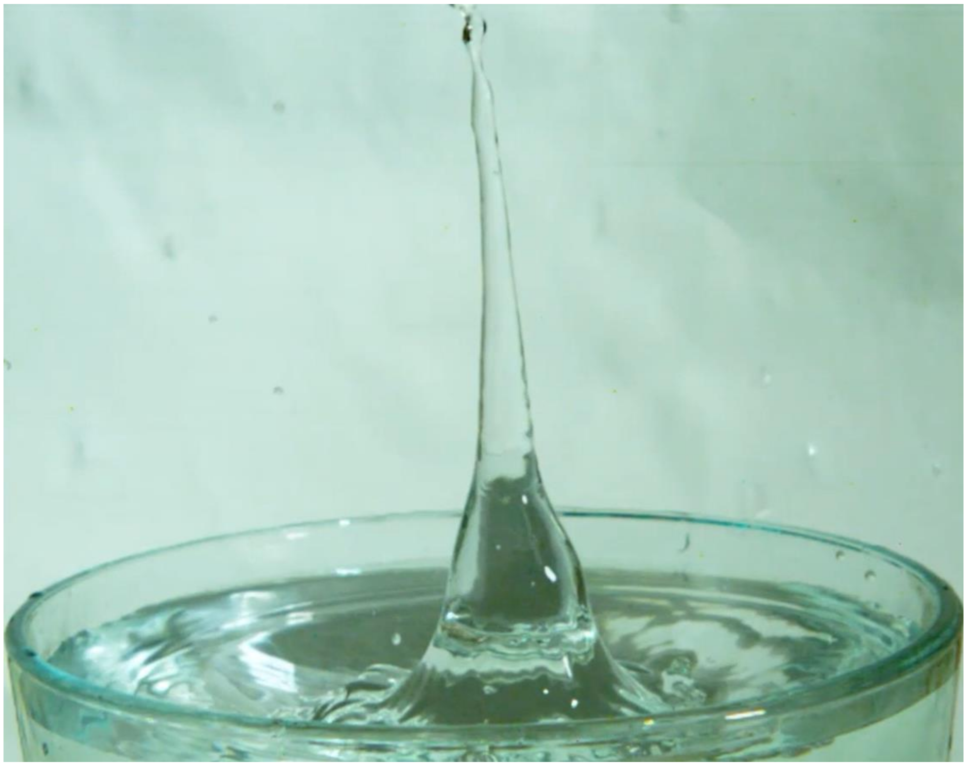

Figure 1: A still image of the video showing a Worthington Jet

Introduction

For the third Image Video assignment in the course of MCEN 5151 Flow Visualization, the team of with Ben Carnicelli, Nathan Gallagher, Alex Kelling, and David Milner focused on using high speed cameras to capture a Worthington Jet. This is the splash seen when an object is dropped in a liquid. Using a high-speed camera would allow the team to visualize throughout its development and decay leading to a better understanding of the fluid physics involved.

Flow Physics

A Worthington Jet is created when an external object impacts a liquid's surface creating a jet of liquid upward. A. M. Worthington published initial work on this topic at the turn of the century (Worthington, 1908) having the phenomenon gain his name. When the object impacts the surface and travels downward it creates a void in the water (Bartolo D, 2006). The void rapidly closes due to hydrostatic pressure and creates a jet that launches above the surface (Bergmann, 2009). The equation for hydrostatic pressure is defined as:

$p = \rho g h$ Eqn. 1 (ToolBox, 2022)

Where p is the hydrostatic pressure, ρ is the fluid density, g is gravity, and h is the height of the water column. Interpolating from the known diameter of the glass, 3.5", the depth of the cavity at its largest point would be roughly 0.82". Converting to metric, the calculation for the hydrostatic pressure is the following:

$$p = \rho g h = \left(1000\, {}^{kg}/_{m^3}\right)\left(9.81\, {}^{m}/_{s^2}\right)(0.0208\, m)$$

$$p = 204.05\, Pa$$

This means the cavity is collapsing from a pressure of 204.05 Pa. This number may seem rather small at just 0.03 pounds per square inch (psi). This number is reasonable due to the small depth of the cavity. A person swimming at a depth of one inch does not experience a crushing force. The jet effect in this situation comes from the fact that the wall of water on the cavity boundary is collapsing nearly unopposed as the cavity is filled with air. This can create a jet exiting at over 40 times faster than the impact speed (Truscott, 2013).

Experimental Set Up

To capture this video, a Phantom Miro C110 high speed camera was loaned from the University of Colorado, Boulder's Integrated Teaching and Learning Laboratory. This camera included a tripod and laptop with processing software allowing the team to set up, capture, and export the video quickly and efficiently. The camera was positioned nearly five feet away from the subject, a glass cup measuring 3.5 inches in diameter. The glass was filled with water. Behind the glass was a blank piece of paper, providing a clean, distraction free background. A standard U.S. quarter dollar, commonly called a quarter, was dropped to into the cup from a height of roughly 18 inches.

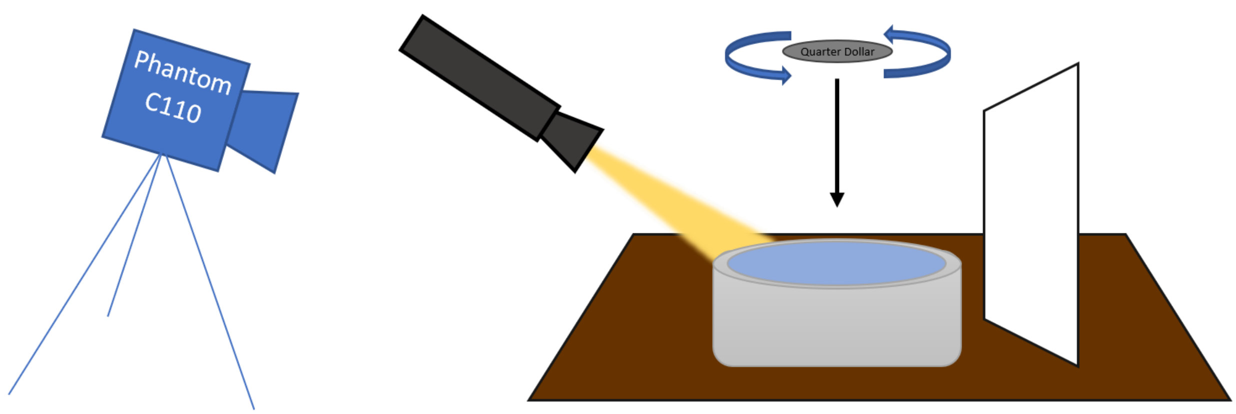

Figure 2: Experimental setup

One team member would trigger the camera. The camera was set to record two seconds before and after the trigger. The trigger button would be pushed as close as possible to the impact on water, but there was a considerable safety factor in the recording time before and after, allowing for human reaction time. Another team member was holding an Energizer Tac1000 flashlight, supplying 1000 lumens of illumination, at roughly a 45-degree angle above and forward of the glass. This would reduce shadows and glare captured in the video. A third team member would drop the quarter. The fourth team member would rotate into any position with new ideas or provide material.

To maximize the effect of the quarter impacting the water, it needed to land as flat as possible. Several trial runs were completed and it was found difficult to predict how the quarter would land. To release the quarter, a team member would pinch the quarter with his index finger and thumb. Friction would often cause one side of the quarter to stick and result in the quarter tumbling into the water. A method was devised that provided much more consistent results. The team ember roping eh quarter would use the index finger from his left hand and the thumb from his right hand. Pulling the hands away from each other would impart a spin on the quarter. The momentum of the quarter creates a gyroscope effect, making the quarters fall much more stable. The quarter can be seen spinning during its fall in the video. After a few trial runs, the quarter would land in the center for the glass near-perfectly flat.

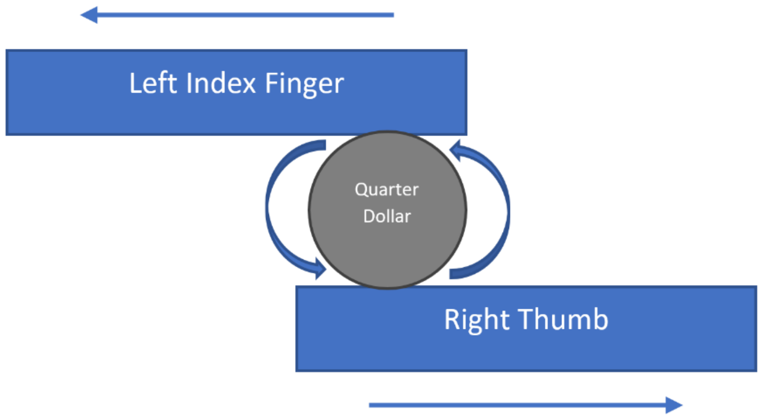

Figure 3: Motion to create a flat falling quarter

Photographic Technique

The camera used was a Phantom Miro C110 high speed camera. The Phantom is capable of 52,445 frames per second (fps) (Darwin Microfluidsics, 2022). A resolution of 1280x1024 is possible at a slower frame rate of 915fps. This video was filmed at 1,200 frames per second and is played back 40 times slower, at 30fps. The resolution for this frame rate is 1024x768. The metadata of the photo file did not include any information on the aperture, exposure, focal length, or ISO.

Editing this video was done with Microsoft ClipChamp. The video was cropped and resized to a square of 1080x1080. The introduction and exit slides were added to give acknowledgements. Royalty free sound effects were added from the website pixabay.com. This included a 'plop' noise when the quarter impacts the water. A 'swoosh' was added that crescendos when the Worthington jet is rising and decrescendos when it collapses back. This was done to add intensity and a little bit of comedy to the video. The video of was uploaded for viewing on YouTube at https://www.youtube.com/watch?v=LJqbieTvGcY.

Conclusion

This video successfully accomplished the objective, filming a Worthington Jet in slow motion. The ability to make a quarter land flat was a small accomplishment along the way gave the team a tool to successfully show the fluid phenomenon. Experimentation with the high-speed camera was an enjoyable process. The resulting video being a great flow visualization allowed for a successful and enjoyable experiment.

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