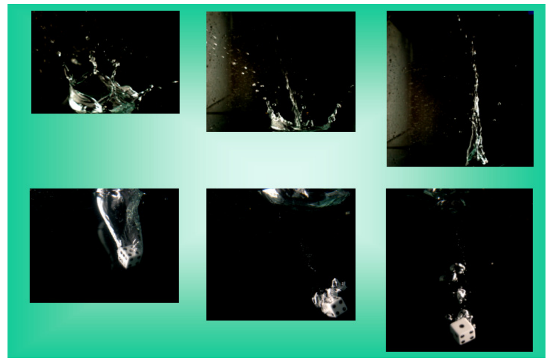
Worthington Jet Experiment

Team ETA

Purpose

An interesting effect known as the Worthington Jet is observed when an object or material travels through the surface of a Newtonian fluid. The purpose of our experiment was to observe the difference in the effect while varying the traveling object and the time lapse of each observation. The six images on the right were chosen because of their brilliant contrast and clear depiction of three distinct stages of the Worthington Jet formation.



Description of Apparatus

A fish tank was used to house the water. Two cameras were positioned above and below the water's surface and focused at a fixed point. A White Lightning X800 Strobe was positioned on the side of the tank (left of the cameras), and set for a 1/3300s flash. The object tested was dropped through a target hole into the take. The drop path was targeted at the fixed focus length of the two cameras. The flash was operated manually at, before, or after point of impact. The experiment was tested at room temperature.

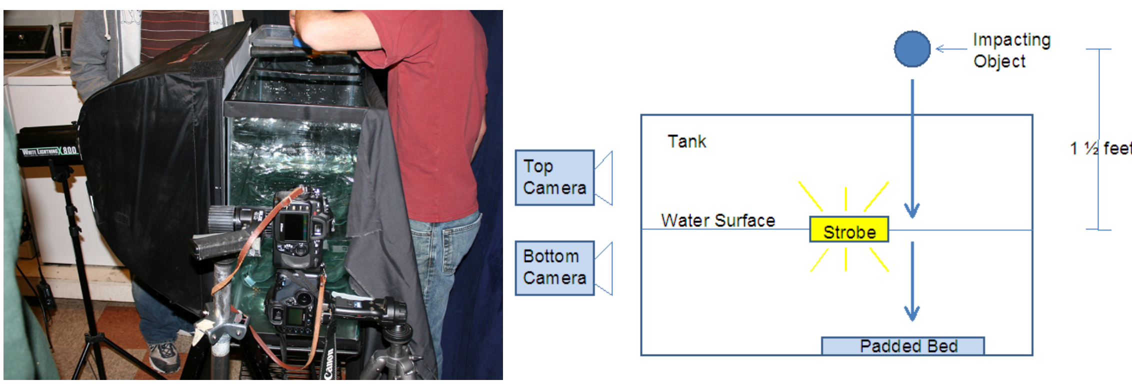


Figure: Left is a picture of the apparatus; right is a schematic of the apparatus.

Description of Flow

Each image is above our below its instantaneous pair. From left to right, there are three separate impacts captured at increased time intervals. The Worthington jet formation begins with a crowning creator as the dice pulls down on the water's surface. Here a turbulent interface is observed between the bending surface of the water and the die. In the middle images, the dice breaks away and the fluid rebounds into the creator to form the Worthington jet. In the third pair, the dice sinks as the Worthington jet leaps to its peak height of about 11cm. These splashes are classified as rough, due to their deep impressions, large air cavities, and large disturbance to the free surface of the water [1]. The texture and shape of the surface of the die likely causes the roughness of the splash. Interestingly, streamlines and surface tension effects can be observed at the dice edges as it passes through the water. Calculation of Reynolds number at impact suggests turbulent flow (Re=Velocity*estimated Diameter)/(Kinematic Viscosity)~=3*10^7. However, shortly after impact the images reveal both laminar and turbulent characteristics. This suggests that the Reynolds number either approaches its critical value or is inconsistent after impact.

Visualization Technique and Lighting

Two cameras were required to focus the same distance through two different mediums, air & water. One camera was position above the water and one below. We used a long shutter speed with a strobe to capture an instantaneous image with both cameras. With these tools we were able to take images with both cameras at exactly the same time with a time lapse equal to the speed of the strobe. The Strobe fired at 1/3300s. The entire room was darkened and the sides of the fish tank were surrounded with black sheets to ensure the strobe as the only light source.

Photographic Information

Field of view:	. 1 m
Depth of field:	20m
Distance from object to lens:	1/3m

<u>Top Camera</u>

Lens focal length:	35mm
Camera:	Nikon D20 8.0 Mega Pixels
Shutter Speed:	4 sec.
Aperture Value:	F8
ISO Speed:	100
White balance:	Auto
Image Processing:	Enhanced contrast

<u>Bottom Camera</u>

Lens focal length:	50mm
Camera:	Canon EOS 10D 6.0 Mega Pixels
Shutter Speed:	4 sec.
Aperture Value:	F8
ISO Speed:	100
White balance:	Auto
Image Processing:	Enhanced contrast

Conclusion

Many images of Worthington jets have been published; however, most of these images are taken using spherical objects. The use of dice in these images displays a slightly different, more interesting, creator shape at impact. Also, the three different images effectively depict the physical process of forming a Worthington jets. In the future, it would be interesting to observe the difference in creator shape from above while varying the shape of impacting object. It would also be useful to observe this phenomenon with a high-speed camera. More physics could have been revealed with images and measurements if distinct time interval were known. Anesthetically, this image is very effective with its high contrast and busy but still motion.

References

[1] J. M. Cheny, K. Walters, Rheological influences on the splashing experiment, Non-Newtonian Fluid Mechanics 86 (1998), 185-210.

[2] Jushua Lampe, Robert DiLalla, Jason Grimaldi, Jonathan P. Rothstein, Impact Dynamics of drops on thin films of viscoelastic wormlike micelle solutions, Non-Newtonian Fluid Mechanics 125 (2005), 11-23.