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Team 2nd Report, Falling Water

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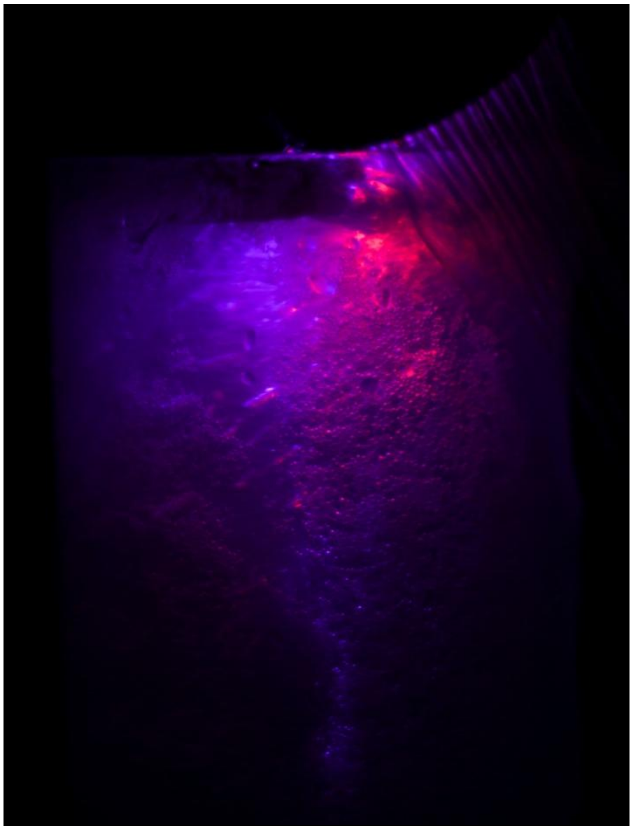
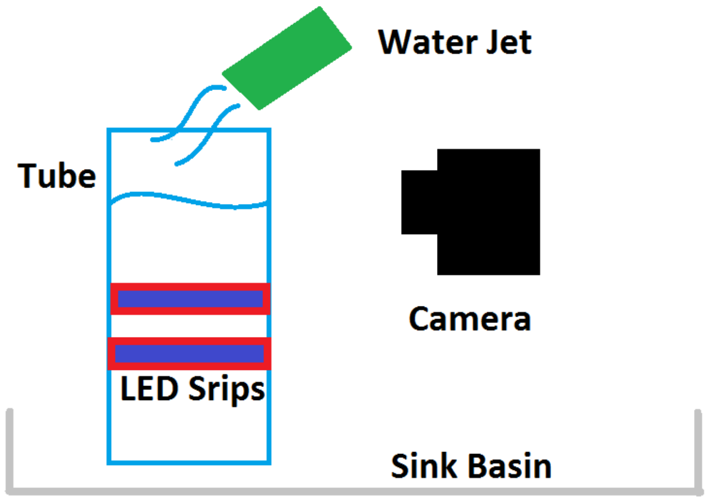


This image titled 'Falling Water' is meant to give a better understanding of a fluid vortex while offering stunning visual effects and lighting. Note that for our second project each member of team epsilon used the same setup in different ways to produce uniquely stunning images. First we intended to look into a solid stream of water, but I found the faucet pouring into the setup to give its own powerful character and beauty. Overall I used all of the lighting and equipment from the first setup to make this colorful and dynamic image.

The image was taken through a 3 inch inner diameter clear acrylic tube, which captures the water. To create the lighting effect, a strip of waterproof LEDs were wrapped around the tube to shine light directly into the water. To generate a fluid stream with this much force and specific fluid profile, an industrial spray nozzle was acquired. Lastly, to make the vortex instead of a general pool of water, the water jet was pointed about at 45 degrees relative the tube, to create a swirling flow. This setup is shown in the figure below. [1]



Probably the most interesting aspect about the image is the turbulent vortex in the center. As shown, the rushing water made a strong vortex, and the bubbles from the turbulence nicely added to the effect. Overall this gave a stunning visual of the physics involved. To quantize these vortices, a force balance can be applied to the system. [2] In this equation, we are measuring how the gravitational and rotational forces balance to make the vortex have the measured angle of ϴ. [3] Further we are able to find the velocity of the fluid.

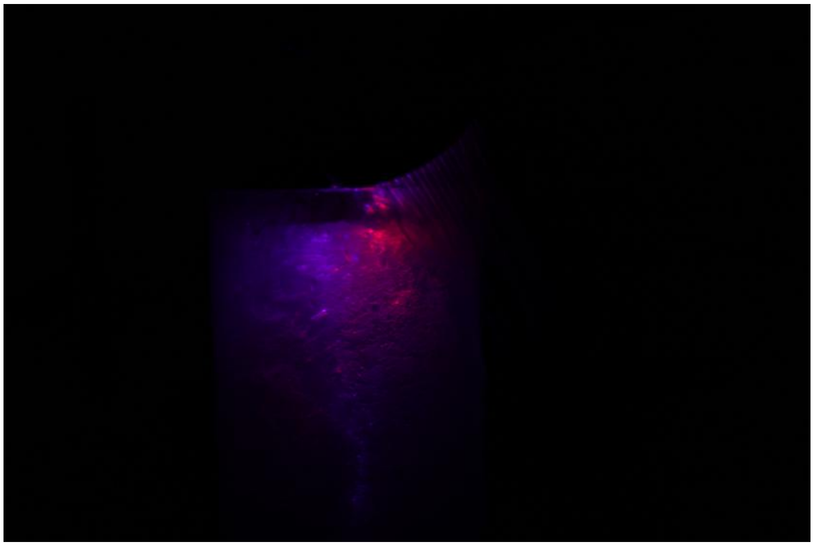
$$F_{out} = \frac{m{V_t}^2}{r} \qquad F_{down} = mg \qquad F_{down} = F_{out} * \tan\theta$$

$$m = NA \qquad r = .04m \qquad g = 9.8\,{}^{m}/_{s^2} \qquad \theta = 30°$$

$$V_t = \sqrt{\frac{g\,r}{\tan\theta}} = .82\,{}^{m}/_{s}$$

The visualization techniques are fairly straight forward. The LED strips shined directly into the liquid, and made the turbulent regions light up due to the refractive properties. Note that there were many air bubbles in the turbulent region which led to better illumination, and an overall more interesting image. Further, there were no external light sources of filtering effects in the setup.

The original image is shown below. This image was taken with a Canon 6D DSLR camera with a fixed 50mm Canon brand lens. The original picture was a JPEG taken at 5472x3648 pixels; note that a JPEG image is not ideal however it is the quickest file format for the camera when taking multiple shots. The picture was taken at F/1.8 to let in as much light as the dim room allowed, and 1/60 sec to capture the quick fluid motion. Also note that the picture was taken at ISO 100 to reduce noise as much as possible. It can also be noted that the image subject was roughly .5m away from the camera, and the field of view is roughly .2m.



Although the picture has moderate color, some post processing should be done to bring out the finer details. First, the overall brightness was increased to show more light. Next the tone curve was reshaped to make the dimmer colors brighter and the brighter colors darker, giving much better contrast. Lastly, the red and blue spectrums were taken up to make the colors pop more. Note that all post processing was done in Adobe Lightroom.

This image reveals much about the fluid flow and their photographic techniques. First, it explores the high turbulence of fluid vortices, and demonstrates how a fluid creates a conical vortex given the right conditions. Next, it shows the refractive properties of the fluid and how they converge and diverge when bubbles are introduced in high turbulence. Laslty, it shows some interesting camera techniques and how the lighting can be changed to make an image more vibrant. Overall, the intent of the image really comes through and gives a great final product.

References

1 - Cwudziński, Adam (2018). "Physical and mathematical modeling of bubbles plume behaviour in one strand tundish". Metallurgical research & technology (2271-3646), 115 (1), p. 101.

2 - O. Rybdylova, S. S. Sazhin, A. N. Osiptov, F. B. Kaplanski, S. Begg, M. Heikal, Modelling of a two-phase vortex-ring flow using an analytical solution for the carrier phase, Applied Mathematics and Computation, 326, (2018), 159-169

3 - N. Srinil, B. Ma, L, Zhang, Experimental investigation on in-plane/out-of-plane vortex-induced vibrations of curved cylinder in parallel and perpendicular flows, Journal of Sound and Vibration Volume 421, 12 May 2018, Pages 275-299