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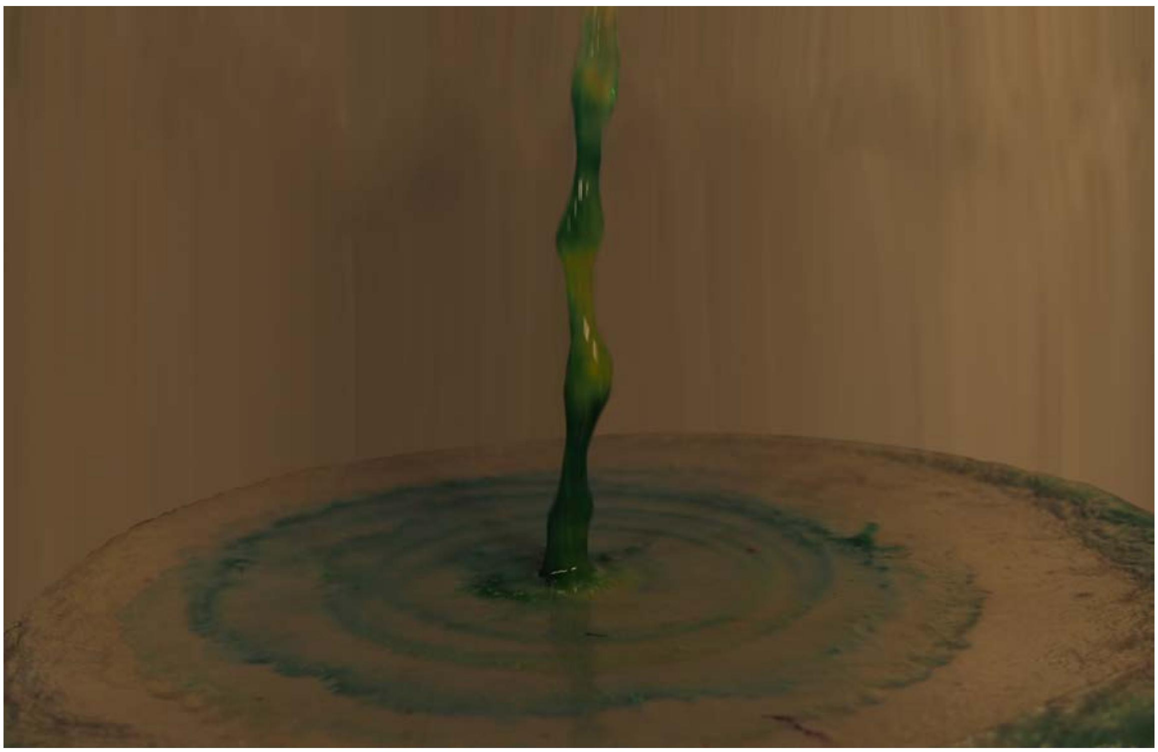
Flow Visualization
Spring 2014



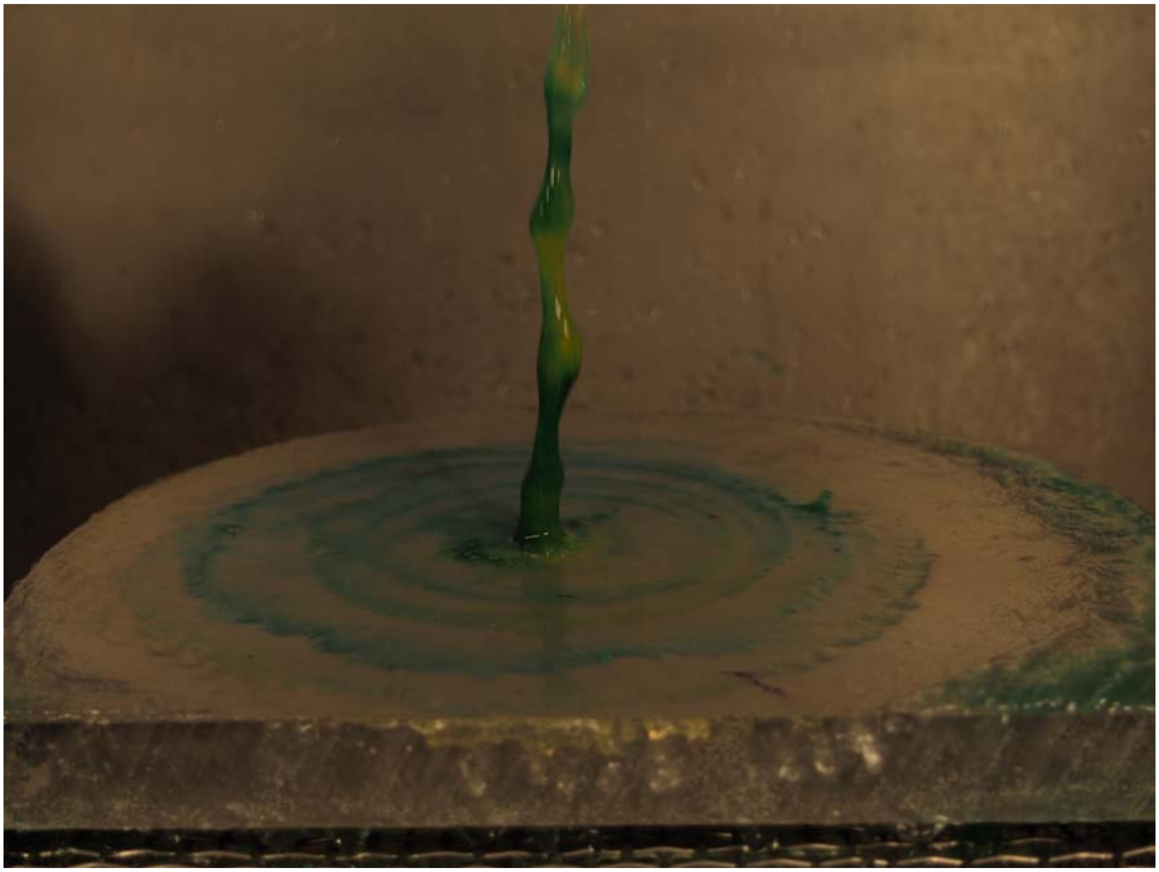
The image shown above was taken for the first flow visualization team project at the University of Colorado at Boulder. It illustrates the motion of India ink falling through water and impacting a metal plate set horizontally on the ground. The primary properties exhibited in this image include hydraulic jumps, cohesion, and surface tension.

In order to create this image a semi circular metal sheet was machined by Kenny Wine that had the approximate dimensions of 1.5"x8.0"x7.0" and was composed of aluminum. The plate was created in the Chemistry machine shop at the University of Colorado at Boulder. The edges were left unfiled in order to create small discrepancies in the metal that could potentially affect the flow. Water was then streamed onto the plate from a faucet while India ink was simultaneously dripped into the water. The colors used were blue and yellow, and as they fell, the two colors mixed causing the green color to appear. The irregularities in the water flow are due to the ink droppers creating a certain amount of chaos in the fluid.

The fluid took 30 seconds to fill a 2-liter bottle, so the velocity of the fluid coming out of the faucet can be calculated using the equations: Flow = Area x Speed, Flow(Faucet) = Flow(Basin), Speed = Volume(Basin)/(Time * Area)[1]. Therefore, Speed = .002/(30 * .00051) → .13 m/s. The plate was at a distance of 18 inches below the faucet and thus the fluid velocity at the plate can be calculated using $x = x_0 + ½(v_1+v_0)\Delta t^2$ where Δt is estimated as 0.2 seconds. The final velocity is found to be 2.16 m/s. This velocity would be large enough to create miniature hydraulic jumps on the metal plate, as can be seen in the image. A hydraulic jump occurs when liquid at a high velocity releases into a zone with a much lower velocity[3]. The quick moving fluid is slowed upon impact with the slow zone, and it causes the liquid to bunch up and increase in height, which accounts for the undulating motion seen in the image. The cohesion element of the picture is due to the polarity of water and it's slightly negative and positive molecular charges that hold multiple molecules together via Van der Waals forces. This also explains the elements of surface tension that are seen in the image.

The original image spanned an approximate eight-inch wide by five-inch high area before being cropped to eight inches by four inches. Many of the default camera capabilities were used as they provided the best focus for the image. The camera, an Olympus Pen E-PL5, was located approximately 18 inches from the water stream. A focal length of 27 mm was utilized in order to best focus on the subject of interest. Alongside the focal length, an F-number of 4.6, an exposure time of 1/1000, and an ISO of 200 were selected to illustrate the best clarity of the situation. With regards to final production value, several modifications were made to the photo in order to keep the viewers eyes on the area of interest and prevent them from straying somewhere else. Obviously, a bit of cropping was done on the image, but the biggest edit was changing the background completely to get rid of shadows and droplet splatter. The original, unedited picture can be seen below with a resolution of 4608x3456.

For future attempts at recreating the image, an identical setup could be crafted without much difficulty. However, in order to achieve a more visually pleasing picture, it would be nice to place the background far enough away from the falling stream that splattered drops would be unable to ruin the background. This would require a much larger sink or basin than the one used for the current image. It would also be nice to have more lighting as the shots were taken with such a quick shutter speed. The lighting in this picture involved three large floodlights, but it would be vastly improved with twice as many.



References:

1) “Engineering Fundamentals, An Introduction to Engineering, SI Edition.” *Google Books.* 17 March 2014
http://books.google.com/books?id=YTcJAAAAQBAJ&pg=PA227&lpg=PA227&dq=average+velocity+of+water+coming+out+of+a+faucet&source=bl&ots=vA7Ok_NOLu&sig=TnJ0xuCeFx2E62dHnDKnYJJt2ak&hl=en&sa=X&ei=h3YnU7uGPMWfqwGdr4GYAg&ved=0CDIQ6AEwAQ#v=onepage&q=average%20velocity%20of%20water%20coming%20out%20of%20a%20faucet&f=false

2) “Equations of Motion.” *The Physics Hypertextbook.* 17 March 2014
http://physics.info/motion-equations/

3) “Hydraulic Jump.” *Wikipedia the free Encyclopedia.* 17 March 2014
http://en.wikipedia.org/wiki/Hydraulic_jump