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MCEN 4228 – Flow Visualization
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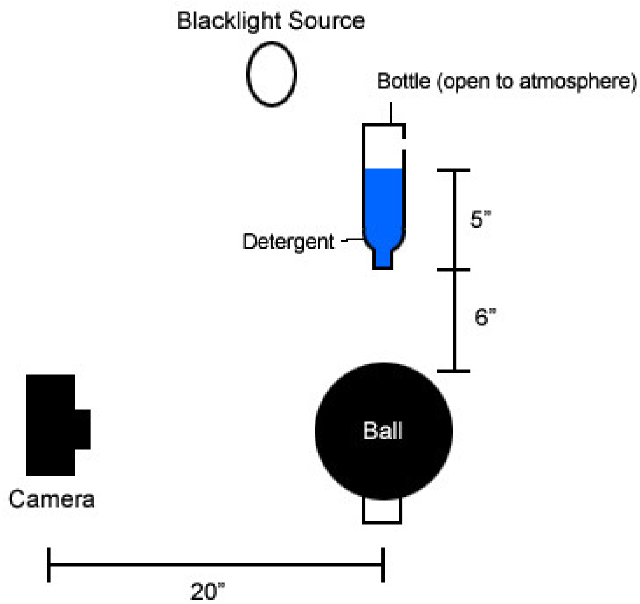
Get Wet

This "Get Wet" flow visualization demonstrates laminar flow of a viscous fluid over a bluff body, in this case a miniature basketball. It also illustrates the effect of a blacklight on a fluorescent fluid—laundry detergent. The color of the image has not been edited. The detergent appears quite blue under the blacklight. Originally, tonic water was to be used because of the extreme florescence that quinine, one of tonic water's ingredients, possesses. However, the carbonation in the tonic water as well as the low viscosity made the flow difficult to capture in a photograph. Instead, laundry detergent was chosen because of its larger kinematic viscosity and fluorescent properties.

The setup for the image consists of a miniature basketball (diameter of 7 inches) placed on a shot glass (which served as a stand). Black trash bags lined the bottom and back of the ball to cover the white walls that surrounded the ball, as well as to aid in the cleanup procedure. A plastic bottle (diameter of 10.5 inches) was filled 5 inches high with detergent. The cap was placed on the bottle, and a small hole was cut in this cap (diameter of 1/8 inches). A hole was also cut in the bottom of the bottle so that the pressure at the top of the fluid was equal to the pressure at the exit of the bottle (atmospheric pressure). The bottle was inverted and placed 6 inches above the exact center of the ball. The blacklight was inserted into the light socket at the ceiling level, and the camera was placed 20 inches from the center of the ball and pointed directly perpendicular to that center.

The setup looked something like this:



In order to approximate the Reynold's number of the flow over the ball, I must first approximate the velocity of the detergent right before it hits the surface of the ball. To do this, I will use Bernoulli's equation. Because the top of the bottle was cut open, the pressure at the top of the fluid was atmospheric (760 torr). The velocity at the top of the fluid can be approximated as 0 ft/sec. Although the fluid here does have some velocity, it is small compared to the velocity of the detergent at the surface of the ball, so it can be neglected. The rest of the Bernoulli calculation is below:

$P_1 + (1/2)(\rho)(V_1)^2 + (\gamma)(z_1) = P_2 + (1/2)(\rho)(V_2)^2 + (\gamma)(z_2)$

$P_1 = P_2$, $V_1 = 0$, $z_1 = 11$ in $= .9167$ ft, $z_2 = 0$

$(\gamma)(z_1) = (1/2)(\rho)(V_2)^2$, $\quad \gamma = (\rho)(g)$

$(\rho)(g)(z_1) = (1/2)(\rho)(V_2)^2$

$V_2 = \mathrm{sqrt}[(2)(g)(z_1)] = \mathrm{sqrt}[(2)(32.2\ \mathrm{ft/s}^2)(.9167\ \mathrm{ft})] = 7.68$ ft/sec

To calculate the Reynold's number, one must have the kinematic viscosity of the fluid. I could not locate the value for detergent, so I will have to approximate it with the value for olive oil, which appears to have similar viscous properties. This value is approximately 40 CentiStokes (cSt) which is equal to 4.31X10^-4 ft^2/sec. The Reynold's number calculation based off of this kinematic viscosity is as follows:

Re = $(\rho)(V)(D)/(\mu)$ = (V)(D)/(kinematic viscosity) , D = 7 in = .583 ft, V = 7.68 ft/sec

Re = (7.68 ft/sec)(.583 ft)/(4.31X10^-4 ft^2/sec) = 1.04X10^4

Because this value is less than 5X10^5, the flow is laminar.

While laundry detergent is quite fluorescent, it is still difficult to capture on camera under a blacklight. After experimenting with several different types, a brand by the name of Xtra-Mountain Rain was chosen because it also had some sort of blue dye in it. This made the glow more profound than it normally would have been under blacklight. There were no other sources of light other than the one blacklight. The image was taken in the darkest room available, and any alternative forms of light leaking in would have been negligible. A flash was not used.

The field of view is approximately 11 inches wide and 16 inches tall. The camera was placed 20 inches from the center of the ball. The focal length of the lens was 7.9 mm. The camera used was a Sony DSC-W5, a digital camera. The original image width was 2592 pixels and the height was 1944 pixels. The ISO setting was 400, and the shutter speed was ¼ second. The aperture was set to 2.8 to allow significant light to enter the lens of the camera since this was a low-light image. Photoshop was used but not significantly. The image was rotated so that it was oriented like it was set up. The image’s levels were changed so that the image would become brighter. No other alterations were made.

The image reveals the effect that gravity has on a fluid, flow over a bluff body, and the fluorescent properties of laundry detergent. This photograph vividly portrays laminar flow of a viscous fluid over a ball and because the viscosity of the laundry detergent is so significant, the image captures the flow half way down the ball. It is interesting to see the specific paths that the fluid takes over the ball. When I imagined how this image would turn out, this is pretty similar to what I was thinking. I had hoped that the detergent would glow better, but I am content with the image that was produced. There is a slight reflection of the blacklight bulb filament on the surface of the fluid. It would have been a better idea to actually use fluorescent blacklights or perhaps reposition the lights so as to avoid this. Also, the camera used did not have the quality settings that I would have liked. The image came out slightly blurry, and it would have improved its aesthetic quality if I had used a better camera. It would be interesting to see what a flow with a significantly higher Reynold’s number would have looked like flowing over the ball. A turbulent flow over the ball would have produced interesting results, and this is something I may try to produce in the future.