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MCEN 5228-002
Assignment 1- Get Wet

This picture was taken for the first assignment (Get Wet) and was an individual project. The picture submitted was a picture of a smoke flowing around a golf ball (in all three dimensions) and the intent of the picture was to show the interaction of a laminar flow over a sphere. The idea was to try to achieve a potential flow over the golf ball, but that proved to be relatively challenging. When a potential flow was observed, the picture didn't turn out well enough to show the phenomenon that was being observed. About 80 pictures were taken in order to get the desired effects that I was trying to demonstrate. Most of the pictures varied by the position of the strobe; as the position changed, different characteristics of the fluid flow were observed.

The apparatus used to photograph this flow was composed of two skis separated by 3 feet, a piece of copper wire that was 4 feet long that was suspended by tying the copper wire to each of the ski bindings, a golf ball that rested on a loop in the copper wire, and an incense that produced the smoke 1 inch below the golf ball. An illustration of the setup is seen below in Figure 1.

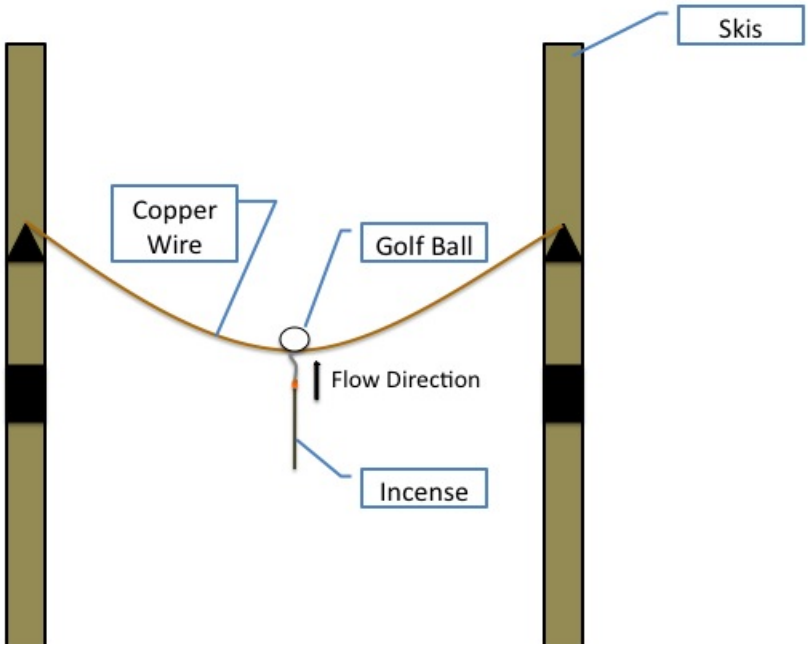

Figure 1: Apparatus setup

With this particular setup, the flow of smoke from the incense was a laminar stream approximately 0.2 inches thick. The diameter of the golf ball was 1.633", measured using calipers. This gives a surface area of 2.094 in^2 which is the area that the smoke "sees" and flows over. The incense was held by hand extremely close to the golf ball so that the flow was still laminar when it reached the golf ball. The approximate position of where the golf ball was located relative to the incense is shown below in

Figure 2. In Figure 3, it is shown how the flow impinging on the golf ball is laminar and remains laminar when interacting with the leading edge of the golf ball.

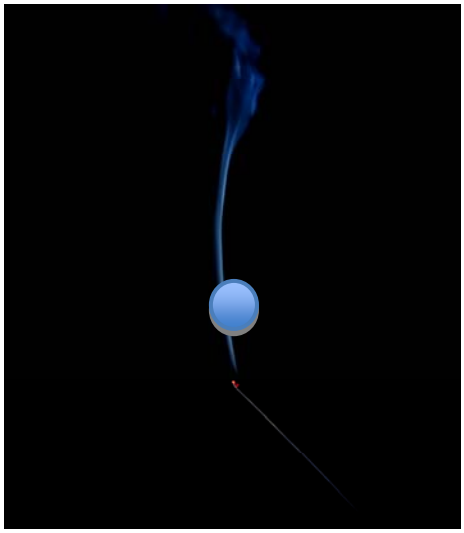

Figure 2: Laminar flow moving over golf ball

Figure 3: Position of golf ball in laminar stream

Using the equation $Re = Ud/(\eta_k/\rho)$[1] with U = 2 in/sec, d=1.633 in, η_k=0.0234 in^2/sec, and ρ=0.038 lb/in^3,[2] gives a Re of 5.3. This is a very low Reynolds number for a golf ball. The time required for this flow to develop was a very short time. Since the flow is constant and the sphere is not moving, the flow really doesn't change significantly over time and thus most of the pictures were similar.

The visualization technique used was scattering of light off of smoke. The room that the photograph taken in was completely dark, and the smoke and golf ball were illuminated by a strobe. As stated above, the smoke was from a burning incense (Moodstar Rain Drops incense) that had a diameter of 0.125". There was no significant movement of air in the room to help keep the flow laminar. The temperature in the room was 70 degrees Fahrenheit. The strobe (Nikon SB-900) was used as the sole light source for the image. It was positioned roughly 120 degrees off of the camera and was held in place by hand and remotely triggered by the camera when the shutter opened.

The size of the field of view for the image is 6.5 inches x 6.5 inches. The golf ball was roughly 2 feet from the camera when the picture was taken. The parameters for the image are as follows:

- Focal length: 55mm
- Aperture: f/4.8
- Exposure: 1/10 sec
- ISO: 500

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[1] H. Yamaguchi, *Engeineering Fluid Mechanics* (Dordrecht, The Netherlands: Springer, 2008

[2] Jetter, Guo, McBrian, Flynn, *Characterization of emissions from burning incense*, The Science of the Total Environment 295(2002) 51-67

The picture was taken with a Nikon D90 (DSLR) and the size of the original image was 4288x2848 pixels and the size of the cropped image is 3408x2848 pixels. Some slight manipulating was done to the photo to remove the copper wiring that was supporting the golf ball because it was distracting and had no influence on what I was trying to show in the picture. This was done in Photoshop CS4.

The photo shows something I found interesting which is that the flow remained laminar over the surface of the golf ball. I didn't expect for this to happen at all due to the dimples that cover the surface of the golf ball. I expected the dimples to disturb the flow and cause it to become turbulent. This shows that the smoke was viscous enough as well as traveled slow enough that it didn't become turbulent until the flow had separated from the sphere and continued downstream. Overall, I like what the image shows, it is simple yet informative. I wish I would have used a faster shutter but I was going for some blur in the smoke. I just wish it was a little less. The aspect I would have liked to improve would be use of another off camera flash. The strobe I used had to be placed to get the smoke on the upstream side of the ball to see that effect, but it couldn't get the smoke on the downstream side without illuminating the material I was using as a backdrop (graduation gown) which was kind of sparkly and extremely annoying for this setup.