Daniel Notary
4228 Flow Visualization

Team Assignment 1

Though this was a team assignment, our team wasn't able to find a time for us all to meet up, so our images were taken individually and were unrelated. I have always been interested in the general behavior of a laminar stream of water coming out of the tap, so my photo was based on the Coanda effect. This effect was named after Henri Coanda in 1930, and it is based on the tendency of moving fluid to follow a curved surface and flow along it ("Coanda Effect"), as will be discussed later in more detail.

The setup for this experiment was quite simple; it consisted of a red folder taped to the faucet as a backdrop while holding a table knife in the stream of water (see Fig. 1). Probably the most difficult part of the setup was getting a thin, even, laminar stream of water, which just took a little finesse with the tap. After that, it was all about getting the framing right and the knife in just the right place to get a good representation of the Coanda effect. If it was too far into the stream, the water would just run over the knife as usual, and if it was moved too far away from the stream, then the water would break away from the knife and flow normally. To get the best view, the macro function on the camera was used to get close in framing with the knife, which was about 1cm at the tip. This dimension was used to approximate the length of the water stream before it hit the knife, which was also about 1cm. To calculate the Reynolds number of this 1cm portion of the flow, we use the equation $Re = \rho VD/\mu$ (Cengel 324), where the density ρ is 1000 kg/m^3, the velocity V is estimated to be about 1 in/s or 0.0254 m/s, the characteristic length D is 1cm, and the viscosity μ is 1.002×10^{-3} Ns/m^2 ("Water…"). Plugging these numbers into the equation yields a Re of 253.5, which indicates a laminar flow (Cengel 324). Knowing the vertical axis of the picture to be about 3cm and 2276, we can also calculate the number of pixels the object moved. The exposure time was 1/40s and we know from earlier that the velocity of the flow was 2.54 cm/s downward, so multiplying those together gives us a travelled length of 0.0635cm, which is about 2% of 3cm or 48 pixels. This is a good spatial resolution because of the flash used, and would not be noticed very easily.

The main driving force behind the Coanda effect is the friction between the fluid and the nearby surface. The layers touching the surface experience friction ("skin friction") and start to slow down, so the attractive forces between the fluid molecules start to pull the rest of the stream towards the frictional layers ("Coanda Effect"). On a large scale, this starts to bend the whole stream in a noticeable way around the object. In this case, the water appeared to be following the edge of the knife instead of continuing downward as one would expect. This effect has played a large role in the field of aerodynamics and wing design, as Henri Coanda proved from his 20 year plus work with airplanes. The result of the effect on a plane's wing is that the air is deflected downward as it curves off the end of the wing, creating a lift force (Burkot). However, this effect is a somewhat young discovery, so the explanations haven't quite fully developed yet.

There was no seeding used for this technique, so the visualization had to be done purely by the shadows and light bending in the water stream. The red folder background (Fig. 1) helped a lot, and the flash picked up some good detail in the water. The shadow of the faucet head from the flash created a dark spot behind the stream which provided nice contrast. The rest of the light in the photo came from an overhead fluorescent light.

I wanted this photo to be a somewhat extreme close up of the effect, so the field of view was around 5cm with the knife blade only 3cm away. The focal length of the digital Sony Cyber Shot H20's lens was 6.3mm with an F stop of 3.5. As stated before, a flash was used and the shutter was open for 1/40s. After cropping some dead space out of the original photo, the resolution came out to be 2821 x 2276 pixels. The only modifications were a bit of cropping, sharpening and color/contrast enhancement in photoshop.

Overall, I really like the image. It is clear, crisp, and I believe it shows the effect very well. I was also very pleased with the extent of focus sharpening photoshop could achieve, and the bright and deep colors added a lot to the final product. As well as the physics were shown in the picture, however, I would like to know about them in more depth than I was able to find. Another unrelated item is the "wrinkling" or "beading" of the water stream right above where it touches the knife, which I would also like to know more about. The one main fault I find with the picture is the table knife; it doesn't look very professional. I was kind of going for a surreal and disorienting effect, and the knife kind of snaps the viewer back to reality. Despite this drawback, it did provide a good sense of scale, which is why I was satisfied using this photo. The overall aesthetics were good and the physics were displayed clearly, but if I were to continue with this idea I would probably experiment with different objects and use a less confined source of water.

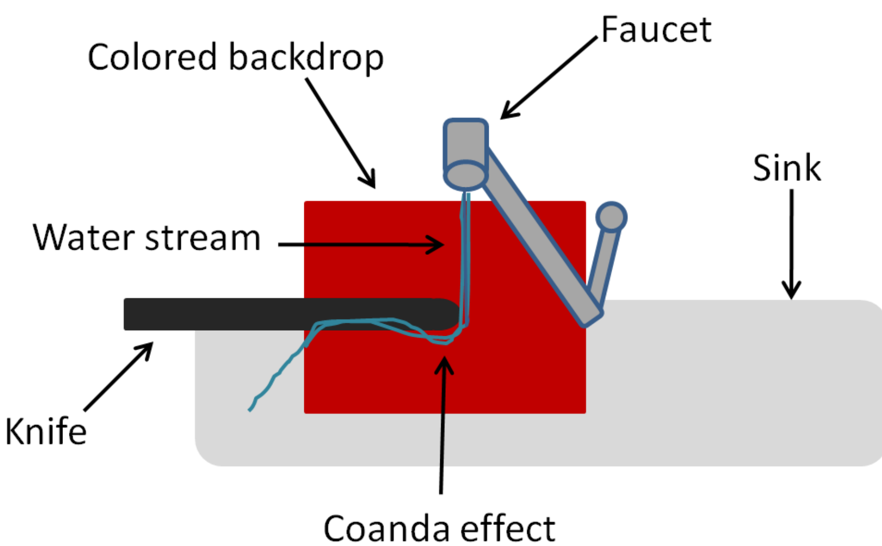

Figure 1: Experimental setup

References

Burkot, Rachel. “What is the Coanda Effect?” WiseGeek. 2003. < http://www.wisegeek.com/what-is-the-coanda-effect.htm>.

Cengel, Yunus A., and John M. Cimbala. Fluid Mechanics: Fundamentals and Applications. New York: McGraw-Hill, 2006.

“Coanda effect.” The Columbia Encyclopedia, Sixth Edition. 2008. *Encyclopedia.com.* 14 Mar. 2010 <http://www.encyclopedia.com>.

“Water – Dynamic and Kinematic Viscosity.” The Engineering Toolbox. 2005. *EngineeringToolbox.com.* 14 Mar 2010. <http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html>.