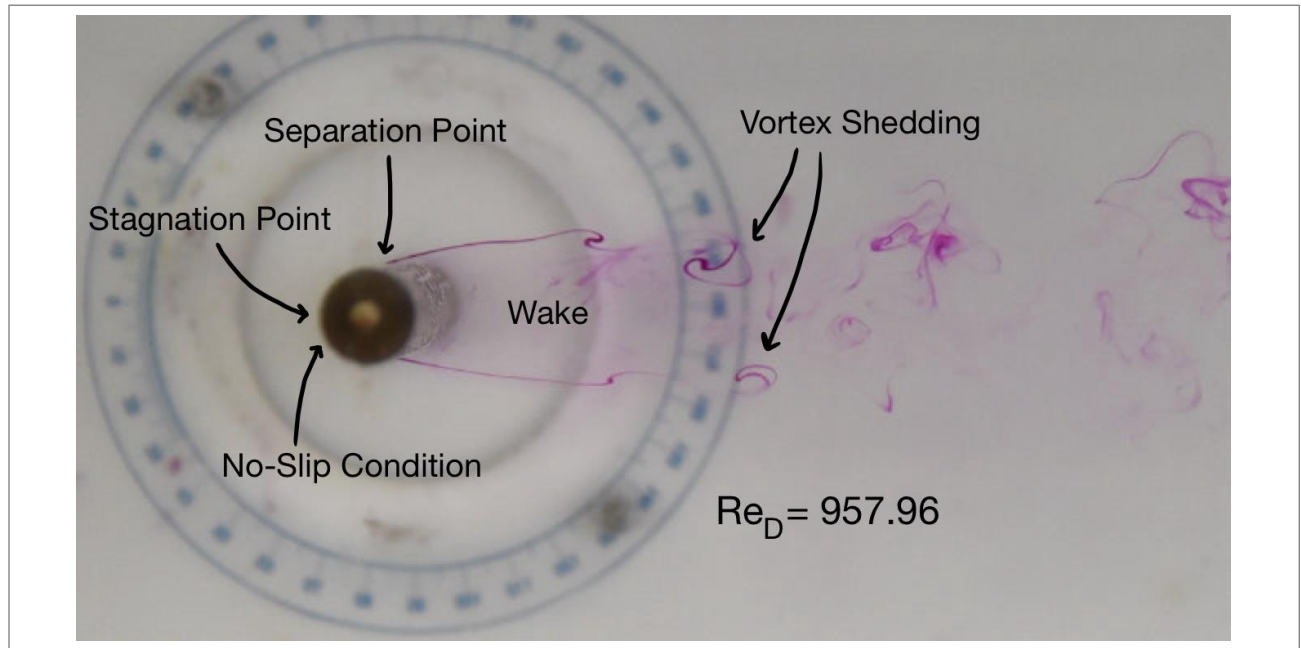
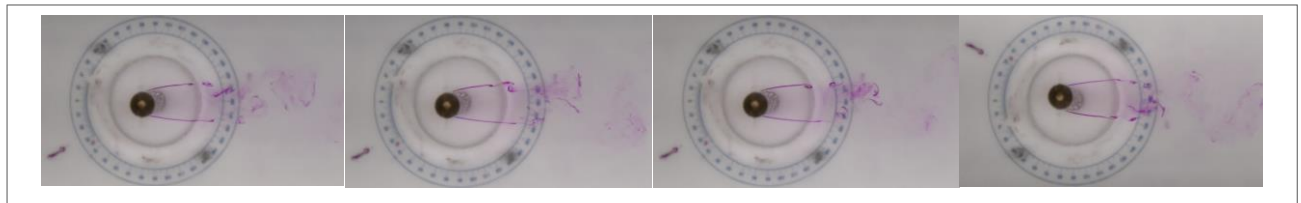


## Flow Visualization Lab

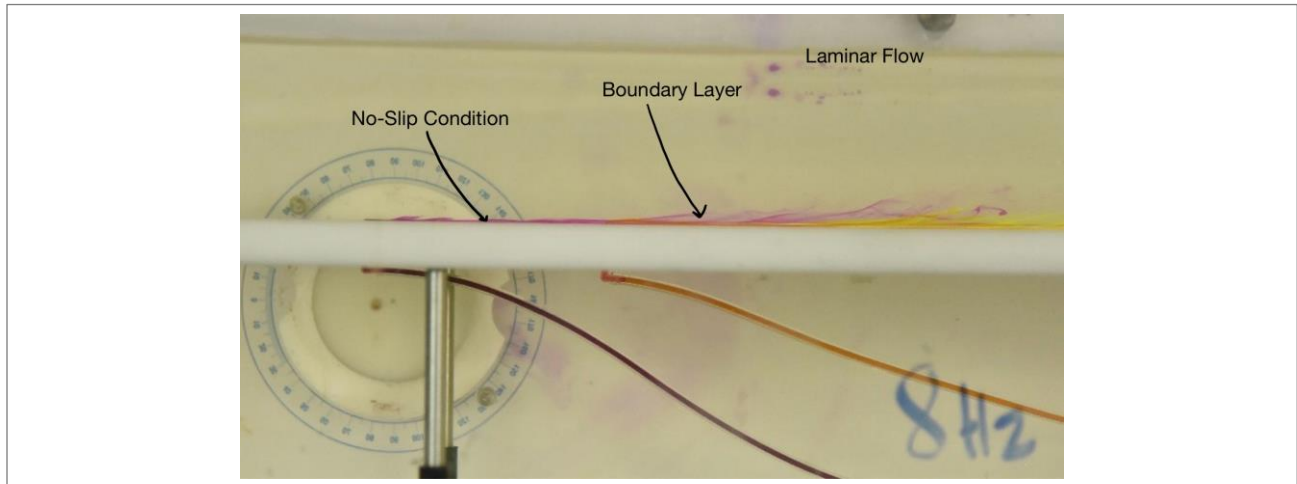
Brandon Lim  
9/11/2024



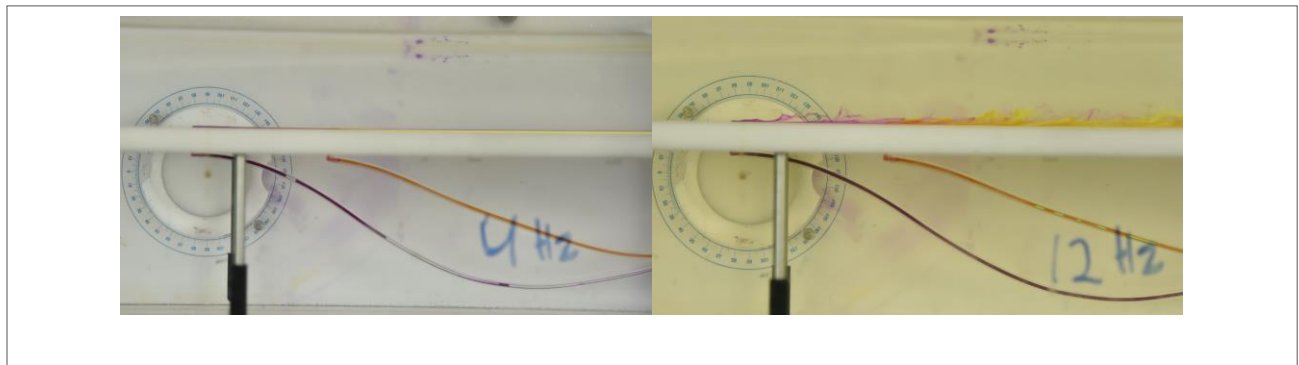
**Figure 1a.** Streaklines around a circular cylinder at a Reynolds number based on cylinder diameter of  $Re_D=957.96$ . The streaklines are marked by neutrally-buoyant dye injected from a small hole at the front of the cylinder. Flow is from left to right.



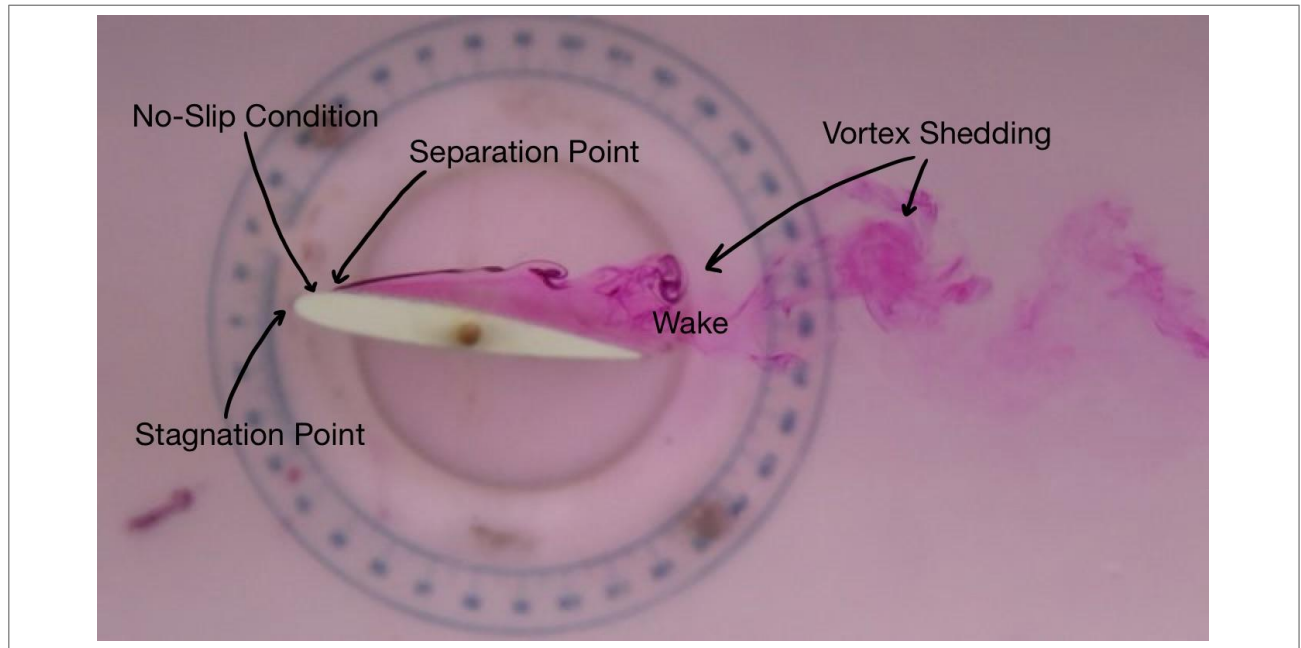
**Figure 1b.** Streaklines around a circular cylinder at a Reynolds number based on cylinder diameter of  $Re_D=1916.52$ . The streaklines are marked by neutrally-buoyant dye injected from a small hole at the front of the cylinder. Flow is from left to right. A sequence of four snapshots are shown with a time of 200 ms between each snapshot.



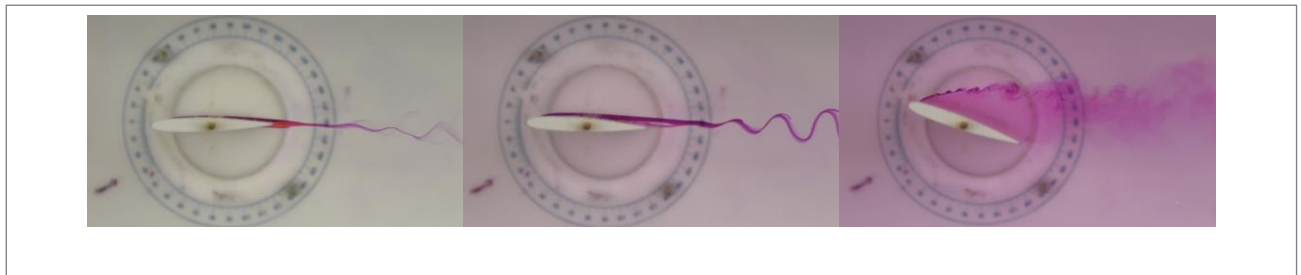
**Figure 1c.** Streaklines in the boundary layer developing along a flat plate. The streaklines are marked by neutrally-buoyant dye injected from a series of small holes along the plate. Flow is from left to right. The Reynolds number based on distance from the leading edge of the plate across the entire plate is  $Re_x = 62465.29$ . The transition Reynolds number is 500000 which corresponds to a length of 3 meters at the speed of this experiment. Therefore, this experiment never transitions to turbulent from laminar.



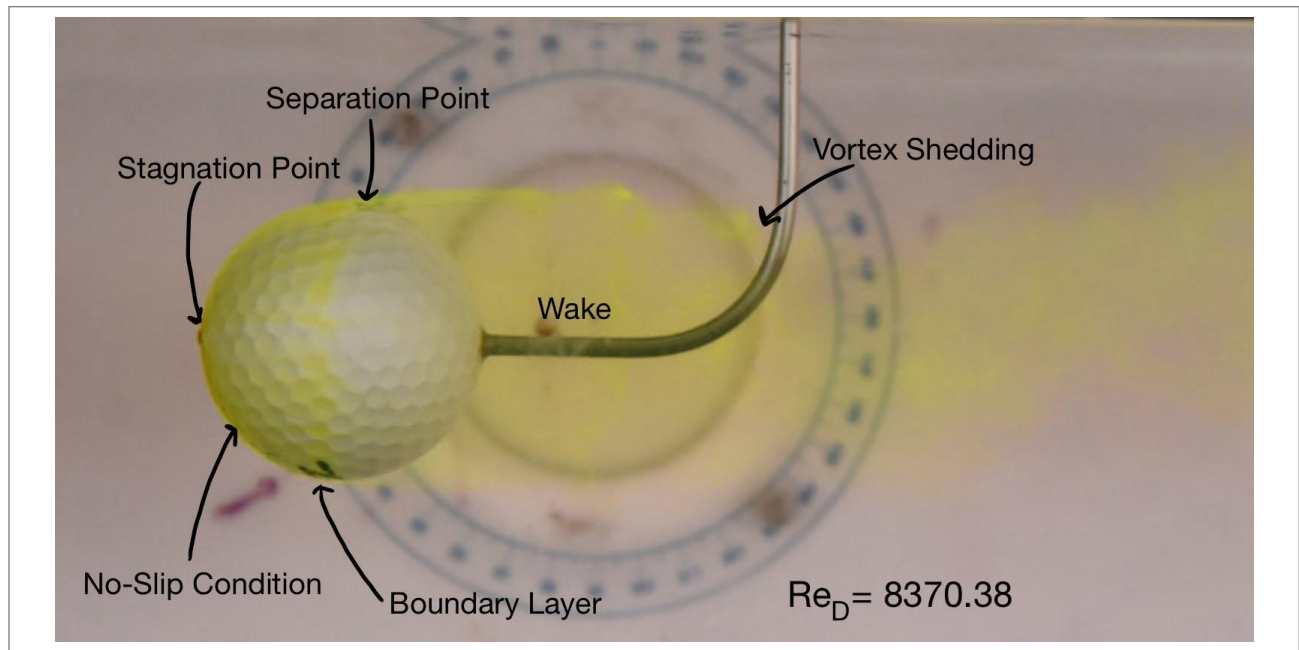
**Figure 1d.** Streaklines in the boundary layer developing along a flat plate: (left) laminar case, (right) turbulent case. The streaklines are marked by neutrally-buoyant dye injected from a series of small holes along the plate. Flow is from left to right.



**Figure 1e.** Streaklines around an airfoil at an angle of attack of  $8^\circ$  and Reynolds number based on chord length of  $Re_c = 9654.41$ . The streaklines are marked by neutrally-buoyant dye injected from a small holes along the surface of the airfoil. Flow is from left to right.



**Figure 1f.** Streaklines around an airfoil at a Reynolds number based on chord length of  $Re_c = 9654.41$ , and three different angles of attack: (left)  $0^\circ$ , (middle)  $4^\circ$ , (right)  $12^\circ$ . The streaklines are marked by neutrally-buoyant dye injected from a small holes along the surface of the airfoil. Flow is from left to right in each image.



**Figure 1g.** Streaklines in the flow over a Golf Ball. The streaklines are marked by neutrally-buoyant dye injected from the stagnation point in the front. Flow is from left to right. The Reynolds number based on the diameter is  $Re=8370.38$ .

## Short-Answer Questions

**2a.** Write one paragraph (using appropriate fluids terminology) that describes the differences in flow phenomena observed between the low and high Reynolds number cases for the cylinder.

The major difference between the low speed vs medium speed flow across the circular cylinder as seen by the photos taken in the lab was location of the separation point. In the low speed flow across the cylinder, it is apparent that separation occurs around 90 degrees, which is what we expect to see from a cylinder in laminar flow. Although the speed of the medium flow experiment was not yet high enough to generate fully developed turbulent flow, the separation point is moved back more due to the faster moving fluid across the cylinder. Another difference in flow phenomena between the two experiments is the amount of vortex shedding after and in the wake. There is less mixing and vortices formed in the low speed flow compared to the medium speed flow. This is expected from the difference in Reynolds number between the two flow speeds where the slower flow speed corresponds to a lower Reynolds number and more laminar phenomena or characteristics.

**2b.** Write one paragraph that discusses the limitations of the dye-injection technique you used in the lab. Suggest an alternative flow visualization technique that might provide better (or additional) information about the flow fields you examined. You will need to perform some research (using the internet or textbook) to answer this question. Include a citation for the reference used.

A limitation of the dye-injection technique used in the lab was the origin of the dye-injection. In each specimen tested in this lab, we observed that the dye was injected on the specimen itself. This is a limitation because we are introducing the dye into the experiment at a velocity that is different than that velocity of the water molecules traveling around it. This can cause inaccurate observations or lagging results of the flow visualization because the observed fluid dynamics originate differently than the steady state fluid dynamics before interaction with the test specimen. An alternative method to this could be the injection of the dye further upstream before its interaction with the test specimen. This way, the steady state fluid dynamics of the dye will be consistent to that of the water molecules around it which can make fluid visualization and results more accurate. By injecting the dye upstream on different height levels, the flow can also be visualized before its interaction with the test specimen to observe how the fluid dynamics are changing in space around the object as well, not just on the object.

Reference:

<https://cfdflowengineering.com/flow-visualization-techniques-in-experiment-and-cfd/>