# Flow Visualization Lab

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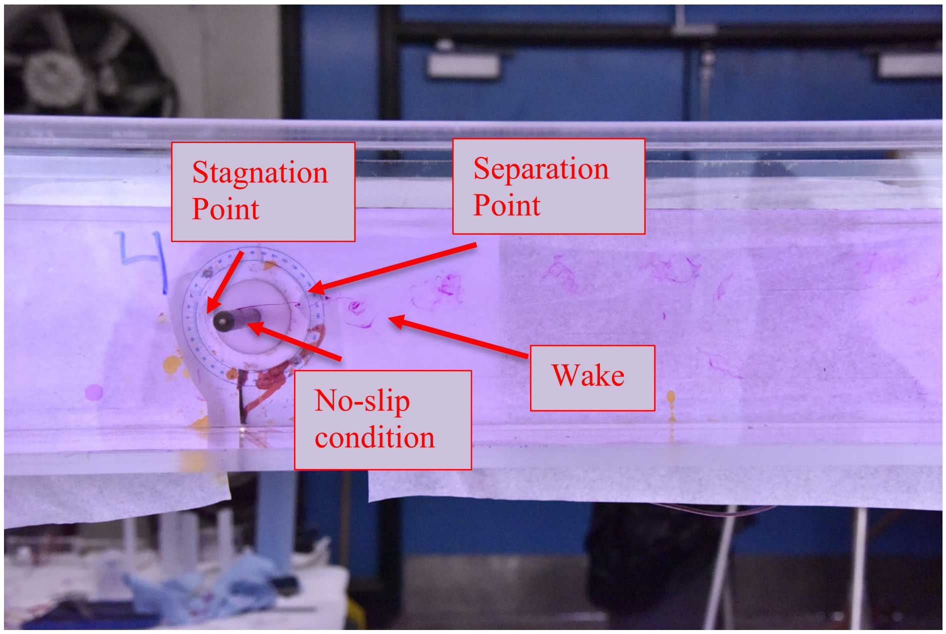


**Figure 1a.** Streaklines around a circular cylinder at a Reynolds number based on cylinder diameter of $Re_D$= 1037.79. The streaklines are marked by neutrally-buoyant dye injected from a small hole at the front of the cylinder. Flow is from left to right.

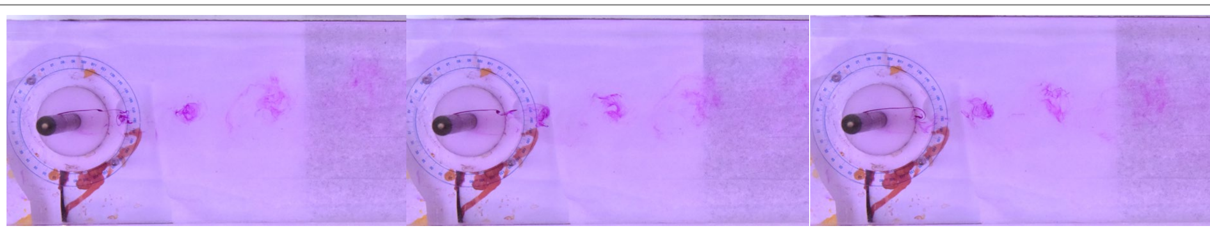

**Figure 1b.** Streaklines around a circular cylinder at a Reynolds number based on cylinder diameter of $Re_D$=2052.83. The streaklines are marked by neutrally-buoyant dye injected from a small hole at the front of the cylinder. Flow is from left to right. A sequence of three snapshots are shown with a time of 200 ms between each snapshot (5 frames per second).

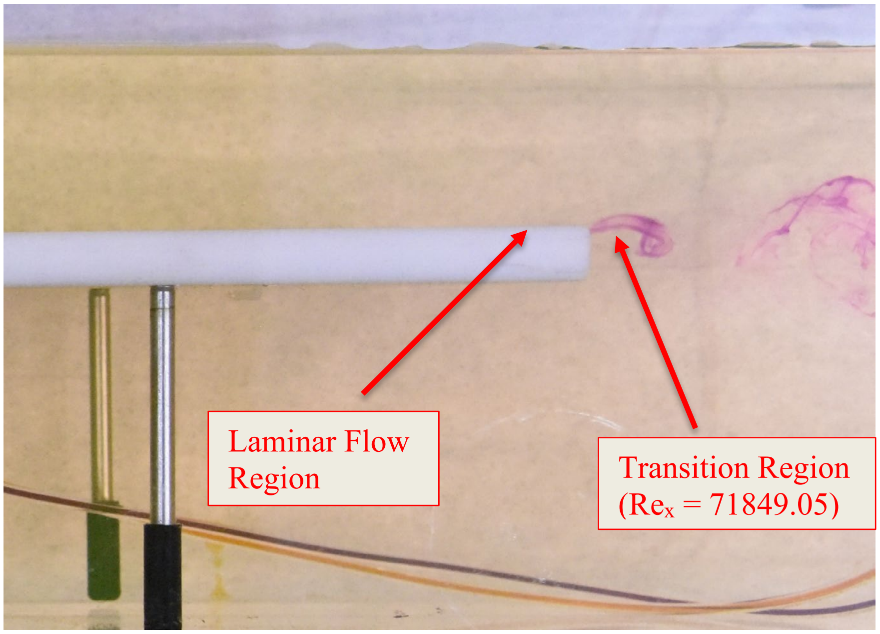


**Figure 1c.** Streaklines in the boundary layer developing along a flat plate. The streaklines are marked by neutrally-buoyant dye injected from a series of small holes along the plate. Flow is from left to right. The arrow indicates the approximate location of transition from laminar to turbulent flow. At this location, the Reynolds number based on distance from the leading edge of the plate is $Re_x = 71849.05$.

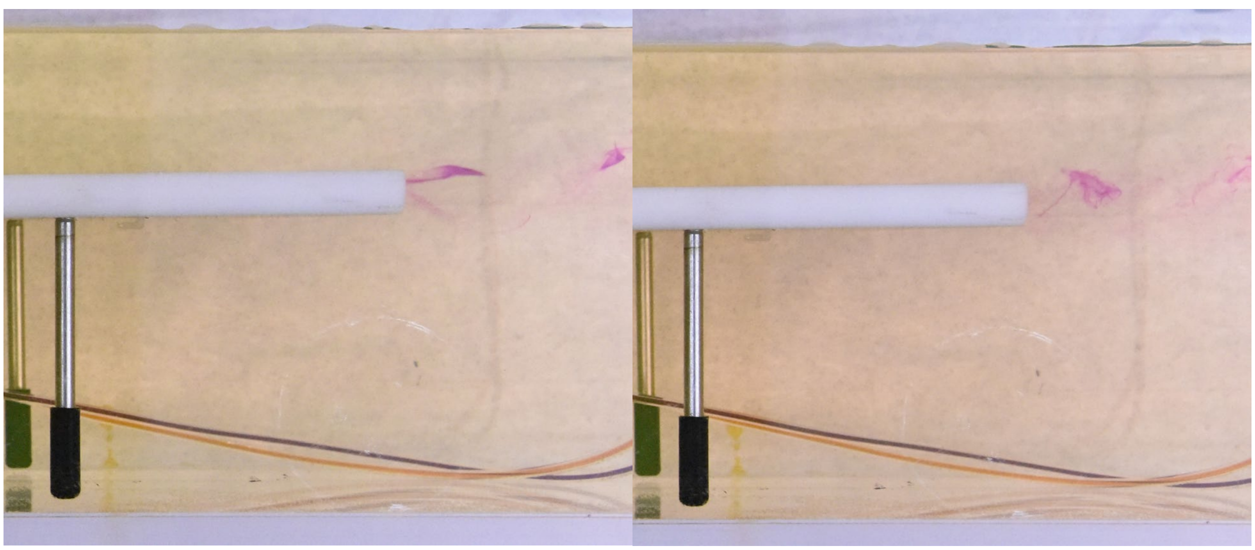

**Figure 1d.** Streaklines in the boundary layer developing along a flat plate: (left) laminar case, (right) turbulent case. The streaklines are marked by neutrally-buoyant dye injected from a series of small holes along the plate. Flow is from left to right.

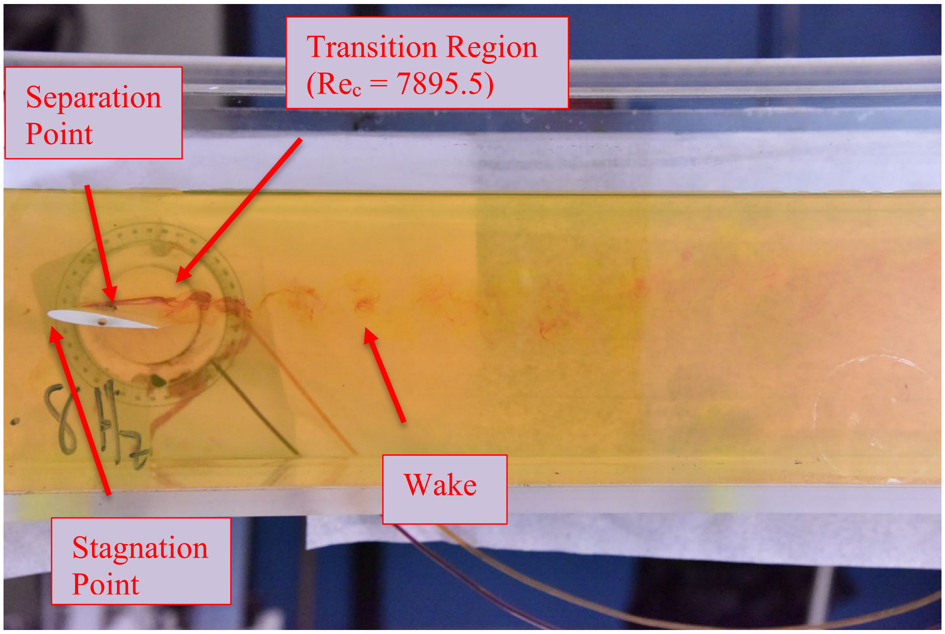


**Figure 1e.** Streaklines around an airfoil at an angle of attack of 8º and Reynolds number based on chord length of $Re_c$= 7895.5. The streaklines are marked by neutrally-buoyant dye injected from a small holes along the surface of the airfoil. Flow is from left to right.

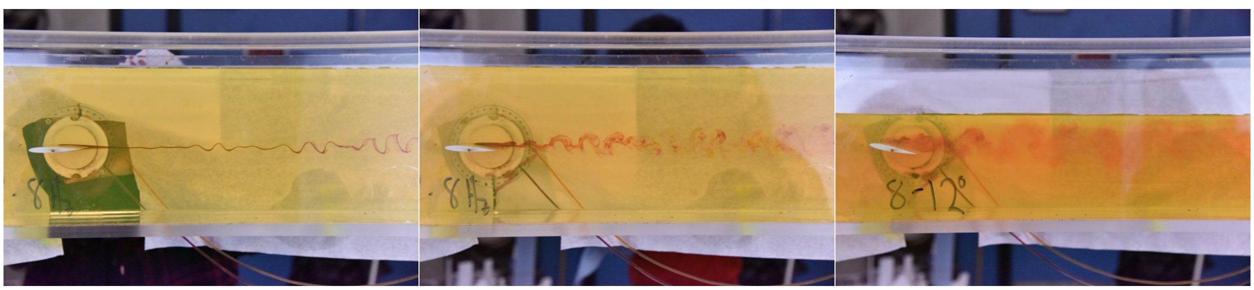

**Figure 1f.** Streaklines around an airfoil at a Reynolds number based on chord length of $Re_c$= 7895.5, and three different angles of attack: (left) 0º , (middle) 4º, (right) 12º. The streaklines are marked by neutrally-buoyant dye injected from a small holes along the surface of the airfoil. Flow is from left to right in each image.

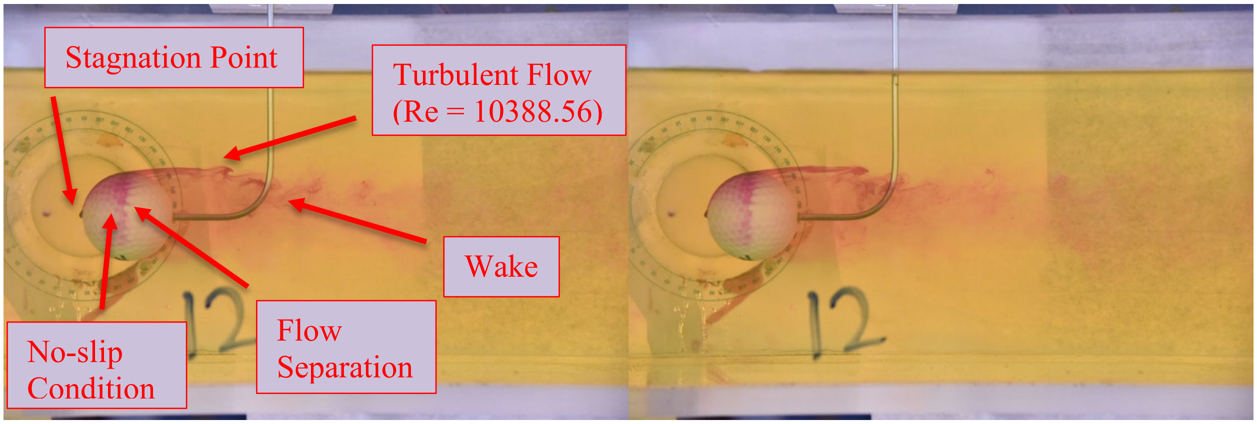


**Figure 1g.** Streaklines in the flow over a golfball. The streaklines are marked by neutrally-buoyant dye injected from the left most face of the golfball from a small hole. Flow is from left to right. The Reynolds number based on the golfballs diameter is $Re$= 10383.56.

## 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.*

At low Reynolds numbers, the flow around the cylinder is primarily laminar, with a smooth and steady streamlines pattern that closely follows the cylinder's contour. Separation occurs relatively early, but due to the low inertia of the flow, fewer and weaker vortices are shed, resulting in a more stable wake with minimal turbulence. The transition point, where the flow shifts from laminar to turbulent, is further downstream, allowing the boundary layer to remain attached for a longer distance. In contrast, at high Reynolds numbers, inertial forces dominate, leading to early boundary layer separation and the formation of an unsteady, chaotic wake characterized by strong vortex shedding.

**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.*

When it comes to the dye-injection technique that was used in lab, there are a few limitations. First, the dye has the possibility of diffusing over time, leading to less precise visualization of the flow structures. This drawback is very evident as the Reynolds number increases and the flow becomes turbulent. A second drawback, is that the density of the dye used must closely match that of the fluid used (in our case, water) in order to avoid buoyancy effects that can distort the flow patterns. Lastly, the injection process itself can disturb the flow field, especially if the injection velocity does not match the local flow velocity. From the internet, an alternative technique to flow visualization would be Particle Image Velocimetry (PIV). PIV involves seeding the fluid flow with a small tracer particle and using laser illumination to capture the motion of the tracer particle, which can be analyzed to obtain detailed velocity fields of your flow. This method would be an improvement as we would be able to accurately capture the velocity fields of our flow, and a tracer particle would not disturb the flow field as it would be small enough to be considered negligible. Additionally, using laser illumination would allow us to track and follow the tracer particle without a risk of losing it as it diffuses over time, unlike the dye-injection technique.

[1] MIT, "Dye Injection Technique," [Online]. Available: http://web.mit.edu/fluids-modules/www/exper_techniques/2.Dye_Injection.pdf. [Accessed: 05-Feb-2025].
[2] DTIC, "Techniques of Flow Visualization," [Online]. Available: https://apps.dtic.mil/sti/tr/pdf/ADA194291.pdf. [Accessed: 05-Feb-2025].