APL103 Experiment - 10
Flow Visualisation

1) **Aditya Agrawal (2021AM10198)**
2) **Swapnil Kashyap (2021AM10782)**

OBJECTIVE:

To use two simple flow visualization techniques to study streamline patterns around objects placed in a fluid stream.

PRACTICAL RELEVANCE:

In the study of complex flows, the first step is usually to visualize them in some manner. This way, one obtains a qualitative picture before rigorous quantitative analysis is begun. No design of hydrodynamic or aerodynamic machines is complete without a detailed qualitative analysis of the flow.

THEORETICAL BACKGROUND:

In the study of flow patterns, three different descriptions may be used:

1) Streamline: This is an imaginary line drawn through the flow field at any instant, such that everywhere in its tangent point is in the direction of the local velocity vector.
2) Pathline: As the name suggests, it's the path traced out by a fluid velocity vector.
3) Streakline: This is the locus, at any instance, of all particles that have passed through a fixed point in space in previous time.

It is easy to see that, for study flow, all three lines described above are identical. Mathematically, the streamline is the most useful; however, it is almost impossible to generate it directly by experiments. On the other hand, the streakline is the most difficult conceptually. Still, it is the easiest to generate in the laboratory – one simply introduces dye continuously at a fixed location and watches the streak develop after some time. In the experiment, the flow is maintained nearly steady so that the observed streak patterns are approximately the same as the expected streamline patterns.

EXPERIMENTAL SET-UP:

The rig consists of a water table which is made very flat and as horizontal as possible. There is an inlet tank and an outlet tank on either side of this water table. The flow of water is maintained with the pump. A schematic diagram of the setup is shown in Figure 1.

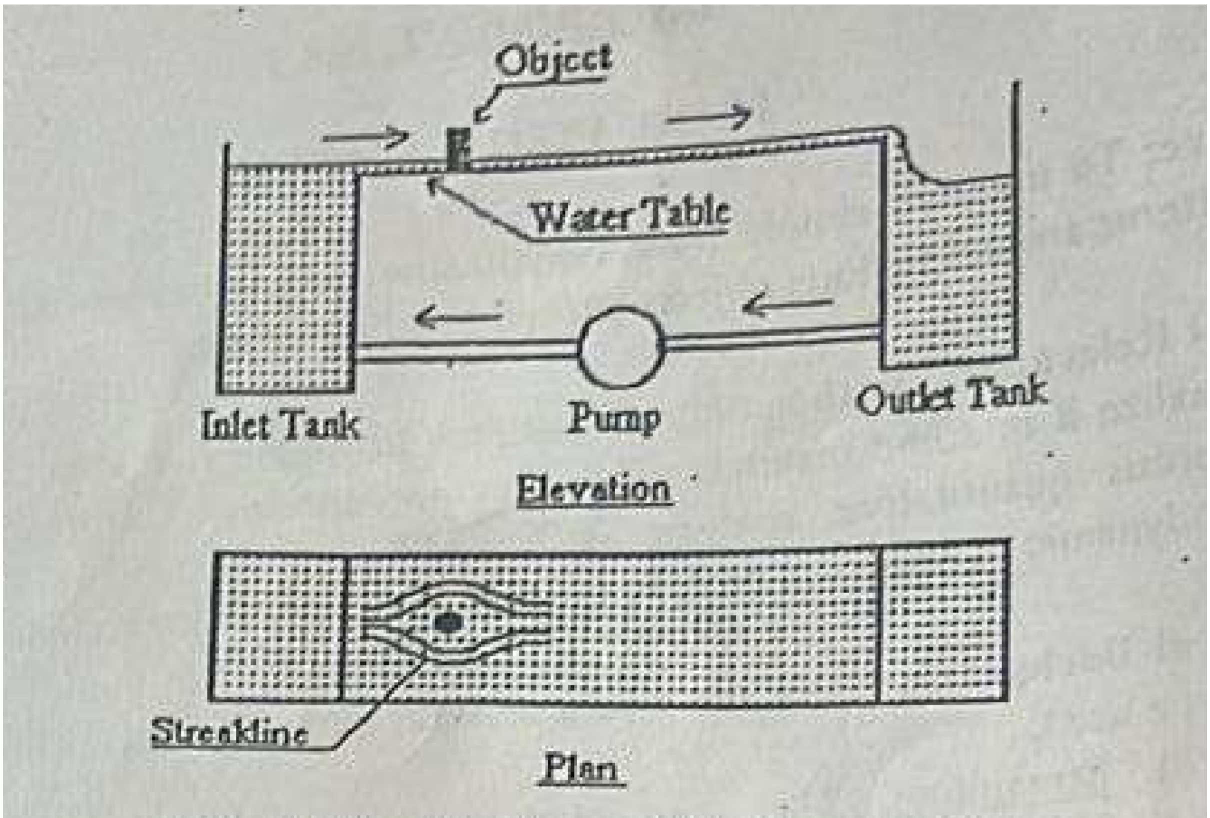


Figure 1: Schematic Diagram of the Experimental Set-up

PROCEDURE:

DYE INJECTION AND POWER SPRINKLING METHOD:

1) Place the cylinder on the water table and start the pump. Ensure that the flow on the table is continuous and without any dry patches.
2) Sprinkle some Potassium Permanganate ($KMnO_4$) crystals upstream of the cylinder and adjust the flow speed such that the observed pattern is nearly steady. (You need a fairly low speed to achieve this.)
3) By judiciously placing $KMnO_4$ crystals, observe the overall streakline pattern.
4) Sprinkle Lycopodium powder upstream and downstream of the cylinder and observe flow features like stagnation points, separation points, recirculation or dead zones, etc.
5) Make sketches of the flow patterns for inclusion in your report.
6) Measure the surface flow speed by measuring the time taken for a small patch of Lycopodium powder to travel a distance of 1m (in the absence of the cylinder).
7) Keeping the flow rate constant, repeat steps 3,4, and 5 for the other objects provided — the aerofoil (at various angles of attack), rectangular body (oriented both ways to the flow), oval cylinder (oriented both ways to the flow), T section, etc.
8) Observe the starting vortex for the aerofoil kept at a non-zero angle of attack of the flow.
9) Measure the projected length perpendicular to the flow of all the objects used in the steps above.

10) Place the cylinder in the flow again and increase the flow speed in small steps till the flow becomes fully turbulent. Describe the intermediate stages observed.

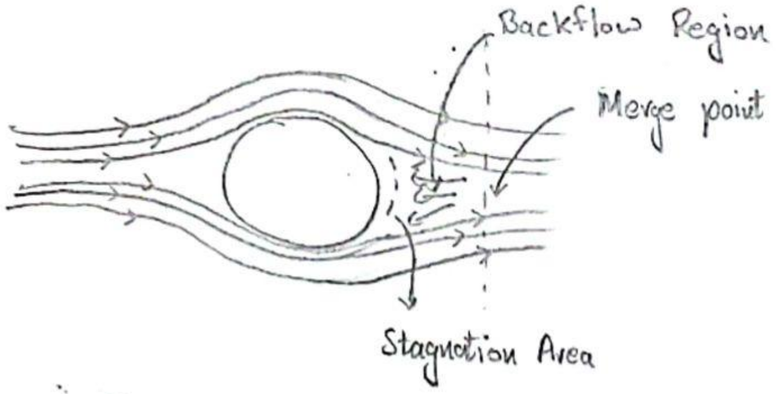
SMOKE METHOD

1) Observe the flow patterns around various objects placed inside the smoke-tunnel and make sketches of the same.

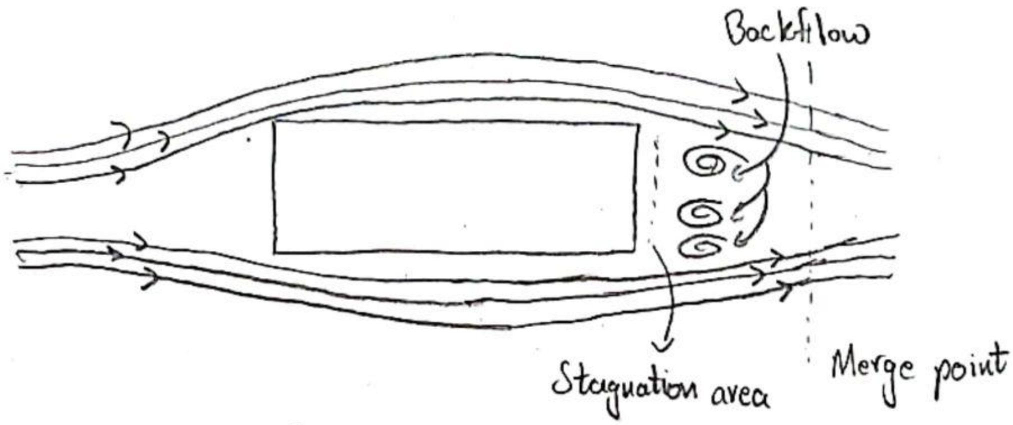
OBSERVATIONS:

a) Time taken for the Lycopodium Powder to travel 1m (Δt):
   1. 4.87s
   2. 4.67s
   3. 4.54s
   4. 4.27s

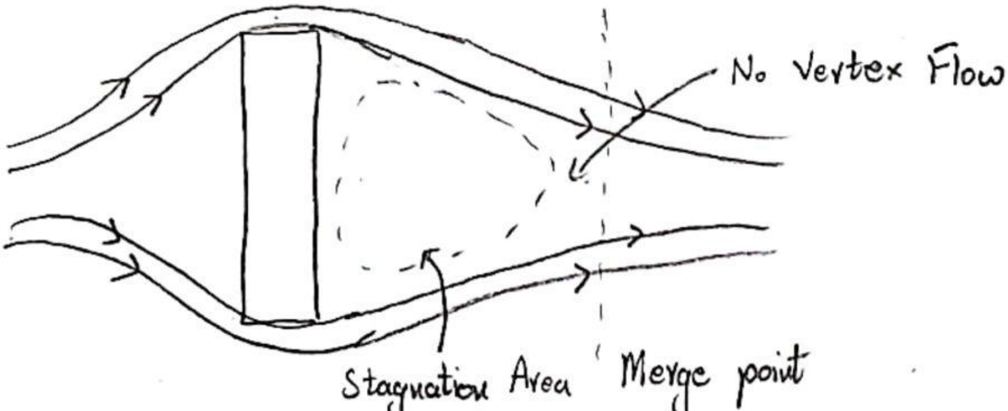
   Average Δt = 4.59s
b) Velocity, U: 0.22 m/s
c) Kinematic viscosity of water [ν] (at room temperature): 0.8007
d) Sketches of various flow patterns:



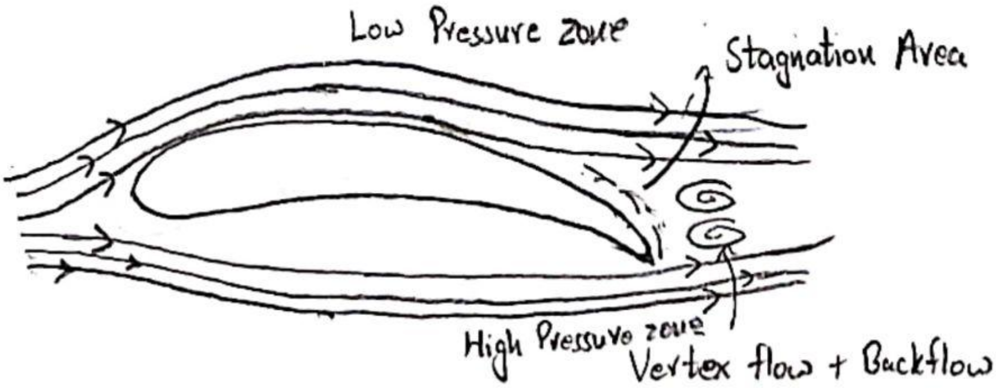
Flow across a cylinder



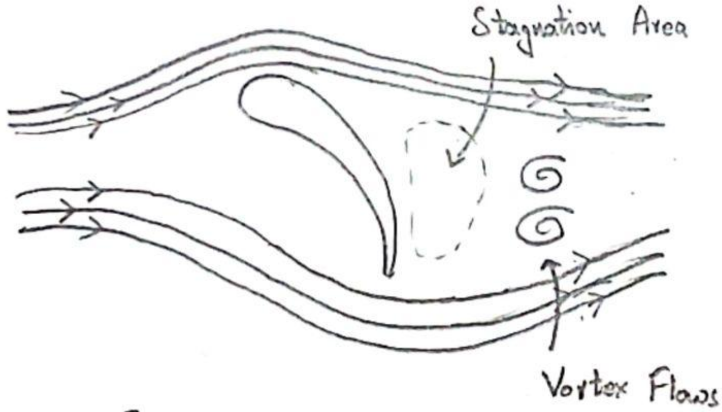
Flow across a Rectangle (broad side along flow)



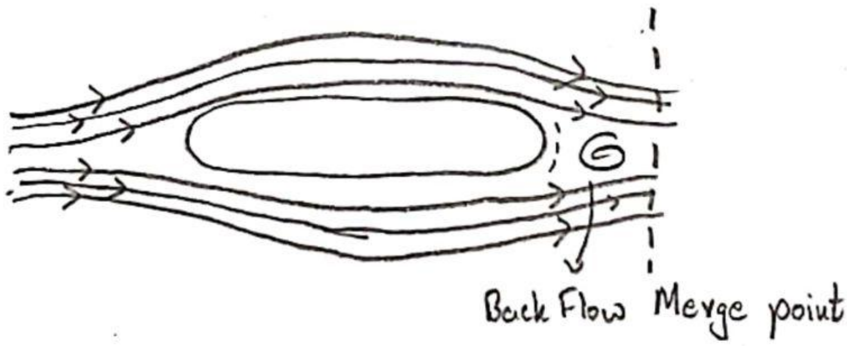
Flow across a Rectangle (narrow side along flow)



Flow across Aerofoil (Low Angle)

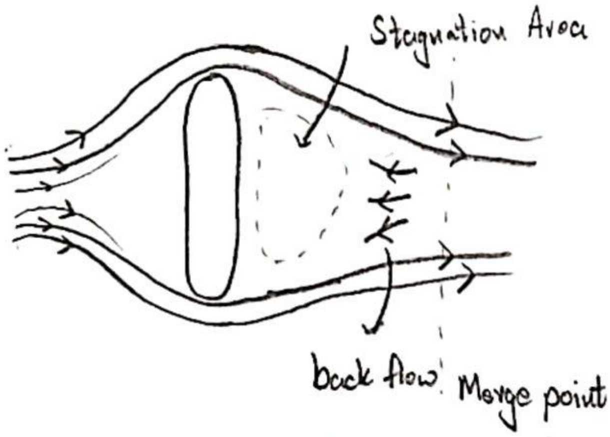


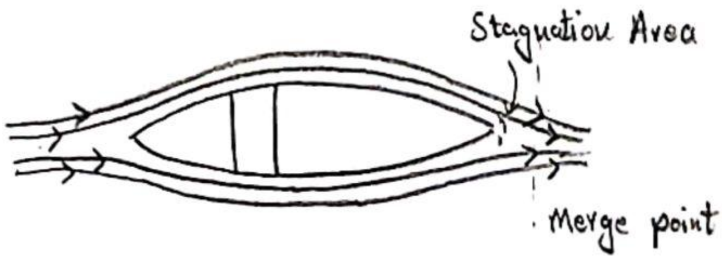
Flow across Aerofoil (Large Angle)



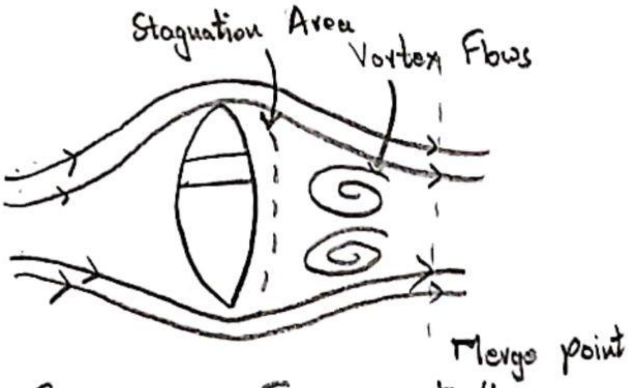
Flow across Oval (broad side along flow)

Flow across Oval (broad side along flow)





Flow across Tea facing flow



Flow across Tea against flow

e) Observation Table:

Object Name and Orientation	**Projected Length, L(cm)**	**Reynolds Number**
Cylinder	5.1	0.014013
Rectangle (narrow side along flow)	5.1	0.014013
Rectangle (broad side along flow)	15.2	0.041763
Aerofoil (low angle of attack)	14.8	0.040664
Aerofoil (high angle of attack)	14.8	0.040664
Oval (narrow side along flow)	5.6	0.015387
Oval (broad side along flow)	15	0.041214
Tee against the flow	15.3	0.042038
Tee facing the flow	3.7	0.010166

DISCUSSION:

1) **Write short notes (3-4 lines) on each of the flow patterns observed.**

- **Cylinder**: The flow pattern observed around a cylinder includes a merge point that is distant from the cylinder, and there is backflow. The stagnation area is small, and very close to the cylinder. Also, flow is almost irrotational.

- **Rectangle (narrow side along flow)**: The flow pattern observed around a rectangular object with the narrow side along the flow is characterized by a large stagnation area, but there is still no vortex flow. Backflow is quite low, and the merge point is very far away from the rectangle. This can lead to high drag and low lift, making it a poor choice for aerodynamic applications.
- **Rectangle (broad side along flow)**: The flow pattern observed around a rectangular object with the broad side along the flow is characterized by a smaller stagnation area, and there are vortices this time. Backflow is significant, and the merge point distance decreases, relative to the narrow side configuration. This can lead to lower drag and higher lift compared to the narrow side configuration.

- **Aerofoil (low angle of attack)**: The flow pattern observed around an aerofoil with a low angle of attack is characterized by a smaller stagnation area. Both vortex flow and backflow is present. As it is an aerofoil, the velocity beneath is smaller than the velocity above, which creates a difference in pressure and the required thrust. This is an ideal shape for many aerodynamic applications.
- **Aerofoil (high angle of attack)**: The flow pattern observed around an aerofoil with a high angle of attack is characterized by a large stagnation area and large vortex flows. This can lead to significant drag and a loss of lift, making it less desirable for aerodynamic applications.

- **Oval (narrow side along flow)**: The flow pattern observed around an oval object with the narrow side along the flow is similar to that of a rectangle with the narrow side along the flow, except that the separation distance has reduced.
- **Oval (broad side along flow)**: The flow pattern observed around an oval object with the broad side along the flow is similar to that of a rectangle with the narrow side along the flow, except that the separation distance has reduced.

- **Tee facing the flow**: The flow pattern observed around a tee facing the flow is characterized by the smallest separation distance, making it the best possible orientation. Backflow is negligible, and velocity is at its maximum in this orientation.
- **Tee against the flow**: The flow pattern observed around a tee against the flow is characterized by the highest amount of backflow, along with double vortices being formed. Merge point is also quite distant.

2) Suggest Methods to improve the experiment.

- **Vary the flow rate:** To gain a better understanding of the physical phenomena, run the experiment at various flow rates to see how the flow pattern varies with varying velocities.
- **Use different flow regimes:** Additional insights into how the flow behaviour varies under various flow circumstances may be gained by testing the forms in various flow regimes, such as laminar or turbulent flow.
- **Increase the number of shapes:** A greater range of data may be obtained from the experiment by using additional shapes, which can result in better analysis and more precise results.
- **Include multiple angles of attack:** Additional information about how the flow behaviour changes as the shape is tilted relative to the flow direction can be gained by testing the forms at various angles of attack.
- **Use computer simulations:** To get more understanding of the underlying fluid dynamics and to support experimental findings, computer simulations of the flow around various forms can be used.
- **Use different materials:** To learn more about how the material affects the flow pattern and gain a deeper understanding of the physical phenomenon, conduct the experiment with several materials of the same shape.