EXPERIMENT
OF
ELEMENTARY FLUID MECHANICS

Visualization of the flow patterns using Laminar Flow Table

Instructor: Seo, Il Won (35-310)
TA: Jung, Young Jai (35-504)
Tel: +82-2-880-7356; e-mail: jyj1123@snu.ac.kr

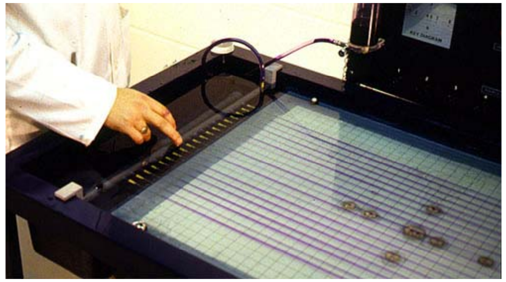
Objectives

Chapter 2. Visualization of the flow patterns using Laminar Flow Table

Using Laminar Flow Table - create the two-dimensional laminar flow
- visualize flow patterns.

Conduct the comprehensive study on the characteristics of streamlines.

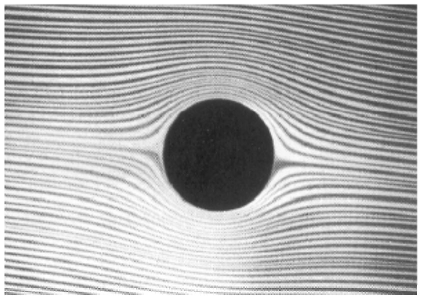
Calculate the Reynolds Number of the flow, and discuss whether the flow is laminar or not.

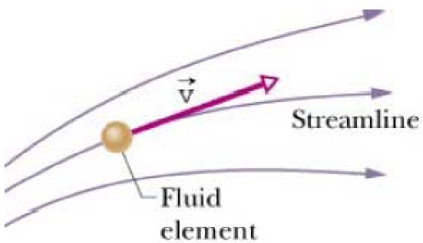


Theoretical Background

Streamlines

- are family of curves that are instantaneously tangent to the velocity vector of the flow.
- show the direction a fluid element will travel in at any point in time.
- Each visible tracer particle follows a streamline which is a path that a fluid element would take.





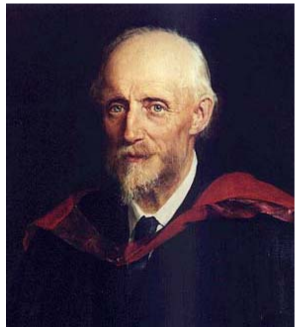
Theoretical Background

Reynolds number, Re

: In fluid mechanics, Re is a <u>dimensionless number</u> that gives a measure of the ratio of inertial forces to viscous forces. Re quantifies the relative importance of these two types of forces for given flow conditions.

$$\mathrm{Re} = \frac{\rho V d}{\mu} = \frac{\text{inertia}}{\text{viscous}}$$

V : mean velocity
ρ : density of fluid
d : diameter of pipe
μ : viscosity of fluid



Theoretical Background

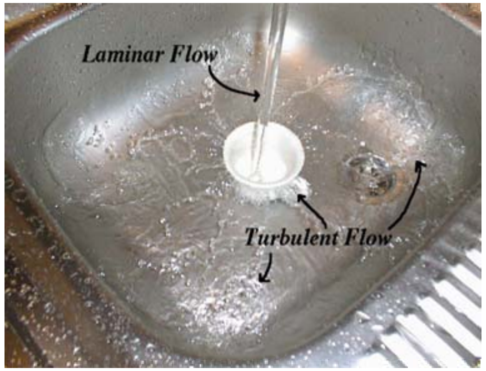
Reynolds number used to characterize different flow regimes,
such as laminar or turbulent flow.

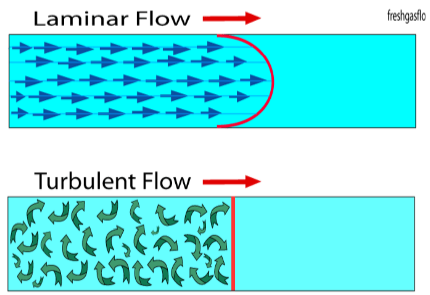
Laminar flow
- occurs at low Reynolds numbers, where viscous forces are dominant
- is characterized by smooth, constant fluid motion.
- Re < 2000 in pipe flow

Turbulent flow
- occurs at high Reynolds numbers and is dominated by inertial forces
- tend to produce random eddies, vortices and other flow instabilities
- Re > 4000 in pipe flow

For 2000 < Re < 4000 : Critical region or transition region
- Flow can either be laminar of turbulent difficult to pin down exactly

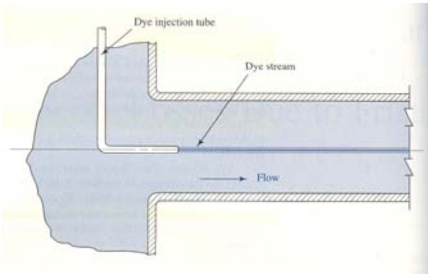
Theoretical Background





Laminar Flow vs. Turbulent Flow

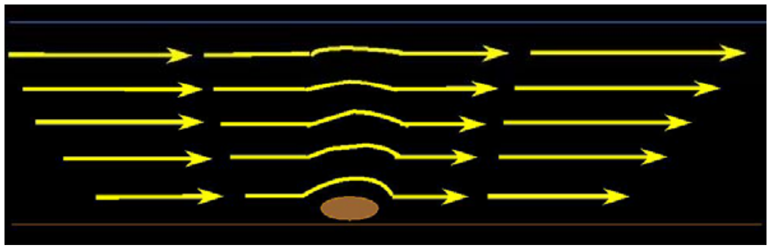
Theoretical Background



Laminar flow

~ Re < 2000
~ ‘Low’ velocity
~ Dye dose not mix with water
~ Fluid particles move in straight lines
~ Motion in parallel paths by the action of viscosity
~ Rare in practice in water systems

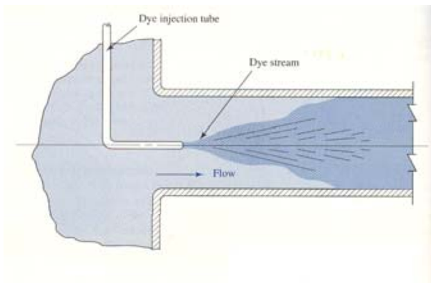
No Mixing between layers



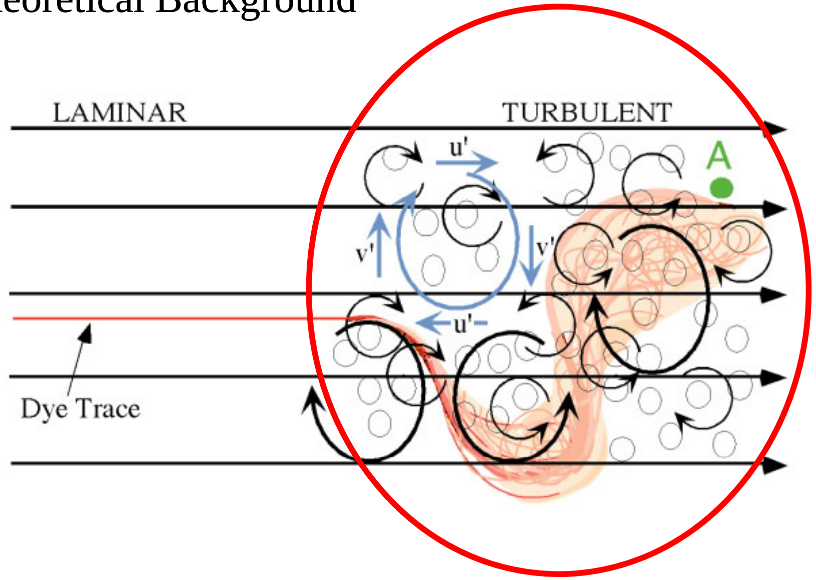
Theoretical Background

Turbulent flow

~ Re > 4000
~ ‘high’ velocity
~ Dye mixes rapidly and completely
~ Most common type of flow
~ Fluid particles move in heterogeneous fashion, random, irregular
~ A fluid regime characterized by chaotic, stochastic property changes



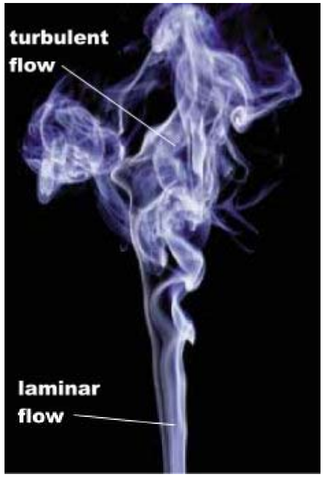
Theoretical Background



Example 1

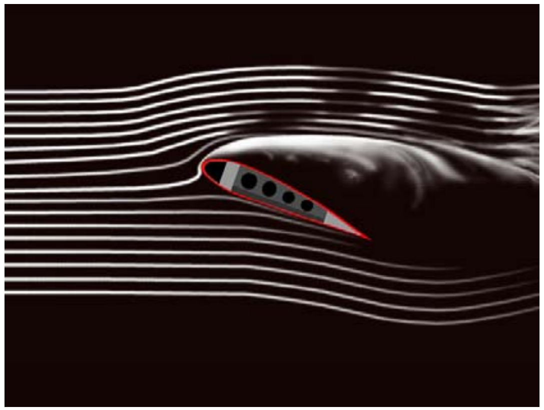
Turbulence happens when two fluids (air or smoke) with different densities are flowing past each other.

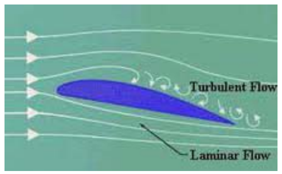
Cigarette smoke

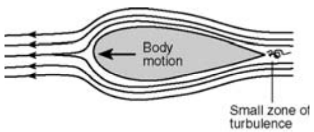


Example 2

Airplanes are designed to have flow be laminar.





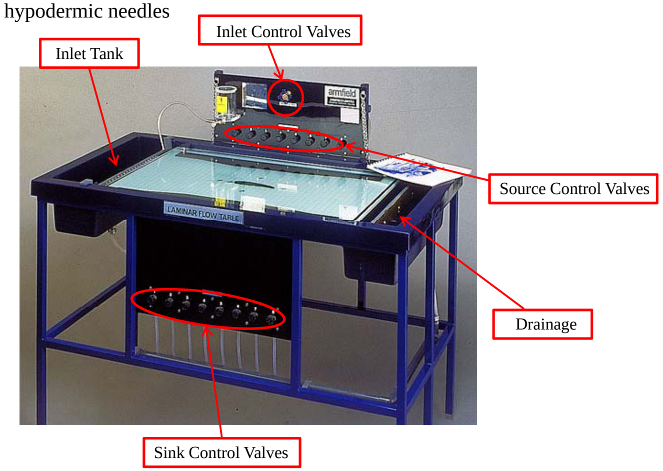


When the landing wheels of an airplane drop, it gets noisy

: the landing gear causes turbulence in the under part of the jet.

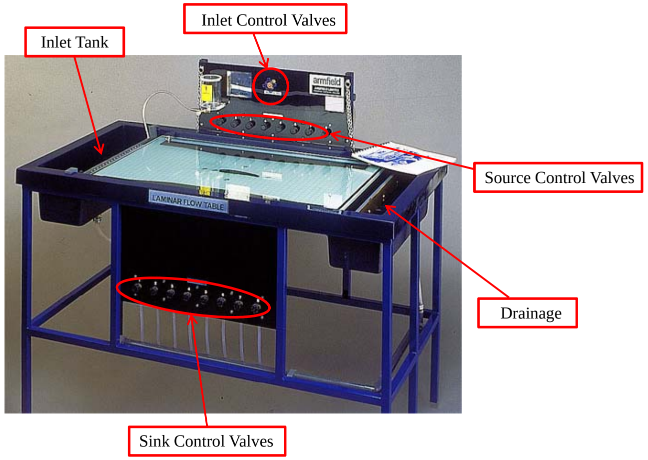
Experimental Apparatus

Width of Working Section: 610mm
Length of glass plates: 892mm
Distance between glass plates: 3.2mm
Sinks/sources: 8 tappings in 7 positions
Dye injectors: 19 hypodermic needles



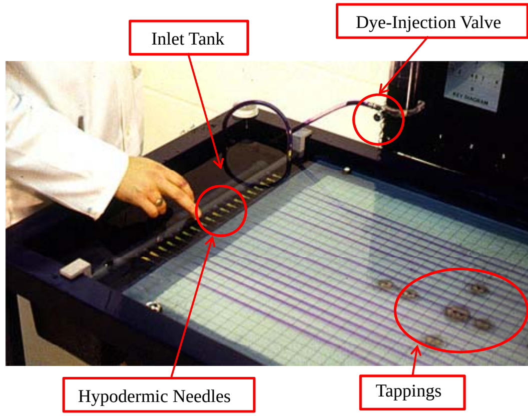
Experimental Apparatus

Two-dimensional laminar flow is created between the two glass plates by the combination of low fluid velocity and the narrow gap between the plates. The resulting flow is free from turbulence and gives a close approximation to the behavior of an ideal fluid.



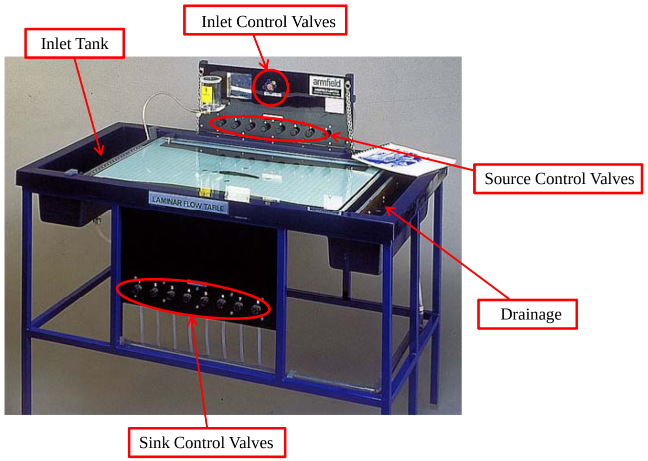
Experimental Apparatus

The Laminar Flow Table consists of two closely spaced sheets of laminated glass, arranged horizontally. Eight miniatures tapping which may be used as sinks or sources are arranged about the centerline of the lower glass plate in a cruciform configuration. A doublet (a sink and source in close proximity) is located at the centre of the pattern. A system of pipes, valves and manifolds enables any combination of the sinks and sources to be used.



Experimental Apparatus

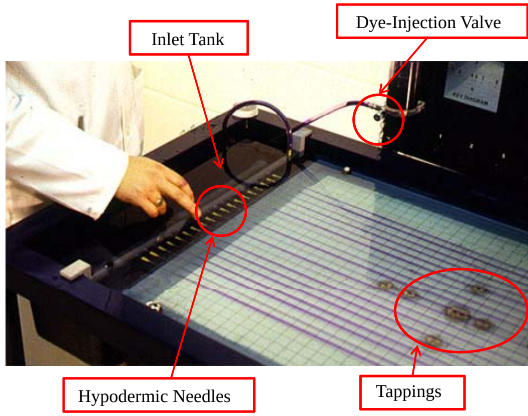
A row of control valves above the flow table is used to adjust the flow through each individual source. A row under the flow table is used to each individual sink.



Experimental Apparatus

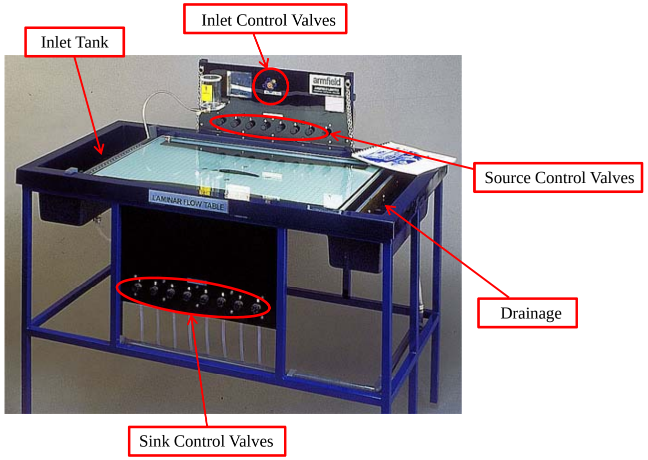
A row of hypodermic needles is positioned between the glass plates at the inlet edge. To visualize the flow of water between the glass plates, dye is injected through the equally spaced needles. The position of each streamline is clearly indicated by the dye.

A black graticule on a white background is printed on the underside of the lower glass plate to aid visualization of the streamlines.



Experimental Apparatus

A diffuser in the inlet tank and an adjustable weir plate in the discharge tank help to promote a uniform flow of water. The flow of water is controlled by an inlet flow control valve. A pressure regulator reduces the main water pressure and helps to minimize variations in flow.



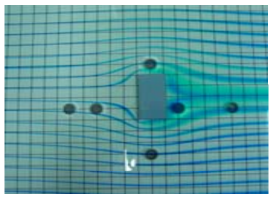
Procedure

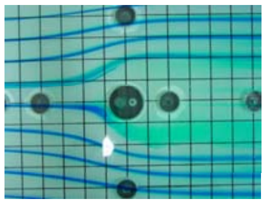
1. Close the Source/Sink valves.
2. Connect water supply to Laminar Flow Table using hose.
3. Adjust the flow table to make it level.
4. Remove air in hypodermic needles with opening the dye-injection valve slightly.
5. Open the inlet flow control valve. Let water flow between the glass plates. (The flowrate should be 0.25 liters/sec.)
6. Make 1 liter of dye solution using 3 g of blue dye powder.
7. Inject dye solution to the glass plates with opening the dye-injection valve.
8. Observe the dye-flow pattern.
9. Using several Models and Sink/Source valves, observe the various flow patterns

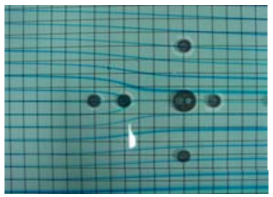
Experiment Example

A set of models are supplied for basic flow studies. These models are manufactured from plastic sheet and are trapped in the required position when the top glass plate is lowered.

Similarly, the sinks and sources may be used in combination with the flow of water between the plates to simulate a variety of flow situations.
For example, the patterns of flow in the vicinity of wells which draw water from underground supplies may be represented using one or more of the tappings as sinks.
The effect of recharging the underground supply may be represented by utilizing one or more of the tappings as sources.

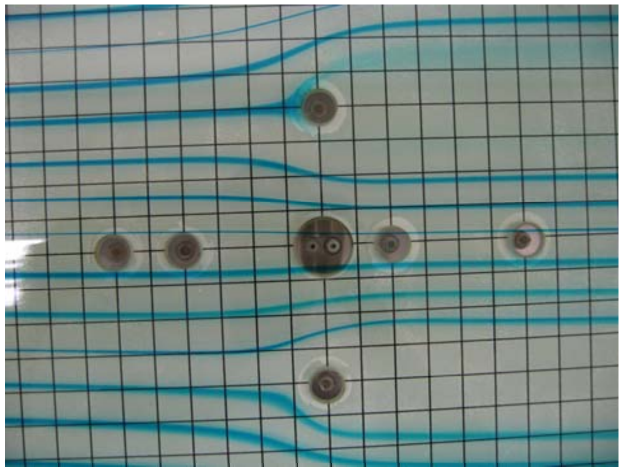

< Using Rectangular Model>


< Using Source Valves>


< Using Sink Valves>

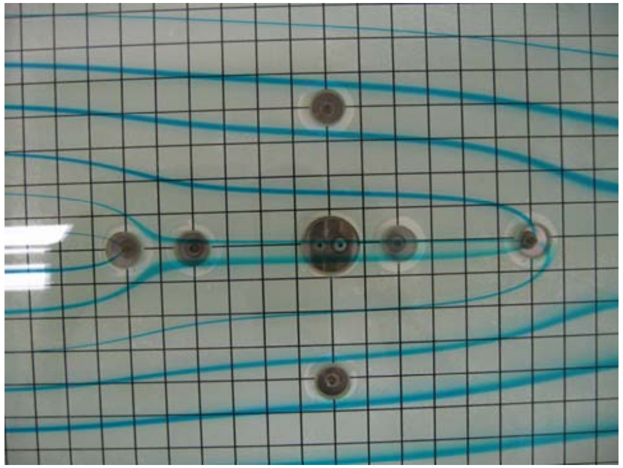
Problem

Infer the Combination of Source & Sink


Case 1

Problem

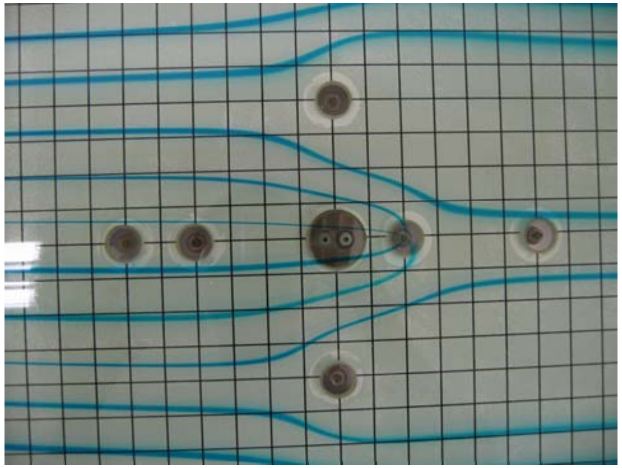
Infer the Combination of Source & Sink (Continue)



Case 2

Problem

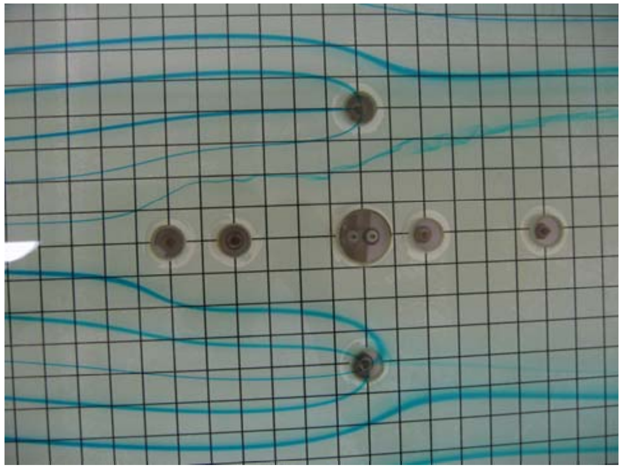
Infer the Combination of Source & Sink (Continue)



Case 3

Problem

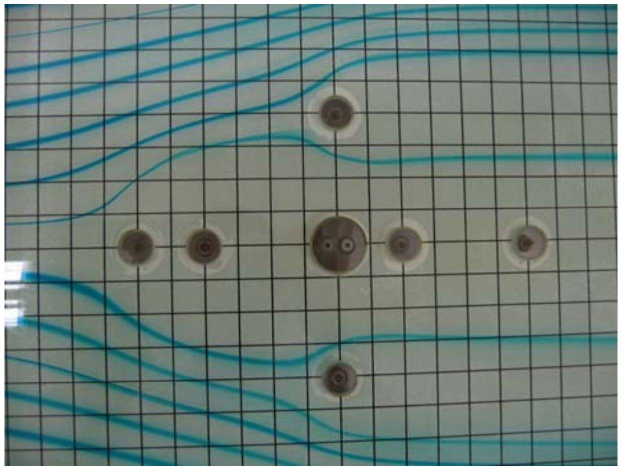
Infer the Combination of Source & Sink (Continue)



Case 4

Problem

Infer the Combination of Source & Sink (Continue)



Case 5

Problem

Infer the Combination of Source & Sink (Continue)
- Fill the result table

Result Table (example)

Case \ Tap No.	1	2	3	4	5	6	7	8
1	sink							
2						source		
3			source					
4		source						
5					source			

Discussion

1. Calculate the Reynolds Number of the flow, and discuss whether the flow is laminar or not.

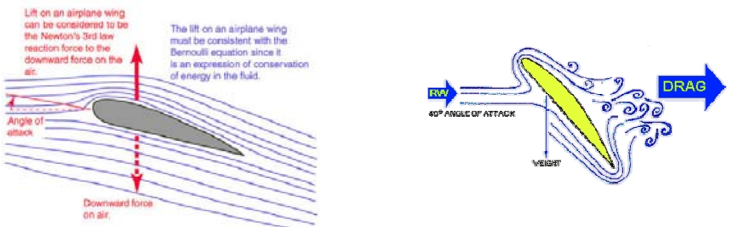
$$\mathrm{Re} = \frac{Vd\rho}{\mu}$$

V : mean velocity
ρ : density of fluid
d : spacing between glass plates
μ : viscosity of fluid $= 1.139 \times 10^{-3}\ \mathrm{N \cdot s / m^2}$

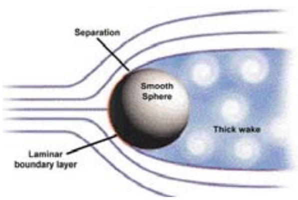
Applying Reynolds' concept to flow between parallel walls, the engineer can predict that the flow will be laminar if R<1000, and turbulent if R>>1000.
In fact, Re is the ratio of the inertia force to the viscous forces in the flow. When Re is small, viscous forces dominate. When Re is large, inertia forces dominate.
It is clear that the laminar of turbulent regimes are not determined just by flow velocity. Laminar flows are characterized by low velocities, small length scales, and fluids with high kinematic viscosity. Turbulent flows are characterized by high velocities, large length scales, and fluids of low kinematic viscosity.

Discussion

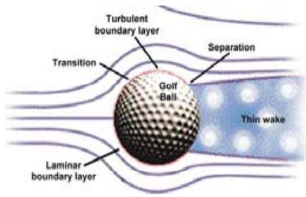
2. Simulate the Several Examples and Discuss on Phenomenon



Wing of an Airplane



Smooth Sphere



Golf Ball (with Dimple)