K.N. Toosi
University of Technology

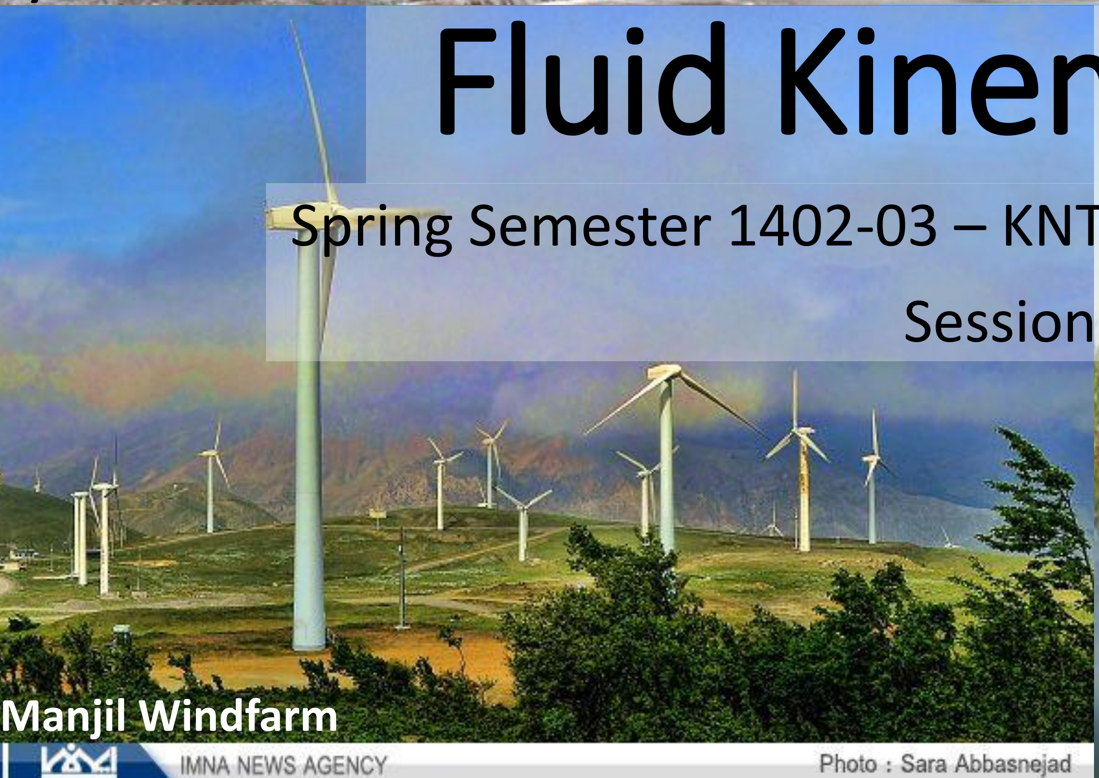
Cyclone Gonu


Shirabad Waterfall, Gorgan

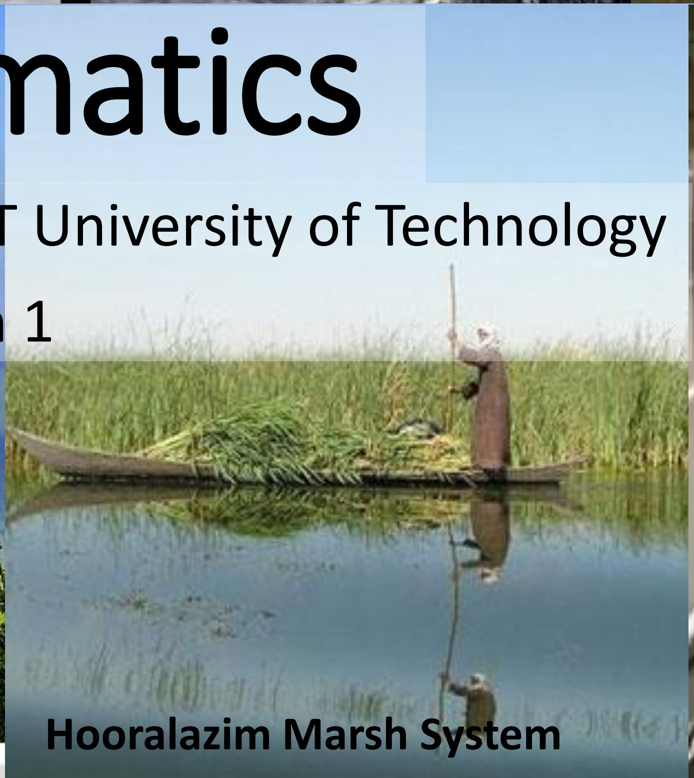
Fluid Kinematics

Spring Semester 1402-03 – KNT University of Technology

Session 1



Manjil Windfarm


Hooralazim Marsh System


Bakeri Highway flood control System

Outline

- What is Fluid (different Types of Fluid)
- Classification of Fluid Flows
- Viscous vs Inviscid Regions of Flow
- Compressible vs Incompressible Flow

Fluid Mechanics

Mechanics: The oldest physical science that deals with both stationary and moving **bodies** under the **influence of forces**.

Statics: The branch of mechanics that deals with **bodies at rest**.

Dynamics: The branch that deals with **bodies in motion**.

Fluid mechanics: The science that deals with the behavior of **fluids** at rest (***fluid statics***) or in motion (***fluid dynamics***), and the **interaction** of fluids with solids or other fluids **at the boundaries**.

Fluid dynamics: Fluid mechanics is also referred to as fluid dynamics by considering fluids at rest as a special case of motion with zero velocity.

Fluid Mechanics

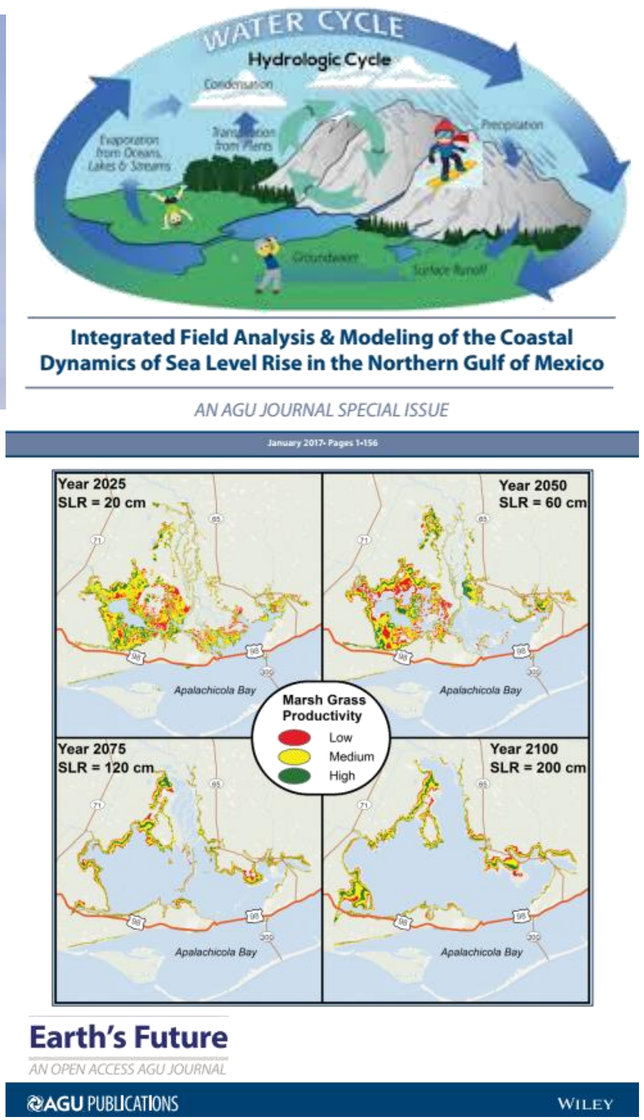
Hydrodynamics: The study of the **motion of fluids** that can be approximated as **incompressible** (such as liquids, especially water, and gases at low speeds).

Hydraulics: A subcategory of hydrodynamics, which deals with **liquid** flows in **pipes** and **open channels**.

Gas dynamics: Deals with the flow of fluids that undergo significant **density changes**, such as the flow of **gases** through nozzles at **high speeds**.

Aerodynamics: Deals with the **flow of gases** (especially air) over bodies such as **aircraft**, **rockets**, and **automobiles** at high or low speeds.

Meteorology, oceanography, and hydrology: Deal with **naturally occurring flows**.



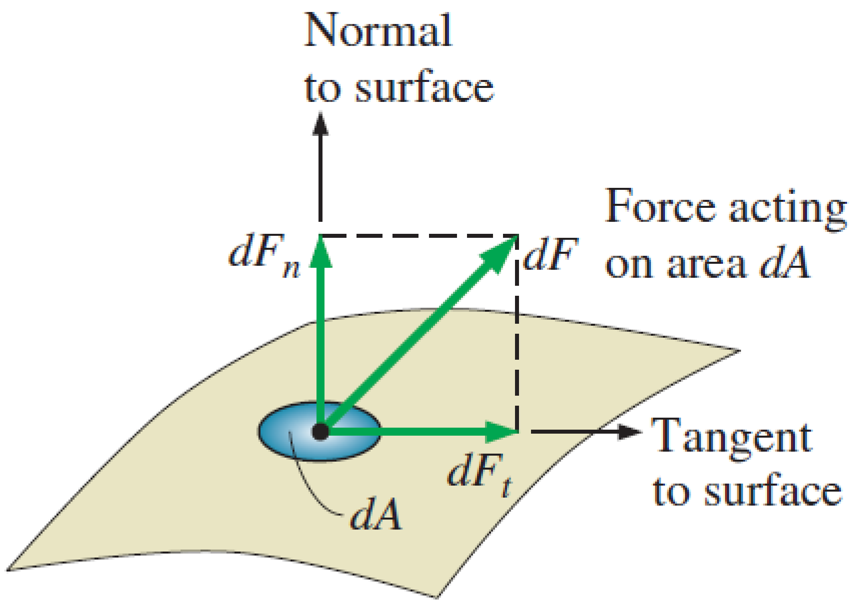
Basic Definitions

Stress: Force per unit area.

Normal stress: The normal component of a force acting on a surface per unit area.

Shear stress: The tangential component of a force acting on a surface per unit area.

Pressure: The normal stress in a fluid at rest.



Zero shear stress: A fluid at rest is at a state of zero shear stress.

$$\text{Normal stress: } \sigma = \frac{dF_n}{dA}$$

$$\text{Shear stress: } \tau = \frac{dF_t}{dA}$$

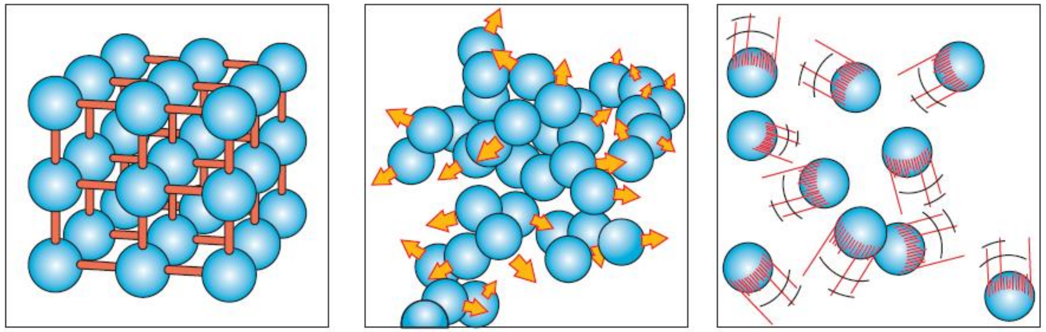
When the walls are removed or a liquid container is tilted,
a shear develops as the liquid moves to re-establish a horizontal free surface.

Micro-scale approach

Solid: Molecules are arranged in a pattern that is repeated throughout.

Liquid: Molecules can rotate and translate freely.

Gas: Molecules are far apart from each other, and molecular ordering is nonexistent.

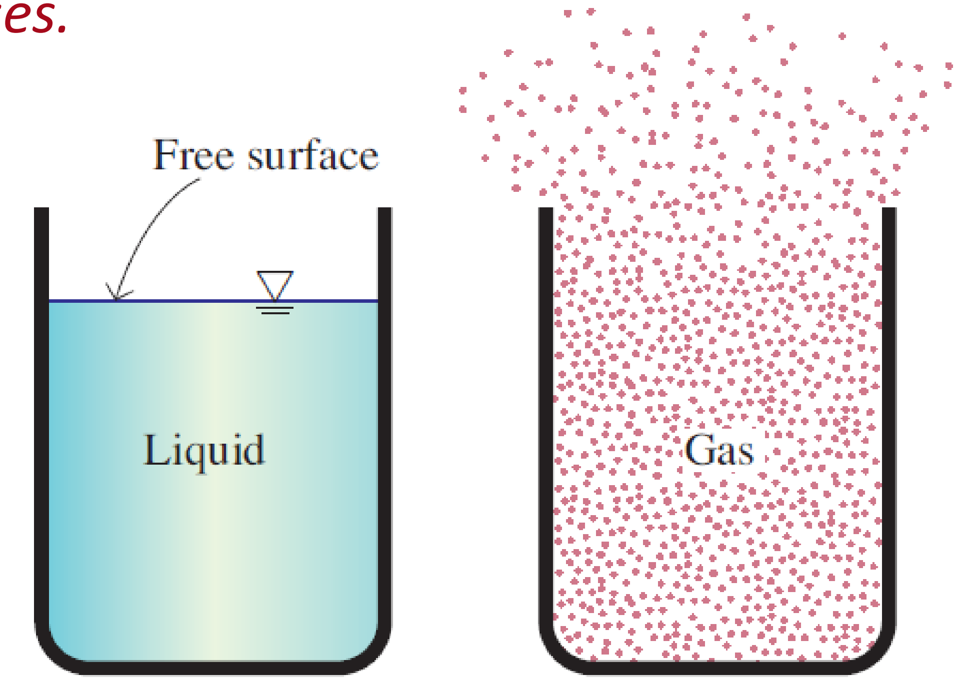


(a) (b) (c)

Intermolecular bonds are strongest in solids and weakest in gases.

Liquid: groups of molecules can **move relative to each other**, but the **volume remains relatively constant** due to the strong **cohesive forces** between the molecules.

Gas: it **expands** until it encounters the walls of the container and **fills** the entire **available space**. This is because the gas molecules are **widely spaced**, and the cohesive forces between them are very small.



What is a Fluid?

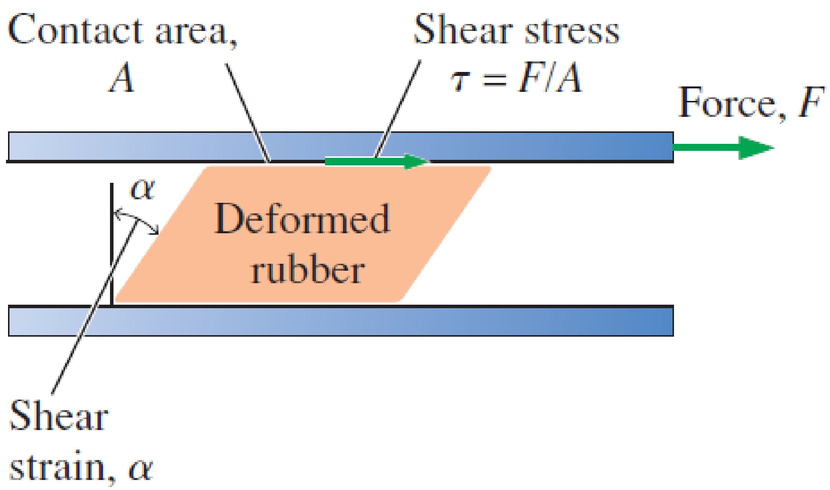
Fluid: A substance in the liquid or gas phase.

A solid can resist an applied shear stress by deforming.

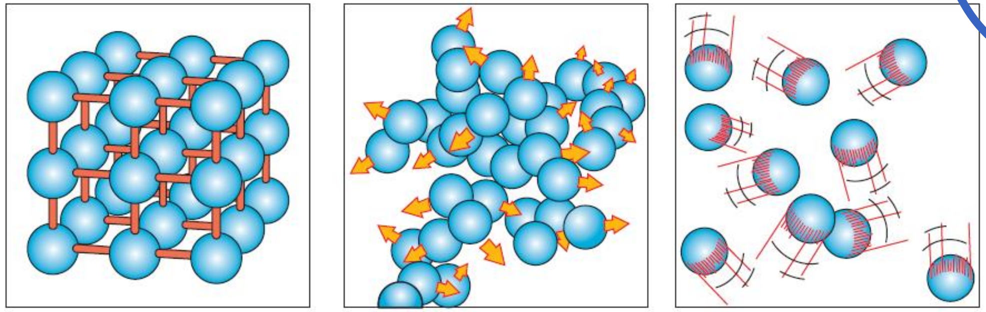
A fluid deforms continuously under the influence of a shear stress, no matter how small.

In solids, stress is proportional to *strain*, but in fluids, stress is proportional to *strain rate*.

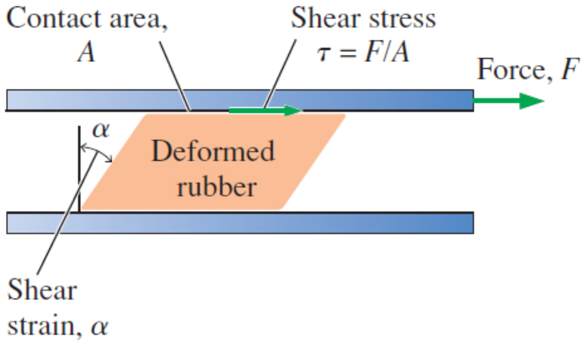
When a constant shear force is applied, a solid eventually stops deforming at some fixed strain angle, whereas a fluid never stops deforming and approaches a constant *rate* of strain.



Fluid Mechanics
مکانیک سیالات



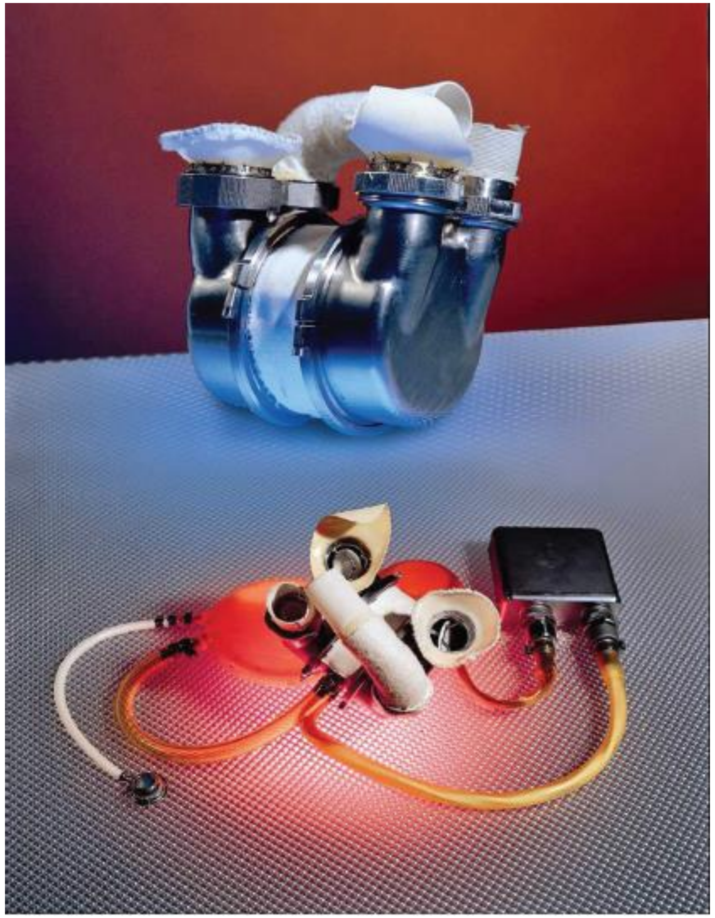
(a) (b) (c)



Statics

Dynamics

Application Areas of Fluid Mechanics


Biomedical

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Natural flows and weather

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Power plants

U.S. Nuclear Regulatory Commission (NRC)


Boats

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Application Areas of Fluid Mechanics

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Wind turbines

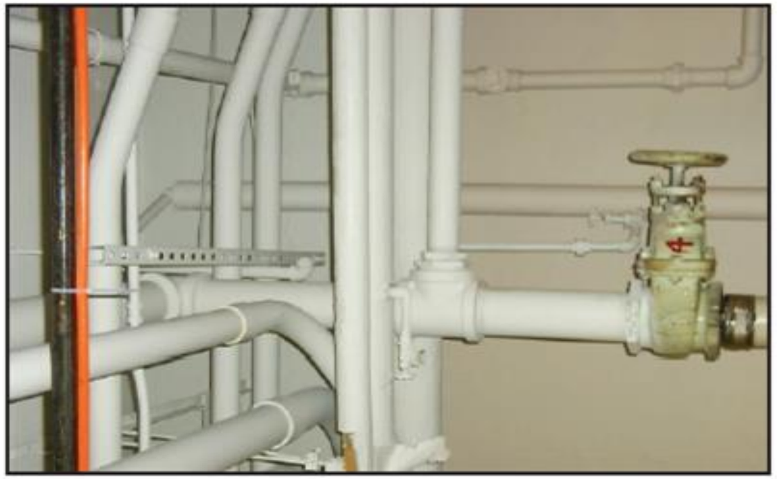

Photo by John M. Cimbala

Piping and plumbing systems

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Industrial applications

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Cars

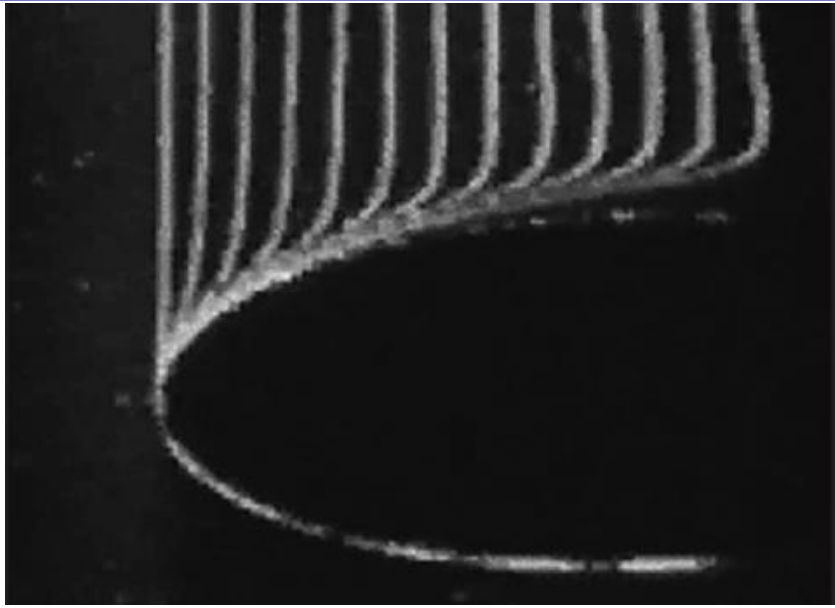
No-Slip Condition

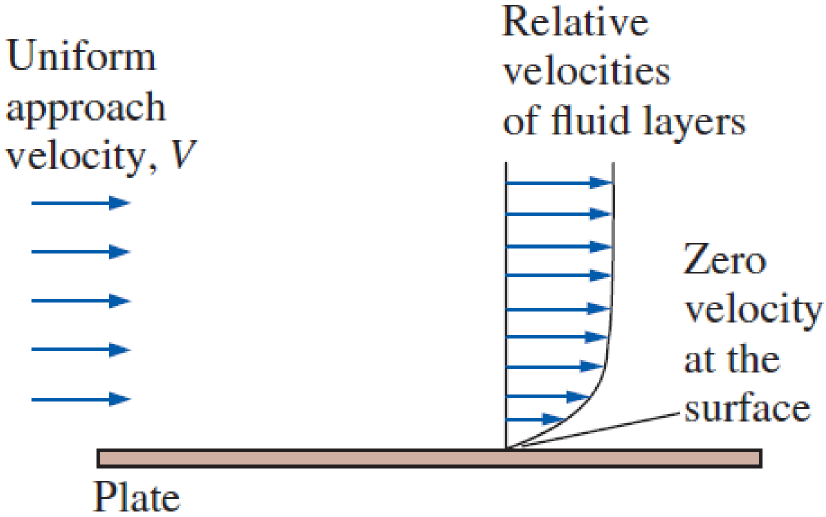
Consider the flow of a fluid in a **stationary pipe** or over a **solid surface** that is **nonporous** (i.e., impermeable to the fluid).

All experimental observations indicate that a fluid in motion comes to a complete **stop at the surface** and assumes a ????? velocity relative to the surface. That is, a fluid in direct contact with a solid "sticks" to the surface, and there is no slip. This is known as the **no-slip condition**.

The fluid property responsible for the no-slip condition and the development of the boundary layer is ***viscosity***.

Boundary layer: The flow region adjacent to the wall in which the viscous effects (and thus the velocity gradients) are significant.





Wrap-up

- What is Fluid? (intermolecular bonds, shear stress, etc)
- Viscous vs Inviscid Regions of Flow (no-slip condition, boundary layer)
- Compressible vs Incompressible Flow (Mach Number)