

Fluid Mechanics - MTF053

Lecture 1

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Fluid Mechanics

*"Fluid mechanics is the branch of physics concerned with the **mechanics of fluids** (liquids, gases, and plasmas) and the **forces** on them. It has applications in a wide range of disciplines, including mechanical, civil, chemical and biomedical engineering, geophysics, oceanography, meteorology, astrophysics, and biology."*

Wikipedia



Fluid Flows in Your Daily Life

"When you think about it, almost everything on this planet either is a fluid or moves within or near a fluid"

Frank M. White



Fluid Flows in Your Daily Life



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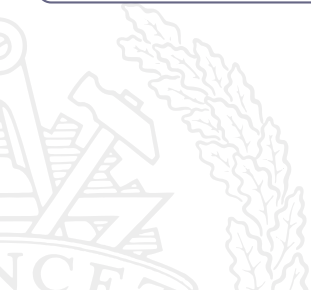
Fluid Flows in Your Daily Life



Governing Equations

Conservation of mass (continuity)

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w) = 0$$



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Conservation of linear momentum (Newton's 2:nd law)

$$\rho \left(\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right) = \rho g_x - \frac{\partial p}{\partial x} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right)$$

$$\rho \left(\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} \right) = \rho g_y - \frac{\partial p}{\partial y} + \mu \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2} \right)$$

$$\rho \left(\frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} + w \frac{\partial w}{\partial z} \right) = \rho g_z - \frac{\partial p}{\partial z} + \mu \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2} \right)$$

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Conservation of energy (1:st law of thermodynamics)

$$\rho C_v \left(\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + w \frac{\partial T}{\partial z} \right) = \rho \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right) + k \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) + \Phi$$

Fluid Flow Applications

Analytical solutions limited to very specific simplified cases

Complex geometries and flows leads to the need for experiments and Computational Fluid Dynamics (CFD)

Chief obstacles to a general theory:

Geometry

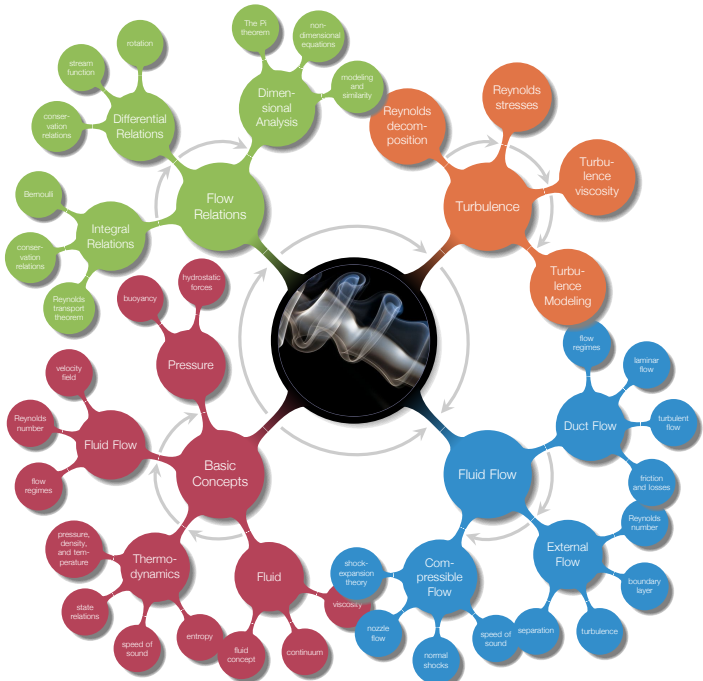
Viscosity

Non-linearity

Turbulence

Understanding the basic principles is a key factor for a correct analysis

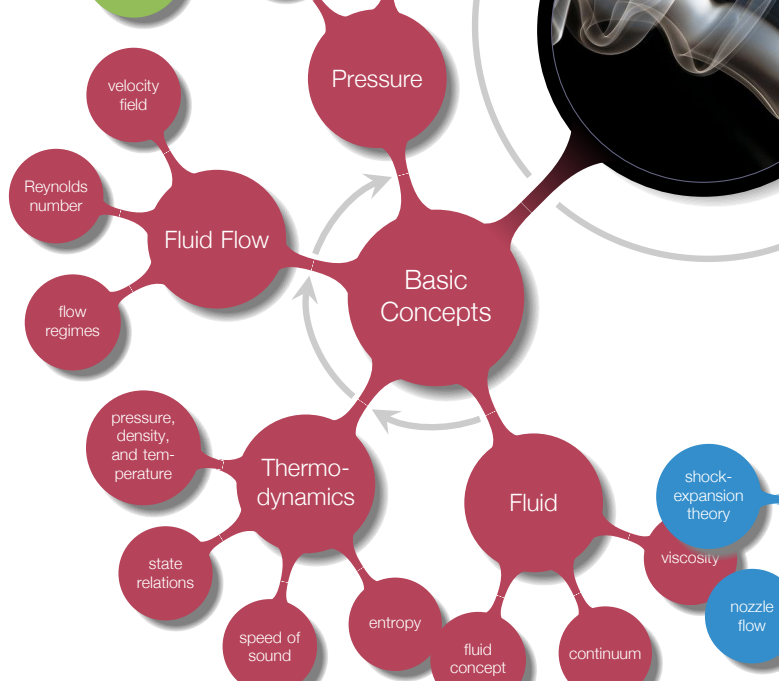
Overview





Chapter 1 - Introduction

Overview

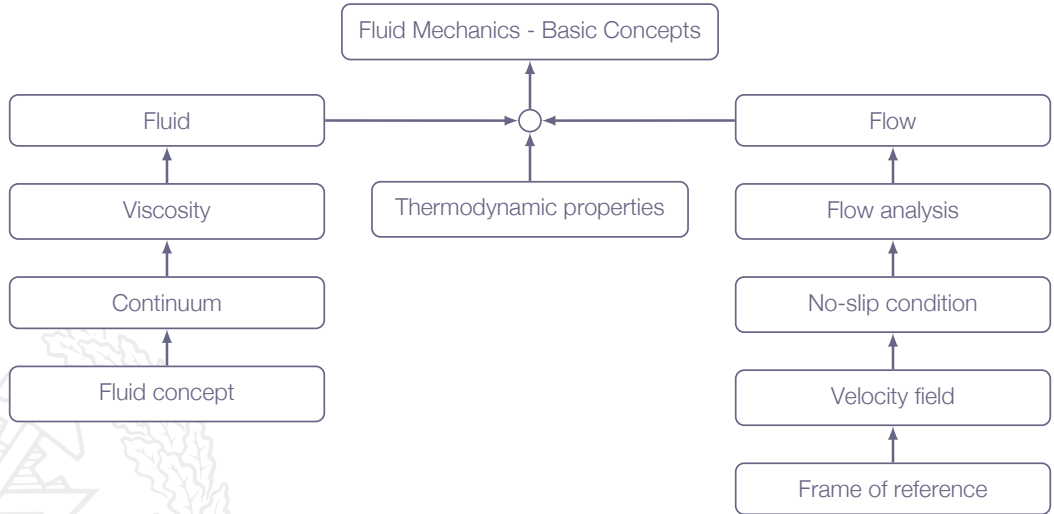


Learning Outcomes

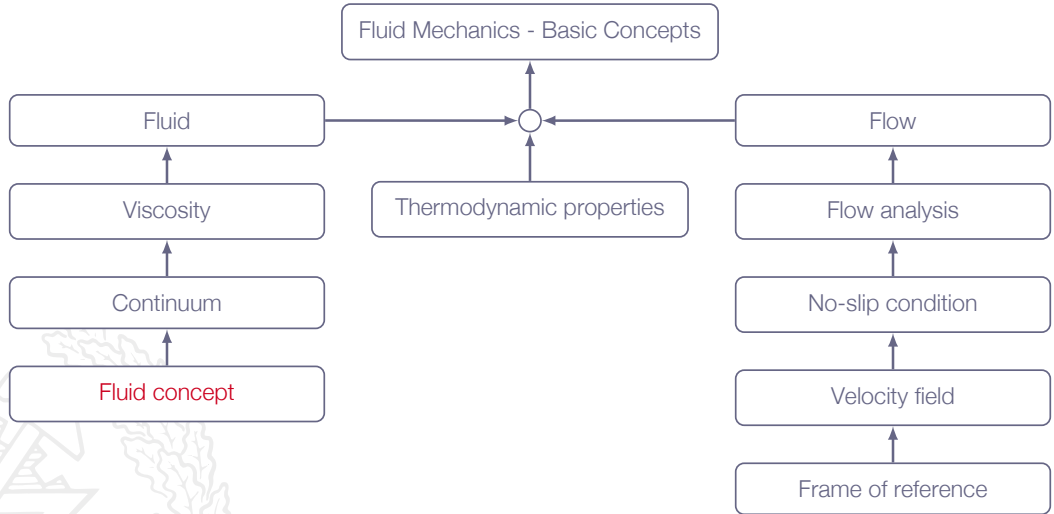
- 1 **Explain** the difference between a fluid and a solid in terms of forces and deformation
- 2 **Understand** and be able to explain the viscosity concept
- 3 **Define** the Reynolds number
- 5 **Explain** the difference between Lagrangian and Eulerian frame of reference and know when to use which approach
- 7 **Explain** the concepts: streamline, pathline and streakline
- 8 **Understand** and be able to **explain** the concept shear stress
- 9 **Explain** how to do a force balance for fluid element (forces and pressure gradients)
- 10 **Understand and explain** buoyancy and cavitation
- 16 **Understand** and **explain** the concept Newtonian fluid

in this lecture we will find out what a fluid flow is

Roadmap - Introduction to Fluid Mechanics



Roadmap - Introduction to Fluid Mechanics



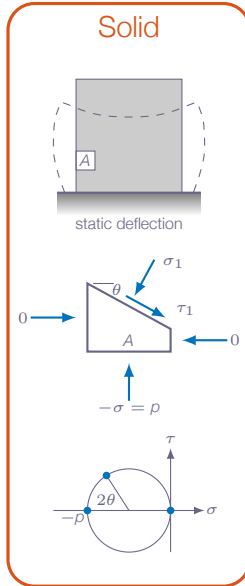
The Concept of a Fluid

"In physics, a fluid is a substance that continually deforms (flows) under an applied shear stress, or external force. Fluids are a phase of matter and include liquids, gases and plasmas. They are substances with zero shear modulus, or, in simpler terms, substances which cannot resist any shear force applied to them."

Wikipedia

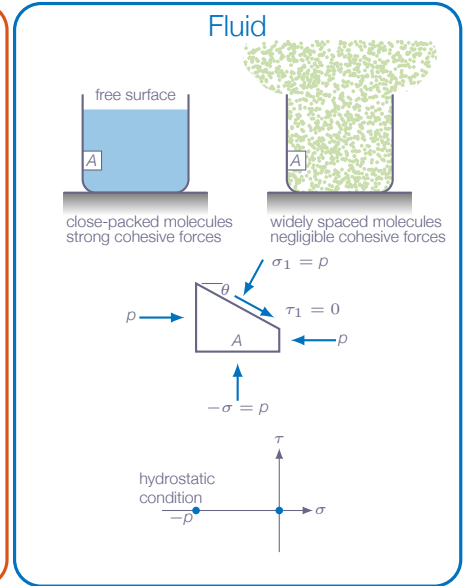
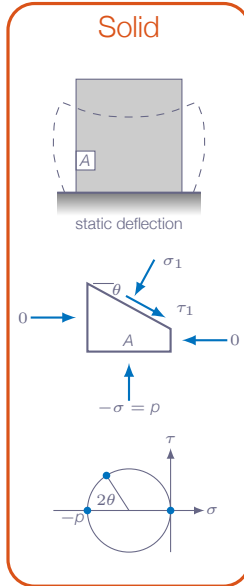


The Concept of a Fluid

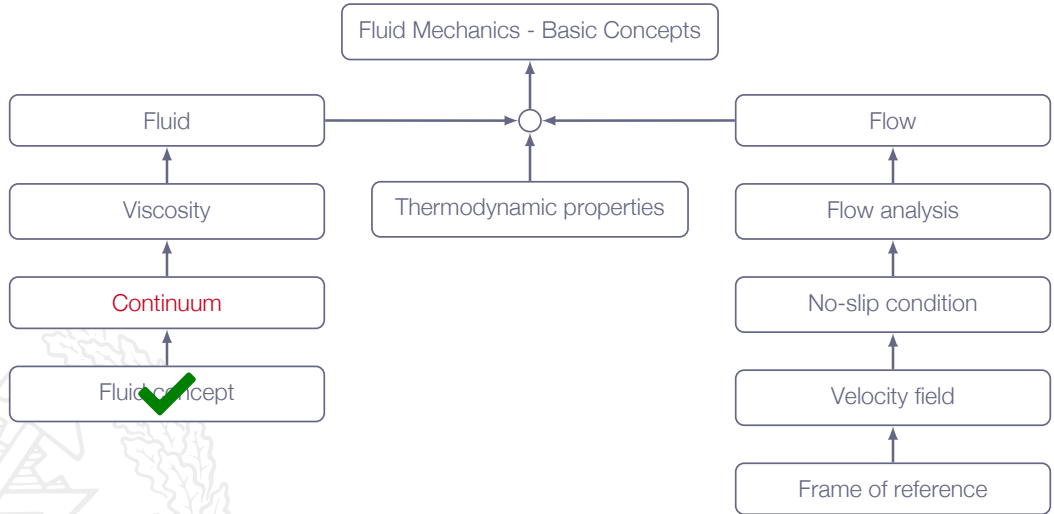


The Concept of a Fluid

"A solid can resist a shear stress by a static deflection; a fluid cannot"



Roadmap - Introduction to Fluid Mechanics



The Fluid as a Continuum

Fluid **density** is essentially a **point function**

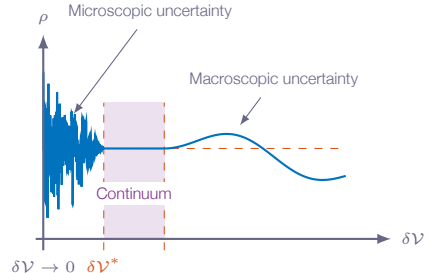
Fluid **properties** can be thought of as **varying continually in space**

Volume large enough such that the **number of molecules** within the volume is **constant**

Volume small enough **not** to **introduce macroscopic fluctuations**

$$\rho = \lim_{\delta V \rightarrow \delta V^*} \frac{\delta m}{\delta V}$$

standard air: $\delta V^* \approx 10^{-9} \text{ mm}^3 \Rightarrow \sim 3 \times 10^7$ molecules



The Fluid as a Continuum

Flow properties varies smoothly $\Rightarrow$ Differential calculus can be used

