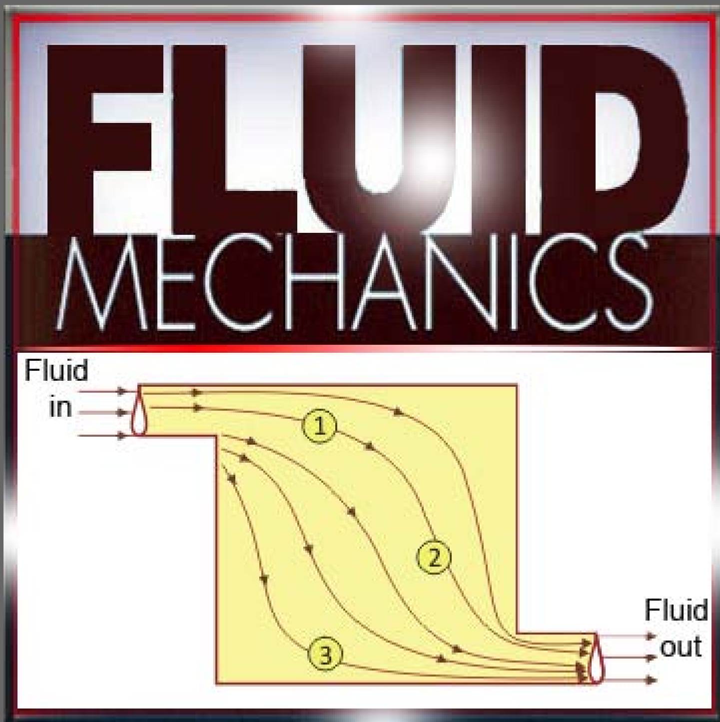

Course Name	Fluid Mechanics
Department	Chemical Engineering IIT Kanpur
Instructor	Dr. Nishith Verma

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Suggested text books:

1. Fluid Mechanics and its Applications
   (Gupta and Gupta)
   New Age international (P) Ltd, New Delhi, 5^{th} Reprint
2. Introduction to Fluid Mechanics
   (Fox and McDonald)
   Wiley, NY, 5^{th} ed.
3. Unit Operations in Chemical Engineering
   (McCabe, Smith, Harriot)
   McGraw Hill, NY, 3^{th} ed.

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Module 1: Introduction

Lecture 1: Definition of a fluid and Newtons' law of viscosity

- Introduction
- Definition of fluid
- Newton's law of viscosity

Module 1: Introduction

Lecture 1: Definition of a fluid and Newtons' law of viscosity

Introduction

Fluid mechanics: Subject that deals with the study of the behavior of a fluid either at rest or in motion.

At this level (undergraduate 2^{nd} year B. Tech. Chemical Engineering), it is expected that the students learn

- Fundamental concept of fluid statics and motions, including governing equations that describe the basic principles
- Pressure-drop calculations for a tubular flow, and flow in packed-beds of solid particles
- Application of the basic knowledge of fluid mechanics in understanding the momentum transfer based chemical engineering unit operations (UOPs), in particular
    - Filtration
    - Agitation
    - Air-particles separation (cyclone)

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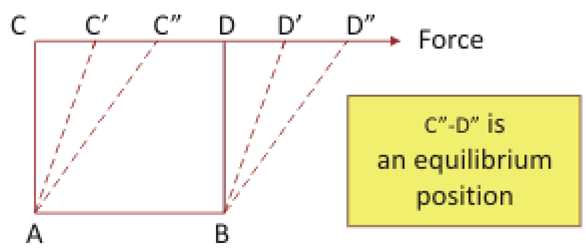
Module 1: Introduction

Lecture 1: Definition of a fluid and Newtons' law of viscosity

Definition of fluid

In the present context of fluid mechanics, it is important to distinguish the behavior of a fluid from that of a solid when subjected to a shear force (parallel to its surface).

Consider a solid element 'ABCD' shown below (Fig 1a). The bottom section A B is fixed. A small horizontal force is applied on the surface CD. The surface is 'sheared'. The element CD deforms into C'D' and then, into C"D". However, an equilibrium position is achieved when the deformation stops. The top layer is now stationary. The solid has, therefore, resisted the applied shear force.



(Fig. 1a)

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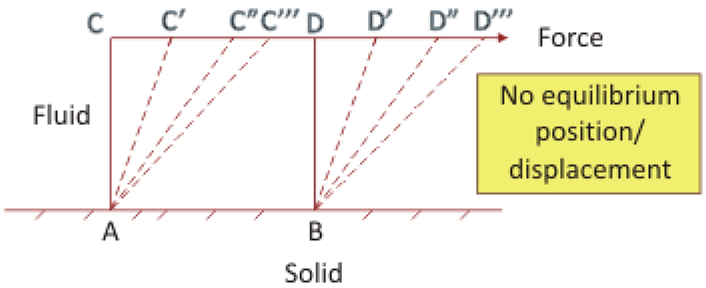
Now, consider a fluid element 'ABCD' shown in Fig 1b. On the application of a shear force (no matter how small it is!), the top surface CD will continue to move as long as the force is applied. There will not be 'equilibrium' position of any fluid element on the surface CD. Such behavior has been validated experimentally, using a dye- marker test.



(Fig. 1b)

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We conclude

- Fluid continues to deform (or move) under the application of a shear force.
- Fluid at rest cannot sustain a shear stress.

Fluid resists deformation by attaining an equilibrium rate of deformation.
Viscosity is a property of the fluid which relates its resistance to the applied shear force.

Newton's law of viscosity

A class of fluids called *Newtonian* fluids such as water and air follow the behavior: “applied shear stress varies linearly with the rate of deformation”. The mathematical representation is

$$\underbrace{\tau =}_{\substack{\downarrow \\ \text{applied} \\ \text{stress}}} \quad \underbrace{\mu}_{\substack{\downarrow \\ \mathrm{Pa-s\ or\ }\frac{\mathrm{N-s}}{\mathrm{m^2}}}} \quad \underbrace{\left(\frac{dV_x}{dy}\right)}_{\substack{\downarrow \\ \text{Rate of strain} \\ \text{or deformation rate}(s^{-1})}} \qquad \text{for 1D-flow}$$

μ = Dynamic (or absolute) viscosity (Pa − s)

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