Ideal / Real Fluids

- Ideal fluid do not actually exist in nature, but sometimes used for fluid flow problems.
- Consider a hypothetical fluid having a zero viscosity ($\mu = 0$). Such a fluid is called an *ideal fluid* and the resulting motion is called as **ideal** or **inviscid flow**. **In an ideal flow, there is no existence of shear force because of vanishing viscosity.**

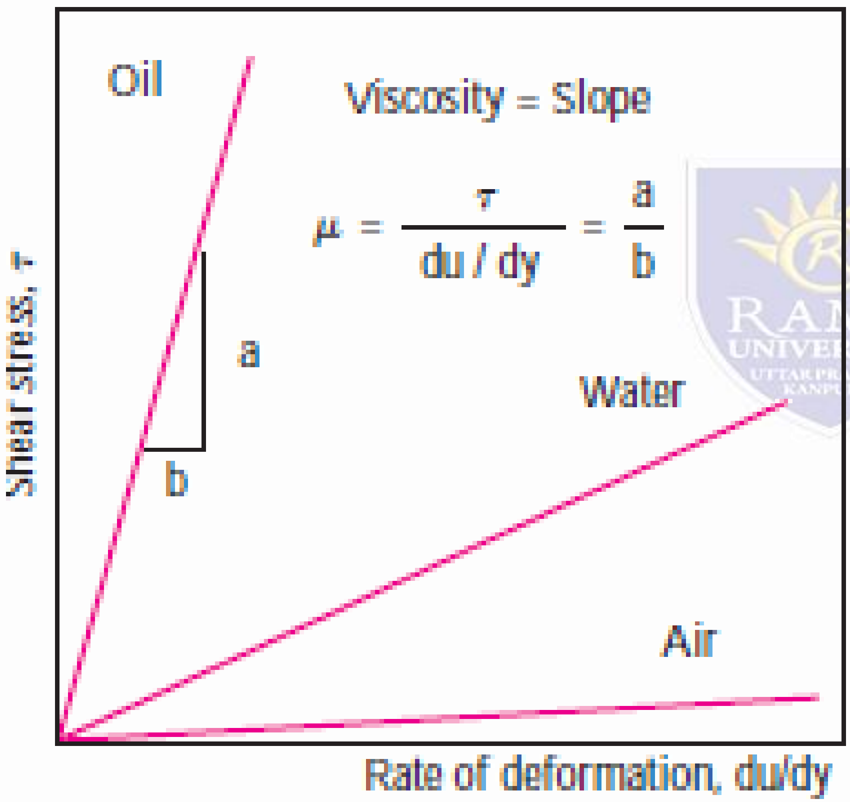
$$\tau = \mu \frac{du}{dy} = 0 \qquad \text{since } \mu = 0$$

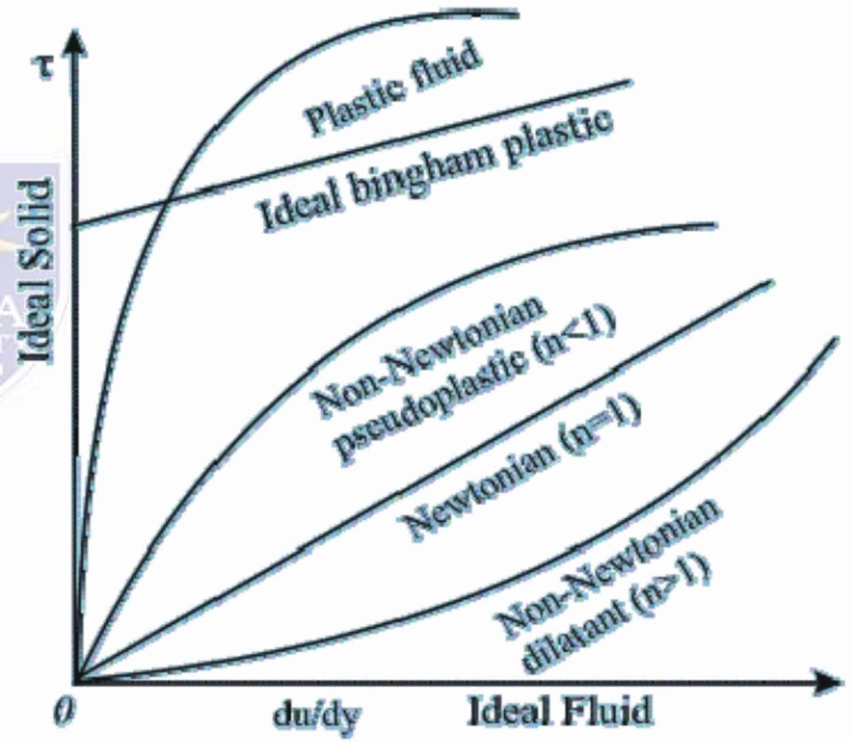
- All the **fluids in reality have viscosity** ($\mu > 0$) and hence they are termed as real fluid and their motion is known as viscous flow.
- Under certain situations of very high velocity flow of viscous fluids, an accurate analysis of flow field away from a solid surface can be made from the ideal flow theory.

Newtonian fluid

- These fluids follow Newton's viscosity equation. For such fluids viscosity does not change with rate of deformation
- The Newtonian fluids behave according to the law that shear stress is linearly proportional to velocity gradient or rate of shear strain . Thus for these fluids, the plot of shear stress against velocity gradient is a straight line through the origin. The slope of the line determines the viscosity.
- In one-dimensional shear flow of Newtonian fluids, shear stress can be expressed by the linear relationship

$$\tau = \mu \, du/dy$$



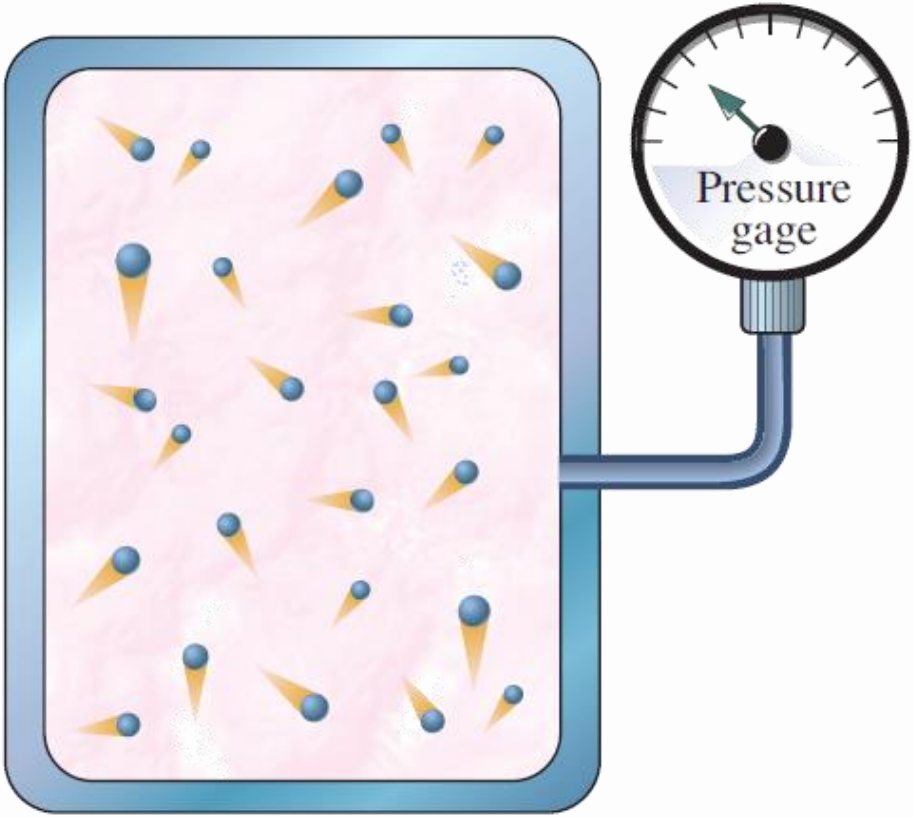


Non Newtonian Fluid

Non-Newtonian Fluids $\left(\tau \neq \mu \frac{du}{dy}\right)$		
Purely Viscous Fluids		**Visco-elastic Fluids**
Time - Independent	**Time - Dependent**	
1. Pseudo plastic Fluids $\tau = \mu\left(\frac{du}{dy}\right)^n ; n < 1$ Example: Blood, milk **2. Dilatant Fluids** $\tau = \mu\left(\frac{du}{dy}\right)^n ; n > 1$ Example: Butter **3. Bingham or Ideal Plastic Fluid** $\tau = \tau_o + \mu\left(\frac{du}{dy}\right)^n$ Example: Water suspensions of clay and flyash	**1.Thixotropic Fluids** $\tau = \mu\left(\frac{du}{dy}\right)^n + f(t)$ *f(t)is decreasing* Example: Printer ink; crude oil **2. Rheopectic Fluids** $\tau = \mu\left(\frac{du}{dy}\right)^n + f(t)$ *f(t)is increasing* Example: Rare liquid solid suspension	**Visco- elastic Fluids** $\tau = \mu\frac{du}{dy} + \alpha E$ Example: Liquid-solid combinations in pipe flow.

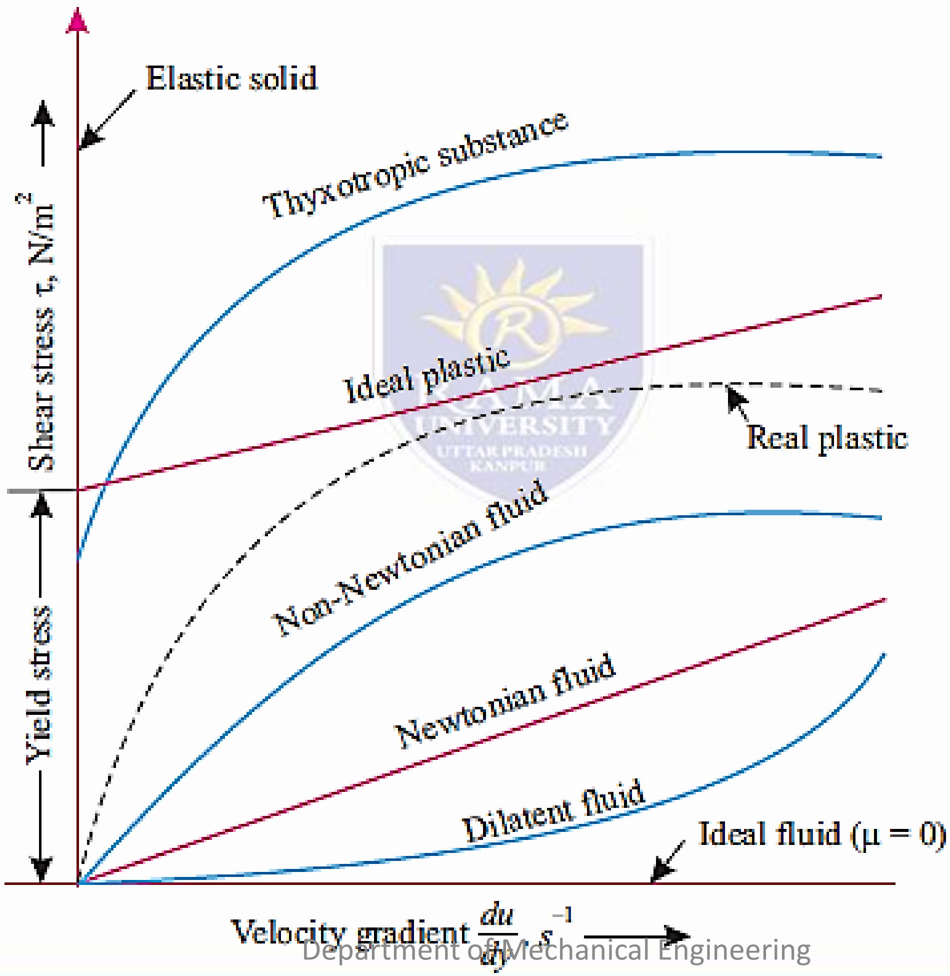
Microscopic and Macroscopic

- Macroscopic or *classical* approach: Does not require a knowledge of the behavior of individual molecules and provides a direct and easy way to analyze engineering problems.
- Microscopic or *statistical* approach: Based on the average behavior of large groups of individual molecules



Lecture -02
Rheology of fluids

- Rheology deals with the flow of complex fluids
- The objective of rheology is to determine the fluid flow that would be produced due to applied forces
- The objective of rheology is to predict the flow that would result in a given equipment under the action of applied forces.
- Rheology generally accounts for the behavior of non-Newtonian fluids, by characterizing the minimum number of functions that are needed to relate stresses with rate of change of strain or strain rates



Fluid types based on **Rheology**

- Fluids for which the apparent viscosity increases with the rate of deformation (such as solutions with suspended starch or sand) are referred to as *dilatant* or *shear thickening fluids*
- hose that exhibit the opposite behavior (the fluid becoming less viscous as it is sheared harder, such as some paints, polymer solutions, and fluids with suspended particles) are referred to as *pseudo plastic* or *shear thinning fluids*.
- Some materials such as toothpaste can resist a finite shear stress and thus behave as a solid, but deform continuously when the shear stress exceeds the yield stress and behave as a fluid. Such materials are referred to as Bingham plastics
- The **shear force** acting on a Newtonian fluid layer (or, by Newton's third law, the force acting on the plate) is

$$F = \tau A = \mu A \frac{du}{dy} \quad \text{(N)}$$

- Again A is the contact area between the plate and the fluid. Then the force F required to move the upper plate at a constant speed of V while the lower plate remains stationary is

$$F = \mu A \frac{V}{\ell} \quad \text{(N)}$$