

Rheology

Rheology

- **Rheology** is the science of flow and deformation of matter, especially liquids and semisolids.
- In **physical pharmaceuticals**, understanding rheology is crucial for:
 - Designing liquid formulations (e.g., syrups, emulsions, suspensions),
 - Semi-solids (e.g., creams, ointments, gels),
 - And ensuring proper processing, mixing, filling, and dispensing of products.

Rheology is important for:

- **Processing** (pumping, mixing, filling bottles)
- **Product performance** (e.g., spreadability of a cream, pourability of a syrup)
- **Stability** (sedimentation in suspensions, creaming in emulsions)

Newtonian Systems

- A **Newtonian system** is a fluid whose flow behavior follows **Newton's law of viscosity**, which means:
 - The viscosity remains constant regardless of the shear rate or the force applied.
 - The relationship between shear stress (F/A) and shear rate (du/dx) is linear.

Definition:

A Newtonian fluid is one for which the shear stress is directly proportional to the shear rate.

Mathematical Form (Newton's Law of Flow):

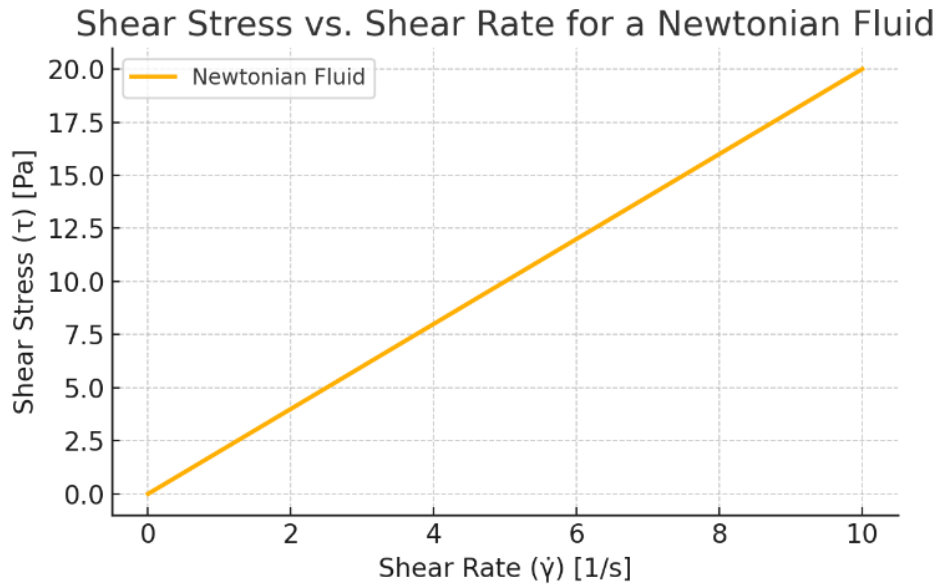
$$\tau = \eta \cdot \gamma$$

➤ Where:

- τ = shear stress (force per unit area, N/m^2 or $dynes/cm^2$)
- η = viscosity (resistance to flow)
- γ = shear rate (rate of change of velocity across the fluid)

Graphical Representation:

- If you plot:
 - **X-axis:** Shear rate γ
 - **Y-axis:** Shear stress τ



Examples in Pharmaceuticals:

- Water
- Ethanol
- Glycerin
- Some dilute solutions (e.g., dilute sugar or salt solutions)

Law of Flow (Newton's Law of Viscosity)

- This refers to the application of Newton's law in describing fluid behavior.

Newton's Law (Restated):

$$\frac{F}{A} = \eta \cdot \frac{du}{dy}$$

- Where:
 - F/A = applied force per area = shear stress (τ)
 - du/dy = velocity gradient = shear rate ($\dot{\gamma}$)
 - η (**eta**) = Viscosity (measure of internal resistance to flow)
- This law explains how a fluid flows under applied stress.

Assumptions for Newtonian Flow:

- Fluid layers move over each other with uniform velocity gradients.
- No yield stress (fluid begins to flow immediately upon stress application).
- Viscosity is constant at a given temperature and pressure.

Explanation:

- This equation states that the **shear stress (F)** needed to maintain flow in a fluid is directly proportional to the rate of shear.
- The constant of proportionality is the **viscosity**.

Units:

- Shear stress: dynes/cm² or Pascals (Pa)
- Shear rate: s⁻¹ (reciprocal seconds)
- Viscosity:
 - CGS system: poise (P), centipoise (cP)
 - SI system: Pascal-seconds (Pa·s)
 - 1 Pa·s = 10 P = 1000 cP

Kinematic Viscosity

Definition:

- Kinematic viscosity is the ratio of **dynamic viscosity** to the **density** of the fluid.

$$\nu = \frac{\eta}{\rho}$$

- Where:
 - ν = kinematic viscosity (units: m²/s or centistokes, cSt)
 - η = dynamic viscosity (e.g., poise, centipoise)
 - ρ = density of the fluid (e.g., g/cm³)

Why is it important?

- It relates viscosity to the physical mass of the fluid.
- It's especially important in flow meters and in hydrodynamics, where fluid movement is also affected by density.

Effect of Temperature on Viscosity

- Viscosity is inversely related to temperature – as temperature increases, viscosity usually decreases.

Why?

- At higher temperatures, the kinetic energy of molecules increases.
- This reduces intermolecular forces (less resistance to flow).



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