RHEOLOGY

1. **Based on the rheological behavior of fluid, all of the following shows time independent property, except [GPAT 2024]**

   (a) Anti-thixotropic
   (b) Plastic
   (c) Non-newtonian
   (d) Pseudoplastic

2. **Which of the following type of viscometer is used for the measurement of viscosity of a Newtonian fluid: [GPAT 2024]**

   (a) Ostwald viscometer
   (b) Brookfield's viscometer
   (c) Cup and bob viscometer
   (d) Pycnometer

3. **Suspensions containing a high percentage (about 50% or greater) of small deflocculated particles would show which of the following flow properties [GPAT-2023 SHIFT-I]**

   (a) Plastic flow
   (b) Dilatant flo
   (c) Newtonian flow
   (d) Pseudoplastic flow

4. **The system volume is increased when sheared is called [GPAT-2021]**

   (a) Dilatant flow
   (b) Newtonian flow
   (c) Plastic flow
   (d) Pseudoplastic flow

5. **When a solid forms a gel more readily when gently shaken or otherwise sheared than when allowed to form the gel while the material is kept at rest, the phenomenon is known as [GPAT-2020]**

   (a) Thixotropy
   (b) Rheopexy
   (c) Negative rheopexy
   (d) Anti thixotropy

6. **Which one of the following viscometers can be used for characterizing Non-Newtonian system [GPAT-2019]**

   (a) Falling sphere viscometer
   (b) Cup and Bob viscometer
   (c) Capillary viscometer
   (d) Hoppler viscometer

7. **Suspensions of starch in water exhibit [GPAT-2018]**

(a) Plastic flow
(b) Pseudoplastic flow
(c) Dilatant flow
(d) None of these

8. **Hoeppler viscometer is a type of [GPAT-2017]**

(a) Falling sphere viscometer
(b) Capillary viscometer
(c) Cup and Bob viscometer
(d) Cone and plate viscometer

9. **Which of the following are NOT true [GPAT-2016]**

[P] Pseudoplastic flow is exhibited by liquid dispersion of tragacanth
[Q] Dilatant material are also called Shear-thickening material
[R] Pseudoplastic flow is characterized by the yield value
[S] Dilatant flow is exhibited by flocculated particles

(a) [P], [Q]
(b) [R], [S]
(c) [P], [R]
(d) [Q], [R]

10. **Thixotropy in a plastic system indicates a gel-sol-gel transformation while negative thixotropy indicates [GPAT-2015]**

(a) Gel-sol-sol transformation
(b) Sol-gel-sol transformation
(c) Sol-gel-gel transformation
(d) Sol-sol-gel transformation

11. **Brookfield viscometer is [GPAT-2015]**

(a) Single point
(b) Rotational
(c) Falling sphere type
(d) Capillary type

12. **Pseudoplastic flow is generally exhibited by [GPAT-2015]**

(a) Viscous pastes
(b) Solutions of mucilages and gums
(c) Gellies
(d) Lotions

RHEOLOGY

INTRODUCTION

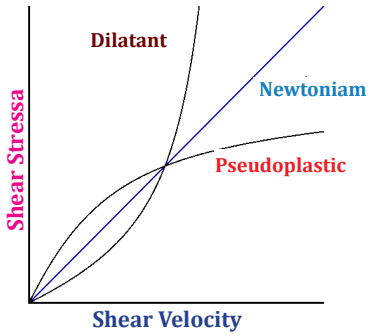
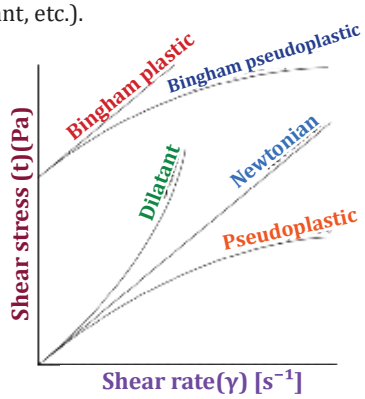
- The term **rheology** was suggested by Bingham and Crawford from the Greek words rheo ("to flow") and logos ("science").
- Rheology is defined as the science that deals with the **flow of liquids and the deformation of solids.**

Flow of Fluid

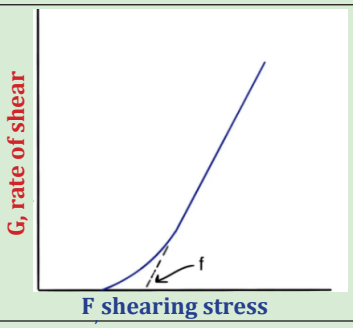
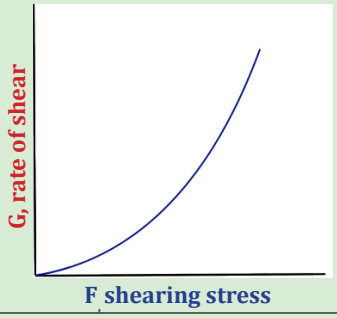
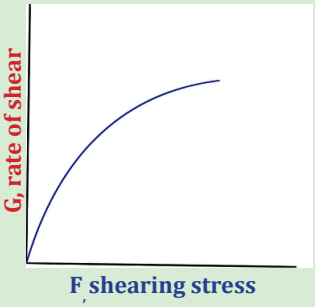
- **Newtonian Flow**
  - **Time Dependent**
    - Thixotropic
    - Rheopexy
- **Non-Newtonian Flow**
  - **Time Independent**
    - Plastic Flow
    - Pseudo Plastic Flow
    - Dilatant Flow

NEWTONIAN AND NON-NEWTONIAN SYSTEMS

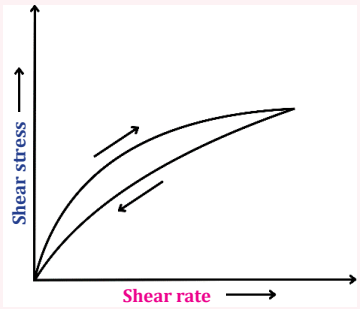
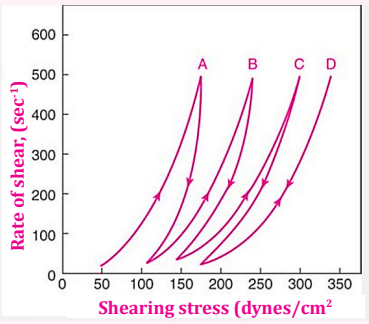
The primary distinction in fluid flow is based on its relationship to Newton's Law of Flow.

Newtonian Flow	Non-Newtonian Flow
Follows **Newton's law of viscosity** (shear stress is directly proportional to shear rate).	Does **not** follow Newton's law of viscosity.
$\eta = \frac{\text{Shearing stress (F)}}{\text{Rate of shear (G)}}$ **Formula:** $\eta = \frac{F}{G} = \frac{\frac{F'}{G}}{\frac{dv}{dr}}$  where: η= viscosity, F= shearing stress, G= rate of shear, F^'= applied force, A= area, dv/dr= velocity gradient	**No single general equation.** Relation between shear stress (τ) and shear rate dv/dr depends on type of flow (plastic, pseudo-plastic, dilatant, etc.). 
Viscosity remains **constant** irrespective of applied stress.	• Viscosity **changes** with applied stress or shear rate. • The rheology of non-Newtonian fluids can be determined using a **Brookfield viscometer**
Examples: Water, Glycerine, Chloroform, Castor oil, Olive oil, Ethanol, Syrup solution, Very dilute colloidal solution. • Viscous oils exhibit Newtonian flow.	**Examples:** Concentrated colloidal solutions, Emulsions, Suspensions, Ointments.

☐ Time-Independent Non-Newtonian Flow

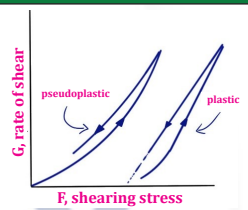
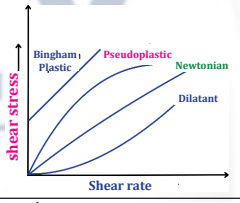
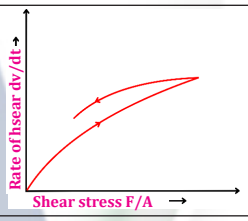
Property	Plastic Flow	Pseudoplastic Flow	Dilatant Flow
Definition / Description	Flow curves do not pass through origin. Material behaves like elastic solid until a yield value (f) is reached. Beyond this point, flow is linear like a Newtonian fluid. Term for plastic fluids = Mobility.	Curve starts at origin, no yield value. Viscosity decreases with ↑ shear rate (polymer chains align in direction of flow, reducing resistance).	Curve starts at origin, no yield value. Viscosity increases with ↑ shear rate (particles pack closely, more interparticle friction).
Also known as	Bingham Bodies	Shear Thinning System	Shear Thickening System
Yield Value	Present (must be exceeded for flow).	Absent.	Absent.
Viscosity Behavior	Viscosity remains constant after yield point → linear shear stress vs shear rate.	Viscosity ↓ decreases with ↑ shear rate.	Viscosity ↑ increases with ↑ shear rate.
Rheogram (Shear Stress vs. Shear Rate)	Line does not start at origin; extrapolated back to axis gives yield value ff. Slope = Mobility.	Starts at origin, concave downward curve.	Starts at origin, concave upward curve.
Graph			
Note	Exhibited by flocculated suspensions.z	Seen with natural & synthetic gums.	Seen with high conc. suspensions.
Examples	ZnO suspension in mineral oil, certain paints, ointments, concentrated flocculated suspensions.	Tragacanth, Sodium alginate, Methyl cellulose, Sodium CMC, polymer dispersions.	Corn starch suspensions, Kaolin in water, Zinc oxide in water, inorganic pigment suspensions.

☐ Time-Dependent Non-Newtonian Flow

Property	Thixotropy	Negative Rheopexy / Antithixotropy
Definition / Description	A phenomenon in which a solid forms a gel more readily when gently shaken or sheared than when allowed to form the gel at rest. **[AMC 2022]** It is a reversible Gel–Sol–Gel transformation. 	A Sol–Gel–Sol system where viscosity increases on the down curve. Also called Rheopexy (anti-thixotropy). 
System Type	Gel–Sol–Gel system	Sol–Gel–Sol system
Shear Behavior	Shear-thinning system → Viscosity decreases as function of time under shear, recovers when shear removed.	Shear-thickening system → Downward curve shifts right (viscosity increases with shear cycling).

Time Dependence	At rest: rigidity is like gel. Under shear: structure breaks, Gel → Sol. On standing: Sol → Gel again (structure re-stored).	Rheogram shows **anti-thixotropic behavior:** material sheared at increasing & decreasing shear rates → at stage D, further cycling does not change consistency (up & down curves coincide).
Rheogram	Hysteresis loop → **down curve shifted left** of upcurve. Indicates lower viscosity on return path.	Down curve shifted right of upcurve (anti-thixotropy).
Examples	Procaine penicillin G (40–70% w/v in water).	Low solid content (1–10%) flocculating systems; Magnesia magma at equilibrium forms solution.

☐ Thixotropic Effects on Various Flow Systems

Flow Type	Without Thixotropy	With Thixotropy	Example	Graph Needed
Plastic Flow (Bingham bodies)	Curve does not pass origin; requires yield value before flow starts; then linear.	Shows hysteresis loop (down-curve shifted left → viscosity ↓ under shear, recovers slowly).	Bentonite gel, Petrolatum	
Pseudoplastic Flow (Shear-thinning)	Viscosity ↓ with ↑ shear (no yield value).	With thixotropy → additional viscosity loss over time under shear; hysteresis loop forms.	Tragacanth, Sodium alginate, Methylcellulose dispersions	
Dilatant Flow (Shear-thickening)	Viscosity ↑ with ↑ shear (suspensions of high solids).	With thixotropy → after shear removal, viscosity recovers slowly (Gel ↔ Sol).	Quicksand, Corn starch suspension	

Determination of Rheological Properties (Viscometers)

Viscometer	Rheology	Examples
Single point viscometer	For Newtonian flow	Falling sphere viscometer, Capillary viscometer
Multi point viscometer	For non-Newtonian flow	Cup and bob, Cone and plate

Viscometer	Name	Principle / Method	Application / Used For
Capillary Viscometer	**Ostwald Viscometer**	The time of flow of the test liquid under gravity through a capillary is compared with the time required for a liquid of known viscosity. Based on **Poiseuille's law.** **Relative Viscosity (Comparison Method)** **Poiseuille's Law** $\eta = \frac{\pi r^4 t \Delta P}{8LV}$ $\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2}$	Measurement of viscosity for Newtonian fluids.
Falling Sphere Viscometer	**Hoeppler Viscometer**	The time for a ball to fall between two marks is measured. The instrument can be used over a range of 0.5 to 200,000 poise.	Measurement of viscosity for Newtonian fluids.

Rotational Viscometer	**Cup and Bob Viscometer**	The torque required to rotate the "bob" in the liquid-filled "cup" is measured. A multipoint viscometer used to determine viscosity. Torque ∝ viscosity ($Z \propto \eta$)	For both Newtonian and Non-Newtonian fluids. Determines viscosity, yield value, and thixotropy.
	Cone and Plate Viscometer	The sample is sheared between a stationary plate and a rotating cone.	Rheological evaluation of some pharmaceutical semisolids.
Brookfield Viscometer	**T – spindle (Spindle type)**	The torque required to rotate a spindle in a fluid indicates the viscosity of the fluid.	Rheological properties of suspensions.

EXAM PUNCH

- The temperature dependence of viscosity is expressed by the **Arrhenius equation of chemical kinetics.**
- At equal concentrations, **potato starch** mucilage will possess the maximum viscosity compared to maize, rice, or wheat starch.
- **Sodium Carboxy Methyl Cellulose (SCMC)** is an agent used to increase the viscosity of a liquid.

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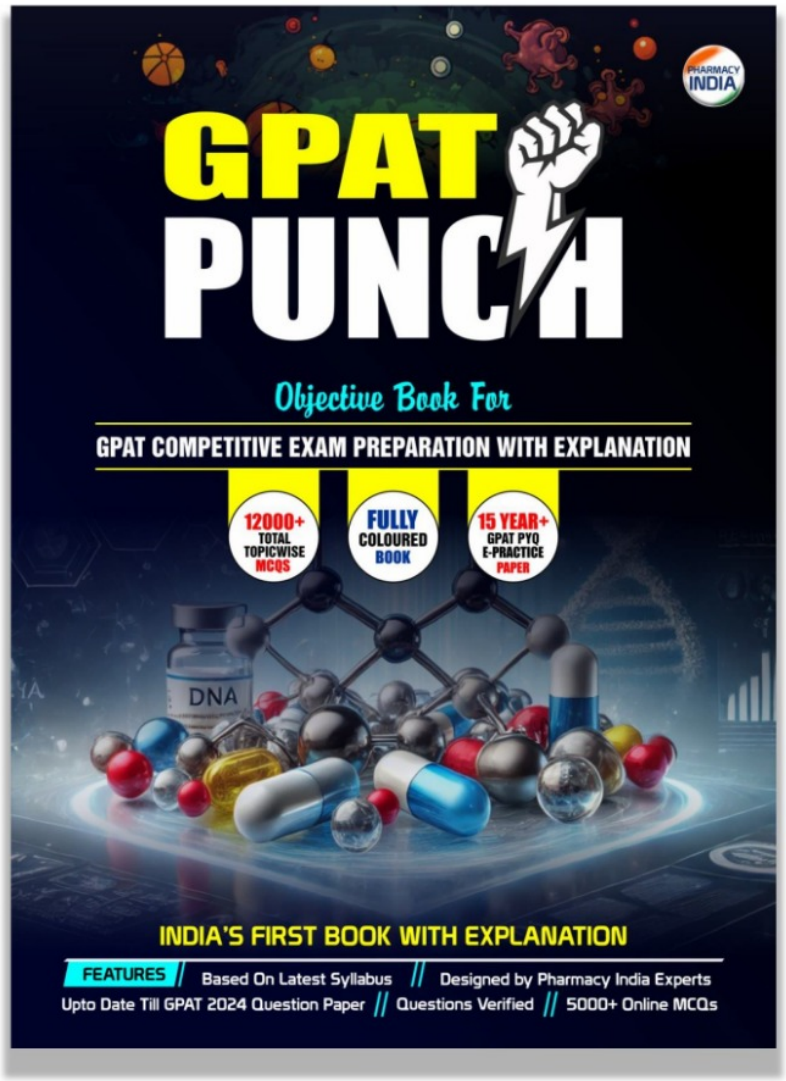

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