Rheology, Newtonian law, viscosity, thixotropy & determination of viscosity

BP 403T
Physical Pharmaceutics-I
Unit 2 (Part-I)

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Rheology

•Rheo – to flow

•logos – science

•Rheology is the study of the flow and deformation of matter

•Rheology is the science/physics that concerns with the flow of liquids and the deformation of solids under stress.

• Study of flow properties of liquids is important for:

❖ Manufacturing of dosage forms: simple liquids, gels, ointments, creams, and pastes.

❖Handling of drugs for administration: Storage, packaging and

usage.

IMPORTANCE OF RHEOLOGY

It has Wide application in Manufacturing of dosage forms & Handling of drugs for administration.

- Formulation of emulsions, suspensions, suppositories, and tablet coating.
- Formulation of medicinal and cosmetic creams, pastes and lotions.
- Fluidity of solutions for injection.
- In mixing and flow of materials, their packaging into the containers,
- Extrusion of a paste from a tube .

- Passage of the liquid to a syringe needle

Newtonian flow or law of Rheology

- Newton's viscosity law's states that, the shear stress between adjacent fluid layers is proportional to the velocity gradients between the two layers.
- The ratio of shear stress to shear rate is a constant, for a given temperature and pressure, and is defined as the viscosity or coefficient of viscosity.
- $F \propto G$ or $F = \eta G$
- Where F= Shear Force and G= rate of shear

Viscosity

Viscosity is defined as the resistance in the flow of liquid. It is also defined as the internal friction between two layers of liquid which resists the flow of liquid. It is denoted by: (η), also known as Viscosity coefficient.

Unit: Poise

Kinematic Viscosity

- It is dependent on the absolute viscosity & density of the system.
- It is the ratio of the absolute viscosity of the system (liquid) to the density of the liquid.
- Denoted by: $\nu = \mu / \rho$
- Unit Stoke and Centistoke

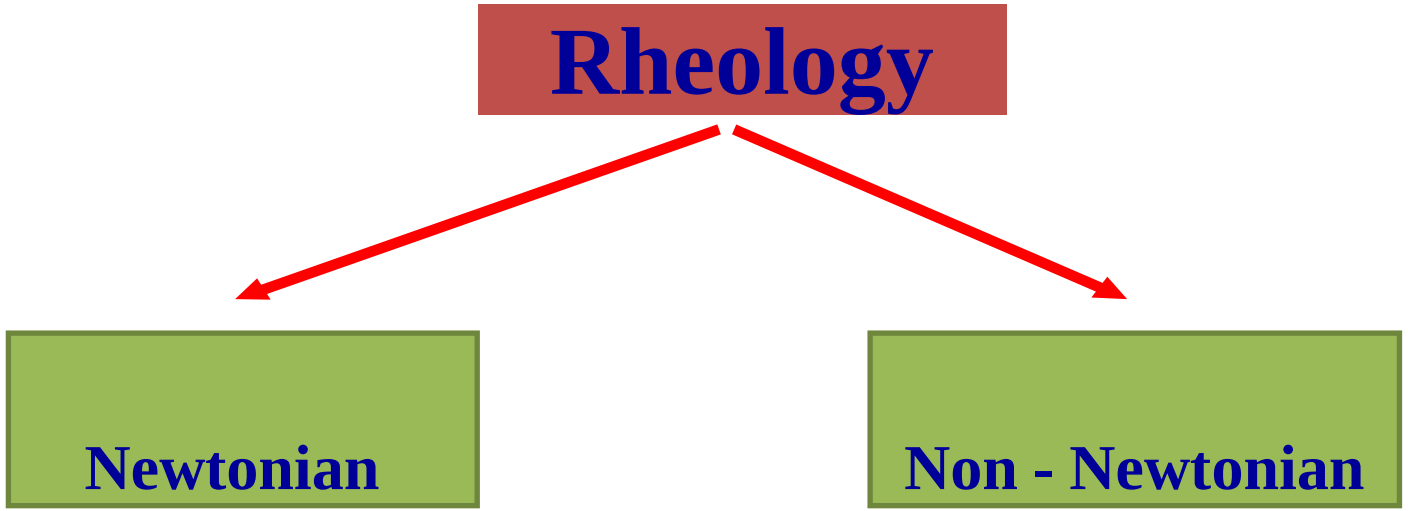
Factors affecting Viscosity

- Size of molecules
- Shape of the molecules
- Inter-molecular forces
- Temperature of the system

Effect of Temperature on Viscosity

- As we know viscosity is the magnitude of intermolecular forces
- As we increase temp. ⟹ The kinetic energy is provided to molecule.
- Resulting in random movement of the molecules, generating higher collision.
- The intermolecular force is reduced ⟹ hence viscosity reduced

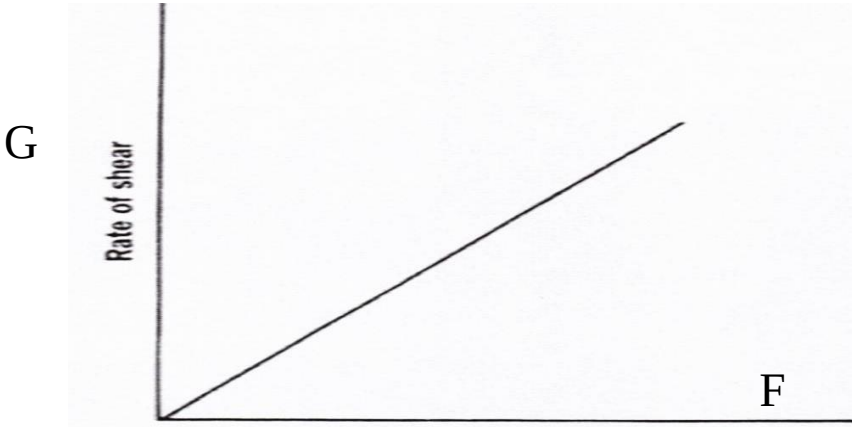
Newtonian and Non-Newtonian Flows



Newtonian Flow

- Newton was the first to study the flow properties of liquids in quantitative terms. Liquids that obey Newton's law of flow are called as *Newtonian fluids.*

$F = nG$



Non-Newtonian Flow

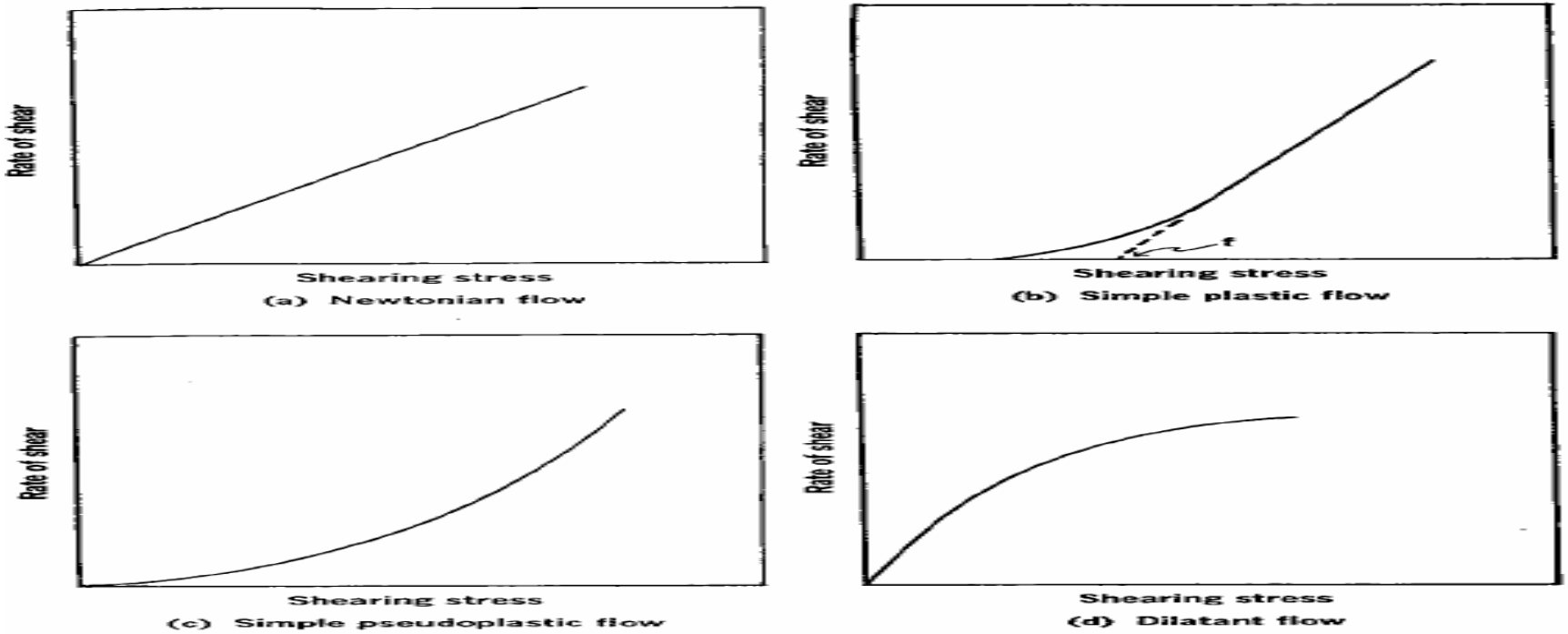
- Non - Newtonian bodies are those substances, which fail to follow Newton's law i.e. liquid & solid , heterogeneous dispersions such as colloidal solutions, emulsions, liquid suspensions and ointments.

They are classified into 3 types of flow:

- Plastic.
- Pseudoplastic.

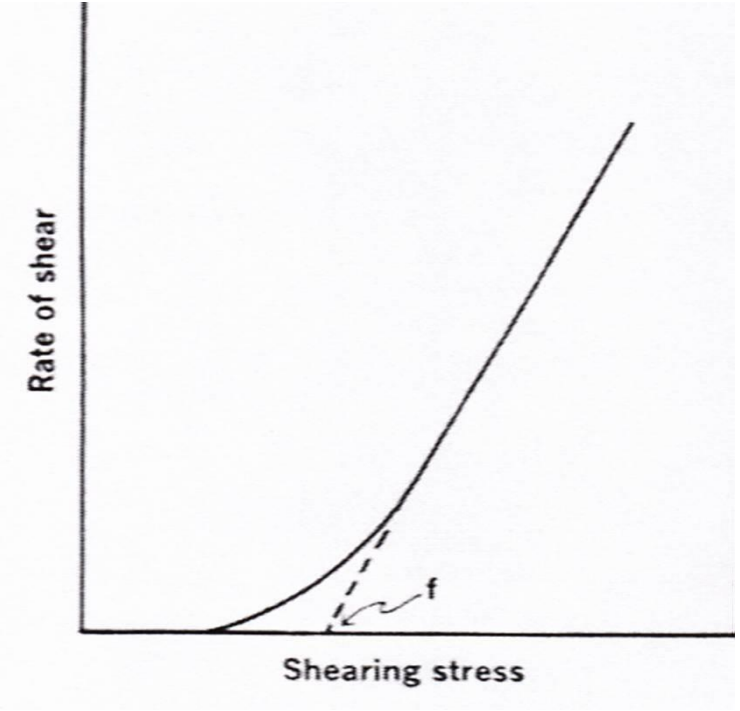
- Dilatant.

Rheograms of different fluids



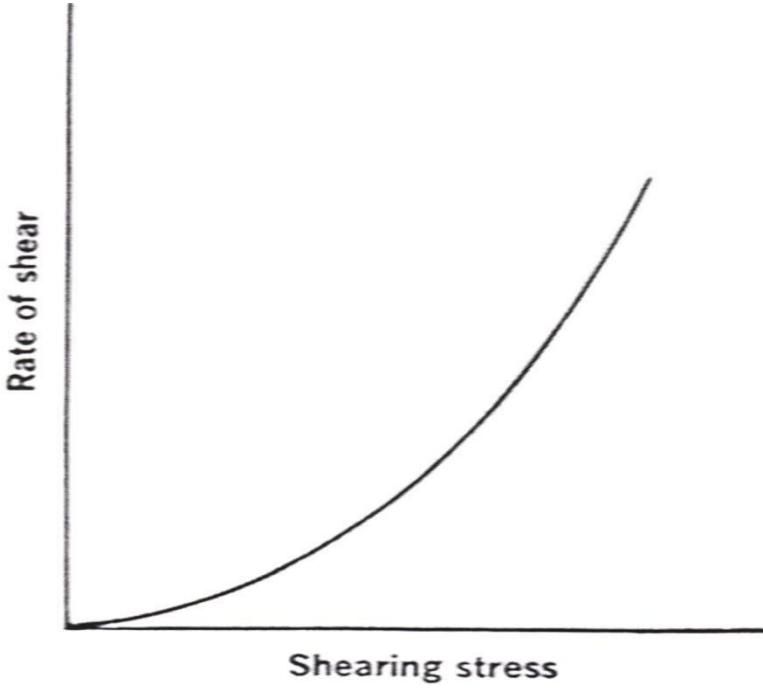
Plastic Flow

- The plastic flow curve does not pass through the origin & it intersects the shearing stress axis (or will if the straight part of the curve is extrapolated to the axis) at a particular point referred to as ***yield value***. (f).



Pseudoplastic Flow

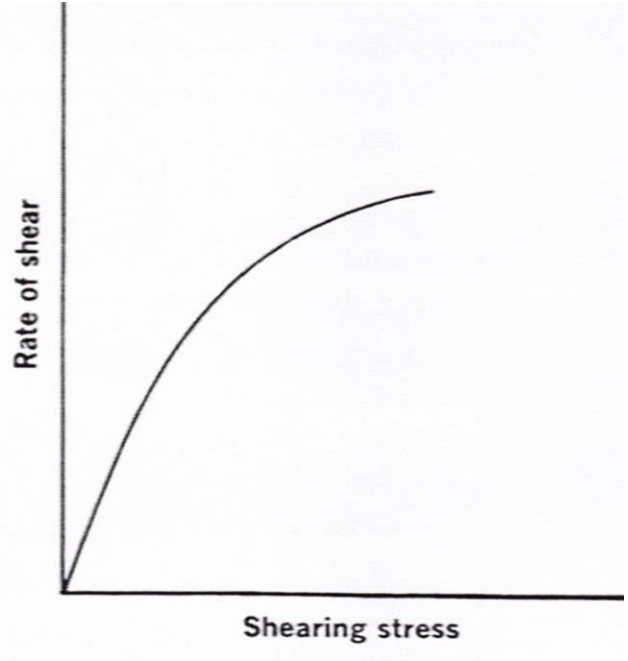
- The curve for a pseudoplastic material begins at the origin (or at least approaches it at low rates of shear).
- The curved rheogram for pseudoplastic materials is due to shearing action on the long chain molecules of materials



such as linear polymers.

Dilatant Flow

- Certain suspensions with a high percentage of dispersed solids exhibit an in resistance to flow with increasing rates of shear.
- Such systems actually increase in volume when sheared & are called
- dilatant. Dilatant materials "shear thickening systems."



When the stress is removed, a dilatant system returns to its original state of

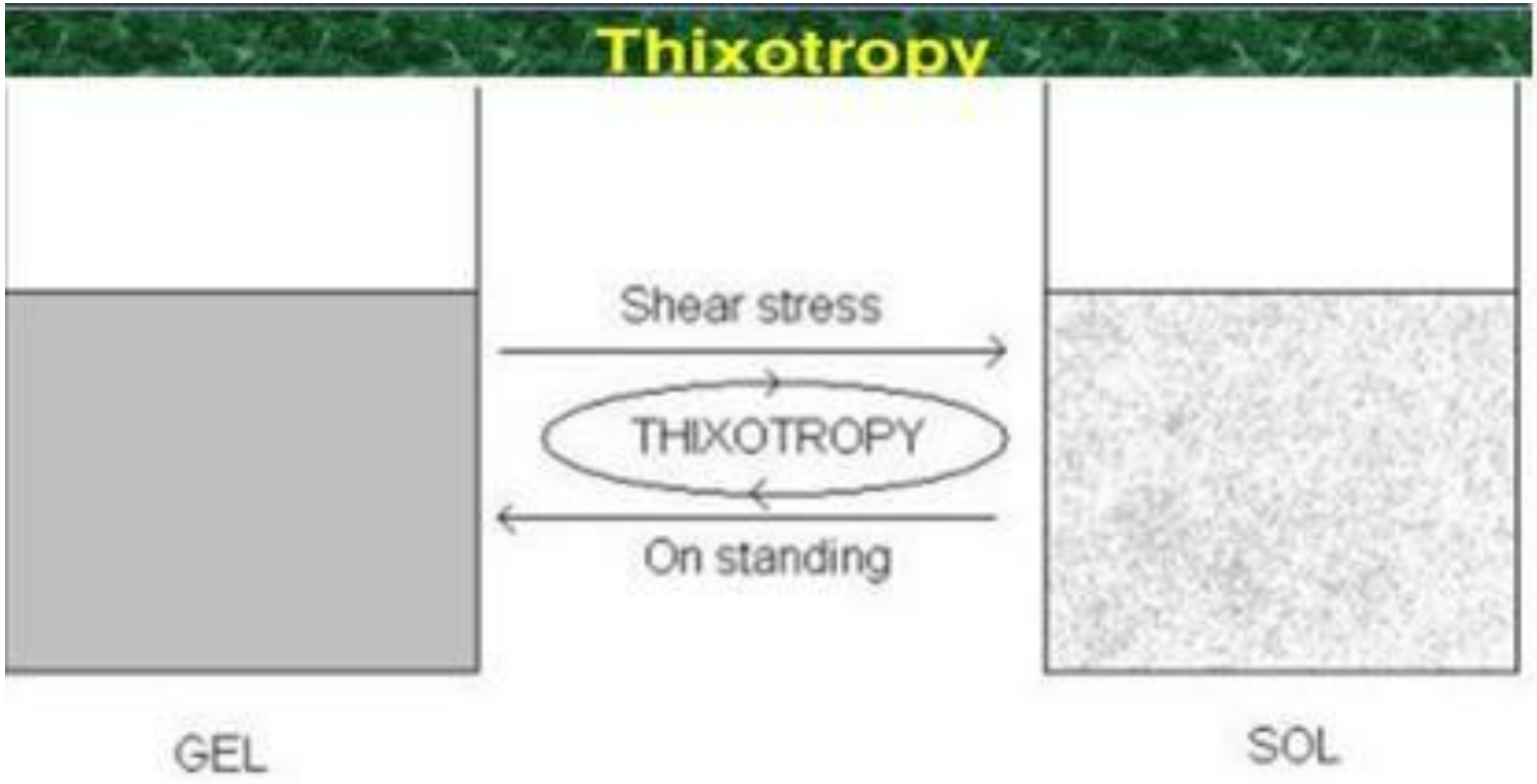
fluidity.

Thixoptopy

It is defined as, isothermal and comparatively slow recovery on standing of material of a consistency lost through shearing.

It is shear thinning system, when agitated and kept aside it is expected to return its original state of

fluidity.


Thixotropy
Shear stress
THIXOTROPY
On standing
GEL
SOL

Pharmaceutical Application of Thixotropy

The time-dependent change in viscous nature of thixotropy finds its major applications in pharmaceutical formulations including:

- Hydrogel,
- Ointment,
- Suspensions, and
- Emulsions.

Through various routes including:

- Oral,
- Topical,
- Ophthalmic, and
- Mucosal administration.

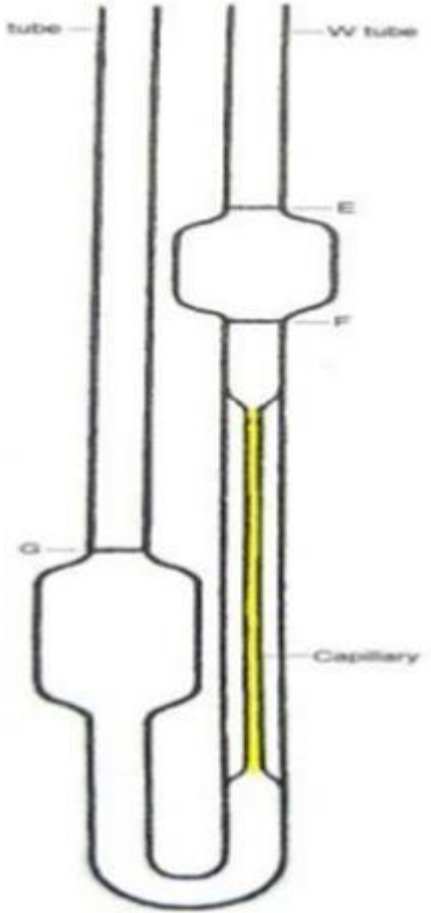
Determination of viscosity

Viscometer	
Single/One point: At a single rate of shear one point on the curve	**Multipoint:** Several rates of shear many points on the curve
Equipment: 1) Ostwald viscometer 2) Falling sphere viscometer	**Equipment:** 1) Cup and bob 2) Cone and plate
Applications: • Newtonian fluids	**Applications:** • Non-Newtonian fluids • Newtonian fluids

Ostwald Viscometer

Capillary Viscometer

- Ostwald viscometer is used to determine the viscosity of a Newtonian liquid. Both dynamic and kinematic viscosities can be obtained.



Principle: When a liquid flows by gravity, the time required for the liquid to pass between two marks (E and F shown in Figure) through a vertical capillary tube is determined.

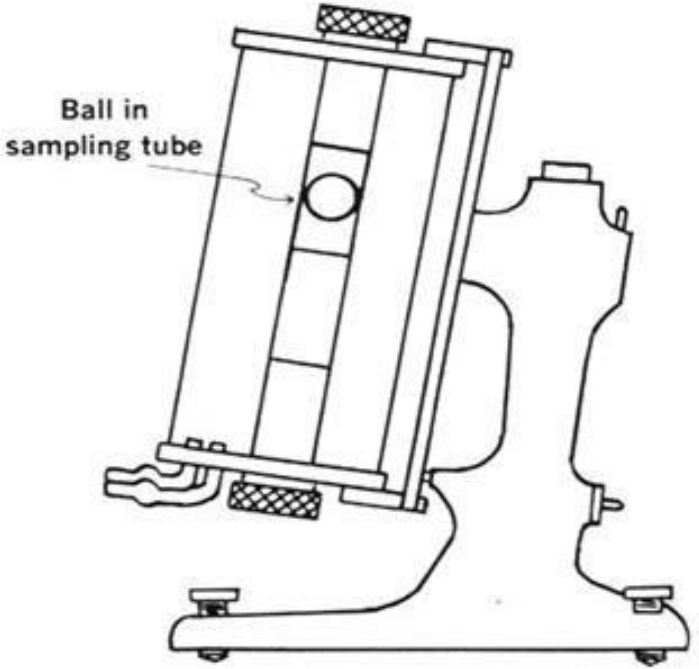
$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2}$$

η = viscosity (cP or mPa sec)

ρ = density (g cm^{-3})

Falling SphereViscometer

- The sample & ball are placed in the inner glass tube & allowed to reach temperature equilibrium with the water in the surrounding constant temperature jacket.
- It is called as Hoeppler falling sphere viscometers.



•**Procedure:** The tube & jacket are then inverted, which effectively places the ball at the top of the inner glass tube.

• The time for the ball to fall between two marks is accurately measured & repeated several times.

Construction:

Glass tube position vertically. Constant temperature jacket with Water circulation around glass tube

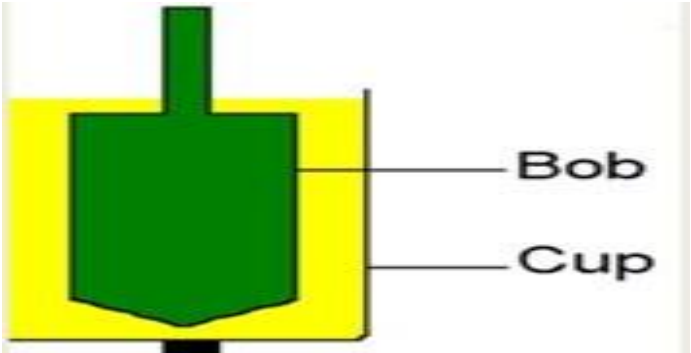
$$\eta = t \quad (Sb - Sf) \quad B$$

Cup and BOB Viscometer

- This is a multipoint viscometer and belongs to the category of rotational viscometers.
- The sample is placed in the cup and the bob is placed in the cup up-to an appropriate height.

Working: The test sample is place in space between cup and bob & allow to reach temperature equilibrium.

A weight is place in hanger and record the time to make 100 rotations by bob, convert this data to rpm.



This value represents the shear rate, same procedure repeated by increasing weight.

•The sample is accommodated between the gap of cup and bob.

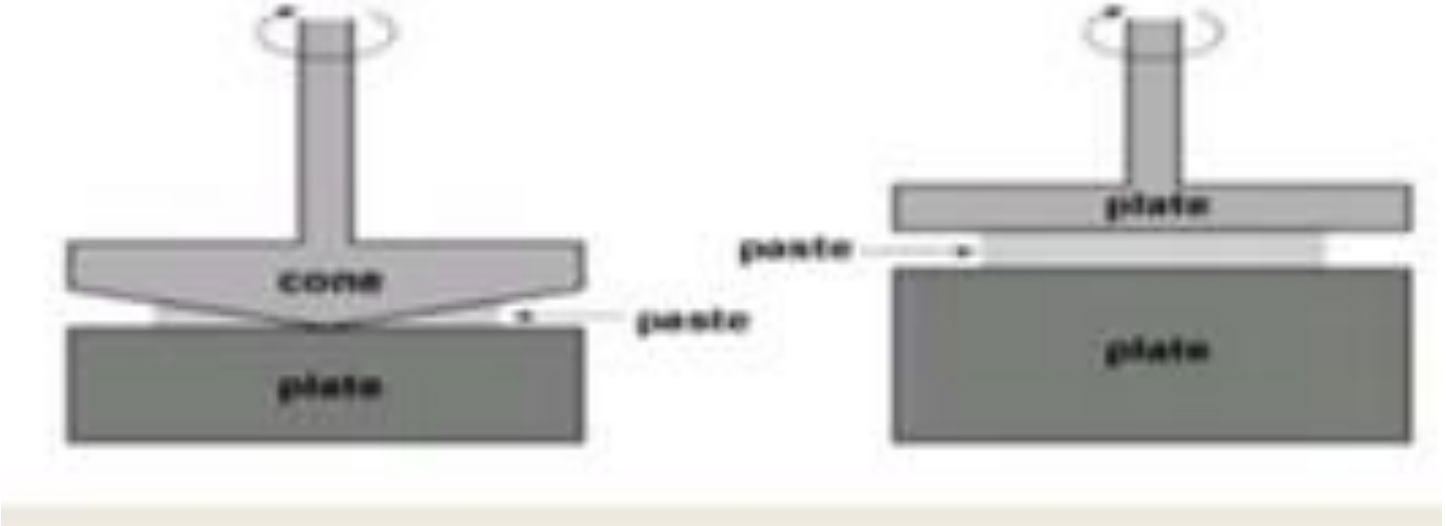
• Cup or bob is made to rotate and
the torque is measured by a spring or sensor in the
Ex. Stormer viscometer

Cone and plate Viscometer

- The sample is placed at the center of the plate which is then raised into position under the cone.
- **Principle:** The sample is placed on at the center of the plate, which is raised into the position under the cone.
- The cone is driven by variable speed motor and sample is sheared in the narrow gap between stationary plate and rotating cone.
- Rate of shear in rpm is increased & decrease by selector dial and viscous traction or torque (shearing stress) produced on the cone.

❖The cone is driven by a variable speed motor & the sample is sheared in the narrow gap between the stationary plate and the rotating cone.

❖The torque is measured by a selector dial.



THANK YOU