FLUID MECHANICS

Classification of Fluids:-

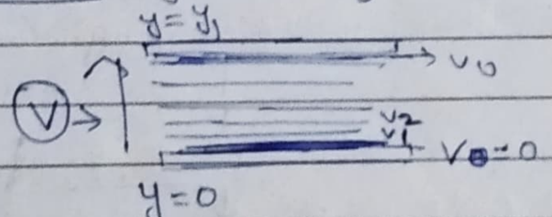
Compressible fluids:-	Incompressible fluids:-
(i) large change in density w.r.t temperature	(i) Moderate change in density w.r.t temperature.
eg:- Gases	eg:- Liquids.

Fluids:-

It is the substance that deform continuosly due to the application of shear stress.

$$\text{Stress} = \left(\frac{F}{A}\right)$$ ↳ Pressure when F is ⊥ to surface.

Newton's Law of Viscosity:-



$V_2 > V_1$

$V_1 \neq 0$

☆ difference in velocity along y is due to viscosity:-

- Newton's law states that Shear stress is directly proportional to velocity gradient

$$\frac{F}{A} = \tau \propto \frac{du}{dy}$$

du ↗ Rate of shear strain.

dy ↳ velocity gradient

Shear stress

$$\boxed{\tau = \mu \frac{du}{dy}}$$

μ = Coefficient of viscosity

unit of viscosity $(\mu) = \frac{Kg}{M\,S}$

$$\frac{Kg\,\cancel{M}\,S^{-2}}{M^{\cancel{2}}} = (\mu)\,\frac{\cancel{M}\,S^{\cancel{-1}}}{\cancel{M}}$$

$$\mu = \frac{Kg}{M\,S}$$

$$\text{Poise} = \frac{gm}{cm\ sec}$$

$$\boxed{\text{Centipoise} = 10^{-2}\ \text{Poise}}$$

Classification of fluids on basis of Newton's law of viscosity.-

Fluid

- **Newtonian fluids**

  Those fluids which follow Newton's law of viscosity are referred as Newtonian fluid

  eg:- water, air, gasoline, likwise.

- **Non-newtonian fluids**

  Those fluids which do not follow Newton's law of viscosity are referred as Non-Newtonian fluids.

  eg:-> Sugar Solution, salt solution, blood.

Non Newtonian fluids

- Time Independent
  - Dilatent
  - Pseudoplastic
  - Bingham Plastic
- Time Dependent
  - Thixotropic
  - Rheopectic

Non Newtonian fluids follow Power Law

Power Law

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

★ A & B are constants and depend on fluid

Dilatent fluid:-

$n>1 \quad B=0$

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

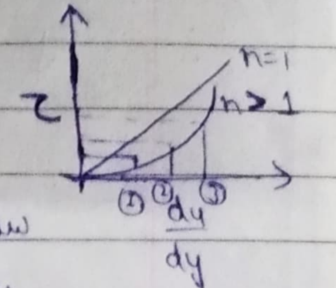
$$\tau = A\left(\frac{du}{dy}\right)^n$$

$$\underbrace{\tau = A\left(\frac{du}{dy}\right)^{n-1}}_{\mu_{app} \to \mu_{apparent}} \frac{du}{dy}$$

Comparing with Newton's law

↳ Rate of deformation / velocity gradient $\tau = \mu \frac{du}{dy}$

➤ Such types of fluids are called shear rate thickening fluid.



eg:- Salt solution
Sugar solution

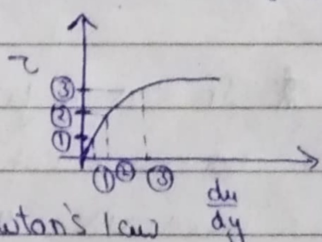
PseudoPlastic fluid

$n<1 \quad B=0$

$$\tau = A\left(\frac{du}{dy}\right)^n + \cancel{B}^{\,0}$$

$$= A\left(\frac{du}{dy}\right)^n \quad n<1$$

➤ Such types of fluids are called shear rate thinning fluid.



$$\tau = A\left(\frac{du}{dy}\right)^{n-1}\left(\frac{du}{dy}\right)$$ Comparing with Newton's law

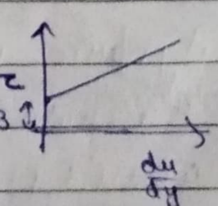
$$\tau = \mu_{app}\left(\frac{du}{dy}\right)$$

eg: Polymeric solution, Pulp

Bingham Plastic

$n=1 \quad B \neq 0$

$$\tau = A\left(\frac{du}{dy}\right) + B$$



eg:- Gypsum

Time Dependent fluid

Thixotropic fluids:- $(\mu\downarrow, t\uparrow)$

Those fluids whose ~~viscosity~~ viscosity decreases with time is called Thixotropic fluids.

eg: Paints, Lipstick.

Rheopectic :- ($\mu\uparrow$, $t\uparrow$)

Those fluids whose viscosity increases with time is called Rheopectic.

eg:- Bentonite Clay Solution in H_2O

μ = Absolute Viscosity $\left(\frac{gm}{cm\ sec}\right)$ = Poise

Kinematic Viscosity

$= \frac{\mu}{\rho} \left(\frac{cm^2}{sec}\right)$ = Stoke.

★ In case of liquid as we increase the temperature, the intermolecular forces weakens and viscosity decreases.

★ In case of gases, due to Intermolecular collision, the ~~momentum~~ (cohesive force not considered) momentum transfer increases, the viscosity increases.

Ques:- Space between two square parallel plates is filled with oil each side of plate is 60 cm. Thickness of oil filled is 12.5 mm. The upper plate which moves at 2.5 m/sec requires a force of 98.1 N. To maintain this speed. Calculate:-

dynamic viscosity of oil in poise.

Kinematic " of oil in stokes if specific gravity is 0.95.

$$\frac{F}{A} = \mu \frac{du}{dy}$$

$$\frac{\mu}{\rho} = \frac{13.625}{0.950}$$

$$= 14.34\ cm^2/s = \text{stokes}$$

$$\frac{98.1}{60 \times 60 \times 10^{-4}} = \mu \frac{2.5 \times 10^{2}}{12.5 \times 10^{-1}}$$

$$\Rightarrow 1.3625\ Ns/m^2$$

$$= 13.625 \text{ poise}$$

$$\mu = 65.4\ \frac{Kg}{m\ sec} = 654\ \frac{gm}{cm\ s}$$

Dt. ______
Pg. ______

Compressibility :- (β)

$$\beta = \frac{1}{K}$$

$$K = \frac{\text{Stress}}{\text{Vol. strain}} = \frac{P}{\left(-\frac{dv}{v}\right)}$$

$$m = \rho V$$
$$0 = \rho dV + V d\rho$$
$$\rho dV = -V d\rho$$
$$-\frac{dV}{V} = \frac{d\rho}{\rho}$$

$$K = \frac{P}{\left(-\frac{dv}{v}\right)}$$

$$\boxed{K = \frac{\rho P}{d\rho}}$$

$$\beta = \frac{1}{K}$$

$$\boxed{\beta = \frac{1}{\rho}\frac{d\rho}{P}}$$

(1) $\beta = 0$; $d\rho = 0$
ρ = constant

★ In incompressible fluids density does not change

(2) $\beta \neq 0$ $d\rho \neq 0$

Compressible

→ eg: Gas

$$C = \sqrt{\frac{K}{\rho}}$$ ρ = density of fluid

Speed of Sound or speed of pressure wave
K = Bulk Modulus

$$\text{Mach Number (Ma)} = \frac{V_{fluid}}{C}$$

Mach Number < 1 Sub Sonic flow

Mach Number = 1 Sonic flow

Mach Number > 1 Supersonic flow

Value of c in Adiabatic condition

Isothermal condition.