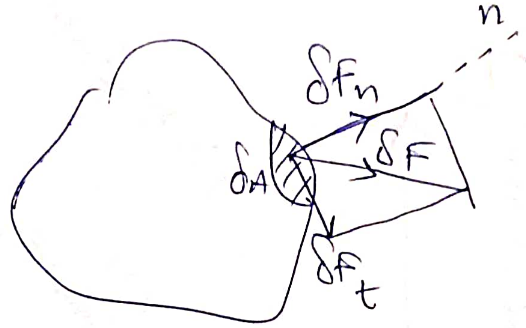
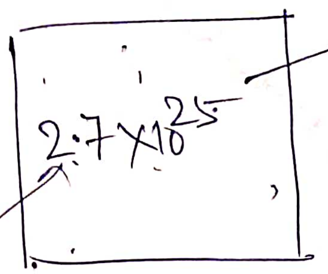
Fluid Properties

Normal stress $\sigma = \lim_{\delta A \to 0} \left(\frac{\delta F_n}{\delta A}\right)$

Shear stress, $\tau = \lim_{\delta A \to 0} \left(\frac{\delta F_t}{\delta A}\right)$



Concept of Continuum



vol (V) = 1 m³

This is the sufficient number to consider gases are continuous in nature

No. of molecules in most gases.

<u>Mean free path (λ)</u>: The distance b/w the molecules i.e. this the distance which each molecule travel before collision with another molecules.

L → characteristic length

Knudsen No $(K_n) = \frac{\lambda}{L}$

$K_n > 0.01$,	Concept of continuum does not hold good.
$0.01 < K_n \leq 0.1$	slip flow
$0.1 < K_n \leq 10$	transition flow
$K_n > 10$	free molecule flow

<u>Newton's law of Viscosity</u> $\tau = \mu \frac{du}{dy}$

<u>Causes of viscosity</u>: (i) intermolecular force of cohesion
(ii) molecular momentum exchange

Ideal fluid (or Inviscid fluid): $\mu = 0$

<u>Non-Newtonian fluid</u> (Power law model or Ostwald-de Waele model)

$$\tau = m\left(\frac{du}{dy}\right)^{n-1}\left(\frac{du}{dy}\right)$$

where m = flow consistency index
n = flow behaviour index

Diffⁿ b/w μ or ν :

$\mu \rightarrow$ Dynamic Viscosity
$\nu \rightarrow$ Kinematic viscosity
μ represents molecular friction within the fluid itself while ν represents depth of penetration of disturbance within the liquid.

$$\nu = \mu / \rho$$

No slip Condition of viscous fluid

When a fluid flow over a solid surface, the fluid elements adjacent to the surface attain the velocity of the surface i.e. relative velocity b/w the solid surface and the adjacent fluid particle is zero. This condition is called no slip condition.

Diffⁿ b/w no slip condition and wetting property of fluid

The wetting property results from surface tension, whereas the no-slip condition is a consequence of fluid viscosity.
eg. Mercury flowing in a stationary glass tube will not wet the surface, but will have zero velocity at the wall of the tube.

Bulk modulus of elasticity (E) ; Compressibility (K)

$$E = \lim_{\Delta V \to 0} \frac{-\Delta p}{\frac{\Delta V}{V}}$$

for a given mass of a substance,

$$\frac{\Delta V}{V} = -\frac{\Delta \rho}{\rho}$$

$$E = \lim_{\Delta \rho \to 0} \frac{\Delta p}{\frac{\Delta \rho}{\rho}} = \rho \frac{dp}{d\rho}$$

for gases, E is high, $E \to \infty$

$E_{water} = 2 \times 10^6 \ kN/m^2$

$E_{air} = 101 \ kN/m^2$

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

K is usually defined for gases,

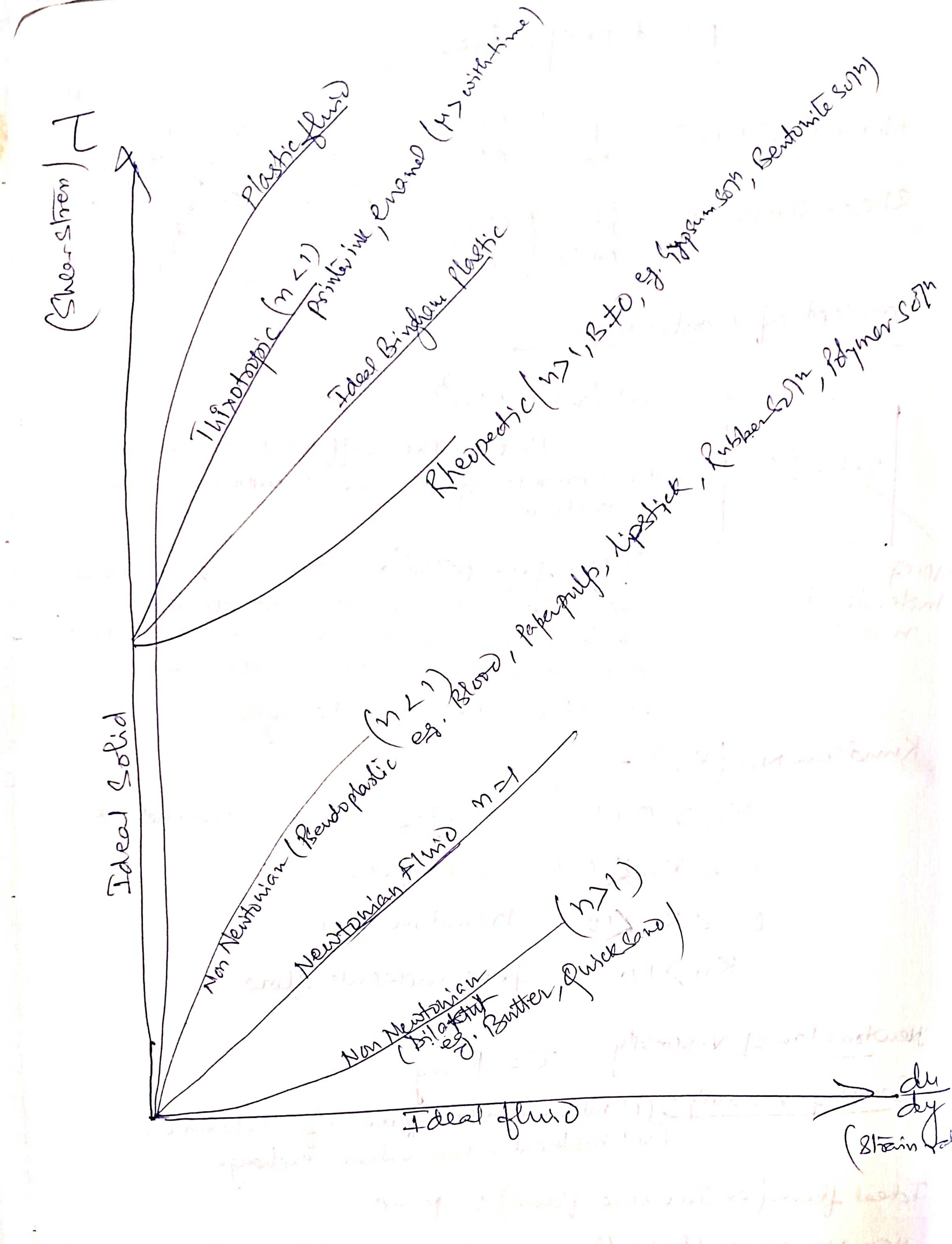
$$K = \frac{1}{\rho}\frac{d\rho}{dp} = -\frac{1}{V}\left(\frac{dV}{dp}\right)$$

Compressible & Incompressible flow

$$M_a \leq 0.33 \quad \Rightarrow \quad \frac{\Delta \rho}{\rho} \leq 5\%$$

Mach No.

When the flow velocity is equal to or less than 0.33 times of the local acoustic speed, flow is incompressible.



(Shear-stress) τ
Plastic fluid
Printer ink, enamel (μ ↑ with time)
Thixotropic (n < 1)
Ideal Bingham Plastic
Rheopectic (n > 1, B ≠ 0, eg. Gypsum soln, Bentonite soln)
eg. Blood, paper pulp, lipstick, Rubber soln, Polymer soln
Non Newtonian (Pseudoplastic (n < 1)
Newtonian Fluid n = 1
Non Newtonian (Dilatant) (n > 1)
eg. Butter, Quick sand
Ideal Solid
Ideal fluid
du/dy
(Strain rate