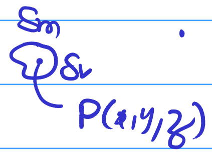
Properties of a fluid

1. **Density of fluid**: mass of fluid within unit volume of the fluid

$$\rho = \lim_{\delta v \to 0} \frac{\delta m}{\delta v}$$ (provided limit exist)



$\rho = \rho(x, y, z, t)$

For gas, (ideal gas) $p = \rho RT$ → $pv = RT$, Eqn of state

actual or real gas. different model - (i) $p = (1+b\rho)\rho RT$

(ii) $p = \frac{\rho RT}{(1-b\rho)}$

Vanderwaals Eqn of state

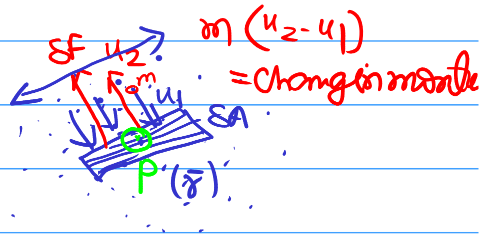
$$\left(p + \frac{a}{v^2}\right)(v - b) = RT \quad , \quad v = \frac{1}{\rho} = \text{specific volume of gas}$$

a, b constant

(2) Specific volume - volume occupied by unit mass of the fluid

$$v_s = \frac{1}{\rho}$$

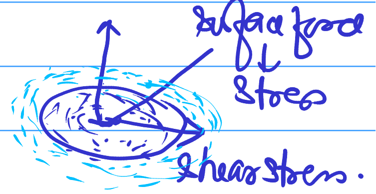
(3) Pressure
- in fluid at rest
- in moving fluid

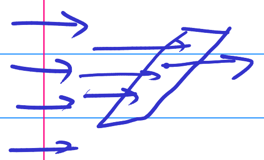


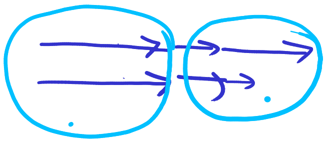
pressure = normal stress

$$\text{pressure} = \lim_{\delta A \to 0} \frac{\delta F}{\delta A} \text{, (if limit exist)}$$

$$= p(\bar{r}, t) = p(x, y, z, t)$$

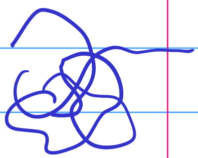


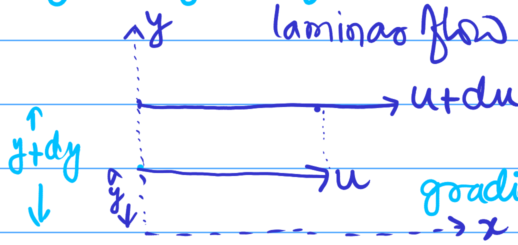




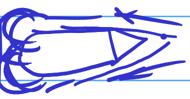
(4) Viscosity of the fluid

A property of fluid which gives rise to shear stress or relative motion b/w different layers of the fluid is called viscosity of the fluid





transverse velocity gradient $= \frac{du}{dy}$



shear stress $\tau \propto$ transverse velocity gradient

$\tau \propto \frac{du}{dy}$ $\qquad$ $u =$ velocity $= \frac{\text{displacement}}{\text{time}}$

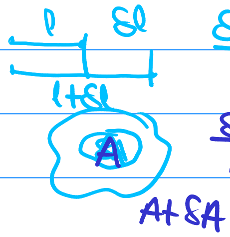
$\tau = \mu \frac{du}{dy}$ $\qquad$ Newton's law of viscosity (1)

$\mu =$ coefficient of dynamic viscosity : char. of fluid

Newtonian fluid – fluid which follow Newton's law of viscosity

– others non-newtonian fluid.

$\mu = \frac{\tau}{(du/dy)} = \frac{\text{shear stress}}{\text{shear strain}}$



$\frac{\delta l}{l}$ $\qquad$ $\frac{\delta A}{A}$

(i) $\tau = 0 \Rightarrow \mu = 0$, (1) exp ideal fluid or perfect

(ii) $\frac{du}{dy} = 0 \Rightarrow \mu = \infty$, (1) " elastic bodies.

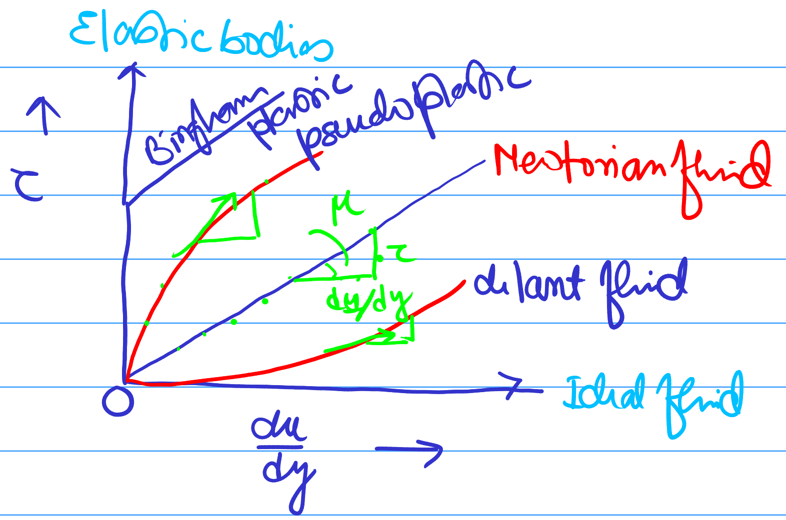
(iii) $\mu =$ Constant, Newtonian fluid

(iv) $\mu =$ not constant, Non Newtonian fluid.

(a) Bingham plastic

(b) Pseudo fluid

(c) Dilatants



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

$\mu = \mu(\rho, T)$

\# For gas, $\mu \uparrow$ with $T \uparrow$
liquid $\mu \downarrow$ with $T \uparrow$

L, T, M, θ, ...

\# Dimension of μ:

$$[\mu] = \frac{[\tau]}{[\frac{du}{dy}]} = \frac{MLT^{-2}/L^2}{LT^{-1}/L} = ML^{-1}T^{-1}$$

unit of μ: $N \cdot m/sec^2$

\# Kinematic coefficient of viscosity

$$\nu = \frac{\mu}{\rho} = \frac{ML^{-1}T^{-1}}{M/L^3} = L^2T^{-1}$$

\#

Velocity of fluid

Acceleration