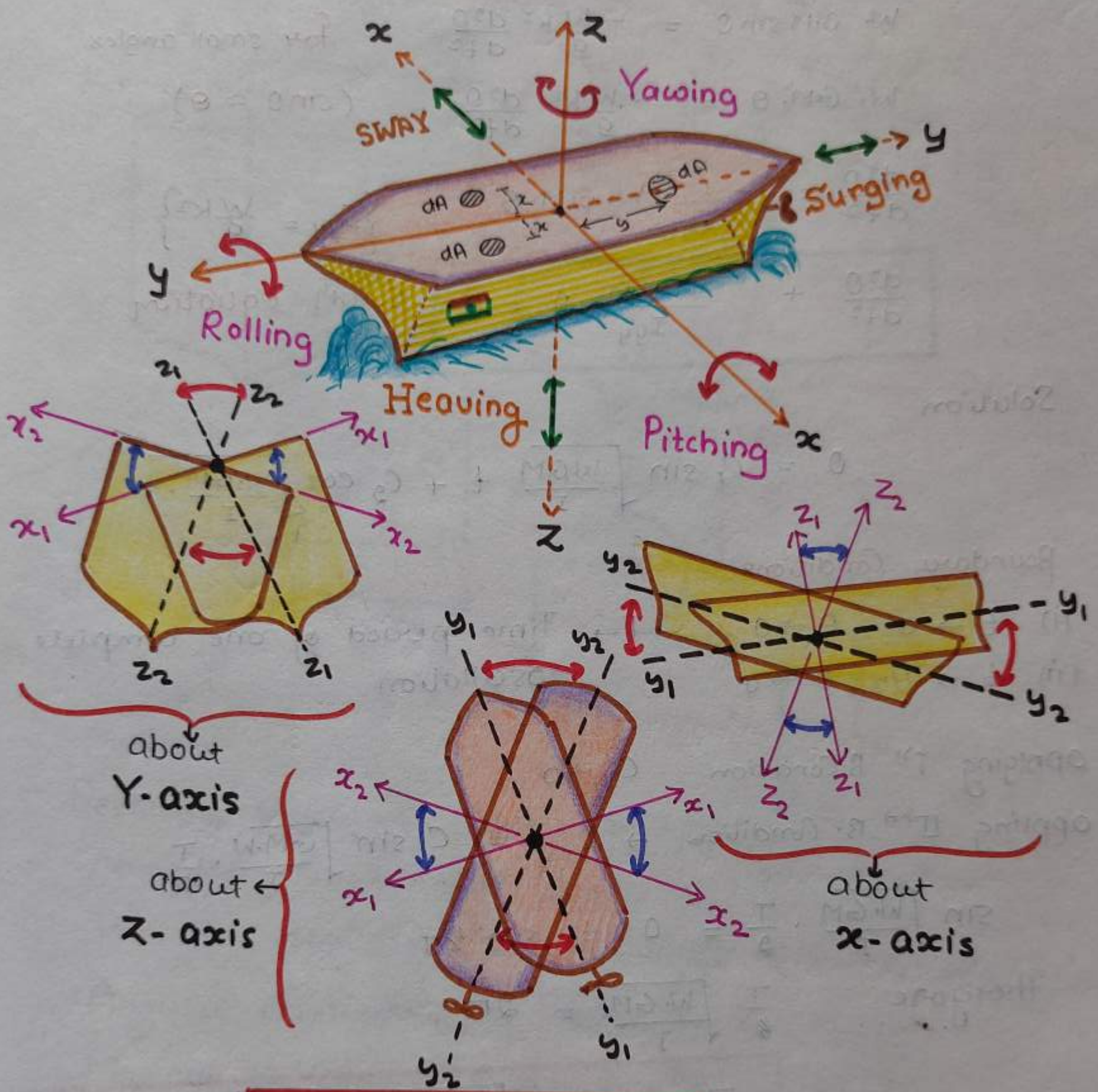
Ship Movements



Because $\boxed{I_{Rolling} < I_{pitching}}$

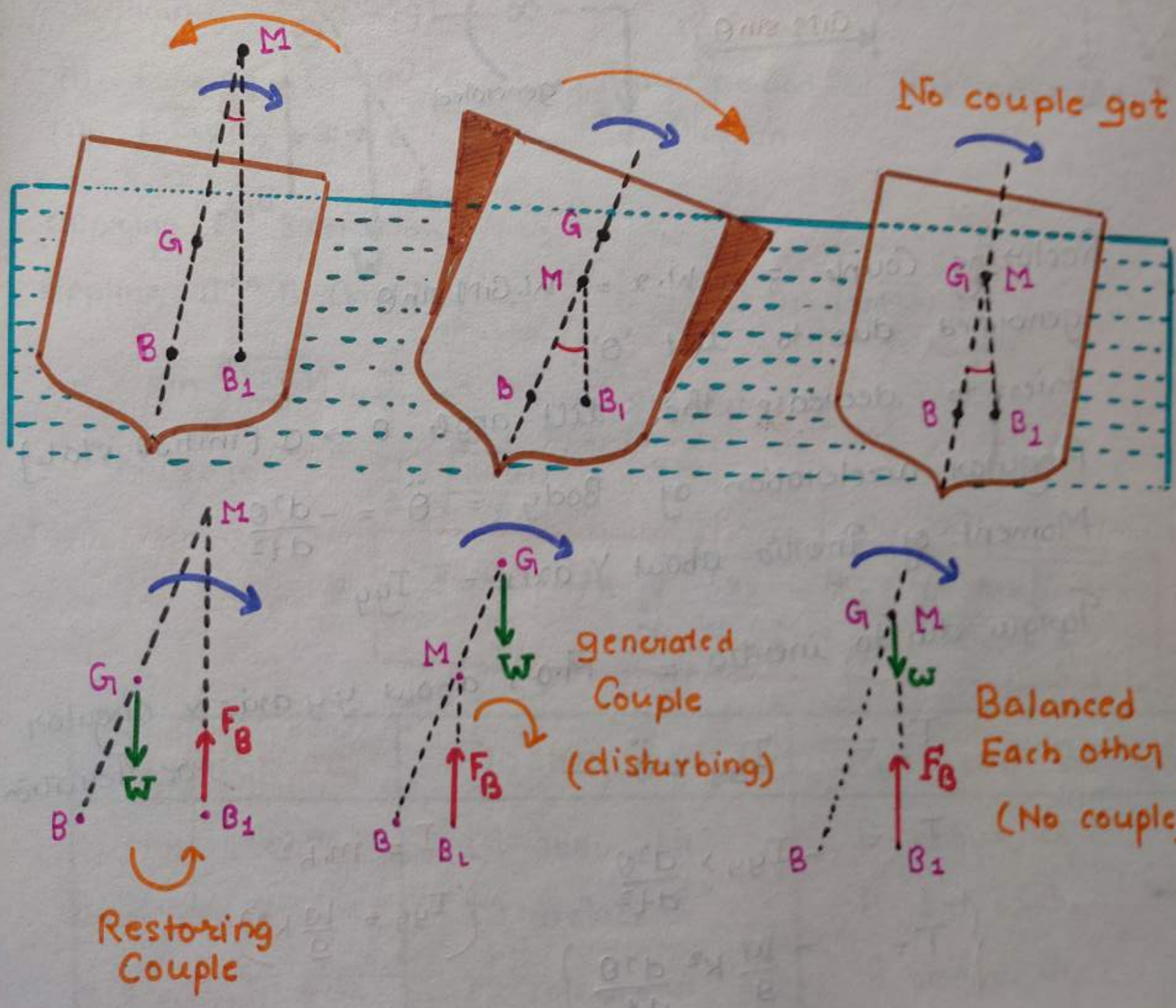
We should Take very much care about Rolling because $I_{Rolling}$ is less, ship can roll very easily,

therefore Management of Rolling very important and it automatically amends the Pitching also.

Equillibrium of floating Bodies

Equillibrium

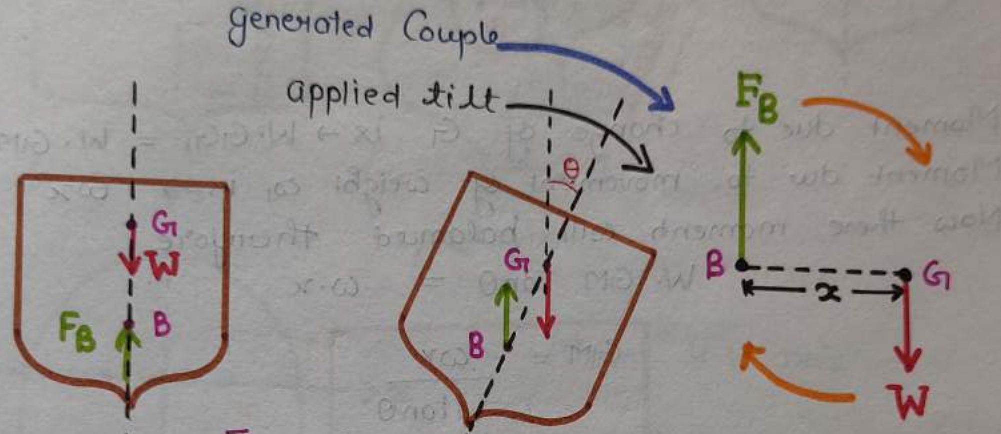
- **STABLE EQUILLIBRIUM** — M above G (+) — $GM > 0$
- **UNSTABLE EQUILLIBRIUM** — G above M (−) — $GM < 0$
- **NEUTRAL EQUILLIBRIUM** — G and M coincide — $GM = 0$



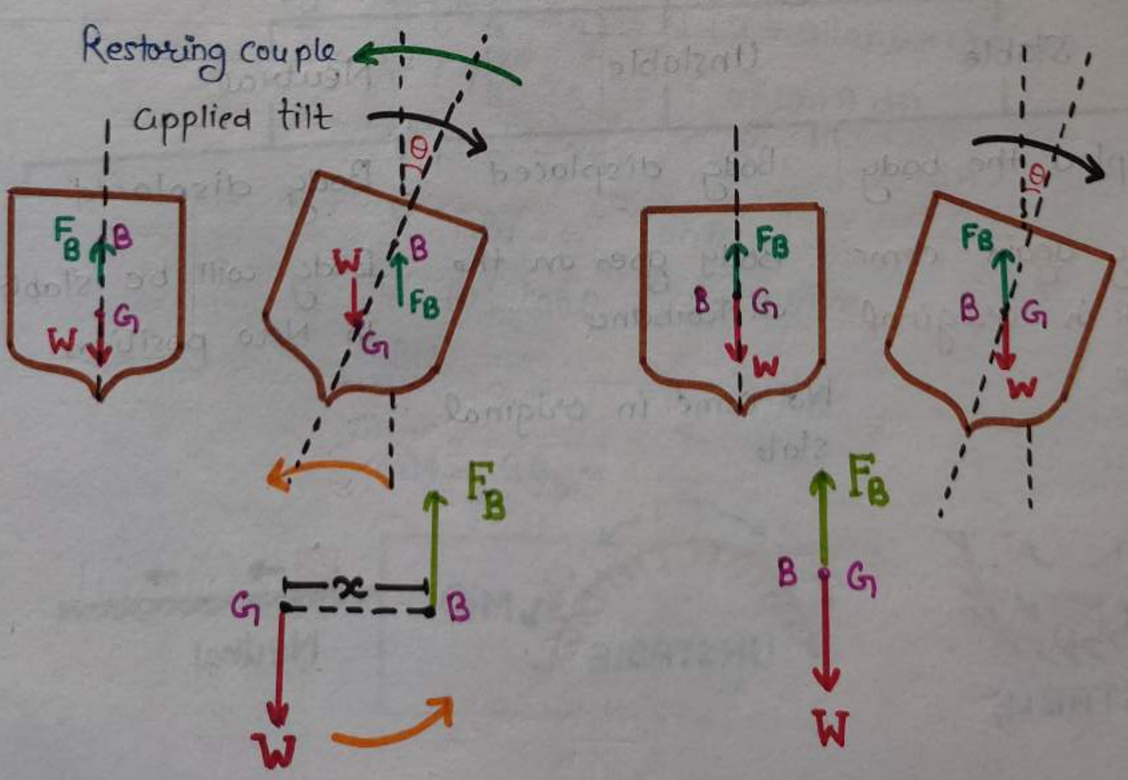
Equillibrium of submerged unconstrained bodies

Unconstrained means → Only weight and Buoyancy force (F_B) are acting.

B below G [Unstable equillibrium]



B above G [Stable Equillibrium] **B over G** [Neutral Equillibrium]



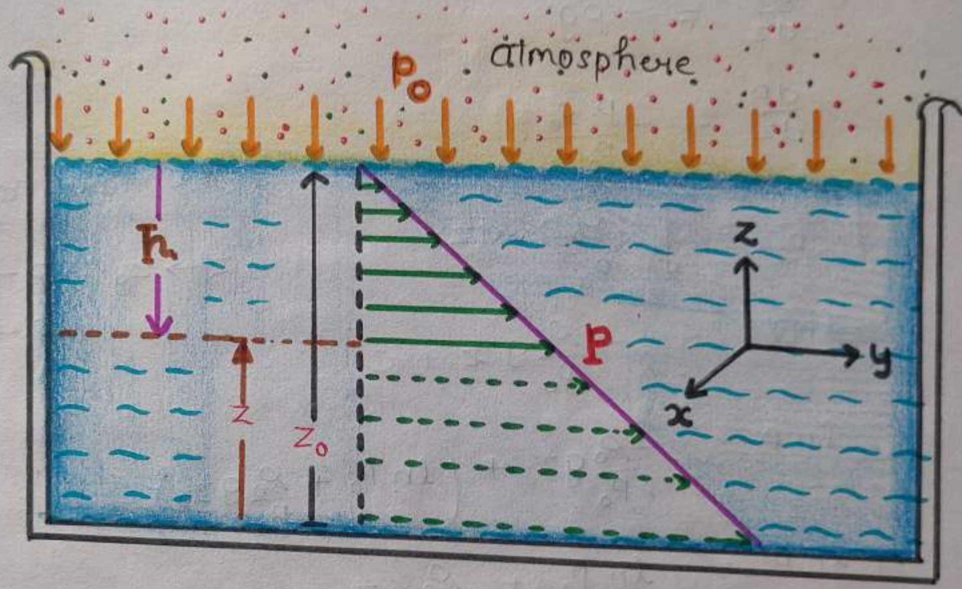
establishing proper boundary condition.

when $z \rightarrow z_0 \Rightarrow p \rightarrow p_0 \rightarrow$ atmospheric pressure.

when $z \rightarrow z \Rightarrow p \rightarrow p$

then $p = -\rho g z + c$ and $p_0 = -\rho g z_0 + c$

$$\boxed{(p - p_0) = \rho g (z_0 - z)}$$



Now

$$(p - p_0) = \rho g (z_0 - z)$$

$$\boxed{\Delta p = \rho g h}$$

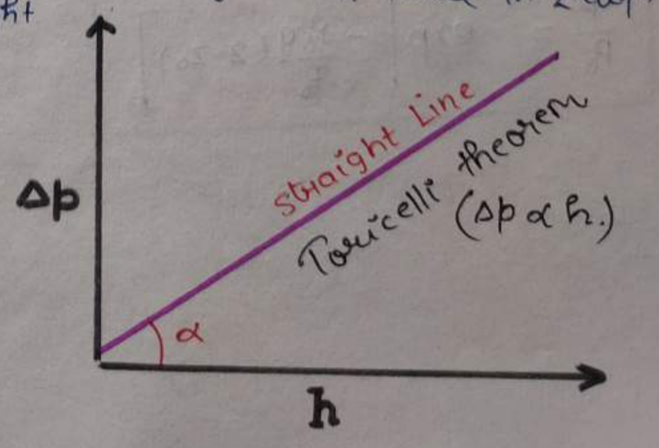
Δp: Pressure excess → Linearly change with height

h: depth from free surface → height difference in z-dirn

$$\boxed{\text{slope} = \rho g}$$

$$\tan \alpha = \rho g$$

$$\therefore \left(\alpha = \tan^{-1}(\rho g)\right)$$



Now Basic Equation of fluid at rest is

$$\nabla p = \rho \vec{b}$$

$$\left(\hat{i}\frac{\partial p}{\partial x} + \hat{j}\frac{\partial p}{\partial y} + \hat{k}\frac{\partial p}{\partial z} = \hat{i}\rho b_x + \hat{j}\rho b_y + \hat{k}\rho b_z \right)$$

Conclusion

$$\frac{\partial p}{\partial x} = \rho \vec{b}_x \qquad \frac{\partial p}{\partial y} = \rho \vec{b}_y \qquad \frac{\partial p}{\partial z} = \rho \vec{b}_z$$

If gravity is the only body force acting downward on body

$$b_x = 0 \rightarrow \frac{\partial p}{\partial x} = 0 \rightarrow p \neq p(x)$$

$$b_y = 0 \rightarrow \frac{\partial p}{\partial y} = 0 \rightarrow p \neq p(y)$$

$$\rightarrow p \neq p(x,y)$$

$$b_z = -g \quad \underbrace{\frac{\partial p}{\partial z} = -\rho g}_{} \rightarrow \underbrace{p = p(z) \text{ only}}_{}$$

therefore

Ordinary differential Equation

$$\boxed{\frac{dp}{dz} = -\rho g}$$

Hydrostatic equation of fluid

Solutions of ODE

Incompressible fluid

Here we regard density $\rho =$ constant

$\rho \neq \rho(x,y,z,t)$ generally

$\Delta\rho$ very very Low/small → Negligible

$$dp = -\rho g \, dz$$

$$\int dp = \int -\rho g \, dz$$

$$\left[p = -\rho g z + c \right]$$

found by suitable Boundary condition

Now, the net surface force acting on the fluid element along i^{th} direction is given by

$$\vec{F}_{surface,i} = \iint_{CS} T_i^n \, dA = \iint (\tau_i \cdot \hat{n}) \, dA$$

Divergence theorem $\iint_{CS} (\vec{F} \cdot \hat{n} \, dA) = \iiint_{C\forall} (\nabla \cdot \vec{F}) \, d\forall$

Now applying

$$\bar{F}_{surface,i} \Rightarrow \iiint_{C\forall} (\nabla \cdot \bar{\tau}_i) \, d\forall$$

$$\bar{F}_{sur,i} \Rightarrow \iiint_{CV} \frac{\partial \tau_{ij}}{\partial x_j} \, d\forall$$

If the fluid is at rest, only Normal component of stress on the surface, that are independent of the orientation of the surface,

stress tensor is Isotropic / Spherically symmetric

therefore $\tau_{ij} = -p\,\delta_{ij}$ $\begin{cases} 0 & \text{if } i \neq j \\ 1 & \text{if } i = j \end{cases}$

thermodynamic pressure

$$\therefore \bar{F}_{surface,i} = \iiint_{CV} -\frac{\partial p}{\partial x_i} \, d\forall = \underbrace{\iiint_{C\forall} -\nabla p \, d\forall}_{\text{Net surface force acting on the element}}$$

$$\bar{F}_{Body} = \iiint_{C\forall} \bar{b} \rho \, d\forall$$

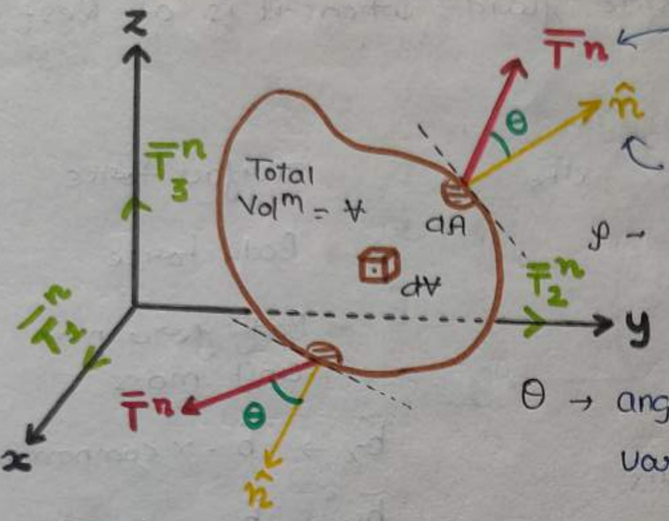
under equillibrium $\bar{F}_{surface} + \bar{F}_{Body} = 0$

$$\iiint_{CV} -\nabla p \, d\forall + \iiint_{C\forall} \bar{b} \rho \, d\forall = 0$$

$$\boxed{\nabla p = \rho \vec{b}}$$

Advanced approach

We will derive Basic equation using the concept of tensor [stress vector] basis.



$\bar{T}^n$ ← Traction vector acting on plane having $\hat{n}$ vector unit

$\hat{n}$ ← unit Normal area vector

ρ – density

θ → angle b/w $\bar{T}^n$ and $\hat{n}$ vary as we travel over surface

$\bar{T}_i^n$ = component of $\bar{T}^n$ along i → 1 along x, 2 along y, 3 along z

we can represent the traction on any arbitrary plane with linear combination of its components of traction with respect to reference cartesian system

Cauchy theorem - $\bar{T}_i^n = \sum_{j=1}^{3} \tau_{ji} \hat{n}_j$

from angular momentum conservation

$$\underbrace{\tau_{ji} = \tau_{ij}}_{\text{Symmetric Tensor}}$$

Now $\bar{T}_i^n = \tau_{ij} \hat{n}_j$

Here

$$\hat{n} = n_1 \hat{i} + n_2 \hat{j} + n_3 \hat{k}$$

$$\tau_{ij} n_j = \tau_{i1} n_1 + \tau_{i2} n_2 + \tau_{i3} n_3$$

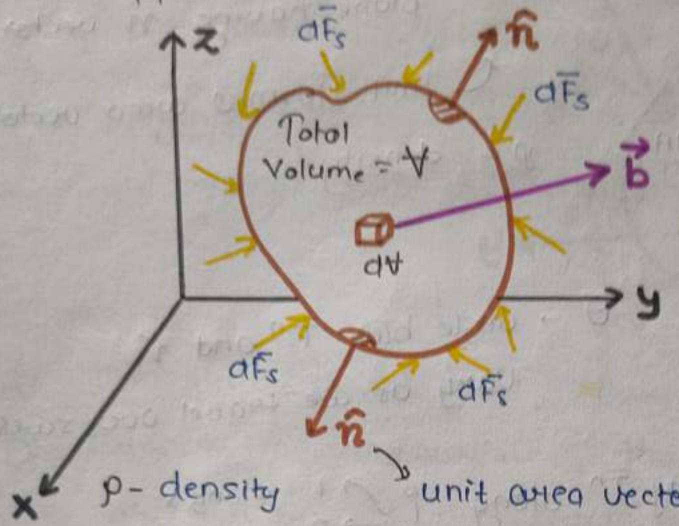
defining about

$$\tau_i = \tau_{i1} \hat{i} + \tau_{i2} \hat{j} + \tau_{i3} \hat{k}$$

Basic EQ^n of Fluid statics.

we will derive fundamental eq^n that shows about pressure variation inside fluid when it is at Rest

Basic approach



$\bar{F}_s$ → surface force

$\bar{F}_B$ → Body force

$\bar{b}$ → Body force per unit mass

$\bar{b}_x$ → $\bar{b}$ - x component

$\bar{b}_y$ → $\bar{b}$ - y component

$\bar{b}_z$ → $\bar{b}$ - z component

ρ - density

$\hat{n}$ → unit area vector

Total Body force $\bar{F}_B = \iiint_{CV} \rho \bar{b}\, d\forall$

Total surface force $\bar{F}_S = \iint_{CA} -\bar{p}\cdot d\bar{A} = \iint -p\hat{n}\, dA$

Body under equillibrium

Body force + Surface Force = 0

$$\bar{F}_B + \bar{F}_S = 0$$

Gauss divergence theorem

$$\iiint_{\forall} \rho \bar{b}\, d\forall + \iint_{A} -p\hat{n}\, dA = 0$$

$$\left\{ \begin{array}{l} \iint_A \vec{F}\cdot d\vec{A} = \iiint_{\forall} (\nabla\cdot\bar{F})\, d\forall \\ \iint_A (F\cdot d\bar{A}) = \iiint_{\forall} (\nabla F)\, d\forall \end{array} \right\}$$

grad F

(if F is scalar)

$$\iiint_{\forall} \rho \bar{b}\, d\forall - \iiint_{\forall} \nabla p\, d\forall = 0$$

$$\iiint_{\forall} (\nabla p - \rho\bar{b})\, d\forall = 0$$

$$\boxed{\nabla p = \rho\vec{b}}$$

We know $d\forall = \left(\frac{dx\,dy\,dz}{6}\right)$ of Tetrahedral element

if $\left.\begin{matrix} dx \to 0 \\ dy \to 0 \\ dz \to 0 \end{matrix}\right\} \to \left.\frac{dx\,dy\,dz}{6} \to 0 \right\} d\forall \to 0$

Now $F_z = (\sigma_z - \sigma_n)\, dA_n \cos\gamma$

Equillibrium

$F_x = 0$	$F_y = 0$	$F_z = 0$
$(\sigma_x - \sigma_n)\, dA_n \cos\alpha = 0$	$(\sigma_y - \sigma_n)\, dA_n \cos\beta = 0$	$(\sigma_z - \sigma_n)\, dA_n \cos\gamma = 0$
$(\sigma_x - \sigma_n) = 0$	$(\sigma_y - \sigma_n) = 0$	$(\sigma_z - \sigma_n) = 0$
$\sigma_x = \sigma_n$	$\sigma_y = \sigma_n$	$\sigma_z = \sigma_n$

Pascal's law $\boxed{\sigma_x = \sigma_y = \sigma_z = \sigma_n = -p}$

$p \to$ thermodynamic pressure /OR/ Hydrostatic pressure } compressive in Nature

also called ↓ Mean pressure, Scalar quantity

NOTE

$(\sigma_x = \sigma_y = \sigma_z = -p = k)$ as according to pascal's law

$\left.\begin{matrix} \sigma_x = k \\ \sigma_y = k \\ \sigma_z = k \end{matrix}\right\}$ adding $\to$ $(\sigma_x + \sigma_y + \sigma_z) = 3k$

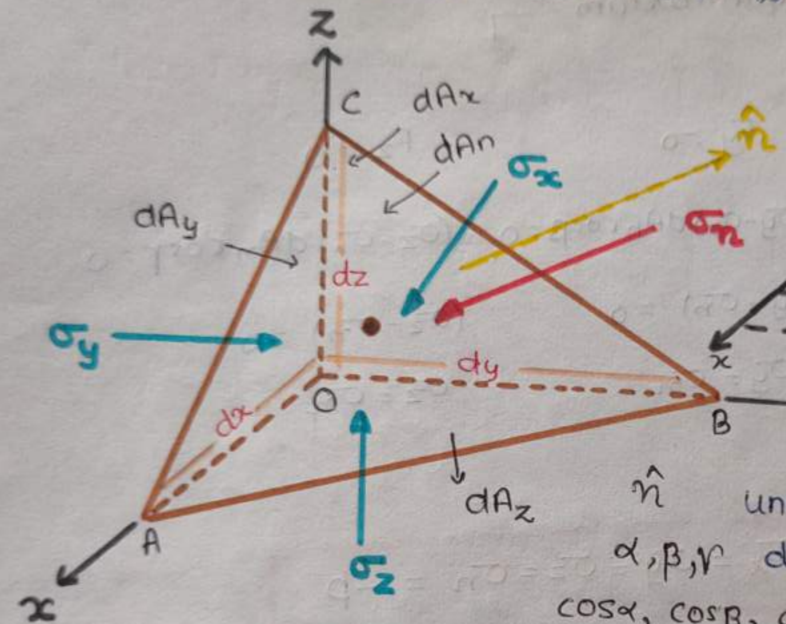
$\frac{(\sigma_x + \sigma_y + \sigma_z)}{3} = k$

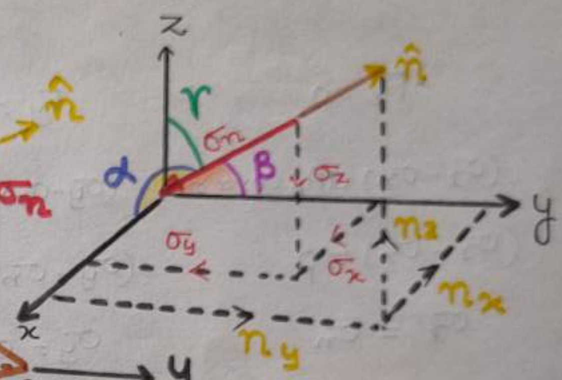
$$\boxed{p = -\frac{(\sigma_x + \sigma_y + \sigma_z)}{3} = -\frac{tr[\underline{\underline{\sigma}}]}{3}}$$

PRESSURE and IT'S MEASUREMENT

Pascal's Law :- State of force in Rest fluid.

Now we have to analyze about the force inside the Fluid domain when our fluid is at Rest.





$\hat{n}$ unit Normal vector of area

α, β, γ direction angles

$\cos\alpha, \cos\beta, \cos\gamma$ direction cosines

Now

$$F_x = \sigma_x \cdot \frac{dy\,dz}{2} - C_x \Rightarrow \sigma_x\, dA_n \cos\alpha - \sigma_n\, dA_n \cos\alpha$$

$$F_y = \sigma_y \cdot \frac{dx\,dz}{2} - C_y \Rightarrow \sigma_y\, dA_n \cos\beta - \sigma_n\, dA_n \cos\beta$$

$$F_z = \sigma_z \frac{dx\,dy}{2} \underbrace{- \sigma_n\, dA_n \cos\gamma}_{\substack{\text{component of } \sigma_n \\ \text{along } -z \text{ direction} \\ \text{surface force}}} \underbrace{- \rho\, d\forall \cdot g}_{\substack{\text{Body weight} \\ \text{Body force}}}$$

$$F_z = \sigma_z\, dA_n \cos\gamma - \sigma_n\, dA_n \cos\gamma - \rho \cdot \frac{dx\,dy\,dz}{6} \cdot g$$

Newton's Law of Viscosity

$\boxed{\text{stress} \propto \text{Rate of strain}}$

$\tau \propto \dot{\gamma}$

$\tau \rightarrow$ shear stress

$\tau \propto \left(\frac{du}{dy}\right)$

$\boxed{\tau = \mu\left(\frac{du}{dy}\right)}$

$\left(\frac{du}{dy}\right) \downarrow$ Velocity gradient

$\mu \rightarrow$ viscosity coeff.

also

$\mu \rightarrow$ dynamic viscosity of fluid

units –
- S.I. – $\left(\frac{N\text{-}s}{m^2}\right)$ — Pa-s
- C.G.S. – $\left(\frac{dyne\text{-}s}{cm^2}\right)$ — Poise

$\boxed{1 \text{ Pa-s} = 10 \text{ Poise}}$

Fluid → a substance which deform continuously under action of very small shear stress

Also One more viscosity comes into existance

ν = kinematic viscosity

$\boxed{\nu = \frac{\mu}{\rho}}$ → dynamic viscosity
→ density of fluid

– this is – ability of any fluid to diffuse a disturbance in molecular momentum

units –
- SI – (m^2/s)
- CGS – (cm^2/s) – 1 stoke

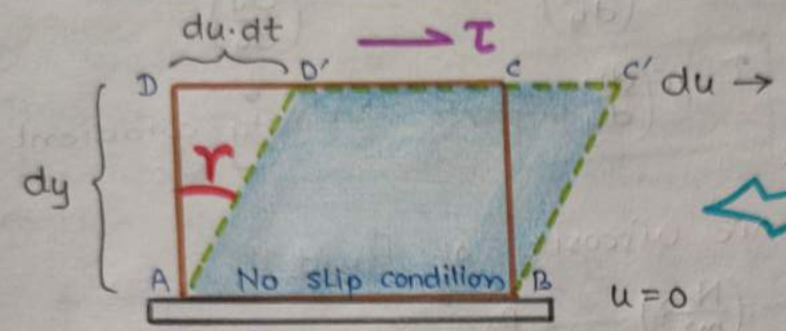
$\boxed{1 \frac{m^2}{s} = 10^4 \text{ stoke}}$

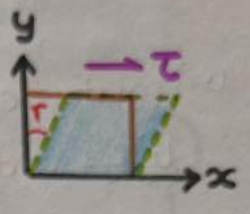
Viscosity ⟶ Resistance to flow of a fluid

↓

Reason →
- → cohesive forces C.F liquid > C.F. air
- → intermolecular momentum exchange

fluid element deformation





velocity of fluid at solid Boundary = 0

velocity of fluid layer at dy altitude = $d\vec{u}$

in time interval → dt

displacement of upper fluid Layer = du·dt

Now

(γ = shear strain) angle travelled through deformation

as; $\tan\gamma = \frac{DD'}{DA} = \frac{du\,dt}{dy} = \left(\frac{du}{dy}\right) dt$

if $\gamma \to$ very small then $\tan\gamma = \gamma$

$\gamma = \left(\frac{du}{dy}\right) \cdot dt$

$\dot{\gamma}$ = rate of shear strain

$\frac{\gamma}{dt} = \left(\frac{du}{dy}\right)$ shear strain per unit time

$\left(\frac{du}{dy}\right)$ = Velocity gradient

$$\boxed{\dot{\gamma} = \left(\frac{du}{dy}\right)}$$

$\boxed{\text{shear strain rate = Velocity gradient}}$

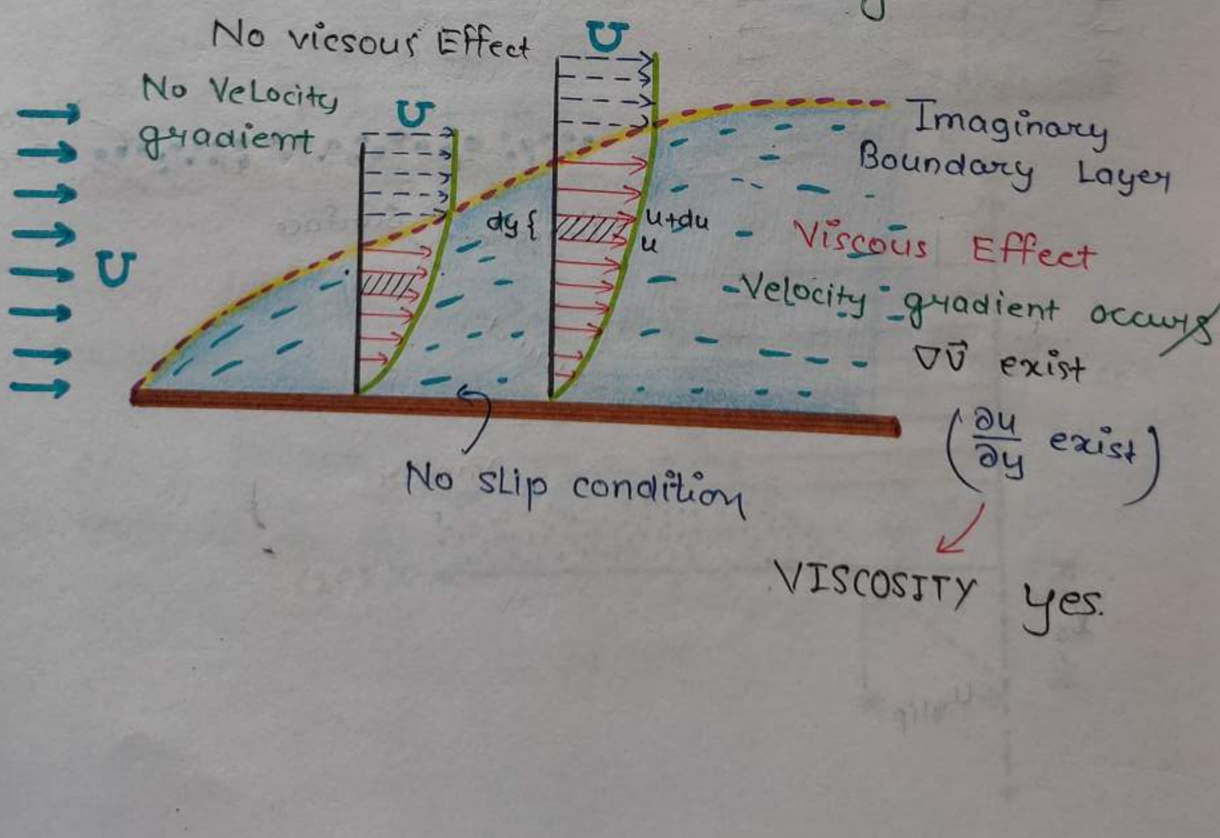
VISCOUS EFFECT

following NO SLIP Boundary condition,
the first layer of fluid molecules, adhering to the plate, feels. the presence of the wall directly and tends to stick to the wall with Relative velocity equal to Zero ($\vec{V}_{relative} = 0$)

Layers above it do not feel presence of wall directly rather it feels the effect of the wall implicitely by virtue of some fluid property

enables the effect of MOMENTUM DISTURBANCE imposed by the wall to propagate from the wall, adjacent layer to the further outer layers

this fluid property a.k.a - Viscosity



Vapour $\longrightarrow$ acts like $\longrightarrow$ shield

↓

preventing the fluid from being directly exposed to the irregularities of the channel surface

↓

liquid not feel the presence of wall directly

[liquid element sailing over intervening vapour bed.]

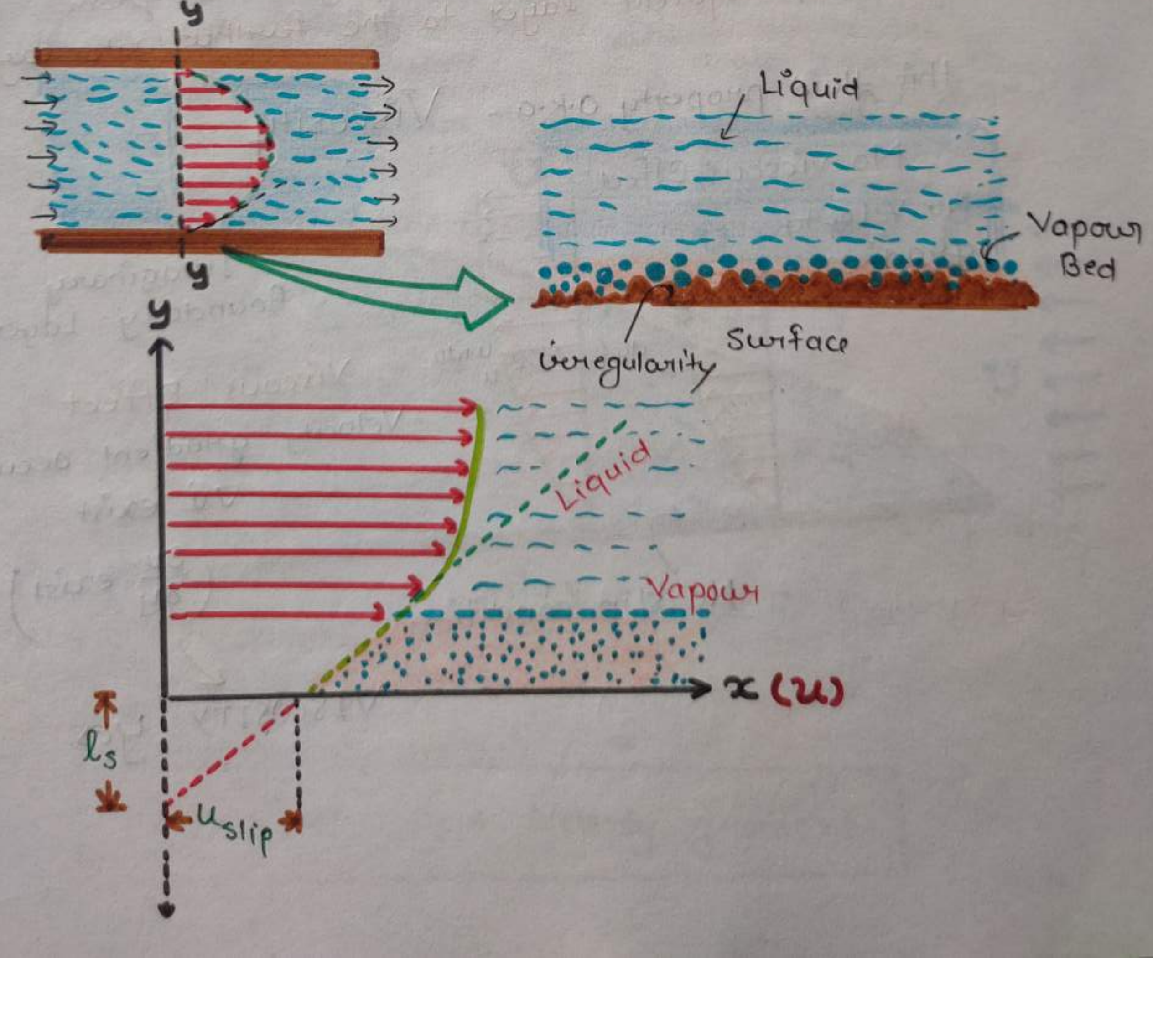
↓

APPARENT - SLIP happens now

Now $\boxed{u_{slip} = l_s \left.\frac{\partial u}{\partial y}\right|_{interface}}$

$l_s \rightarrow$ slip length (Height of Vapour bed)

$u_{slip} \rightarrow$ slip velocity of liquid (sailing over vapour)



Second theory

No SLIP boundary condition arises due to

microscopic boundary roughness, since fluid elements may get trapped within the surface asperities,

if the fluid is liquid, it may not be possible for the molecules to escape from trapping because of compact molecular packing.

otherwise smooth boundary allow to slip

But recent study have demonstrated that the intuitive assumption of "NO SLIP at Boundary" can fail greatly not only when surface is smooth But also when surface is sufficiently Rough.

Don't use True slip Rather use Apparent SLIP

attempt to resolve apparent anomaly of "reduced" fluid friction in the presence of rough surface elements under specific conditions.

Roughness impedes motion of adhering fluid

A thin Layer of Vapour formed on Roughness (manometer scale) spontaneously by

because of Hydrophobic surface

Narrowness of the confinement. [surface donot easily get wet]

First Theory →

molecules of the fluid next to solid surface, are absorbed onto surface for a short period of time, and are then desorbed and ejected into the fluid. this process slows down the fluid and renders the Tangential component of the fluid velocity equal to the corresponding component of Boundary velocity.

remains valid only if

Fluid adjacent to solid Boundary is in the state of

THERMODYNAMIC EQUILLIBRIUM

infinitely large No. of collisions needed b/w fluid molecules and the solid surface

Not Possible for rarefied or Less dense medium

may result in a "SLIP" between fluid and solid boundary in small channels. ($\lambda \approx$ channel dimensions)

this event may be more aggravated by the

Presence of local gradient of

Temperature (∇T) — thermophoresis

density ($\nabla \rho$) — diffusophoresis

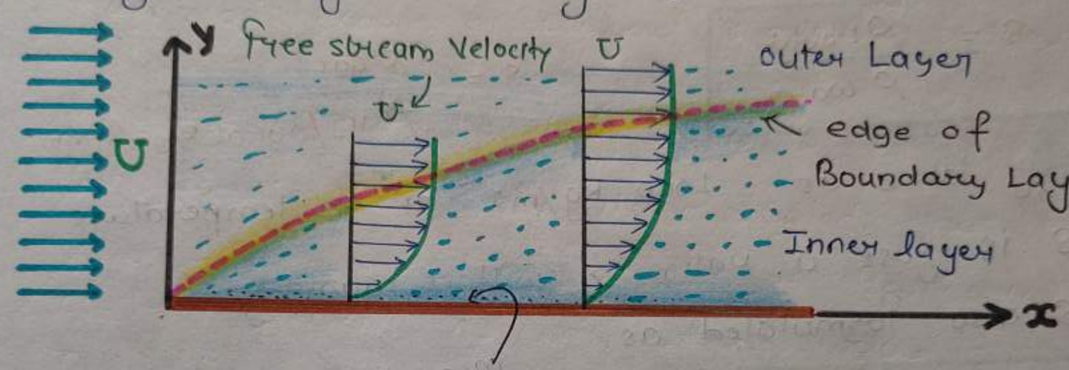
Molecules tending to slip on the wall experience a Net driving force

due to
- ∇T local Temp. gradient
- $\nabla \rho$ local density gradient

VISCOSITY

The No-SLIP Boundary Condition

Consider a flat plate of large width being kept in a "free stream" flow. So that the fluid just before encountering with the plate is having a uniform velocity U



No slip Boundary condition

First set of fluid molecules comes in contact with the plate, These molecules tend to stick to the solid plate.

↓

No Relative Tangential velocity component b/w fluid and solid Boundary at their contact points,

↓

this concept used in common fluid dynamics engineering problem.

NOTE

Physical origin of NO-SLIP Boundary Condition over a solid Boundary has Not been established with certainity

A matter of strong debat in Research Comm also known as Relative density

Specific gravity shown by symbol S

measurement of - to find any substance lighter or havier with respect to reference substance

$$S = \frac{\text{density of substance}}{\text{density reference subst.}}$$

Liquid: H_2O gas: H_2/air

$$\boxed{S = \frac{\rho_{Liquid}}{\rho_{water}}}$$

$$S = \frac{\rho_{gas}}{\rho_{H_2/air}} \text{ at Room Temp.}$$

ρ_{H_2O} taken as 1000 kg/m³ at 4°C temperature

S is just a ratio → unitless quantity

S also formulated as

$$\boxed{S = \frac{m_l}{m_{H_2O}} = \frac{\omega_l}{\omega_{H_2O}}}$$

$$S = \frac{m_{substance}}{m_{Reference}} = \frac{\omega_{substance}}{\omega_{reference}}$$

Mercury (Hg) = 13.6

S

Apparent specific gravity (ASg)

$$\boxed{S_{app} = \frac{W_{liquid}}{W_{H_2O}} \quad \Big| \text{ Volume Constant}}$$

API gravity measure of how heavy or light petrolium liquid is as compared to water

$$\boxed{API = \frac{141.5}{S} - 131.5}$$

API > 10° Lighter than H_2O

API < 10° Heavier than H_2O

mass (m) is amount of the substance

unit S.I. Kg

CGS. g $\quad 1\ \text{Kg} = 10^3\ \text{g}$

mass = density x volume

m

cartesian $= \int \rho \cdot dv = \iiint \rho \, dx\, dy\, dz$

cylindrical $= \int \rho \cdot dv = \iiint \rho \, r\, dr\, d\phi\, dz$

spherical $= \int \rho \, dv = \iiint \rho \, r^2 \sin\theta \, dr\, d\phi\, d\theta$

Weight (W) is amount of force any substance is pulled by earth (or any planet)

it can vary

Unit - S.I. - Newton N

MKS - 1 kgf (≈ 9.8 N)

Weight = mass x acceleration due to gravity

W

cartesian $= mg = \int \rho g \, dv = \iiint \rho g \, dx\, dy\, dz$

cylindrical $= mg = \int \rho g \, dv = \iiint \rho g \, r\, dr\, d\phi\, dz$

spherical $= mg = \int \rho g \, dv = \iiint \rho g \, r^2 \sin\theta \, dr\, d\theta\, d\phi$

Specific Properties

Specific Volume

shown by v or $\forall$

is volume per unit mass

$$\boxed{v = \frac{V}{m} = \frac{1}{\rho}}$$

Unit m^3/kg (S.I.)

cm^3/gm (C.G.S)

Specific weight

shown by ω

is weight per unit Volume

$$\boxed{\omega = \frac{W}{V} = \rho g}$$

Unit. N/m^3 (S.I.)

$dyne/cm^3$ (C.G.S)

density → H_2O → 1000 kg/m^3

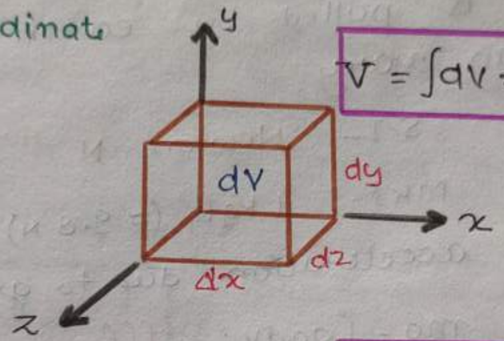
maxᵐ at 4°C → Volume minimum; density maximum

due to → Anamalous Behaviour

Reason → H_2 Bonding

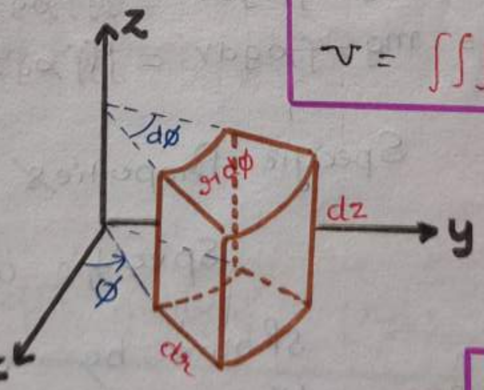
Volume – is quantity of space occupied
– formulated in different coordinate system differently

Cartesian Coordinate system



$V = \int dV = \iiint dx\,dy\,dz$

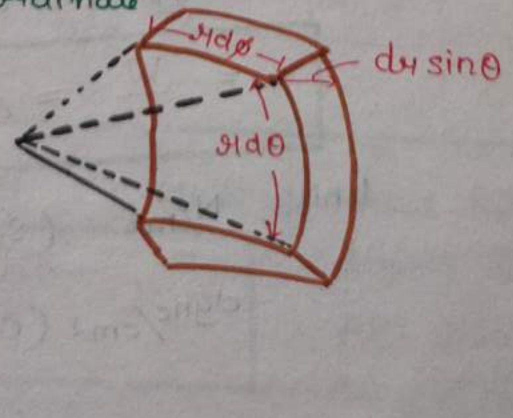
cylindrical coordinate system



$dV = r\,dr\,d\phi\,dz$

$V = \iiint r\,dr\,d\phi\,dz$

Spherical coordinate system



$dV = r\,d\theta \cdot r\,d\phi\,dr\sin\theta$

$V = \iiint r^2 \sin\theta\,dr\,d\theta\,d\phi$

if $\delta V \rightarrow$ Too Large

there will be density variation within volume then average density must differ from the actual density at the center of sampling volume

spatial variation of density

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

Macroscopic Uncertainity

therefore $\delta V \rightarrow$ Not Too Large, Not so tiny

must contain around million molecules.

density at a point in space is specified by

$$\boxed{\rho = \lim_{\delta V \to \delta V^*} \left(\frac{\delta m}{\delta V}\right)}$$

$\rho \rightarrow$ continuous and continuously differentiable function

can be termed as

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

similarly, other parameters such as - Velocity also shows continuous & differentiable functionality.

$u = u(x,y,z,t)$ $\quad v = v(x,y,z,t)$ $\quad w = w(x,y,z,t)$

Velocity vector $\vec{V} = u\hat{i} + v\hat{j} + w\hat{k}$

NON- VALIDATION

- Rarefied gases (when pressure $\rightarrow 0$)
  No continuum concept can sustain
- microfluidics application
- Flow devices at micro & nano scale

PROPERTIES OF FLUIDS

we will study, here, some mathematical and conceptual details of fluidic properties.

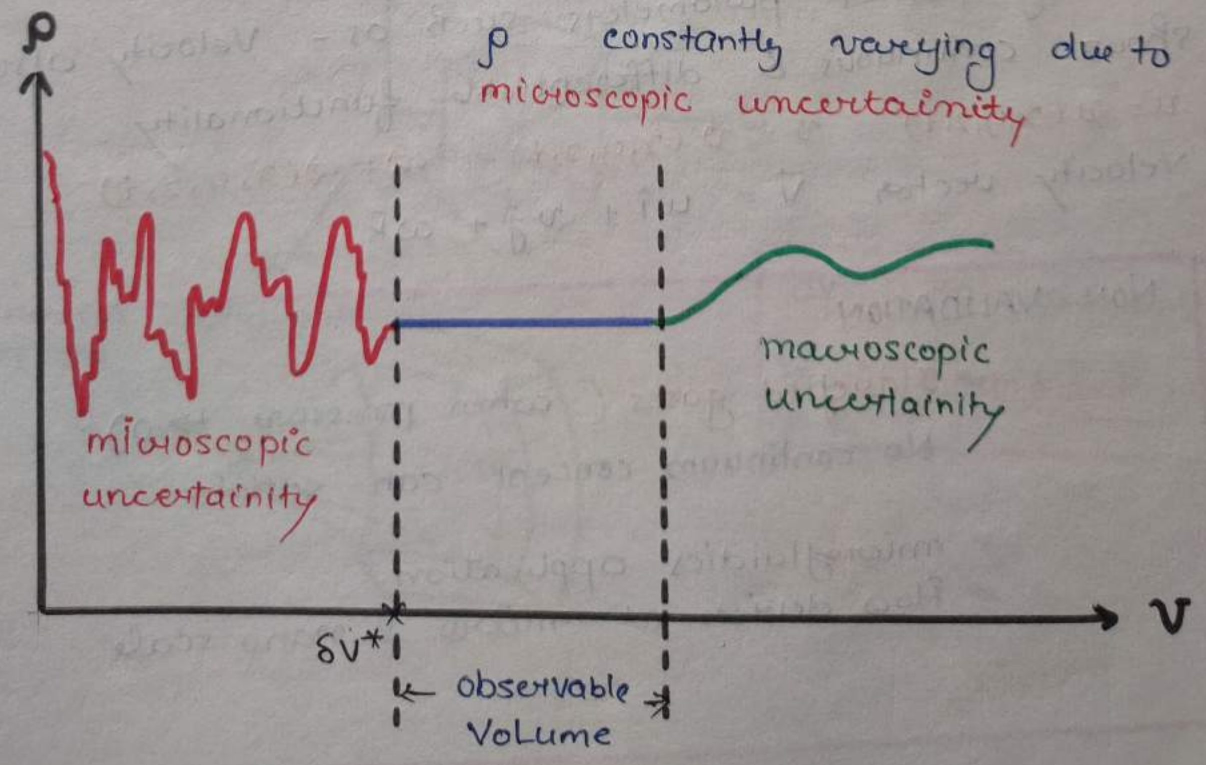
Density (ρ) –
- also known as mass density
- is mass per unit Volume
- formula – $\boxed{\rho = m/V}$
- Units –
  - SI unit kg/m3
  - CGS unit g/cm3
- dimension

detailed discussion

under consideration of continuum

density $\rho = \frac{\delta m}{\delta v}$ sampling mass / sampling volume

if $\delta V \rightarrow$ very small random motion dominant. then ρ constantly varying due to microscopic uncertainity



Knusden Number

(λ/L)

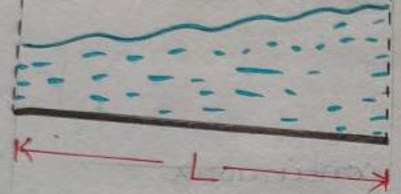
indicator of degree of rarefaction of system

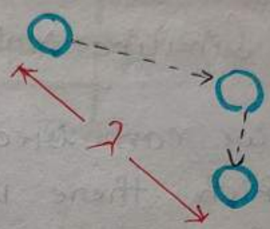
determines the extent of deviation from a possible continuum behaviour

$$\boxed{K_n = \frac{\lambda}{L}}$$

λ → mean free path

L → characteristic length





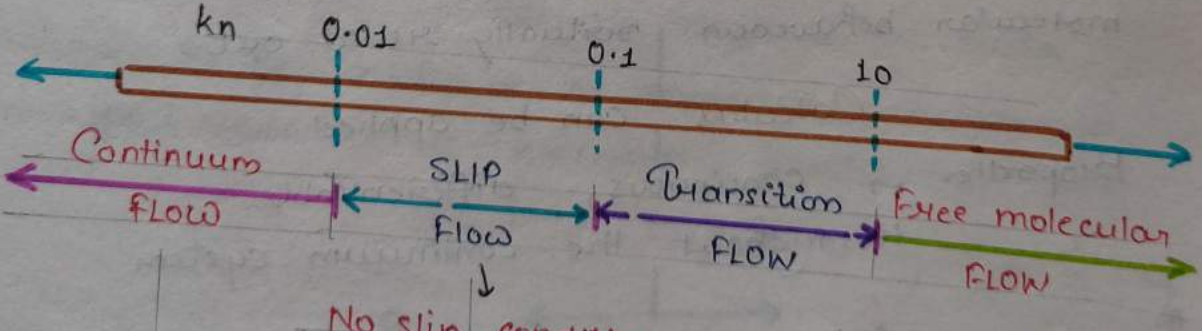
average distance travelled b/w to successive collisions

↓

λ

Length over which we have to measure the property (Length of observation)

Knusden Number ranging flow



↓

No slip condition

Invalid

Continuum → Continuous Medium

Too small

Lot of uncertainity here because of larger fluctuation of the values of our property

$\lambda > L$

Too large

we shall not be able to capture the local variation of properties.

$\lambda <<< L$

Limiting Volume

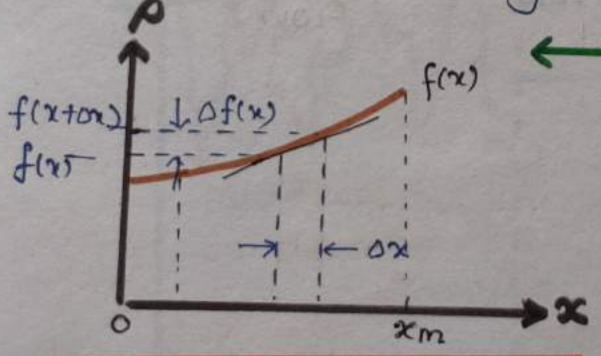
above which we can treat as continuous medium in which there is no significant uncertainity in pridiction of the averaged behaviour of molecules in the system.

variation of the properties within this medium is smooth enough

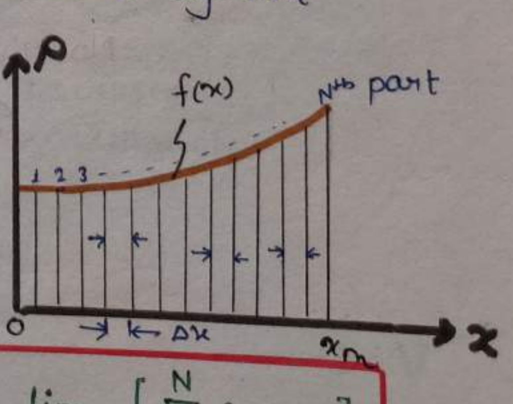
randomness due to uncertainities in the molecular behaviour virtually ruled out.

Calculus can be applied

Properties → continuous, differentiable throughout the continuum system



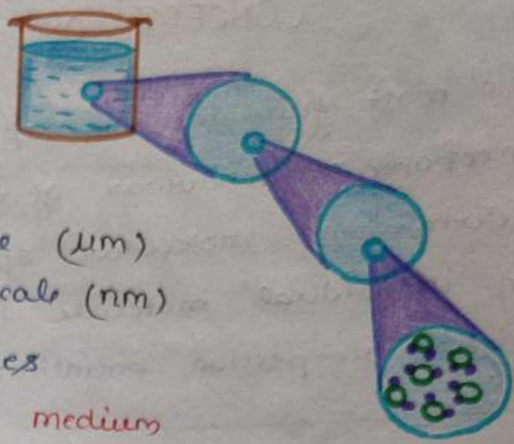
$\Delta x = \left(\frac{x_m}{N}\right)$



$$\frac{df}{dx} = \lim_{\Delta x \to 0} \left\{ \frac{f(x+\Delta x) - f(x)}{\Delta x} \right\}$$

$$\int_0^{x_m} f(x)\,dx = \lim_{\Delta x \to 0} \left[\sum_{i=1}^{N} f_i(x)\,\Delta x \right]$$

Continuum Hypothesis



fluid appears continuous
Made of molecules
Empty space b/w molecules
Quantify fluid properties
On microscopic length scale (µm)
NOT on molecular length scale (nm)
Ignore molecular details / spaces
Assume fluid as continuous medium
Continuous function to quantify fluid properties

Need to make continuum Hypothesis

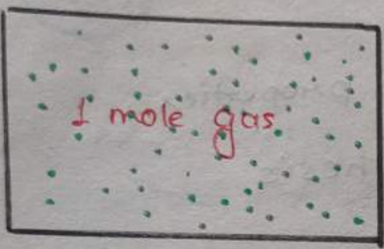
Artificial model for convinience
Do not consider
Motion of individual molecule
forces on individual molecule
Involves fewer and fewer details
Easy to compute the data
Behaviour of billiones of molecules sumarized in few continuous function
density pressure velocity Temperature concentration

Lost is not important
→ details of molecular arrangement and its motion
→ Brownian motion type

MACROSCOPIC and MICROSCOPIC point of View

CONCEPT OF CONTINUUM

the most fundamental approach to analyse the mechanical behaviour of a fluidic system may be a deterministic molecular approach in which dynamics of individual molecule is investigated by writing their respective equations of motions.



6.023×10^{23} molecules

6.023×10^{23} equations of motion

Very hard to compute today even to search for an approach which can reduce No. of equations

MICROSCOPIC approach

statistically averaged behaviour of many molecules

MACROSCOPIC approach

gross effect of many molecules that can be captured by our sensoring measurement techniques

Pressure

Microscopic approach

Macroscopic approach

Pressure = Rate of change of the molecular momentum

Pressure = force per unit area

$$P = \left(\frac{\vec{F}}{\vec{A}}\right) \frac{N}{m^2}$$

Solid | Fluid (Liquid)

: Can resist applied shear stress τ by deforming

: Can't resist applied shear stress (τ)

: No continuous deform^n

: Contuous deformation (γ Not fixed)

: Hook's Law of elasticity

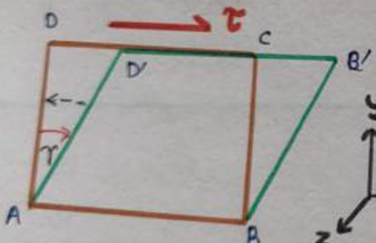
$\boxed{\text{stress} \propto \text{strain}}$

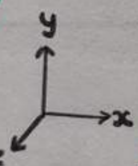
: Newton's Law of viscosity

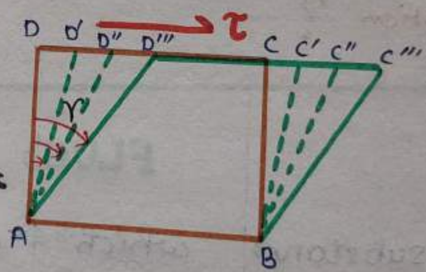
$\boxed{\text{stress} \propto \text{strain Rate}}$

: Can restore its original shape after τ removal

Can't Restore when τ removal







why strain rate not strain ?

as we know, fluid element tends to deform continuously.
in angle of deformation (shear strain) continuously changes with time.
Therefore to measure the deformation we use rate of strain
(Change of strain along with time)

Broad Perspective to FLUID MECHANICS

Fluid mechanics deals with the behaviour of fluid (liquids and gases) in rest or in motion.
Some question can be tackled with Fluid Mechanics

: How does a rocket go up ?
: How do ensect fly ?
: How does blood flow through arteries and viens?
: How does a human heart act like a pump?
: How are ocean currents form?
: How should one design the shape of a car to minimise the wind resistance against its motion ?

FLUID

any substance which can flow

substance: [Finite mass, occupy space, Tangible]

flow: [relative change of position of particles with respect to time]

- Liquid, Gas
  - Viscosity ✓
  - shape / Volume indefinite
  - flow under own weight ✓
  - Continuous deformation ✓
- solids
  - Viscosity ✗
  - Flow ✗
  - Flow under own weight ✗
  - Continuous deformation ✗