IES MASTER

Civil Engineering

Toppers Handwritten Notes

FLUID MECHANICS

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

Fluid Mechanics

Content

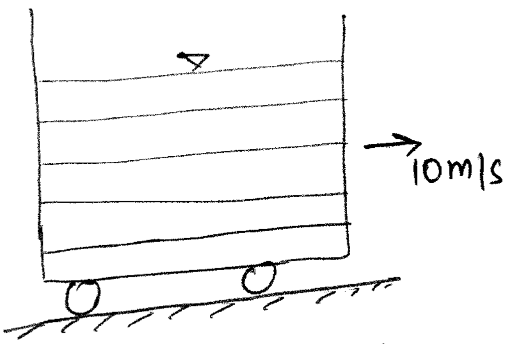
1. Fluid properties *****
2. Pressure & its measurement ****
3. Hydrostatic forces on plane & curved surface ****
4. Buoyancy & Flotation ***
5. Liquid in relative equilibrium. ***

(1–5) → Fluid Statics

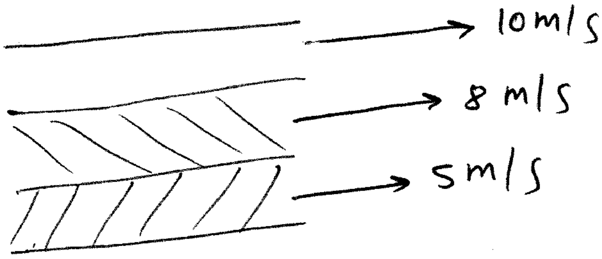
6. Fluid Kinematics ***** → we study fluid in motion without considering the force responsible for motion
7. Fluid Dynamics ***** → we study fluid in motion with the forces responsible for motion
8. Flow over weir & Notches *
9. Laminar flow *****
10. Turbulent flow. *****
11. Boundary layer Theory *****
12. Drag & lift *
13. Dimensional analysis & modal studies ***
14. Pipe flow. *****

1. Fluid properties

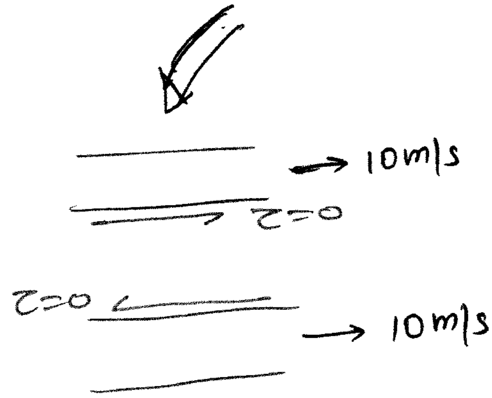
- Substance in liquid and gaseous phase is referred to as fluid.
  They are capable of deforming continuously under the action of shear stress. however small the shear stress might be.
- Liquid is said to have a flow if there is relative motion between different layers of fluid.

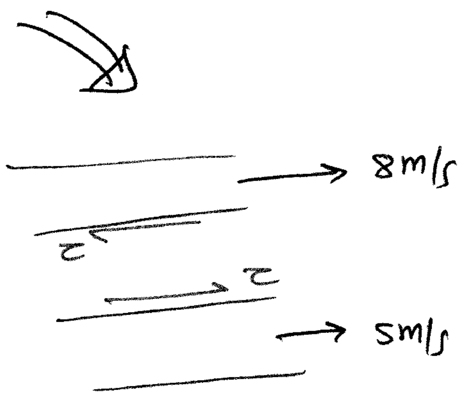


Rigid body motion



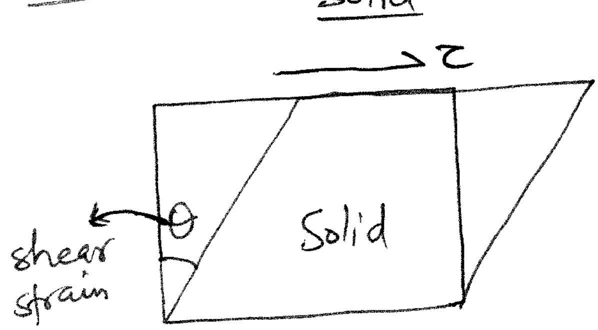
fluid flow





Note:

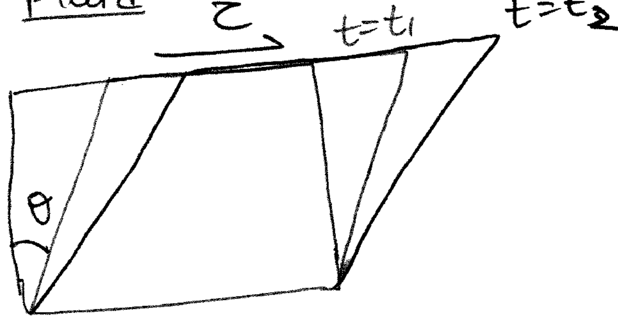
Solid



$\frac{\tau}{\theta} = G$ = modulus of rigidity

$\boxed{\tau \propto \theta}$

Fluid

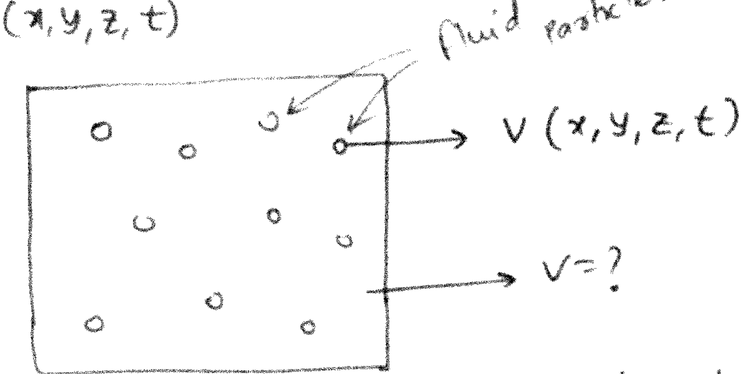


$\boxed{\tau \propto \frac{d\theta}{dt}}$

In case of solid, shear stress is proportional to shear strain but in case of fluid shear stress is proportional to shear strain rate.

Continum Approach:

- In fluid mechanics we assume continum approach i.e. we assume no void space in the fluid. This helps in defining velocity, acceleration etc as a point function i.e. $v = f(x, y, z, t)$



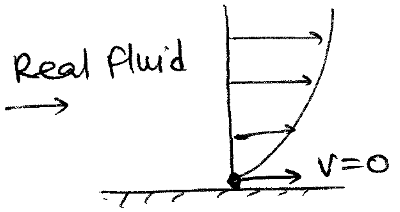
= Continum approach will be invalid when mean free path is large as compare to characteristic dimension.

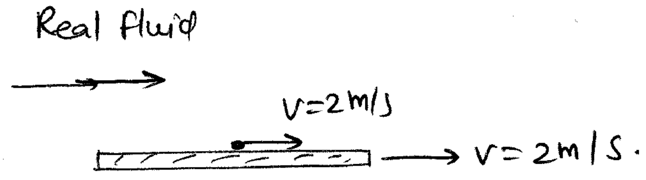
Ideal & Real Fluid:

- Ideal fluid is a theoritical ~~approach~~ assumption made to simplify the analysis, no such fluid exist in reality.
- Ideal fluid does not have viscosity, surface tension, and are incompressible.

No-slip condition:

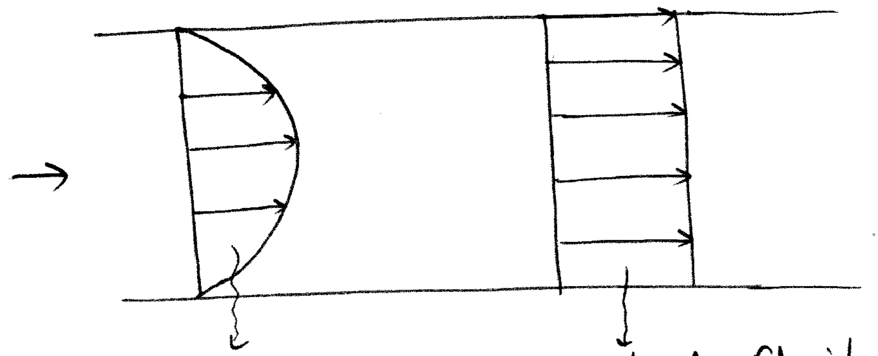
- At the interface of fluid and surface the fluid adheres to the surface due to the property called viscosity.
- Thus at the surface, velocity of fluid would be zero if surface is stationary. And if surface is moving with velocity v, fluid on the surface will also will move with velocity v.





Note: No wetting is due to surface tension.
No wetting & No-slip condition are different. like mercury flowing in a glass tube will have no slip condition but it will not wet the surface.

velocity distribution



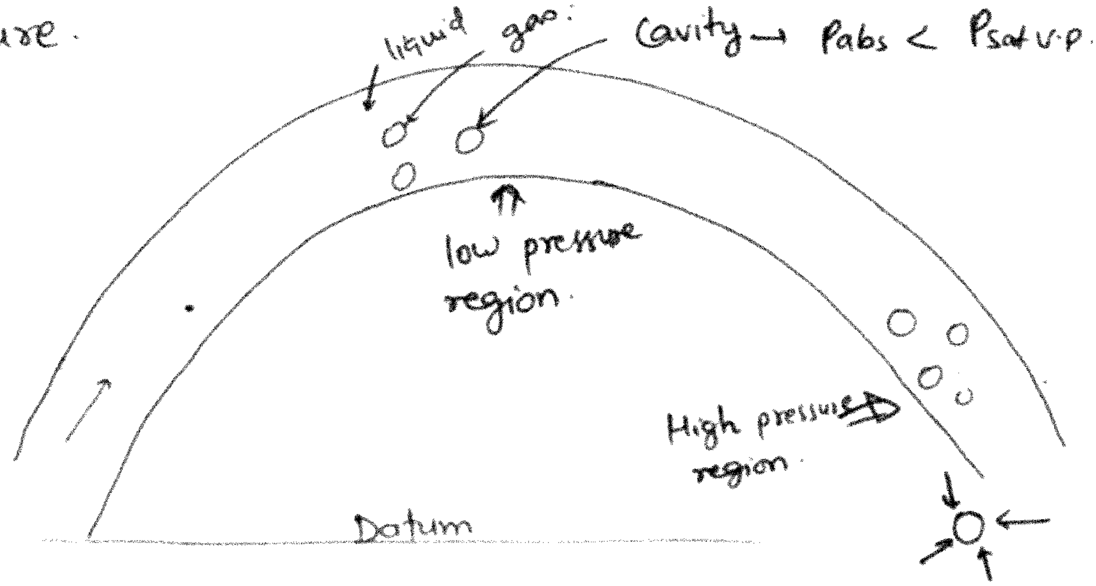
Note: Specific wt of water $= \gamma_w = 9.81\ kN/m^3$.

$$\boxed{\gamma_l = G \cdot \gamma_w}$$

Vapour pressure & Cavitation:

- Saturation vapour pressure is the pressure exerted by vapour when it is in phase equilibrium with the gases.
- Saturation vapour pressure increases with increase in temperature. $\boxed{P_{s.v.p} \propto T}$
- If at any point in the flow absolute pressure (Patm + Pgauge) falls below the saturation vapour pressure, dissolved gases start coming out in the

form of bubble creating cavity in the flow. These bubble travel due to momentum of flowing fluid and when it reaches the high pressure zone the bubble collapses giving rise to high pressure waves which causes noise, vibration surface pitting and fatigue failure.



- Cavitation is generally observed
  - in siphon
  - at inlet of centrifugal pump
  - at exit of reaction turbine etc.

Note: Cavitation occurs when, $P_{abs} < P_{sat\ v.p}$

- chances of cavitation increases if elevation increases, velocity increases, atmospheric pressure decreases and temp increases.

$$\downarrow \frac{P}{\gamma} + \overset{\uparrow}{z} + \overset{\uparrow}{\frac{v^2}{2g}} = \text{const}$$

$$\downarrow P_{abs} = \downarrow P_{atm} + P_{gauge}$$

$$P_{sat.\ v.p} \uparrow \qquad T \uparrow$$

Bulk modulus & Compressibility

Bulk modulus $= K = \dfrac{dP}{-\left(\frac{dv}{V}\right)}$

N/m^2

$\frac{1}{K}$ = compressibility.

$\rho V = m$ = constant.

$\Rightarrow \rho\, dv + v\, d\rho = 0$

$\Rightarrow -\dfrac{dv}{V} = \dfrac{d\rho}{\rho}$

$$\Rightarrow \boxed{K = \rho \frac{dP}{d\rho}}$$

$$\boxed{\frac{1}{K} = \frac{1}{\rho}\frac{d\rho}{dp}}$$

isothermal bulk modulus

→ isothermal means constant temperature.

$P = \rho RT$, $R = 0.287 \dfrac{KPa \cdot m^3}{kg \cdot kalvin}$

$dP = (d\rho) RT$

$\Rightarrow \dfrac{dP}{d\rho} = RT$

$\Rightarrow \rho \dfrac{dP}{d\rho} = \rho RT = P$

$$\Rightarrow \boxed{K_{isothermal} = P}$$

Adiabatic bulk modulus

Adiabatic process → No heat exchange with the surrounding.

PV^{γ} = constant,

$\gamma = \frac{C_p}{C_v}$

C_p → sp. heat at constant pressure.

C_v → sp heat at const volume

γ = adiabatic constant

$P\left(\frac{m}{\rho}\right)^{\gamma}$ = const.

m = const.

P = (constant) ρ^{γ}

$\Rightarrow \frac{dP}{d\rho} = \gamma(\text{constant}) \cdot \rho^{\gamma-1}$

$\Rightarrow \rho\frac{dP}{d\rho} = K = \gamma \cdot \text{constant} \cdot \rho^{\gamma} = \gamma P$

$$\boxed{K_{adiabatic} = \gamma P}$$

Note: Bulk modulus increases with increase in pressure and decreases with increase in temperature.

Note: Liquids are generally considered to be incompressible except under very high pressure. as in water hammer pressure.

Air is generally 15,500 times more compressible then water.