# Fluid Mechanics

For a fluid, the fundamental laws that we will take into

- law of conservation of Mass
- law of conservation of momentum
- Newton's 2nd law of Motion
- law of conservation of Energy
- laws of Thermodynamics.
- Angular momentum

## Control Volume

Control volume as the name suggests, is a shaped volume (like cuboid, cube etc) through whose faces mass can come in and leave in any arbitrary way possible.

Now the face through which mass can leave or enter depends on the pressure field in the domain

Each of these faces are called control surfaces which can be considered as infinitely thin surface through which mass can come in, but it's mass is so small that it can't hold any fluid.

A control volume has a fixed mass, but a porous boundary.

## System

A system is control volume whose surfaces aren't porous to the flow of mass.
A system also defines fixed mass of the fluid.
In a system, the mass is always constant.

Whereas in a control volume, mass can come in, mass can go out or mass can even get accumilated (eg. when the density of the fluid is changing, so the mass of fluid contained may change)

## Differential approach and Integral approach

Differential approach starts with infinitesmly small system and goes into a finite system

Integral approach starts with finite system and gives us the gross behaviour of the finite system as a whole.

Based on the application, sometime we use diff approach and some time integral approach.

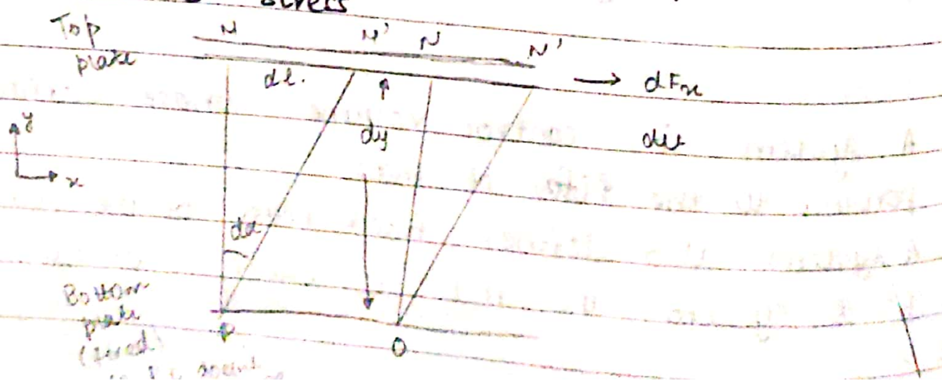
→ Viscosity of solid is ∞, liquid is small and gases is negligable.

## Stress

When there is a force on an area, it can resolved into two components,

The stress due to normal comp. of force is called normal stress

The stress due to parallel comp of force is called shear stress



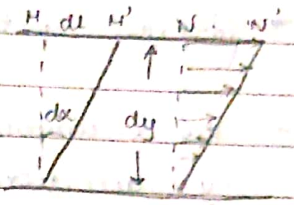
Deformation rate is the rate of change of angle ($\alpha$)

Shear stress ($\tau_{yx}$) = $\dfrac{dF_x}{dA_y}$ → written to denote that area and force are perpendicular

$y$ → Area being acted upon

$x$ → direction of force

Normal stress ($\sigma_{yy}$) = $\dfrac{dF_y}{dA_y}$




$dl = du\, dt$ , $dl = dy\, d\alpha$

$$\frac{d\alpha}{dt} = \frac{du}{dy}$$

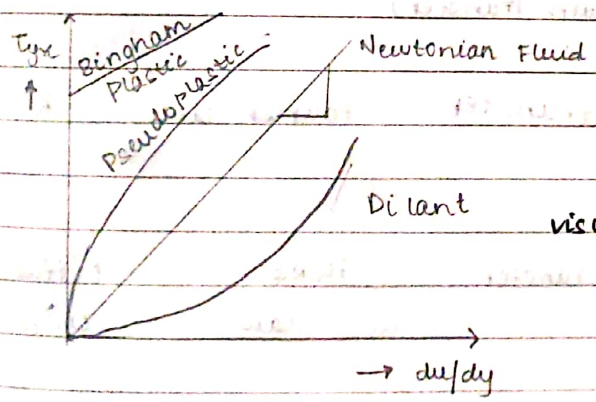
$\dfrac{d\alpha}{dt}$ → Deformation rate

$\dfrac{du}{dy}$ → rate of change of x-comp of velocity

## Newton's law of Viscosity

$$\tau_{yx} \propto \frac{du}{dy} \Rightarrow \tau_{yx} = -\mu \frac{du}{dy}$$

$\mu$ → Viscosity




Viscosity is a function of tem

$\mu$ units are $Ns/m^2$

$\mu/\rho$ is called kinematic viscosity and its units are $m^2/s$

$\mu$ → viscosity, $\rho$ → density

Note :

→ Until and unless there are other external forces or pressure difference, $\dfrac{du}{dy}$ is a constant in the above case, as $u = k(y) + c$ and $\dfrac{du}{dy} = k$ a constant

• Bingham plastic is a viscoplastic material that behaves but flows as

as a rigid body at low stresses but flows as a viscous fluid at high stress

→ Viscosity aids in momentum.

→ viscosity of liquid decreases with increase in temp while for gases, viscosity of gases increases with increase in temp (Think on this based on cohesive forces)

→ The x-component of momentum is transferred in -y direction

$$\tau_{yx} = -\mu \frac{dv_x}{dy}$$

Shear stress ~~is decreasing~~ in +y direction

| Cause | Effect | Law | Property |
|---|---|---|---|
| Velocity Gradient | Shear stress (Momentum Transfer) Molecular Transfer | Newton's Law | $\mu$ |
| Temp. Gradient | Heat transfer | Fourier law | k |
| Conc. Gradient | Mass transfer. | Fick's law | Diffusion co-eff ($cm^2/s$) |

$D_{AB}$ - Mass diffusivity ($cm^2/s$)

$k/\rho c_p$ - Thermal diffusivity ($cm^2/s$)

$\mu/\rho$ - Momentum diffusivity ($cm^2/s$)

Mass flux, heat flux are vectors while momentum flux is tensor