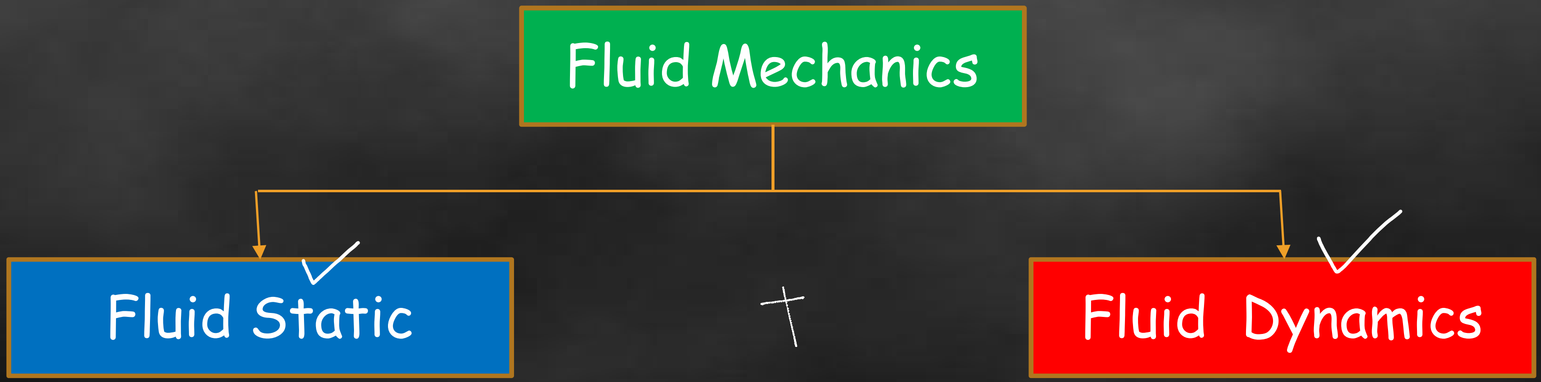
Subject: **Fluid Mechanics and Hydraulic machine**

Chapter : **Fluid and their Properties**

Topic : **Fluid and Their Properties**

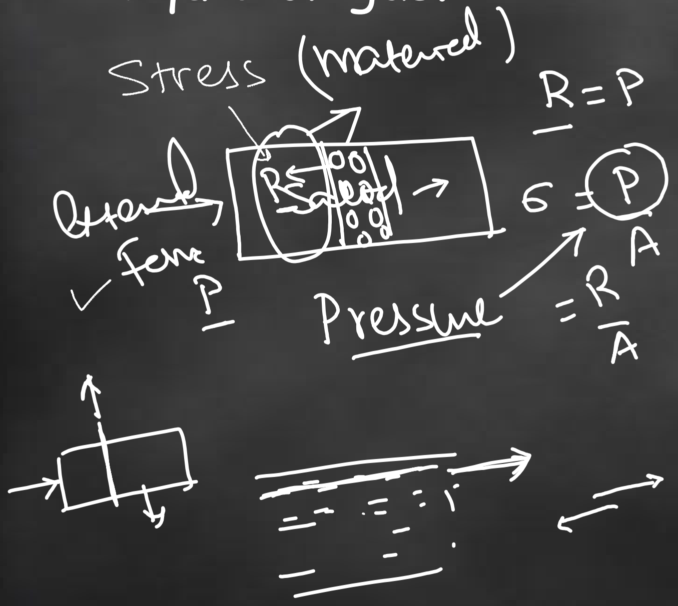
Introduction of Fluid

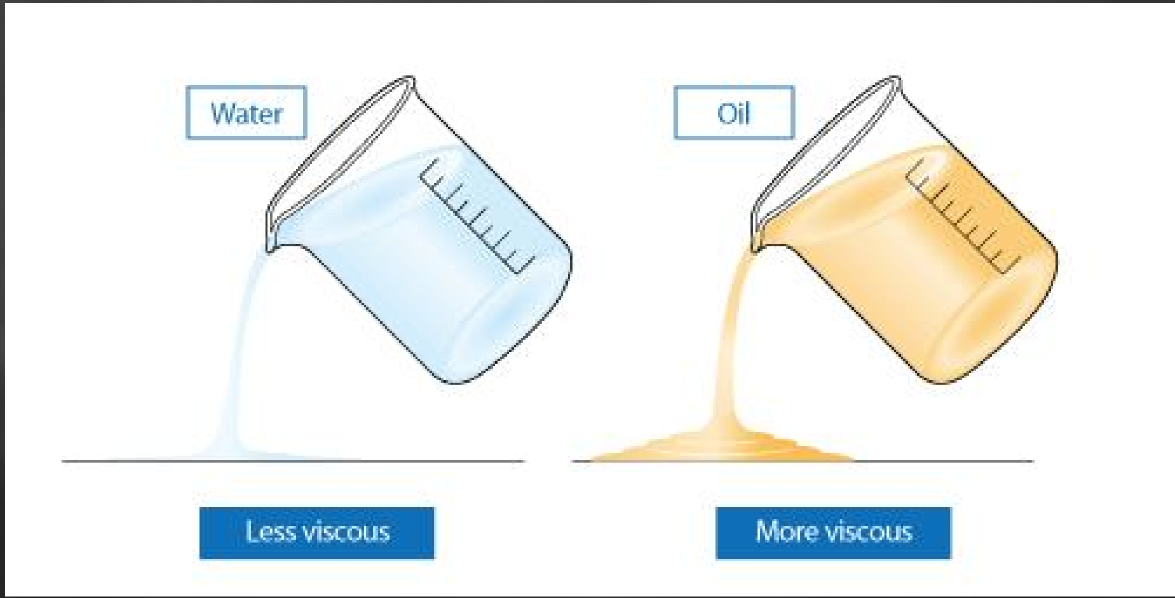
- Fluid mechanics is a study of the behavior of fluids, either at rest (fluid statics) or in motion (fluid dynamics).
- The analysis is based on the fundamental laws of mechanics, which relate continuity of mass and energy with force and momentum.
- An understanding of the properties and behavior of fluids at rest and in motion is of great importance in engineering.



Definition of Fluid

- Fluid can be defined as a substance which can deform continuously when being subjected to shear stress at any magnitude. In other words, it can flow continuously as a result of shearing action. This includes any liquid or gas.





Density

Density of a fluid,

Definition: mass per unit volume,

- slightly affected by changes in *temperature* and *pressure*.

ρ = mass/volume = m/V

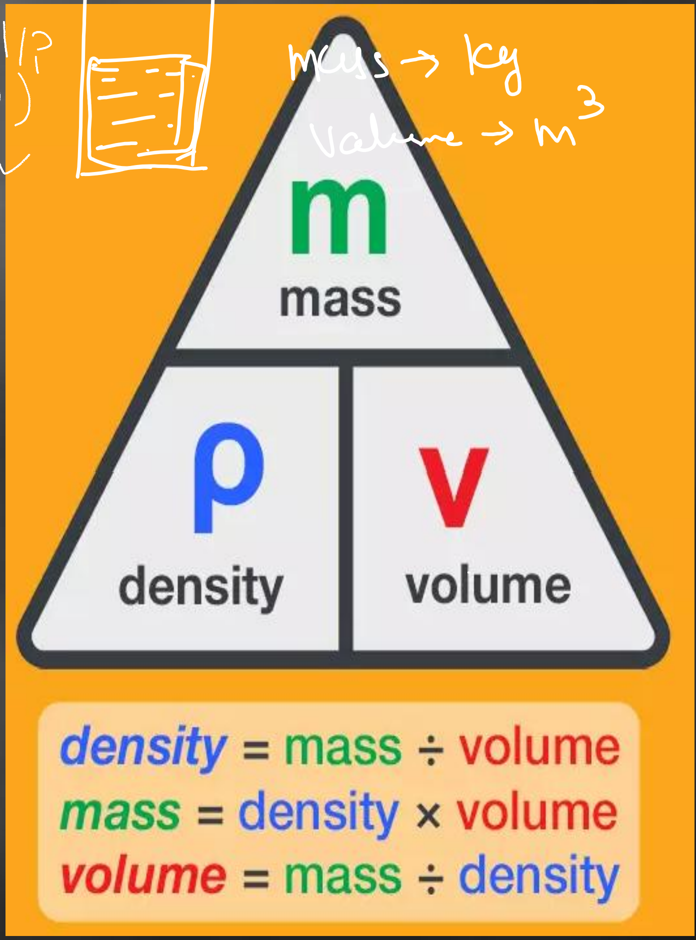
$1\ m^3 = 1000$ litre

Units: kg/m^3 or g/cm^3

Typical values:

Water = 1000 kg/m^3; = 1 kg/l

Air = 1.23 kg/m^3 (Temp STP)



Specific weight or Weight Density

Specific weight of a fluid, ¥

- Definition: weight of the fluid per unit volume

- Arising from the existence of a gravitational force
- The relationship γ and g can be found using the following:

Since $\rho = m/V$

therefore $\gamma = \rho g$

Units: N/m^3

Typical values:

Water = 9814 N/m^3; Air = 12.07 N/m^3

Specific gravity or Relative Density

The specific gravity (or relative density) can be defined in two ways:

gay   Sp. grav = $\frac{\rho_{gas}}{\rho_a}$ $\frac{kg/m^3}{kg/m^3}$

__Definition 1__:

A ratio of the density of a substance to the density of water at standard temperature (4°C) and atmospheric pressure, or

Sp. gravity = $\frac{\rho_F}{\rho_w}$

__Definition 2__:

A ratio of the specific weight of a substance to the specific weight of water at standard temperature (4°C) and atmospheric pressure.

Unit: dimensionless.

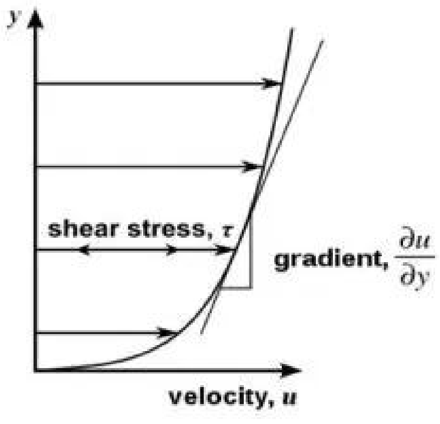
$$SG = \frac{\rho_s}{\rho_w} = \frac{\gamma_s}{\gamma_w}$$

Viscosity (Dynamic viscosity)

- Viscosity, μ, is the property of a fluid, due to cohesion and interaction between molecules, which offers resistance to shear deformation.

- Different fluids deform at different rates under the same shear stress. The ease with which a fluid pours is an indication of its viscosity. Fluid with a high viscosity such as syrup deforms more slowly than fluid with a low viscosity such as water. The viscosity is also known as dynamic viscosity.

Units: $N.s/m^2$ or kg/m/s



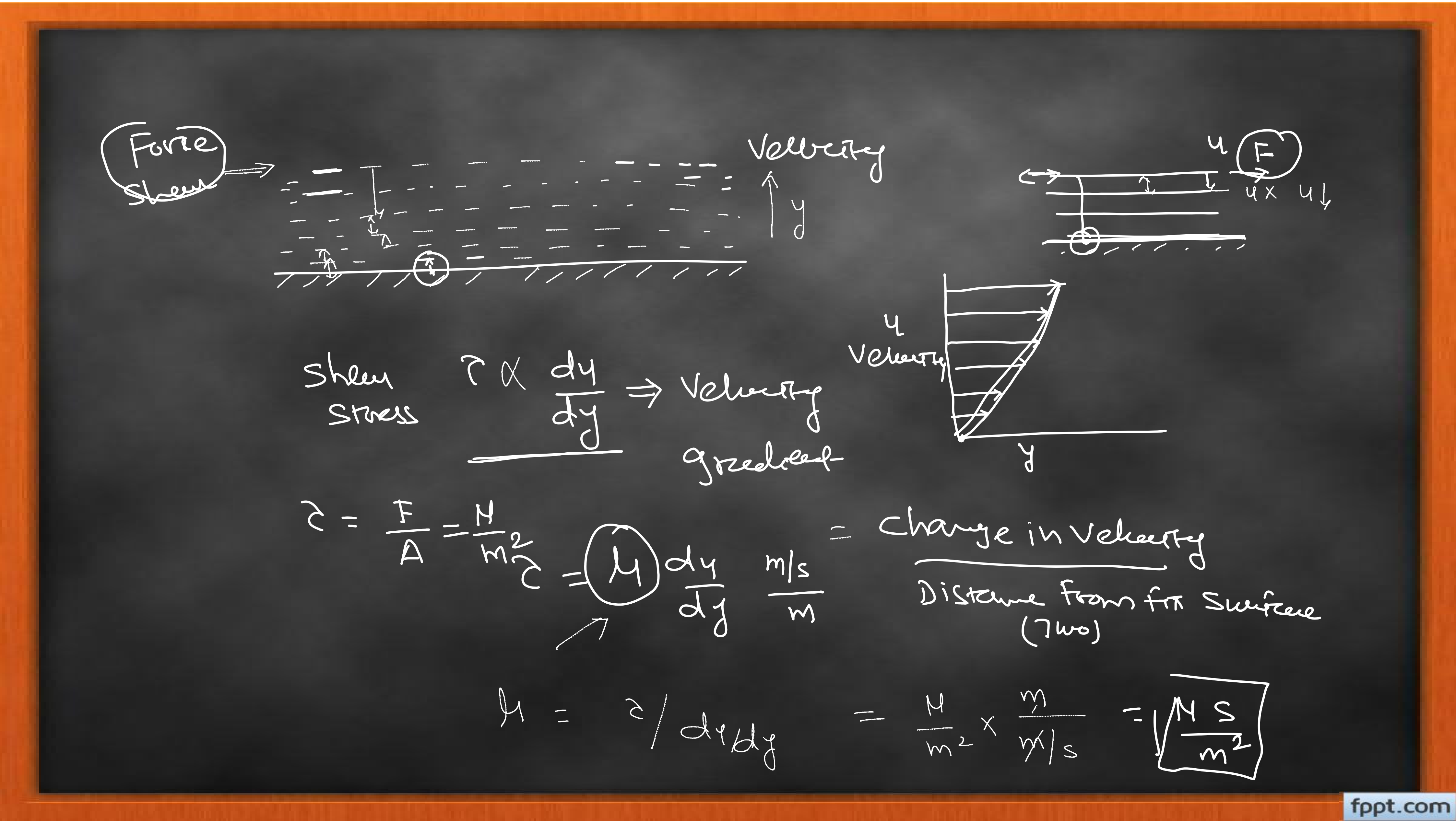
Viscosity, $\tau = \mu \frac{du}{dy}$

Where,

μ = Dynamic viscosity

τ = Shear stress= F/A

$\frac{du}{dy}$ = Rate of shear deformation


Force
Shear
Velocity
y
u
F
Shear stress
τ ∝ du/dy ⇒ Velocity gradient
Velocity
τ = F/A = N/m²
τ = μ du/dy
m/s / m
= Change in Velocity / Distance from fix Surface
(Two)
μ = τ / du/dy = N/m² × m/(m/s) = N s/m²
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Newtonian and Non-Newtonian Fluid

Fluid --obey--> Newton's law of viscosity --refer--> Newtonian fluids

Example:
- Air
- Water
- Oil
- Gasoline
- Alcohol
- Kerosene
- Benzene
- Glycerin

Newton's' law of viscosity is given by;

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

τ = shear stress
μ = viscosity of fluid
du/dy = shear rate, rate of strain or velocity gradient

- The viscosity μ is a function only of the condition of the fluid, particularly its temperature.

Newtonian and Non-Newtonian Fluid

Fluid --- Do not obey ---> Newton's law of viscosity --- refer ---> Non- Newtonian fluids

- The viscosity of the non-Newtonian fluid is dependent on the *velocity gradient* as well as the *condition of the fluid*.

Newtonian Fluids

- a linear relationship between shear stress and the velocity gradient (rate of shear),
- the slope is constant
- the viscosity is constant

$$\tau = \mu \frac{du}{dy} + 0$$

$$y = mx + c$$

Non-Newtonian fluids

- slope of the curves for non-Newtonian fluids varies

Types of Fluids

$$\tau = \mu \left(\frac{du}{dy}\right)^n + C$$

$y = mx^n + c$

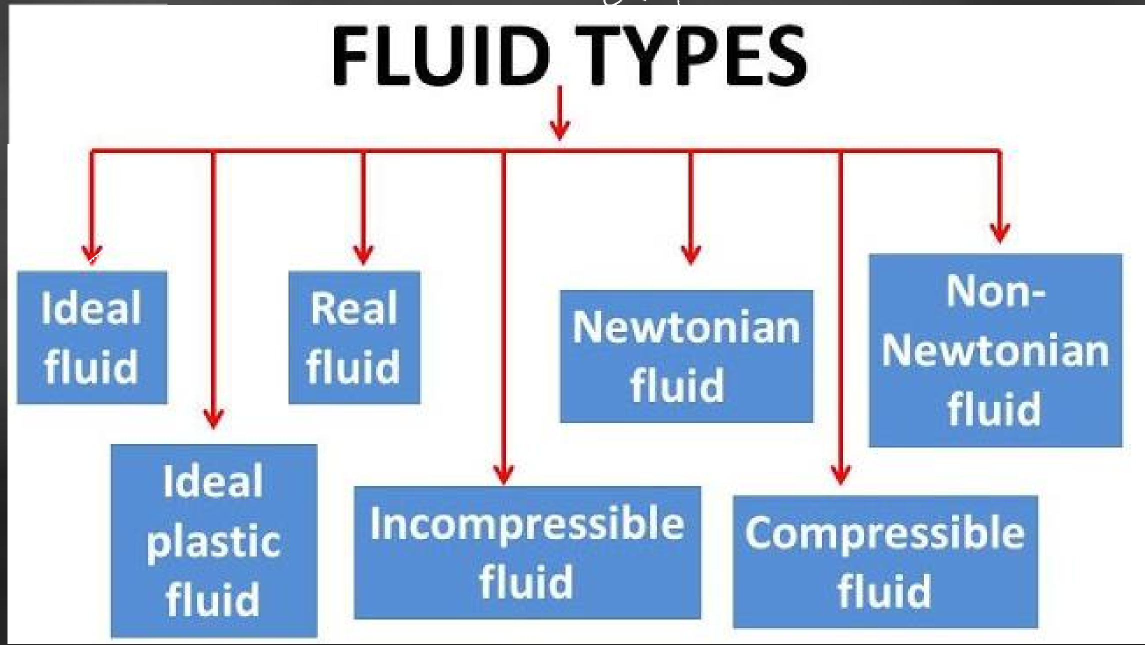
$n = 1$

$y \rightarrow x$

$c \neq 0 \quad n \neq 1 \Rightarrow \tau = \mu \frac{du}{dy}$

Types of fluid based on two value

1. Value of n
2. Value of C



Types of Fluids

1. Newtonian Fluids:

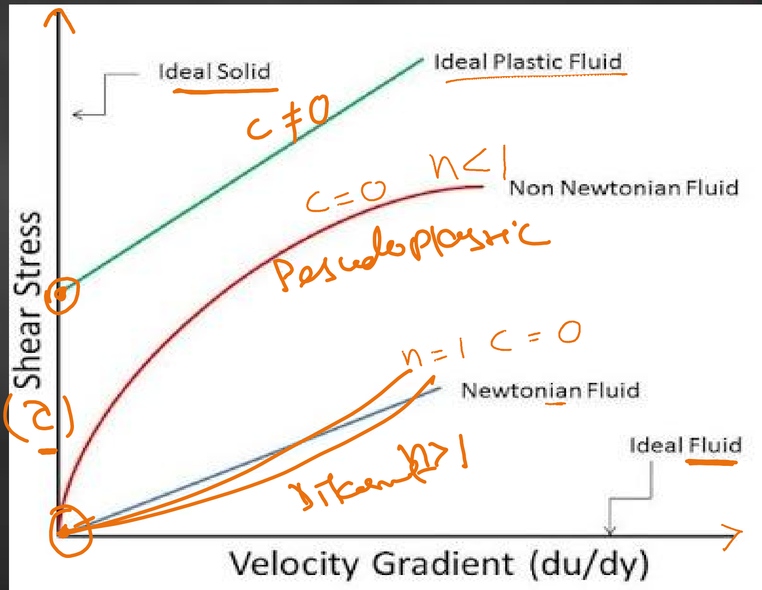
- Value of $n = 1$ and $C = 0$ in equation then the fluid is known as Newtonian fluid

2. Non-Newtonian Fluids:

- Value of $n > 1$ or $n < 1$ and $C = 0$ in equation then the fluid is known as Non-Newtonian fluid

- $N < 1$ -------

Pseudo plastic: most non-Newtonian fluids fall under this group. Viscosity decreases with increasing velocity gradient,
e.g. colloidal substances like clay, milk, and cement.



Types of Fluids

❑ N > 1 -----

Dilatants: viscosity decreases with increasing velocity gradient, e.g. quicksand.

3. Idea Fluid

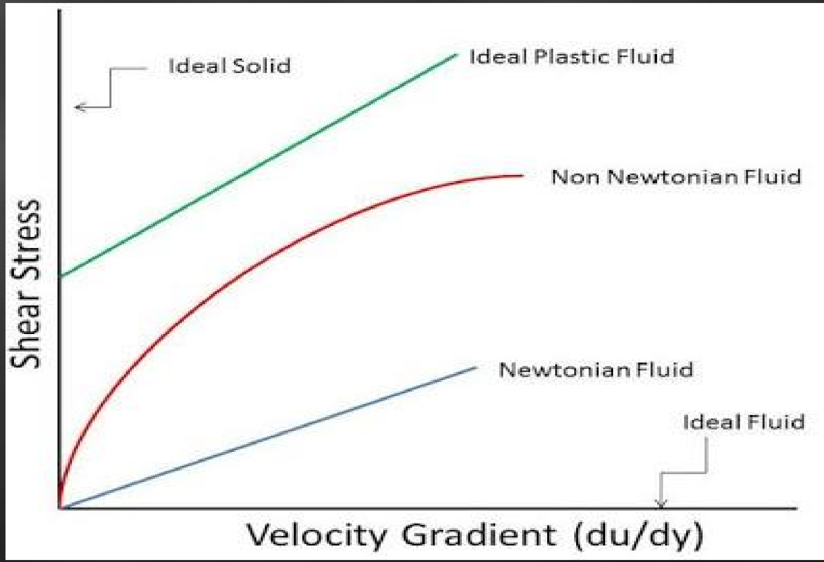
If $\tau = 0$ in the equation then the fluid is known as Ideal Fluid.

4. Ideal Solid

If du/dy = 0 in the equation then substance is Known as Ideal Solid.

5. Ideal Plastic Fluid

If n = 1 and C > 0 then the fluid is known as Ideal Plastic fluid.



Surface Tension

There are mainly two forces are acting on Fluid Particles

1. Cohesion ✓
2. Adhesion ✓

Water ↔ water

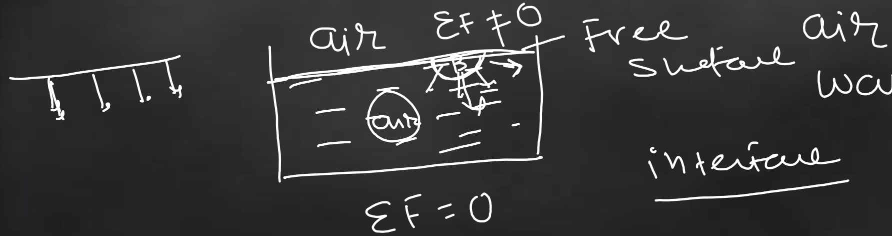
1. Cohesion

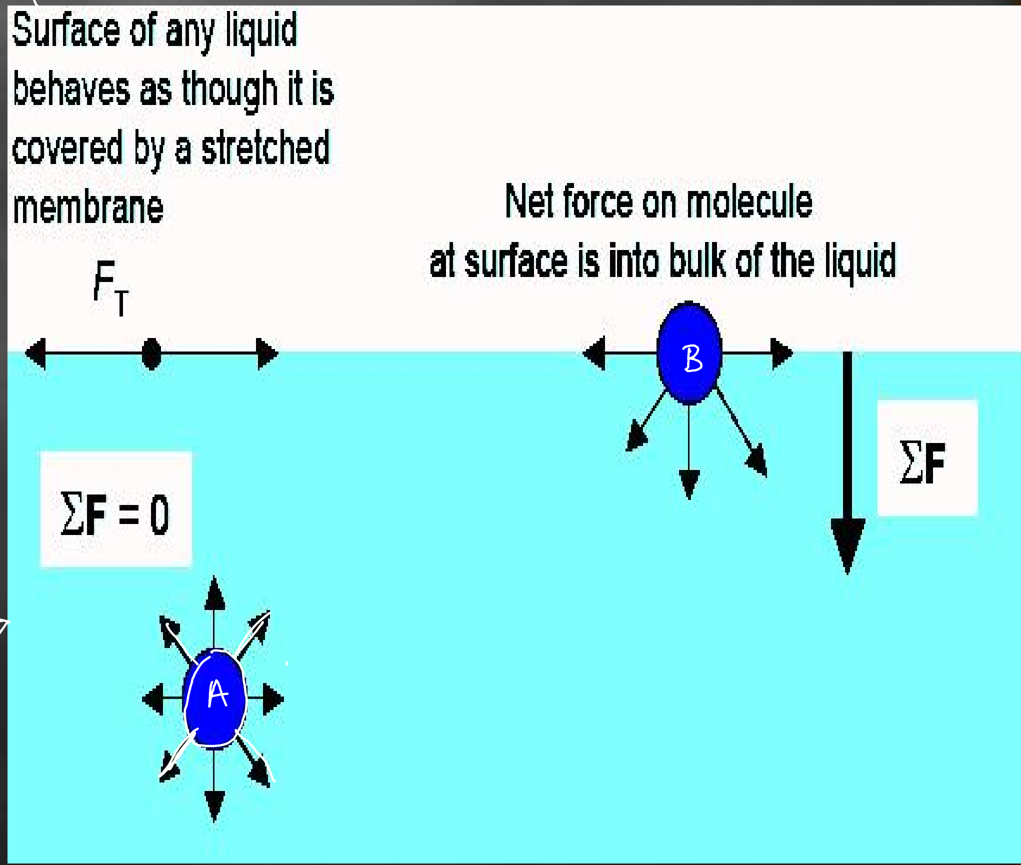
The force between molecules of same fluid then this force is known as Cohesion force.

oil ↔ water

2. Adhesion

The force between Molecules of different fluids then force is known as Adhesion force.





Surface Tension (σ)

- Surface tension is a resultant force which is produced because of combine effect of Cohesion force and Adhesion force.

$\sigma = \frac{F}{l} = \frac{N}{m}$

- It will be measured as Force per unit length. So unit will be N/m.

- Equation of calculating surface tension of the fluid:

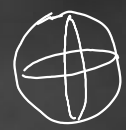
Pressure created on particles of fluids = Surface tension force on Particles

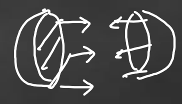
$\sigma = \frac{F}{l}$ $\quad A = \frac{\pi}{4} d^2$

$P = \frac{F}{A}$ $\quad l = \pi d$

$$P \times \frac{\pi}{4} \times d^2 = \sigma \times \pi \times d$$

$$P = 4\sigma / d$$





P

σ

hallow bubble

$l = 2(\sigma \times \pi d)$

$P = \frac{8\sigma}{d}$

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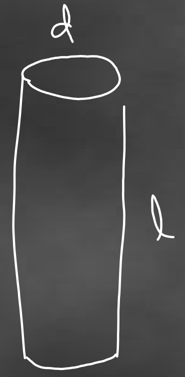
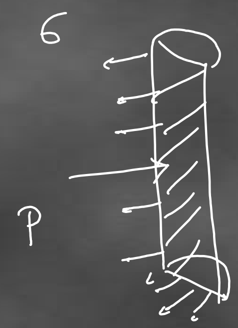




Force due to pressure

$= P \times \text{area}$

$= P \times l \times d$

Surface Tension force

$= \sigma \times \text{length}$

$= \sigma \times (2l)$

$$P \times \cancel{l} \times d = \sigma \times 2\cancel{l}$$

$$P = \frac{2\sigma}{d}$$

$$P = \frac{4\sigma}{d}$$

$$P = \frac{8\sigma}{d}$$

$$P = \frac{2\sigma}{d}$$

Capillary Effect

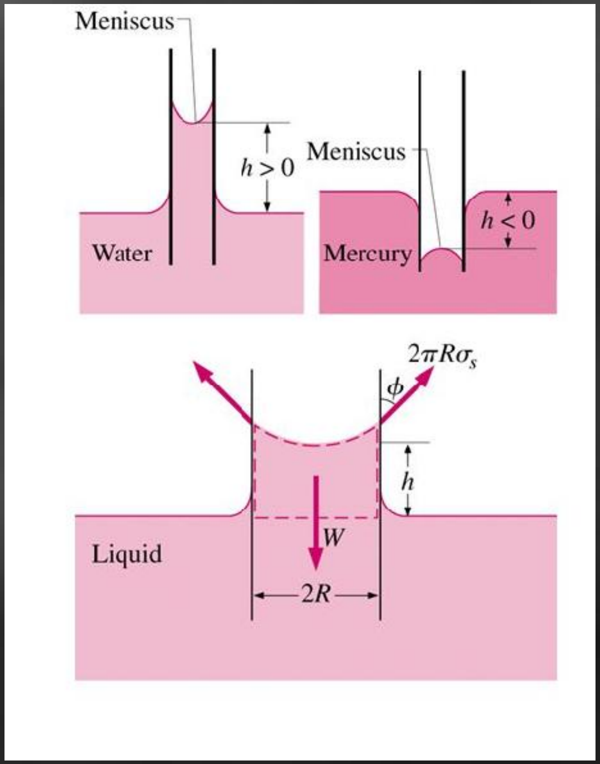
- When any small diameter tube with open ends submerged in any fluid then The level of fluid will be raised or fall in that tube, this effect is known as Capillarity effect.

- Level of fluid will be rise or fall.

So the capillarity effect is divided into two types

1. Capillarity Rise – Possible in Light liquid (Water)
2. Capillarity Fall - Possible in Heavy liquid (Mercury)

$\rho_w = 1000$ $\rho_m = 13000$



Capillary Effect

Equation of the capillarity effect:

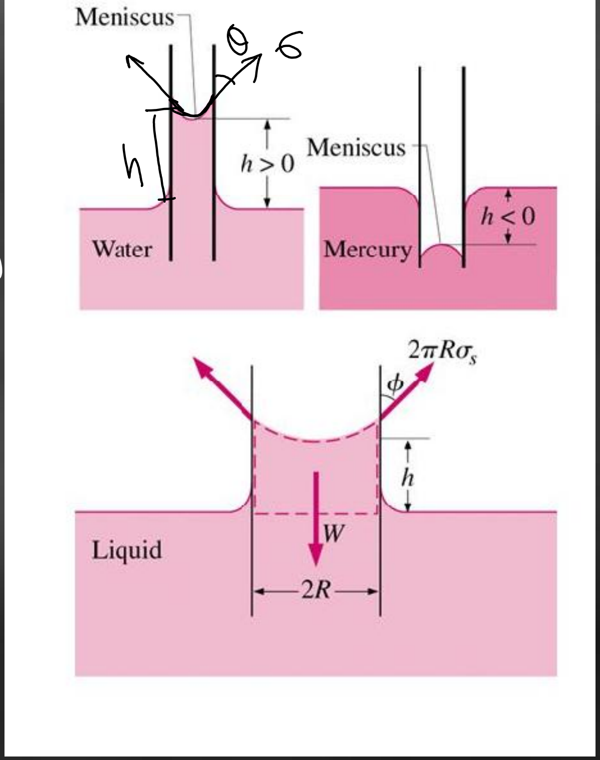
$P = 4\sigma / d$

But here Surface tension for created in Inclined Direction as shown in figure.
Surface tension is considered in vertical direction only.

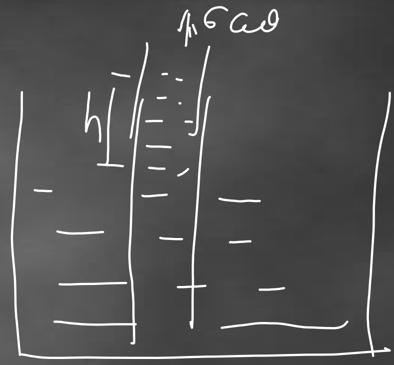
So component of σ in vertical direction is **σ Cosθ.**

$\rho g h = 4\sigma \cos\theta / d$

$$h = 4\sigma \cos\theta / \rho g d$$



Vertical Plate



$$P = (l \times t) \times h \times \rho \times g$$

$$\text{Surface Tension force} = \sigma \cos\theta \times 2l$$

$$l \times t \times h \times \rho \times g = \sigma \cos\theta \times 2l$$

$$\boxed{h = \frac{2\sigma\cos\theta}{\rho g t}}$$

Compressibility

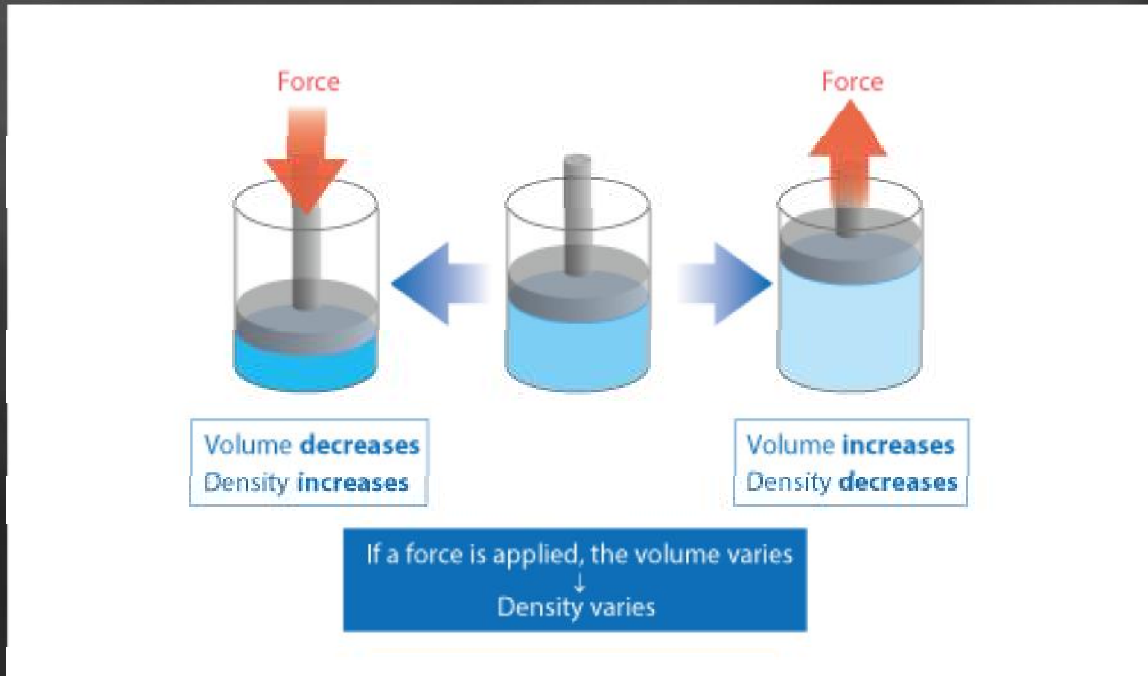
It is the ability of any fluid to be compressed means If you compress any fluid then some fluids are compressed more and some fluids are compressed less because of its Compressibility.

It can be also defined as reciprocal of Bulk Modulus (K).

$$K = -\frac{\Delta P}{dV/V}$$

Compressibility = 1/K

$$= -\frac{dV/V}{\Delta P}$$



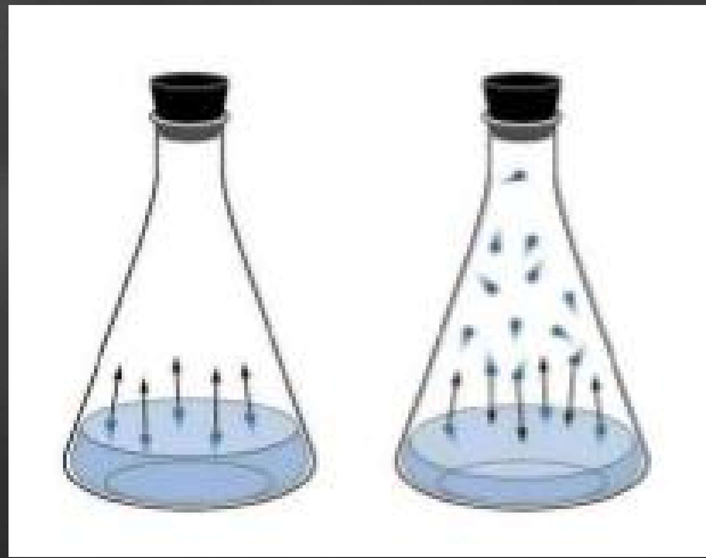
Vapour Pressure

The **pressure** exerted by the gas in equilibrium with a solid or liquid in a closed container at a given temperature is called the vapour **pressure**.

Means in any fluid, the pressure of particles goes below than vapour pressure At given temperature then they will be converted in to vapour form.

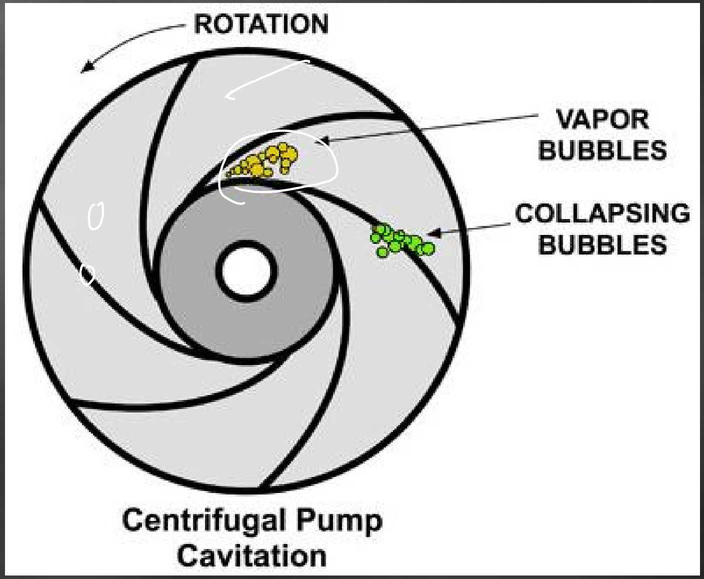
Which is undesirable for working.

Because of this cavitation is Produced among the solid surface.



Cavitation

- For any fluid passing or flowing in some solid surface, If the pressure of any particle goes below than vapour pressure then this particle becomes a vapour Bubble.
- These types of many bubbles create cloud of bubble and carried out with fluid while passing.
- This cloud of bubbles collapse with solid surface and create cavities on the surface of solid surface
- This effect is known as Cavitation.



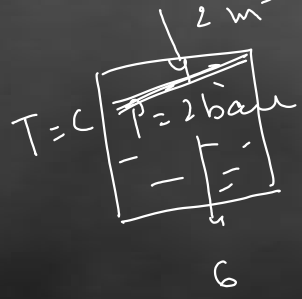
$$\text{Comp} = \frac{-dv/v}{dP}$$

2) Adiabatic

$$PV^{\gamma} = C \qquad x^{n}$$

$$P\,\gamma\,V^{\gamma-1}\,dv + V^{\gamma}\,dP = 0 \qquad n\,x^{n-1}$$

$$\boxed{K = \gamma P}$$



1) isothermal

$$PV = C \quad \text{— (I)} \qquad \vec{x}\cdot\vec{y} = c$$

$$P\,dv + v\,dP = 0 \qquad x\,y' + x'\,y = 0$$

$$P\,dv = -v\,dP$$

$$P\,\frac{dv}{v} = -dP$$

$$\frac{-\frac{dv}{v}}{dP} = \frac{1}{P}$$

$$\boxed{K = P}$$