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FLUID MECHANICS
HYDRAULIC MACHINERY

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FLUID MECHANICS

1 FLUID PROPERTIES

FLUID MECHANICS

- Fluid mechanics is the branch of science which deals with the behaviour of fluids (i.e liquids and gases) under the conditions of rest and motion.
- Fluid mechanics is divided into three branches.

Fluid Statics

- It is the study of incompressible fluids which are at rest.

Fluid Kinematics

- It deals with velocities, accelerations and the patterns of flow without considering the forces or energy which is responsible for it's motion.

Fluid Dynamics

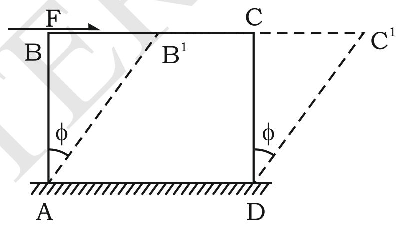
- It deals with velocities, accelerations and the patterns of flow with considering the forces or energy which is responsible for it's motion.

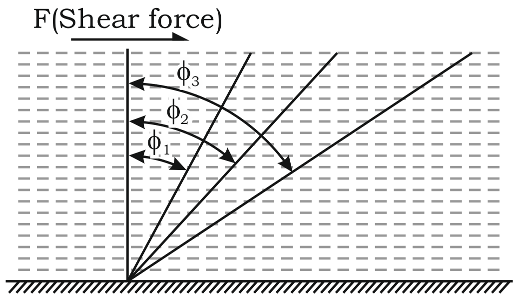
Definition of Fluid

- A fluid is a substance which deforms continuously when subjected to external shear stress however smaller the shear stress may be.
- Both the liquids and gases come under the category of fluids but liquids are very difficult to compress where as gases can be easily compressible.

Difference Between Fluids and Solids

- The molecules of a solid are more closely packed as comparred to that of a fluid.
- Fluids don't have any particular shape and it will obtain the shape of the container in which it is present but solids have a definite shape.
- Attractive (cohesive) forces between the molecules of a solid are larger than those of a fluid.
- In case of fluids, on removal of loads, they will never try to regain their original position but whereas in solids, on removal of loads they will try to regain their original position.
- A fluid has no tensile strength and it can resist the compressive forces only but a solid can show the resistance to all kinds of loads like tensile, shear and compressive loads etc.
- A solid can resist an applied shear stress by a definite angular defor mation.Where as a fluid deforms continuously under the influence of a shear stress.





- In solids, shear stress (τ) is directly proportional to shear strain (ϕ)

$$\tau \propto \phi$$

$$\tau = G\phi$$

In fluids shear stress is directly proportional to rate of shear strain

$$\tau \propto \frac{d\phi}{dt}$$

$$\tau = \mu \frac{d\phi}{dt}$$

μ =Co-efficent of viscosity

Cohesion

- Force of attraction between the molecules of the same liquid.

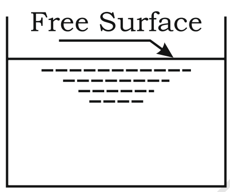
Adhesion

- Force of attraction between the molecules of different liquids (or) between the liquid molecules and solid boundary containing the liquid.

Difference Between Liquid and Gas

Liquids:

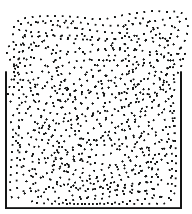
- Liquids have constant volume
- The molecules of liquid are closely packed
- In liquids cohesive forces predominate than the molecular momentum transfer due to closely packed molecules
- Liquids are almost incompressible
- Liquids have free surface.



Eg: Water

Gases:

- Gases don't have constant volume
- The molecules of gas are wide apart
- In gases molecular momentum transfer predominates than the cohesive forces
- Gases are compressible fluids
- Gases don't have free surface



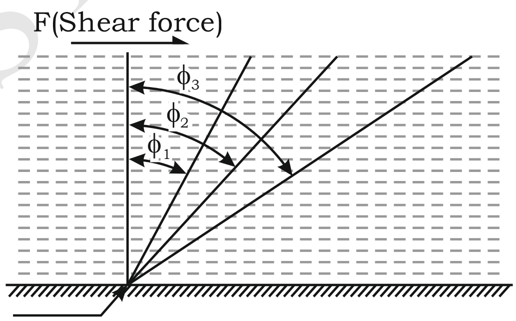
Eg: Air

CONCEPT OF CONTINUUM

- A continuous and homogeneous medium is called continuum.
- It is a kind of idealization of the properties of the matter.
- Any matter which is composed of several molecules assumes as a continuous distribution of mass within the matter with no empty space. In this approach, fluid properties will be expressed as continuous functions of space and time.

NO SLIP CONDITION

- When the real fluid flows over a solid boundary,the relative velocity of the fluid layer in contact with the boundary is tends to zero. This fundamental condition of zero velocity is known as No-slip condition.



No Slip Condition

PROPERTIES OF FLUID

- Properties are measurable characteristics of a fluid which are quantified and with the help of properties, fluid can also be identified.

DENSITY (or) MASS DENSITY (ρ)

- It is the mass of the fluid (or) any matter which occupies an unit volume at standard temperature and pressure.

$$\boxed{\text{Density} = \frac{\text{Mass}}{\text{Volume}}}$$

$$\rho = \frac{m}{V}$$

- **S.I. units :** kg/m^3

Density values of different matters

Matter	Mass density (ρ)kg/m^3
Air	1.24
Water	1000
Mercury	13600
Steel	7850
Concrete	2400

SPECIFIC WEIGHT (or) WEIGHT DENSITY (γ)

- It is the weight of the fluid (or) any matter per unit volume and it is also represented as a force exerted by gravity on a unit volume at standard temperature and pressure.

$$\text{Specific Weight} = \frac{\text{Weight}}{\text{Volume}}$$

$$\gamma = \frac{W}{V} = \frac{mg}{V} \quad [\because W = mg]$$

$$\boxed{\gamma = \rho g} \quad \left[\because \rho = \frac{m}{V}\right]$$

- **S.I. units :** N/m^3
- Specific weight of water, $\gamma = \rho g$

$\therefore \gamma = 1000\ kg/m^3 \times 9.81\ m/sec^2$

$= 9810\ N/m^3$

$= 9.81\ KN/m^3$

$\cong 10\ kN/m^3$

Specfic Weight values of different matters

Matter	Specific weight (γ)
Air	$11.77\ N/m^3$
Water	$9.81\ KN/m^3$
Mercury	$133.4\ KN/m^3$
Steel	$77\ KN/m^3$
Concrete	$23.54\ KN/m^3$

Note : Specific weight depends on the gravitational acceleration (g) and the mass density (ρ). Since the 'γ' varies from place to place then the value of 'g' also vary.

SPECIFIC VOLUME (v)

It is the volume occupied by unit mass of fluid.

$$\text{Specific Volume} = \frac{\text{Volume}}{\text{Mass}}$$

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

- It is the reciprocal of mass density.
- **SI units :** m^3/kg
- Specific volume is applied for gases as their densities are very small

Note : For liquids the mass density, specific weight and specific volume all are vary slightly only with the variation of temperature and pressure. It is due to the molecular structure of the liquids in which the molecules are arranged very compactly.

SPECIFIC GRAVITY (or) RELATIVE DENSITY (S)

- It is the ratio of weight density (mass density) of a fluid to the weight density (mass density) of a standard fluid.
- For liquids, the standard fluid is pure water at 4^0C
- For gases, the standard fluid is either air or hydrogen.

$$\text{Specific gravity} = \frac{\text{Specific weight of a fluid}}{\text{Specific weight of a standard fluid}}$$

$$S = \frac{\gamma}{\gamma_{water}} \text{ (or) } \frac{\rho}{\rho_{water}} \text{ for liquids}$$

$$S = \frac{\gamma}{\gamma_{Air}} \text{ (or) } \frac{\rho}{\rho_{Air}} \text{ for gases}$$

- It is an dimensionless quantity
- Hydrometer is used to measure the specific gravity
- Specific gravity values for different matters.

Matter	Specific Gravity
Air	0.0012
Water	1.0
Mercury	13.6
Steel	7.85
Concrete	2.4

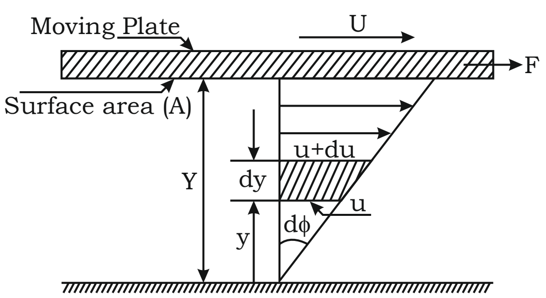
Note :
- If the specific gravity of the fluid is greater than 1 then it is heavier than water and if it is less than 1 then it is lighter than water. If it is equals to 1 then the fluid itself is water.
- All the specific gravities are relative densities but not converse

Viscosity (or) Dynamic Viscosity (μ)

- It is defined as the internal resistance against motion of the one fluid layer over another adjacent fluid layer under the influence of shear force.
- **Viscosity is due to:**
  - Intermolecular cohesive forces between the fluid layers
  - Transfer of molecular momen-tum between the fluid particles
- As the flow occurs, these effects appear because of shear stress between the moving layers of fluids.

Newton's Law of Viscosity

- It states that the shear stress which is applied on a fluid layer is directly proportional to the velocity gradient of fluid



$$\boxed{\tau \propto \frac{du}{dy}}$$

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

Where,

τ = Shear stress between any two fluid layers in $N/m^2 = \frac{F}{A}$

F=Force requirred to move the plate of surface area (A)

$\frac{du}{dy}$ = Velocity gradient or rate of angular deformation or rate of shear strain in $\frac{1}{sec}$

μ = Dynamic viscosity or co-efficient of viscosity in $\frac{N-sec}{m^2}$

Units of Viscosity (μ)

M.K.S : $\frac{Kgf-sec}{m^2}$

S.I : $\frac{N\text{-}sec}{m^2}$ (or) Pa-sec

CGS : $\frac{Dyne-sec}{cm^2}$ (or) Poise

Conversion : $1\ Poise = 0.1\ \frac{N-s}{m^2}$ =0.1 Pa-sec

$$\boxed{1\,Newton = 10^5\ Dynes}$$

$$1\,Centi\ Poise = \frac{1}{100}\,Poise$$

Viscosity of different fluids at 20°C

$$(\mu)_{water} = 10^{-3}\frac{N-s}{m^2}$$

$$(\mu)_{air} = 1.81\times10^{-5}\frac{N-s}{m^2}$$

Kinematic Viscosity (ν)

It is the ratio of dynamic viscosity to mass density of the fluid.

$$\text{Kinematic viscosity} = \frac{\text{Dynamic viscosity}}{\text{mass density}}$$

$$\nu = \frac{\mu}{\rho}$$

Units :

S.I (or) M.K.S : m^2/sec

CGS : cm^2/sec (or) Stoke

Saybolt universal viscometer is used to measure the kinemetic visosity

Effect of Temperature on Viscosity

Dynamic Viscosity

- **For liquids:**
  - For liquids dynamic viscosity (μ) is decreases with increase in temperature because in liquids the viscosity is governed by the cohesive forces between the molecules of the liquid.

$$\mu_T = Ae^{\beta/T}$$

Where

  - μ_T = Dynamic Viscosity at absolute temperature, T
  - A, β = Constants for a given liquid
- **For Gases:**
  - For gases, the viscosity is mainly due to molecular collisions. Due to molecular collisions, there will be increase in molecular momentum transfer and decrease in cohesive forces. These molecular collisions are mainly due to increase in temperature which results in random movement of the gas molecules and due to random movement, molecular collisions will be takes place.

$$\mu_T = \frac{bT^{1/2}}{1+\frac{a}{T}}$$

where

  - μ_T = Dynamic viscosity at absolute temperature T
  - a, b = constants for a given gas

Kinematic Viscosity (ν)

- For liquids, as temperature increases the kinematic viscosity decreases.

$$\nu_{liq} = \frac{\mu_{liq}}{\rho_{liq}}$$

- For gases, as temperature increases the kinematic viscosity of gases increases at a faster rate. This is known from sutherland's equation, it states that

$$\mu_{gas} \propto \sqrt{T}$$

$$\nu_{gas} = \frac{\mu_{gas}}{\rho_{gas}} = \frac{\sqrt{T}}{\rho_{gas}} = \frac{T}{1/T} = (T)^{3/2}$$

$$\left[\therefore p = \rho RT, \rho = \frac{P}{RT}, \rho \propto \frac{1}{T}\right]$$

TYPES OF FLUIDS

- The fluids may be classified into four types:
  - Ideal fluid (or) Perfect fluid
  - Real fluid
  - Newtonian fluid
  - Non-Newtonian fluid

Ideal fluid (or) Perfect fluid

- A fluid which is incompressible and non viscous (frictionless) i.e viscosity equal to zero is known as Ideal fluid (or) perfect fluid.
- These are imaginary fluids which doesn't exist in reality and does not offer any shear resistance when fluid is in motion.

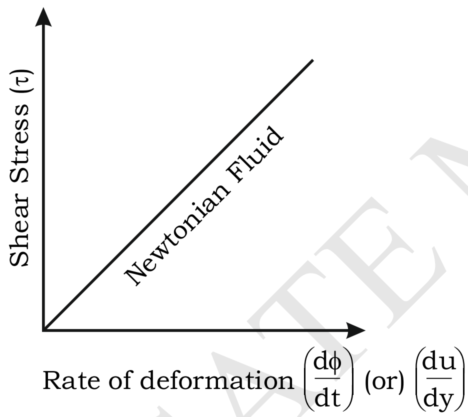
Real Fluids

- The fluids which possess the properties such as viscosity, surface tension and compressibility are known as "real fluids".
- All the fluids in practice are real fluids and they offer the resistance when fluid is in motion.

Newtonian Fluids

- A real fluid is a fluid which obeys the Newton's law of viscosity.
- These fluids have constant viscosity which is independent of shear stress.
- In these fluids, there exists a linear relationship between shear stress and resulting rate of angular deformation.

Eg: Air, water, light oils and gasoline.



Non-Newtonian Fluids

- A real fluid which do not follow the Newton's law of viscosity which means the shear stress is not proportional to the rate of angular deformation.
- In these, the relationship between shear stress and velocity gradient is given as

$$\tau = A\left[\frac{du}{dy}\right]^n + B$$

Where

A, B = constants which depends upon the type of fluid and conditions imposed on flow

A = Flow consistency index

B = Shear stress at yield point
n = Flow behaviour index

Based on power index 'n' and constant 'B', with respect to the time, the Non-newtonian fluids can be divided into two types

- Time Independent fluid
- Time dependent fluid

Time Independent Fluid

This is again divided into three types

- Dilatant fluid (or) shear thickening fluids
- Pseudo plastic fluid (or) shear thinning fluids
- Bingham plastic fluid (or) Ideal plastic fluid.

- **Dilatant fluid:**
  - If the apparent viscosity increases with increasing deformation rate then the fluid is known as dilatant fluid.

    Generalized equation of Time Independent fluid is given as

$$\tau = A\left[\frac{du}{dy}\right]^n + B$$

  - If B=0 and n>1 then it is dilatant fluid.

$$\tau = A\left[\frac{du}{dy}\right]^n$$

$$\tau = A\left[\frac{du}{dy}\right]^{n-1}\left[\frac{du}{dy}\right]$$

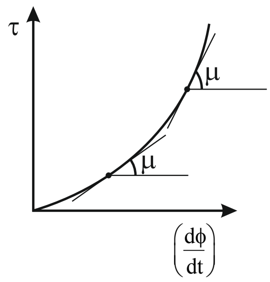
$$\tau = \eta\left[\frac{du}{dy}\right] \qquad \left[\therefore A\left[\frac{du}{dy}\right]^{n-1} = \eta\right]$$

where η = apparent viscosity

for n>1, (n-1) = +ve value

- It is also known as shear thickening fluid because as velocity gradient increases, the apparent viscosity is also increases.

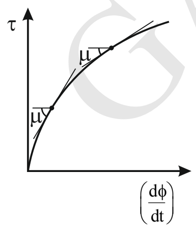
Eg: Butter, quick sand, Rice starch, Sugar solutions.



- **Pseudo Plastic fluid:**
  - If the apparent viscosity of the fluid decreases with increase in deformation rate of the fluid is termed as pseudo plastic fluid.
  - If we put B=0 and n<1 in generalized equation then we get equation for pseudo plastic fluid.

Eg: Blood, Milk, Paper Pulp, Polymeric Solutions such as rubber, suspension paints.

  - It is also known as shear thinning fluids.

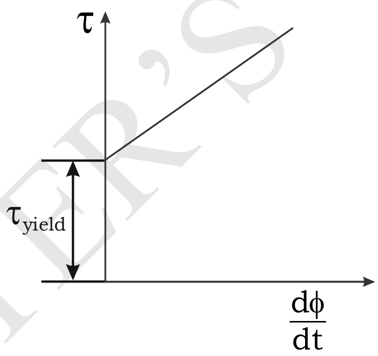


- **Bingham Plastic fluid**
  - If a fluid that behaves as solid till a minimum yield stress and flows after reaching the yield stress limit is known as Bingham plastic (or) Ideal plastic fluid.
  - Here we can take B = τ_{yield} and n=1

    then $\tau = \tau_{yield} + \mu\left[\frac{du}{dy}\right]$

Eg : Sewage sludge, tooth paste, Gel Creams.... etc.

  - Yield stress is (τ_y) certain amount of minimum shear stress required for a bingham plastic fluid to start flowing.

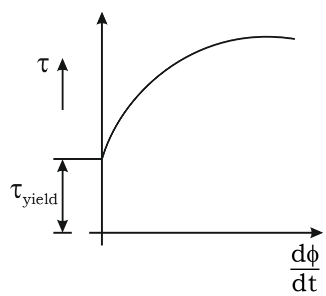


Time Dependent Fluid

This is again divided divided into two types

- Thixotropic fluid
- Rheopectic fluid

- **Thixotropic fluid:**
  - If the apparent viscosity of a fluid decreases with the time under constant applied shear stress then the fluid is known as "Thixotropic fluid".



  - Here we can take $B \neq 0$ and n<1

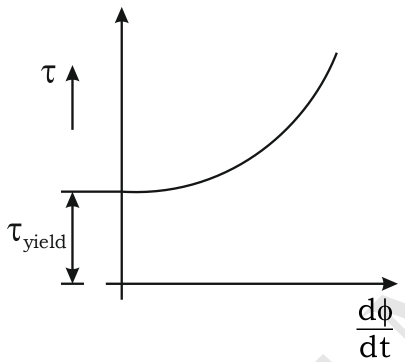
    So B = τ_{yield} and n< 1

then $\tau = \tau_{yield} + A\left[\frac{du}{dy}\right]^{n<1} = \tau_{yield} + \eta\left[\frac{du}{dy}\right]$

Eg: Paints, clay, enamel etc...

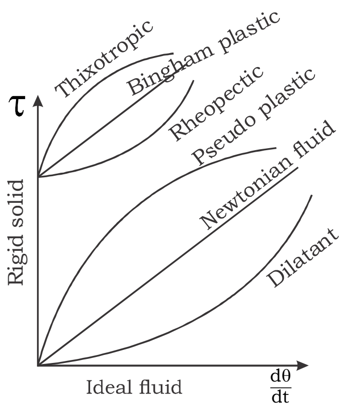
- When subjected to high shear by the brush during application of paint, the apparent viscosity is reduced, the paint covers the surface smoothly and brush marks disappears subsequently.

- **Rheopectic fluid:**
  - If the apparent viscosity of a fluid increases with the time under the application of constant shear stress then the fluid is known as "Rheopectic fluid".

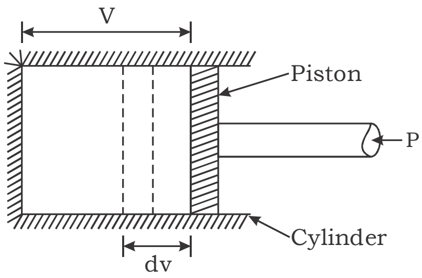


Eg: Gypsum pastes, printer inks, lipstick

- Time dependent fluid i.e viscosity depend upon both the shear stress and duration of application and viscosity may increase or decrease with time.



BULK MODULUS (K)



Let

- V= Volume of a gas present in the cylinder
- P = Pressure of a gas when the volume of gas is V.

$$\text{Bulk modulus} = \frac{\text{Change in Pressure}}{\text{Volumetric Strain}}$$

$$K = \frac{dP}{\frac{-dV}{V}} \text{ (or) } \frac{dP}{\frac{d\rho}{\rho}}$$

$$K = \frac{-VdP}{dV} = \frac{\rho dP}{d\rho}$$

Note : Negative sign indicates a decrease in volume due to increase in pressure

Units : S.I : N/m^2

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

$$dV = -\frac{1}{\rho^2} d\rho$$

$$= \frac{-1/\rho^2 d\rho}{V}$$

$$= \frac{-1/\rho^2 d\rho}{1/\rho}$$

$$\therefore \frac{dV}{V} = \frac{-d\rho}{\rho}$$

For incompressible fluid, $K = \infty$ because dV=0

COMPRESSIBILITY (β)

- Compressibility is equal to reciprocal to the bulk modulus 'K'.
- $$\text{Compressibility} = \frac{1}{\text{Bulk modulus}}$$

$$\beta = \frac{1}{K}$$

Units : SI - m^2/N

- Since most of the liquids have a comparatively high value of bulk modulus. So the compressibility is close to zero hence the liquids are considered as practically incompressible.

Eg: Water.

- The compressibility of water is considered in the case of water hammer problems. Due to sudden closure of valves in pipe lines,a high pressure wave is generated. It is observed in hydroelectric water power plant and long pipe flow lines with flow regulation.

SURFACE TENSION (σ)

- It is defined as the tensile force exerted by the free surface of the liquid per unit length.

(or)

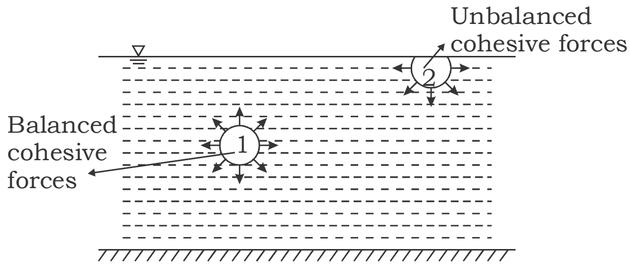
- It is also expressed as surface energy (or) work done per unit surface area

$$\text{Surface tension} = \frac{\text{Tensile force}}{\text{Unit length}}$$

$$\sigma = \frac{F}{L}$$

Units: $\frac{N}{m} (\text{or}) \frac{J}{m^2}$

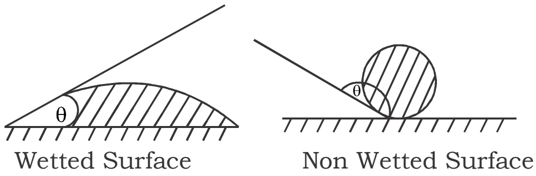
- σ_{H_2O} with air interface is 0.0736 N/m
- σ_{Hg} with air interface is 0.48 N/m
- Surface tension is due to cohesion between particles at the surface of liquid.
- Let us know the phenomenon of surface tension with following example



- Consider two molecules 1, 2 of a liquid in a given amount of liquid. The molecule 1 is inside the surface of a fluid and it is attracted in all the direction equally by the surrounding molecules of the liquid. This is due to the balanced cohesive forces of attraction between the molecules of liquid.Due to the action of balanced cohesive forces, the resultant force acting on the molecule 1 is zero so this molecule will be under the equilibrium.
- Now consider second molecule which is on the surface of the liquid. This molecule is under the action of unbalanced cohesive forces and due to this the molecule is under the pull and the molecule will be stretched.Due to this reason, there appears a membrane over the surface of the fluid which can bear small loads and this will experience a downward force. Thus the free surface of the liquid acts like a very thin film under tension of the surface of the liquid act as an elastic membrane under tension.
- So the main reason of surface tension is unbalanced cohesive force. With increase in temperature cohesive bonds will breakdown and surface tension decreases.

Eg: Detergents are used while washing cloths to reduce surface tension. Detergents break the cohesive bonds chemically and then dirty particles come out.

- The contact angle and surface tension both of these depends upon the type of liquid and the type of solid surface.



- For wetted surface, the liquid spread on the surface and the contact angle is acute (i.e ($\theta<90^0$)). This is due to adhesion is more effective than cohesion

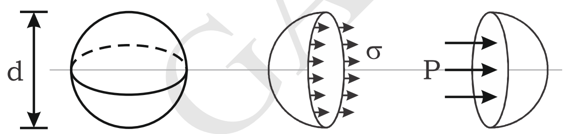
Eg: H_2O in glass tube $(\theta = 0^0)$

- For non wetted surface, the liquid forms a spherical droplet and the angle of contact is obtuse $(\theta > 90^0)$. This is because the cohesion dominates the adhesion between liquid and solid surface.

Eg: Hg in glass tube $(\theta = 128^0)$

- A "Tensiometer" and "Stalagmometer" are the experimental instruments used to measure the surface tension (σ) of liquids.
- Due to cohesion, surface tension causes pressure change across curved surfaces.

Pressure Intensity Inside a Liquid Droplet



- Consider a spherical droplet of liquid with diameter 'd'. In this on the entire surface of the droplet the tensile force due to surface tension will be acting.

  Let

  σ = Surface tension

  d = Diameter of liquid droplet

- P = Pressure intensity inside the droplet (internal pressure)

- Force due to surface tension acting around the half of the circumference portion

  $= \sigma \times$ circumference

  $= \sigma \times \pi d$ .....(i)

- Pressure force on the area [due to internal pressure]

  $= P \times A$

  $= P \times \frac{\pi}{4} d^2$ .... (ii)

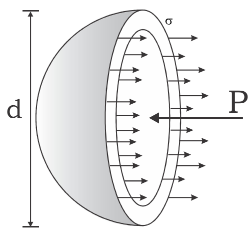
- For equilibrium condition,
- Pressure force = Tensile force

$$P\left(\frac{\pi}{4} d^2\right) = \sigma \times \pi d$$

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

$$\boxed{P = \frac{4\sigma}{d} = \frac{2\sigma}{r}}$$

Pressure Intensity Inside a Soap Bubble

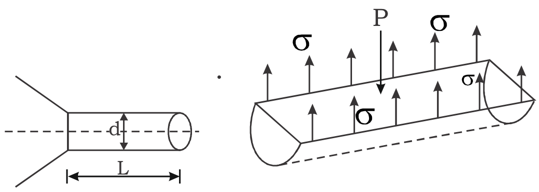


- The spherical soap bubble or hollow bubble has two surfaces in contact with air, one is inside and other is outside. These both contributes the same amount of tensile force due to surface tension.
- For equilibrium condition.
- Pressure force = Tensile force

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

$$\boxed{P = \frac{8\sigma}{d} = \frac{4\sigma}{r}}$$

Pressure Intensity Inside a Liquid Jet

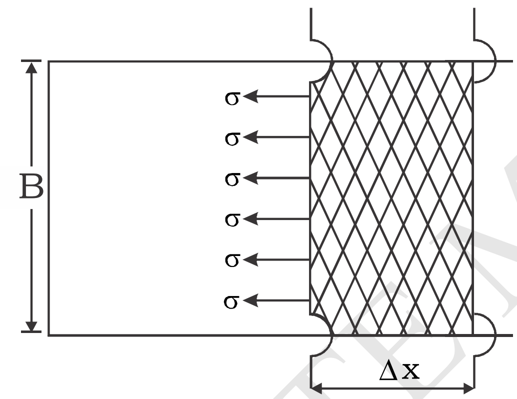


- Consider a liquid jet of diameter 'd' and length 'L' with internal pressure of P.
- For equilibrium condition:
- Pressure force = Tensile force

$P \times L \times d = \sigma \times 2L$

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

Workdone in Increasing The Surface Area



$$(W.D)_{\text{increasing surface area}} = F_s \times \Delta x$$

$$\sigma = \frac{\text{Work done}}{\text{Increase in surface area}}$$

CAPILLARITY

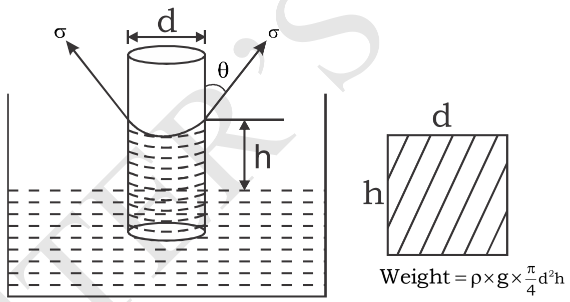
- Capillarity is defined as a phenomenon of rise or fall of a liquid surface when a small diameter glass tube is inserted in it.
- The rise of liquid surface is known as capillary rise where as the fall of the liquid surface is known as capillary fall.
- Capillarity is due to both cohesion and adhesion

Capillary Rise

- The capillary rise is due to adhesive forces which are greater than the cohesive forces, which results in the liquid surface as concave upward and the angle of contact is less than 90^0.

Eg : Water in glass tube

Expression for Capillary Rise



h=The level of liquid rises above the general liquid height

σ = Surface tension of liquid

θ = Angle of contact between liquid and glass tube

ρ = Density of liquid

Weight of the liquid of height 'h' above the general liquid surface is,

$$W = \gamma V = \rho g \times \frac{\pi}{4} d^2 h$$

Vertical force due to surface tension

$$= \sigma \times \text{circumference} \times \cos\theta$$

$$= \sigma \times \pi d \times \cos\theta$$

For equilibrium :

Weight of liquid column of height 'h' = Vertical force due to surface tension

$$\rho g \times \frac{\pi}{4} d^2 h = \sigma \times \pi d \times \cos\theta$$

$$h = \frac{4\sigma\cos\theta}{\rho g d}$$

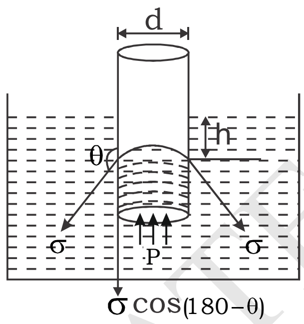
Note :
- The value of "θ" between water and clean glass tube is approximately equal to zero and hence cosθ is equal to unity. Then the rise of water is given by
$$h = \frac{4\sigma}{\rho \times g \times d}$$
- With increase in diameter of the tube, capillary rise decreases. So the diameter of the tube need not be more than 6mm. If it is more than 6mm, the capillary rise is negligible.

Capillary Fall

- The capillary fall is due to cohesive forces which are greater than the adhesive forces. This results in that the surface as concave downward and the angle of contact is more than 90^0.

Eg : Mercury (Hg) in glass tube.

Expression of Capillary Fall



If the glass tube is dipped in mercury, the level of mercury in the tube will be lower than the general level of the outside liquid.

Here, two forces are acting on the mercury which are inside the tube, they are

Force acting due to surface tension in downward direction

$$= \sigma \times \pi d \times \cos(180 - \theta)$$

Force due to intensity of pressure is in upward direction

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

$$= \rho g h \times \frac{\pi}{4} d^2 \qquad [\because P = \rho g h]$$

For equalibrium

$$\sigma \times \pi d \times \cos(180 - \theta) = \rho g h \times \frac{\pi}{4} d^2$$

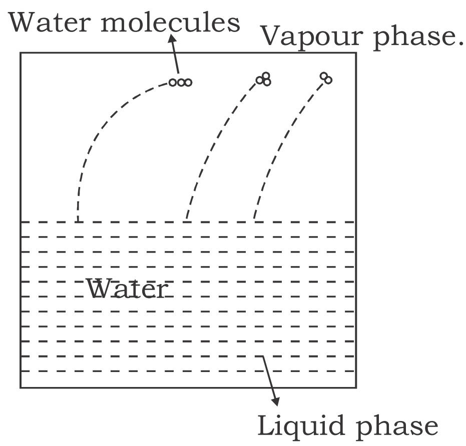
$$\sigma \times \pi d \times -\cos\theta = \rho g h \times \frac{\pi}{4} d^2$$

$$\boxed{h = \frac{-4\sigma \cos\theta}{\rho g d}}$$

Note :
The value of angle of contact in between mercury and glass tube is 128^0.

VAPOUR PRESSURE (P_v)

- The vapour pressure of a pure liquid is defined as the pressure exerted by its vapour in phase equilibrium. It is a property of a liquid vapour.



- Vapour pressure increases with temperature.
- Highly volatile fluids like petrol and benzene have high vapour pressure.

Liquid	Vapour pressure at 20^0 C
Mercury	0.16 Pa
Water	2.30 KPa
Ethanol	5.80 KPa
Benzene	10.0 KPa
Methyl	12.5 KPa
Petrol	30.0 KPa

Note :

The low vapour pressure of mercury (along with high density) makes it very suitable for use in barometers and other pressure measuring devices.

CAVITATION

- In any flow system, the pressure at any point in a liquid less than (or) equal to vapour pressure, vapouriation of liquid starts and vapour bubbles are formed. These vapour bubbles enter into high pressure region where they collapse. The pressure developed by collapsed bubbles is so high hence the materials from boundaries get eroded and cavities are formed on them this phenomena is called Cavitation.

Cavitation Occurs in

- Turbine runners exit
- Pump suction pipes and impellers
- Siphon pipes
- Ship propellers
- Hydraulic structures like sluice, spill way etc..

Effects of Cavitation

- Damages the pipe boundaries
- Create a lot of noise
- Decreases the efficiency of machine

CLASSWORK

1. Fluid is a substance that
   a) cannot be subjected to shear forces
   b) always expands untill it fills any container
   c) has the same shear stress at a point regardless of its motion
   d) cannot remain at rest under action of any shear force.

2. When subjected to shear force, a fluid
   a) deforms continuously no matter how small the shear stress may be
   b) deforms continuously only for large shear force
   c) undergoes static deformation
   d) deforms continuously only for small shear stress

3. Specific Gravity of fluid is measured by
   a) Hydrometer b) Anemometer
   c) Pitot tube d) Mmanometer

4. Newton's law of viscosity states that
   a) shear stress is directly proportional to the velocity
   b) shear stress is directly proportional to velocity gradient
   c) shear stress is indirectly proportional to velocity
   d) shear stress is directly proportional to the shear strain

5. Viscosity of water
   a) Decrease with temperature
   b) Increase with pressure
   c) Increase with temperature
   d) Decrease with velocity

6. A perfect fluid (also known as an ideal fluid) is
   a) a real fluid
   b) the one which obeys perfect gas laws
   c) compressive and gaseous
   d) incompressible and frictionless

7. Match **List - I** (Type of fluid) with **List - II** (properties)

List - I

A. Ideal fluid

B. Newtonian fluid

C. Non - Newtonian fluid

D. Bingham plastic

List - II

1. Shear stress varies linearly with the rate of strain
2. Shear stress does not vary linearly with the rate of strain
3. Fluid behaves like a solid until a minimum yield stress beyond which it exihibits a linear relationship between shear stress and the rate of strain
4. Shear stress is zero

Codes :

	A	B	C	D
a)	3	1	2	4
b)	4	2	1	3
c)	3	2	1	4
d)	4	1	2	3

8. Match **List -I** (Rheological equation) with **List - II**(Types of fluids) and select the correct answer using the codes given below the lists:

List -I

A. $\tau = \mu\left(\frac{du}{dy}\right)^n, n = 1$

B. $\tau = \mu\left(\frac{du}{dy}\right)^n, n < 1$

C. $\tau = \mu\left(\frac{du}{dy}\right)^n, n > 1$

D. $\tau = \tau_0 + \mu\left(\frac{du}{dy}\right)^n, n = 1$

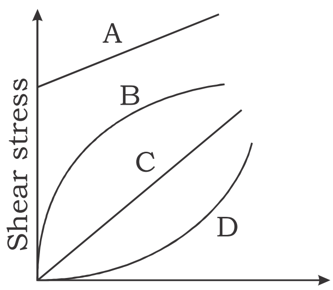
List -II

1) Bingham plastic
2) Dilatant fluid
3) Newtonian fluid
4) Pseudo - plastic fluid

Codes :

	A	B	C	D
a)	3	2	4	1
b)	4	1	2	3
c)	3	4	2	1
d)	4	2	1	3

9. Match **List -I** (Curve identification in figure) with **List - II** (Nature of fluid) and select the correct answer using the codes given below the lists



List -I	**List-II**
A. Curve A	1) Newtonian
B. Curve B	2) Dilatant
C. Curve C	3) Ideal bingham plastic
D. Curve D	4) Pseudo-plastic

Codes :

	A	B	C	D
a)	3	4	1	2
b)	2	4	1	3
c)	3	1	4	2
d)	2	1	4	3

10. Compressibility is equal to

a) $\frac{\frac{-dV}{V}}{dp}$ b) $\frac{dp}{-\left(\frac{dV}{V}\right)}$ c) $\frac{dp}{\rho}$ d) $\sqrt{\frac{dp}{d\rho}}$

11. At a liquid-air-solid interface the contact angle θ measured in the liquid is less than 90°. The liquid is,

a) wetting
b) non-wetting
c) ideal
d) does not form a stable bubble

12. Mercury does not stick to a glass surface because

a) cohesive forces are greater than adhesive forces
b) adhesive forces are greater than cohesive forces
c) cohesive forces are equal to adhesive forces
d) internal friction is negligible

13. At 20°C, pure water will have a vapour pressure, in kPa, of about

a) 0.5 b) 2.34 c) 101.3 d) 8.67

14. Match **List - I** with **List - II** and select the correct answer using the codes given below the lists :

List - I (Description)

I. Property which explains the spherical shape of the drop of a liquid
II. Property which explains the phenomenon of cavitation in a fluid flow
III. Property which explains the rise of sap in a tree
IV. Property which explains the flow of a jet of oil in an unbroken stream

List - II (Property of fluid)

A. Viscosity
B. Surface tension
C. Compressibility
D. Vapour pressure
E. Capillarity

Codes :

	I	II	III	IV
a)	A	B	D	E
b)	B	D	E	A
c)	D	B	E	A
d)	A	B	C	D

15. Match **List-I** with **List - II** and select the correct answer using the codes given below the lists :

List - I

a) Specific Gravity

b) Coefficient of viscosity

c) Kinematic viscosity

d) Stress

List - II

1) $M^0L^2T^{-1}$ 2) $M^0L^0T^0$

3) $ML^{-1}T^{-1}$ 4) $ML^{-1}T^{-2}$

Codes :

	A	B	C	D
a)	2	3	1	4
b)	4	3	1	2
c)	2	1	3	4
d)	4	1	3	2

16. A liquid at 20°C has a relative density of 0.80 and a kinematic viscosity of 2.3 centistoke. Determine its (i) unit weight in kN/m^3 and (ii) dynamic viscosity in Pa.s.

a) $7.832 kN/m^3$ and 1.836×10^{-3} Pa.s
b) $8.832 kN/m^3$ and 2.836×10^{-3} Pa.s
c) $6.832 kN/m^3$ and 3.836×10^{-3} Pa.s
d) $9.832 kN/m^3$ and 0.836×10^{-3} Pa.s

17. A flow of a viscous fluid with $N\text{-}s/m^2$ has a velocity distribution given by $u = 0.9y - y^2$. The shear stress at y = 0.45 m is

a) $0.90\ N/m^2$ b) ∞
c) zero d) $-0.90 N/m^2$

18. When a pressure of $2 \times 10^4 kN/m^2$ is applied to 50 litres of a liquid, its volume is decreased by 0.5 litre. The bulk modulus in N/m^2 is

a) 20×10^9 b) 2×10^9
c) 4×10^9 d) 40×10^9

19. An apparatus produces water droplets of size $70\mu m$. If the coefficient of surface tension of water in air is 0.07N/m, the excess pressure in these droplets, in kPa, is

a) 5.6 b) 4.0 c) 8.0 d) 13.2

20. The capillary rise of water at 20°C in a clean glass tube of 1.0 mm diameter tube is about

a) 15mm b) 50mm c) 25mm d) 30mm

21. The capillary rise in a 3 mm tube immersed in a liquid is 15 mm. If another tube of diameter 4 mm is immersed in the same liquid the capillary rise would be

a) 11.25 mm b) 20.00 mm
c) 8.44 mm d) 26.67 mm