BME

UNIT-3

FLUIDS

Unit-3 → Fluids

Fluid

It is defined as a substance that deforms continuously when an external shear force is applied on it.

Fluid is a substance which offers no resistance to shear deformation. The continuous deformation of fluid does not stop until the force is removed. This continuous deformation of a substance is known as flow.

Important properties of fluids are as follows:

1. Density
2. Specific Weight or Weight Density
3. Specific Gravity
4. Viscosity
5. Pressure
6. Vapour Pressure
7. Cohesion
8. Adhesion
9. Surface Tension
10. Capilarity
11. Compressibility
12. Bulk Modulus

Density or Mass Density (ρ)

It is defined as the ratio of the ~~fluid~~ mass of the fluid to its volume ie mass per unit volume ~~is~~ of a fluid is called density.

$$\text{Density, } \rho = \frac{\text{mass}}{\text{Volume}}$$

$$\boxed{\rho = \frac{m}{V}} \quad kg/m^3$$

unit → kg/m^3

Dimensionless formula → $ML^{-3}T^{0}$

Water → $\rho = 1000\ kg/m^3$

ρ → Temperature ↑ ⟹ ρ ↓

ρ → Pressure ↑ ⟹ ρ ↑

Specific Weight or Weight Density (ω)

It is defined as the ratio of weight of the fluid to its volume ie weight per unit volume of fluid is called specific weight.

$$\boxed{\omega = \frac{\text{Weight}}{\text{Volume}}} \quad N/m^3$$

(N → Newton, unit of weight)

$$\Rightarrow \omega = \frac{mg}{V} = \left(\frac{m}{V}\right)g = \rho g$$

$\left\{ \begin{array}{l} \text{Weight} = mg \\ \rho = \frac{m}{V} \end{array} \right.$

$$\Rightarrow \boxed{\omega = \rho g} \quad N/m^3$$

Unit → N/m^3

Dimensional Formula → $ML^{-2}T^{-2}$

Water → $\omega = \rho g = 1000 \times 9.81 = 9810 \ N/m^3$

Extra

$\omega \rightarrow \rho \rightarrow$ Temperature

$\rho \rightarrow$ Pressure

$\omega \rightarrow g \rightarrow$ location

⇓

ie 'ω' changes from place to place

Specific Volume (v)

It is defined as the volume of a fluid occupied by a unit mass ie volume per unit mass of a fluid is called specific volume.

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

$$\Rightarrow \boxed{v = \frac{V}{m} = \frac{1}{\rho}} \quad m^3/kg$$

unit → m^3/kg

Dimensionless formula → $M^{-1}L^{3}T^{0}$

Specific Gravity (s)

It is defined as the ratio of density of fluid to the density of standard fluid (ρ_{std}).

$$\boxed{s = \frac{\rho}{\rho_{std}}} \rightarrow s = \frac{\rho \cdot g}{\rho_{std}\, g} = \frac{w}{(w_{std})} = \frac{\text{Specific Weight}}{(\text{Specific Weight})_{std}}$$

→ For liquids, the standard fluid is water ie $\rho_{std} = 1000\ kg/m^3$

→ For gases, the standard fluid is air or hydrogen at a given temperature and pressure.

unit → it has no unit

Dimensional Formula → it is dimensionless, ie $M^0 L^0 T^0$

Compressibility (β)

It is ratio of volumetric strain (fractional change in volume) to the change in pressure.

or

Volumetric strain per unit change in pressure.

or

Fractional change in volume or density corresponding to a unit change in pressure is called the

compressibility.

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

or

$$\frac{\text{Fractional Change in Volume}}{\text{Change in Pressure}}$$

$$\boxed{\beta = \frac{\left(\frac{-dV}{V}\right)}{dP}}$$

Bulk Modulus (K)

It is ratio of change in pressure to the volumetric strain of fluid.

or

Change in pressure corresponding to a fractional change in volume or density of fluid while temperature constant.

$$\boxed{K = \frac{dP}{\left(\frac{-dV}{V}\right)} = \frac{1}{\beta}}$$

$\Downarrow$

ie it is just reciprocal of Compressibility.

$$\rho = \frac{m}{V} \Rightarrow \rho V = m = \text{Constant}$$

$$\rho dV + V d\rho = 0$$

$$\rho dV = -V d\rho$$

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

$$K = \frac{dP}{\left(\frac{-dV}{V}\right)} = \frac{dP}{\frac{d\rho}{\rho}} = \rho \frac{dP}{d\rho}$$

$$\boxed{K = \frac{\rho dP}{d\rho}}$$ $\Rightarrow$ ie Bulk modulus is resistance offered by fluid for further compression.

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

$$\boxed{\beta = \frac{d\rho}{\rho dP}}$$

$$\beta = 0 \Rightarrow d\rho = 0$$

$$\Rightarrow \rho_2 - \rho_1 = 0$$

$$\Rightarrow \rho_2 = \rho_1 = \rho = \text{Constant}$$ ie incompressible

Pressure (P)

It is defined as normal force exerted by a fluid per unit area. It is always compressive in nature

The counterpart of pressure in solids is normal (compressive) stress.

Pressure, $p = \frac{\text{Force}}{\text{Area}}$

$$\boxed{P = \frac{F}{A}} \quad N/m^2$$

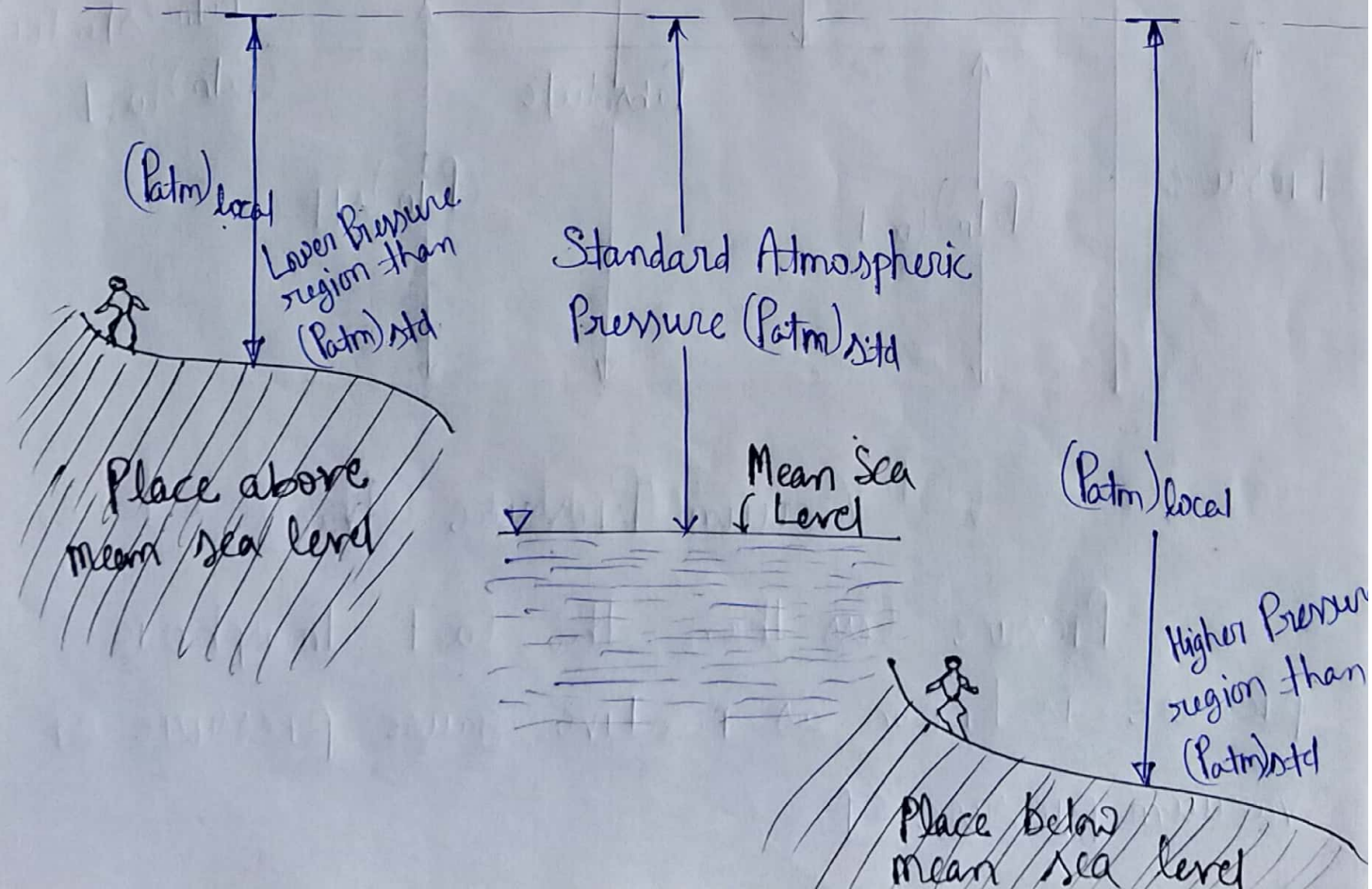
unit → $N/m^2 = Pa$

Dimensional Formula → $ML^{-1}T^{-2}$

$1 \text{ bar} = 100 \text{ kPa} = 100{,}000 \text{ Pa} = 100{,}000 \text{ N/m}^2$

Atmospheric Pressure (P_{atm})

The pressure exerted by environmental mass is known as atmospheric pressure.



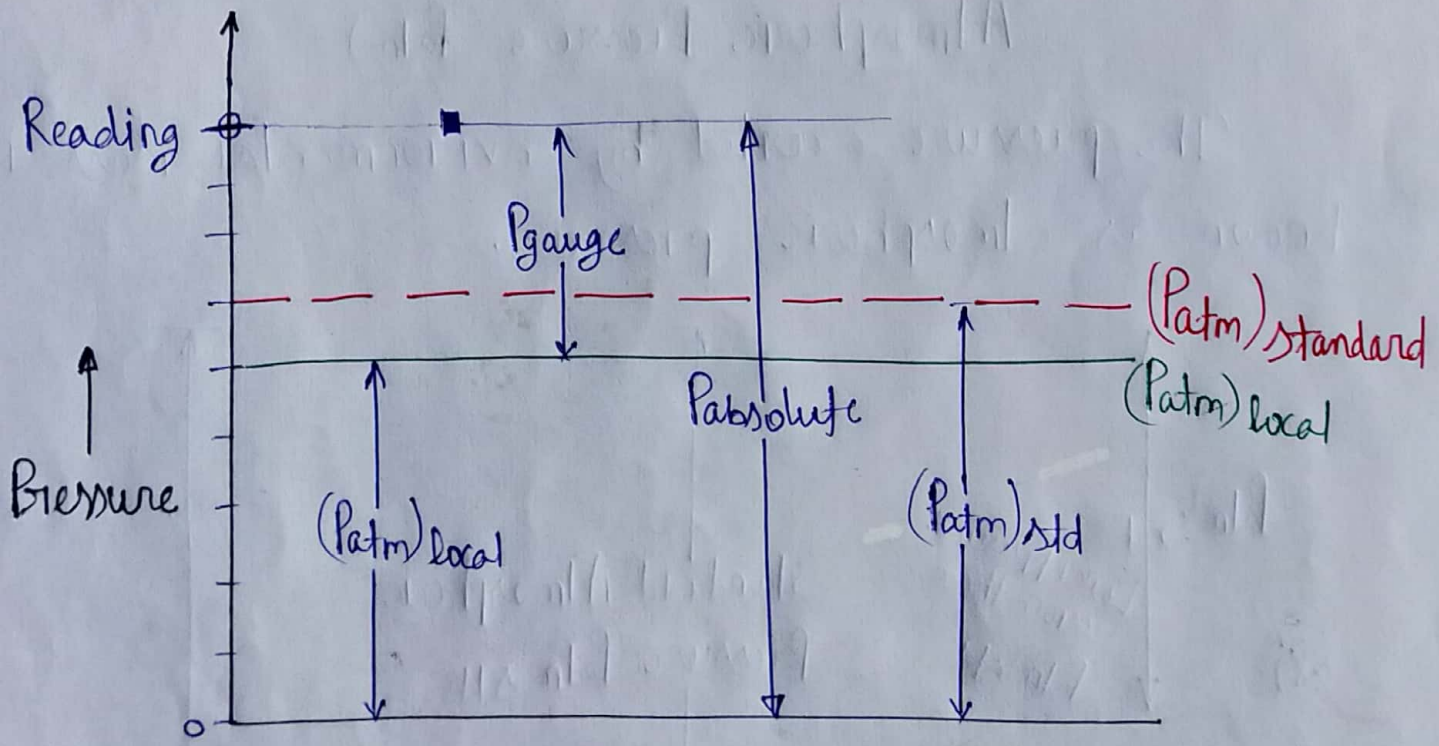
Gauge Pressure (P_{gauge})

Pressure which is measured with the help of pressure measuring instrument, for which local atmospheric is taken as datum or reference.

Absolute Pressure (P_{abs})

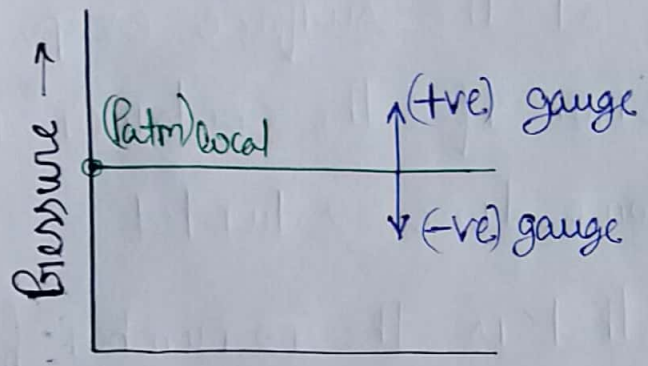
Pressure measured with respect to zero pressure is known as absolute pressure.

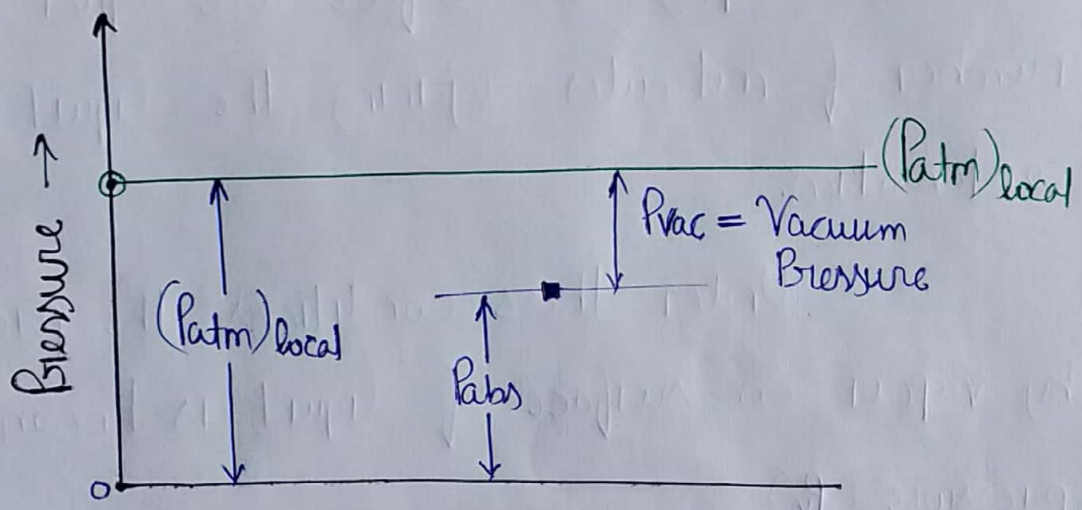
$$\boxed{P_{abs} = P_{gauge} + (P_{atm})_{local}}$$



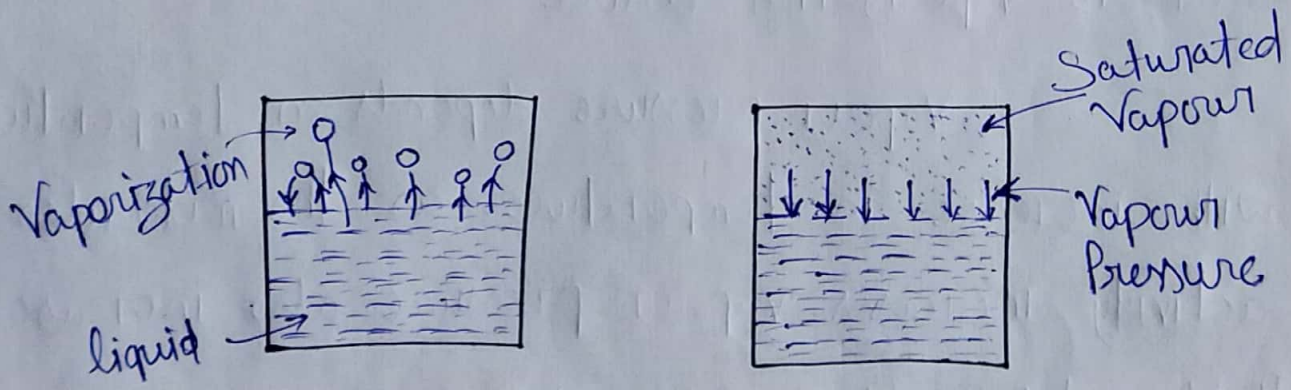
Vacuum Pressure (P_{vac})

Pressure less than the local atmospheric pressure is known as negative gauge pressure or vacuum pressure.





Vapour Pressure (P_v)



(a) initial stage (b) after some time

Fig:- Container filled with liquid (water)

The liquid molecules at the surface escape due to more translational energy. If the container is closed once then after some time, saturated conditions are reached, that is the number of molecules escaping the surface are equal to the number of molecules rejoining the liquid surface on condensation.

Under these conditions the pressure exerted by vapour on surface of liquid is known as vapour pressure (P_v).

If the pressure of liquid at any point falls below vapour pressure the bubbles are formed and ie vaporization occurs.

Vapour pressure depends on temperature with increase in temperature, as the molecules activity increases, vapour pressure also increases. Highly volatile fluids like petrol has more vapour pressure. and Mercury has very low vapour pressure. and because of this quality it is used in manometers.

Cohesion

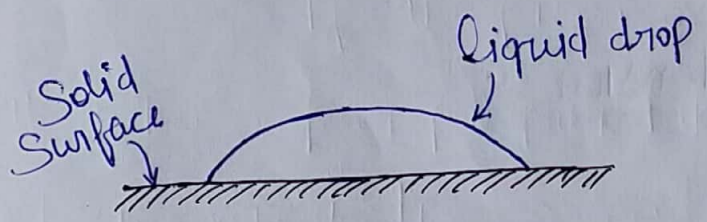
Intermolecular attraction between similar molecules (molecules of same fluid) is known as cohesion. or Forces between two similar molecules.

Adhesion

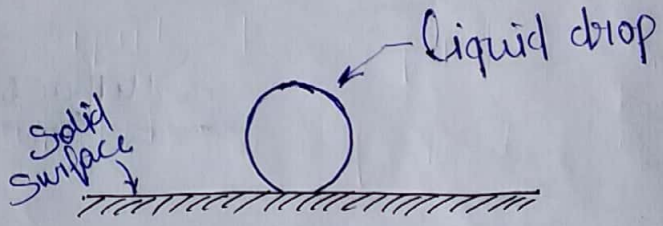
Molecular attraction towards different molecules is known as adhesion.

ex → Glue (गोंद) has good adhesive property.

Adhesion is forces between two dissimilar molecules.



Wetting Liquids
(Adhesion is more)



Non-Wetting Liquids
(Cohesion is more)

Capillarity (केशिकता)

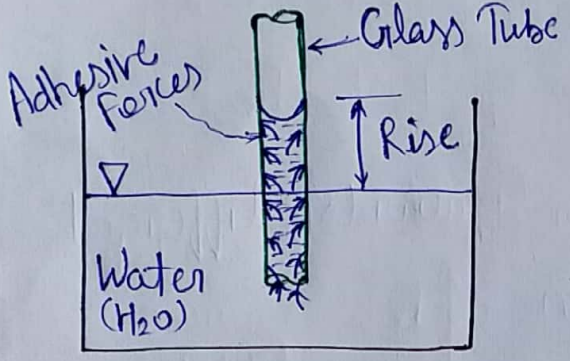
Rise or fall of a liquid when the glass tube is immersed into the liquid is known as capillarity.

(1) Capillary Rise is due to adhesion
ex → water

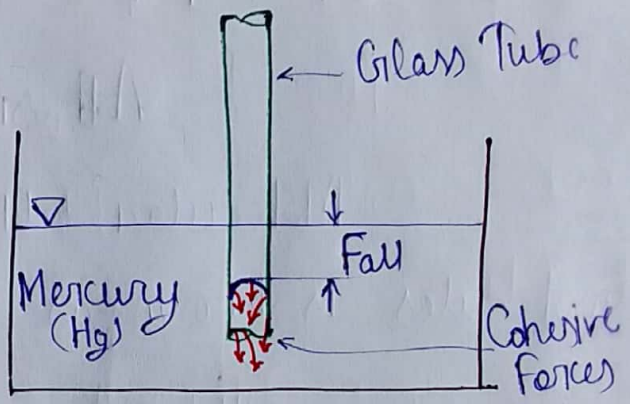
(2) Capillary Fall is due to cohesion

ex → Mercury

Therefore capillarity is due to both adhesion and cohesion.

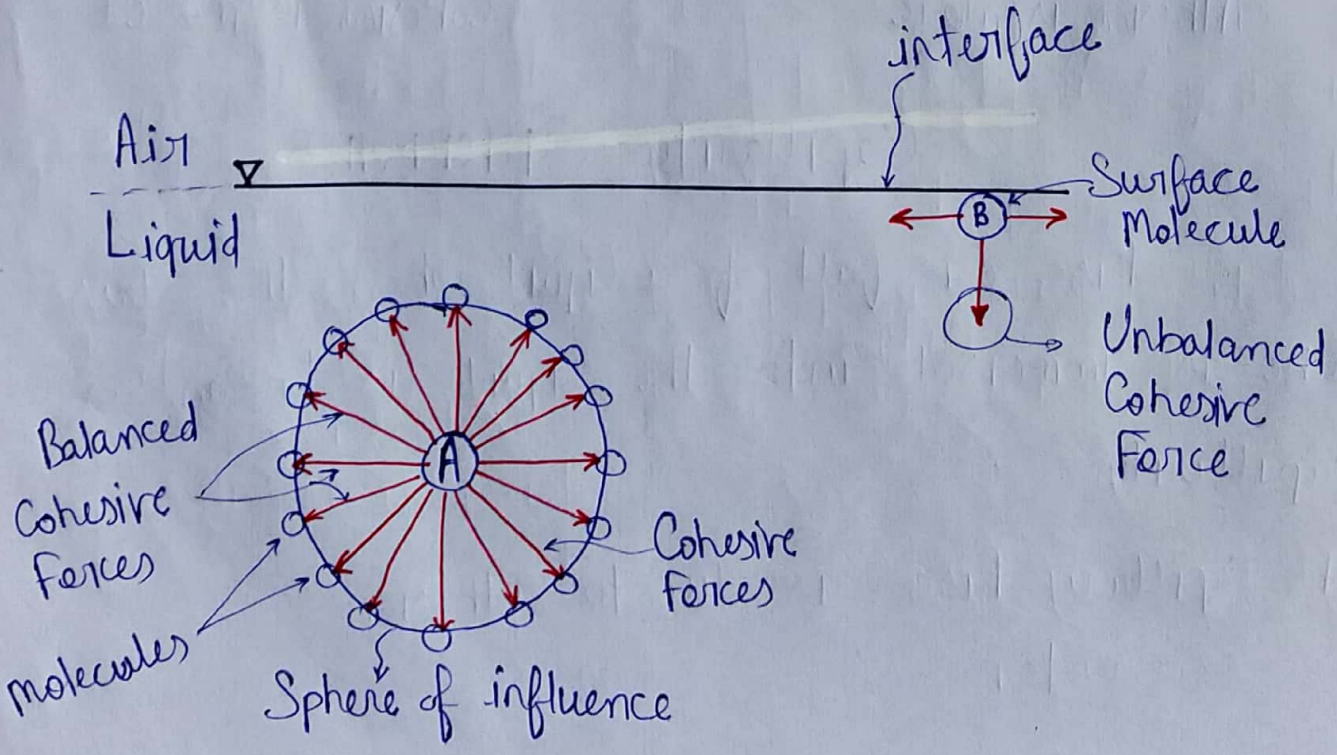


(a) Rise
⇓
Adhesion is large



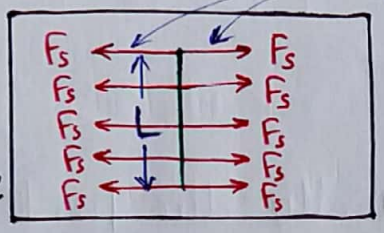
(b) Fall
⇓
Cohesion is large.

Surface Tension (σ)



Surface Tension (Stretching)

Liquid Surface



Surface Tension, $\boxed{\sigma = \frac{F_s}{L}}$ N/m

where, F_s = Surface tension force

L = length of film on surface

N/m → Newton per meter.

Consider molecule 'A' which is below the surface of the liquid, this molecule is surrounded by various corresponding molecules & hence due to the influence of these forces (cohesive forces).

Now consider molecule 'B' which is on the surface of the liquid, this molecule is under the influence of net download force and because of this, the horizontal balanced cohesive forces seem to be a membrane formed at the surface, which can resist small tensile load, this phenomena is called surface tension.

Definition → Surface tension is a line force and it is expressed as force per unit length drawn on the surface and it acts normal to the line in the plane of surface

unit → $\frac{N}{m}$

Dimensional Formula → MT^{-2}

Surface tension is basically due to the unbalanced cohesive force and with rise in temperature cohesive fores decrease and hence surface tension also decreases.

Viscosity (μ)

⇓

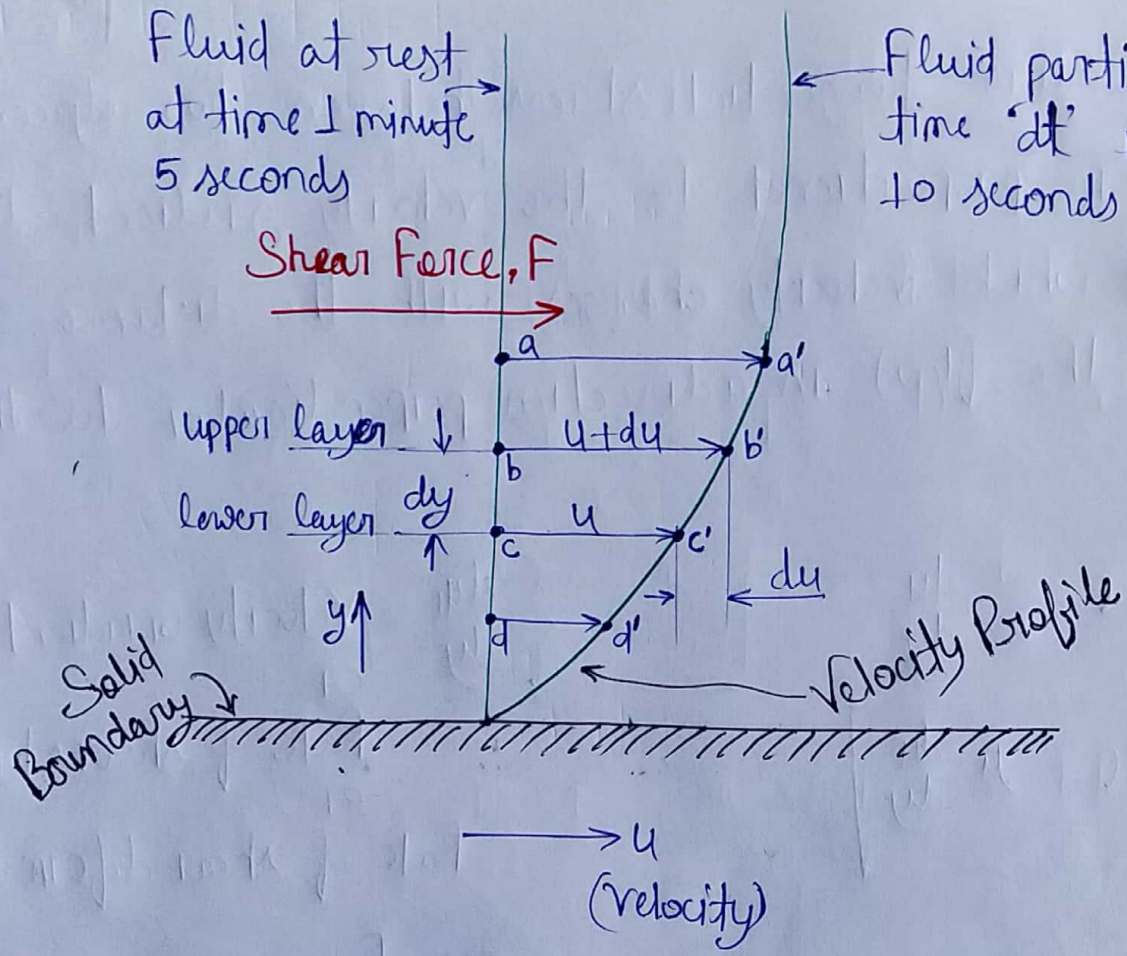
or Dynamic Viscosity or Coefficient of Viscosity or Absolute Viscosity

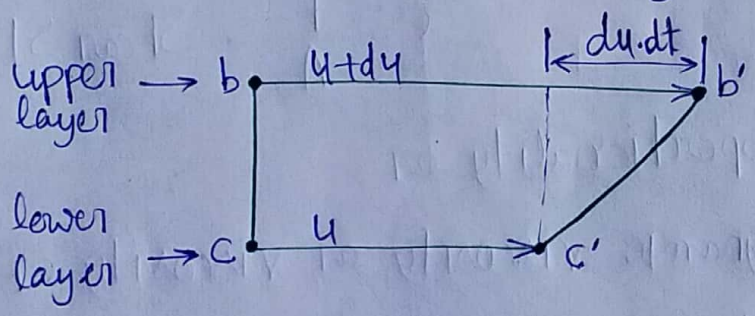
The property of fluids which offers resistance to deformation under the action of a shear force, is called viscosity.

It is the internal resistance offered by one layer of fluid to the other adjacent layer.

Consider a fluid at rest and apply a shear force F on upper most fluid layer. which start moving.

As the upper fluid layer moves with higher velocity relative to the lower one, the upper layer try to move the lower layer with the same→





Shear Stress,

$$\tau = \frac{\text{Shear Force}}{\text{Area of fluid layer}}$$

$$\boxed{\tau = \frac{F}{A}}$$

→ velocity, but lower layer, which move with smaller velocity, oppose the motion of upper layer.

It means that the upper layer which is moving relative faster causes a shear stress on the lower layer in the direction of flow whereas lower layer causes shear stress in opposite direction to the upper layer.

This tangential stress between two adjacent layers is proportional to the velocity gradient (the rate at which velocity changes with the distance across the flow). in a direction perpendicular to the layers.

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

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

$\left\{ \frac{du}{dy} = \text{Velocity Gradient} \right\}$
or
Rate of shear strain
or
Rate of shear deformation.

$\tau = \frac{F}{A}$ ← Shear Stress

where,

μ = Constant of proportionality or coefficient of dynamic viscosity or viscosity or dynamic viscosity.

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

Thus shear stress required to produce unit rate of shear strain is called viscosity.

Units of Viscosity

SI Unit →

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

$$\frac{N}{m^2} = \mu \frac{\cancel{m}}{s \cdot \cancel{m}} \Rightarrow \mu = \frac{N.s}{m^2}$$

$$\mu \rightarrow \boxed{\frac{N.S}{m^2} = Pa.S = \frac{kg}{m.S}}$$

$F = ma = kg.\frac{m}{S^2}$

$\left\{ \frac{(N)S}{m^2} = \left(\frac{kg.m}{S^2}\right).\frac{S}{m^2} = \frac{kg.}{S.m} \right.$

$\left. \text{or} = \frac{kg}{m.S} \right\}$

Dimensional Formula $\rightarrow$ $ML^{-1}T^{-1}$

C.G.S. Unit $\rightarrow$

$$\frac{kg}{m.S} \longrightarrow \boxed{\frac{gm}{cm.S} = Poise}$$

$$\frac{1\ kg}{m.S} = \frac{1000\ gm}{100\ cm.S} = 10\ \frac{gm}{cm.S}$$

$$\boxed{1\ \frac{kg}{m.S} = 10\ \frac{gm}{cm.S}}$$

Newton's Law of Viscosity

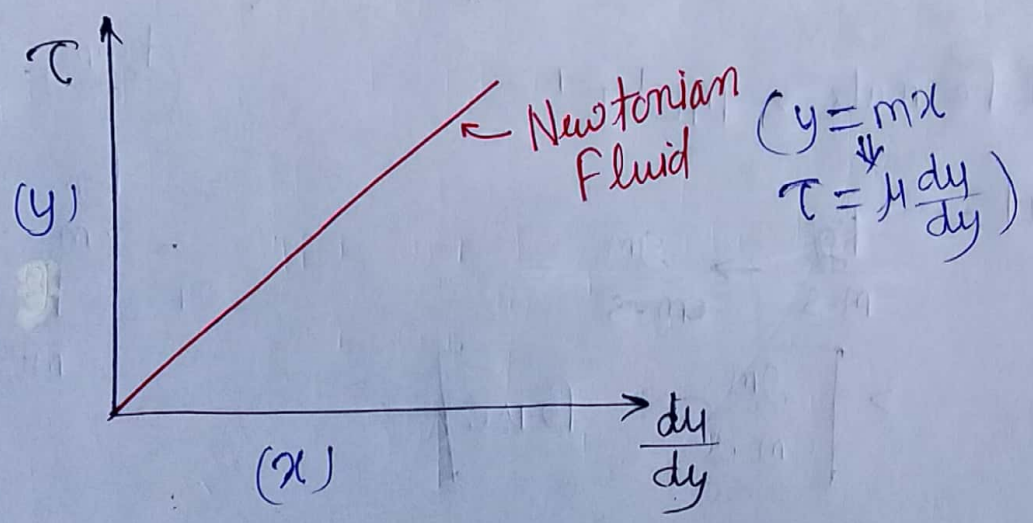
A fluid is said to be newtonian fluid if shear stress is directly proportional to rate of shear strain or velocity gradient. ie for a newtonian fluid.

$$\tau \propto \frac{du}{dy} \quad \text{or} \quad \tau \propto \frac{d\theta}{dt}$$

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

ie for a newtonian fluid, 'μ' or viscosity is constant.

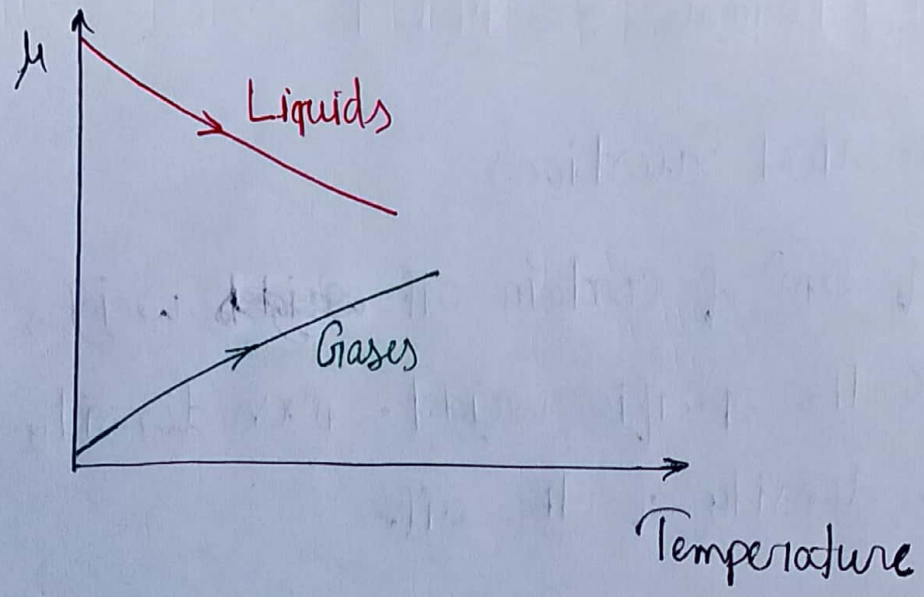
Ex → Air, H_2O, Kerosene, Diesel, Petrol, Mercury etc.



Variation of viscosity with Temperature

In case of liquids, intermolecular distance is small and hence cohesive forces are large. With rise in temperature cohesive forces decrease and resistance to the flow is also decreases, therefore viscosity of liquid decreases with increase in temperature.

In cases of gases the intermolecular distance is large and cohesive forces are negligible with rise in temperature, molecular agitation or disturbance increases and hence resistance to the flow is also increases therefore viscosity of a gas increases with increase in temperature.



Kinematic Viscosity (ν)

(it is said → new)

Dynamatic → Force is Considered
⇓
(Cause of force is mass)

Kinematic → Force is not considered.

Kinematic viscosity is the ratio of dynamic viscosity (μ or viscosity) to the density of fluid (ρ).

$$\nu = \frac{\mu}{\rho} \qquad \frac{kg}{m.s\left(\frac{kg}{m^3}\right)} = \frac{\cancel{kg}\cdot m^{\cancel{3}\,2}}{\cancel{m}.s.\cancel{kg}} = \frac{m^2}{s}$$

$$\boxed{\nu = \frac{\mu}{\rho}} \quad m^2/s$$

SI Unit → $\frac{m^2}{s}$

C.G.S Unit → $\boxed{\frac{cm^2}{s} = \text{Stoke}}$

Dimensional Formula → $M^0 L^2 T^{-1}$

→ Numerical Questions

Que 1 – If $5 m^3$ of certain oil weighs 40 kN, calculate the specific weight, mass density and relative density of the oil.

Solution →

Given:

Volume of oil, $V = 5 m^3$

Weight of oil, $W = 40 kN = 40,000 N$

→ Specific Weight of oil; $\omega = \frac{\text{Weight of oil}}{\text{Volume of oil}}$

$$\omega = \frac{40,000}{5} \frac{N}{m^3}$$

$$\omega = 8000 \ N/m^3$$

or $\boxed{\omega = 8 \ kN/m^3}$

→ Mass Density: $\rho = \frac{m}{V}$ $\left\{ \text{Weight, } W = mg, \ m = \frac{W}{g} \right\}$

$$\Rightarrow \rho = \frac{W}{g \cdot V}$$

$$\Rightarrow \rho = \frac{40,000}{9.81 \times 5} \quad \{ g = 9.81 \ m/s^2 \}$$

$$\Rightarrow \boxed{\rho = 815.494 \ kg/m^3}$$

Relative Density:
or Specific Gravity

$$S = \frac{\rho}{\rho_{std}}$$

$$S = \frac{\rho_{oil}}{\rho_{water}}$$

{Since oil is liquid ie $\rho_{std} = \rho_{water}$}

$$\Rightarrow S = \frac{815.494}{1000}$$

$$\Rightarrow \boxed{S = 0.815494}$$

{$\rho_{water} = 1000\ kg/m^3$}

Question 2 → Calculate specific weight, density, specific volume and specific gravity of petrol, if one litre of petrol weighs 6.867 N.

Solution → Given data

Volume of petrol (V) = 1 litre = $\frac{1}{1000}\ m^3 = 10^{-3}\ m^3$

Weight of oil (W) = 6.867 N

Specific Weight:

$$\omega = \frac{\text{Weight}}{\text{Volume}} = \frac{6.867}{1/1000} = 6867\ N/m^3$$

Mass Density:

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

{$\omega = \rho g$ Specific Weight}

$$\rho = \frac{\omega}{g} = \frac{6867}{9.81}\ kg/m^3$$

$$\rho = 700\ kg/m^3$$

Specific Volume:

$$v = \frac{1}{\rho} = \frac{1}{700}\ m^3/kg$$

$$v = 1.428 \times 10^{-3}\ m^3/kg$$

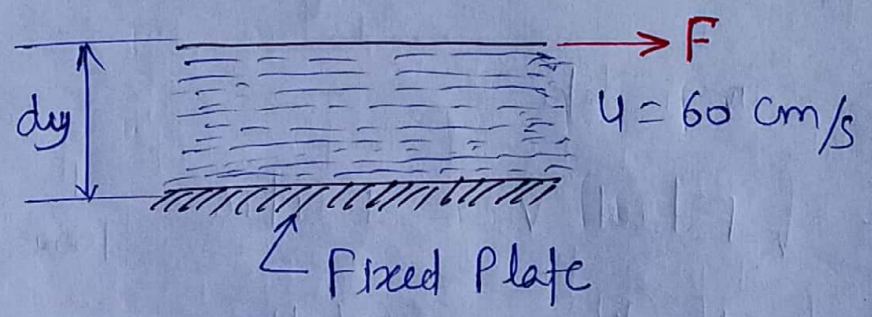
Specific Gravity: $S = \frac{\text{Density of Petrol}}{\text{Density of Water}}$

$$S = \frac{\rho}{\rho_{std}}$$

$$S = \frac{700}{1000} \Rightarrow S = 0.7$$

Question 3 → A plate 0.025 mm distant from fixed plate, moves at 60 cm/s and requires a force of 2 N per unit area ie $2\,N/m^2$ to maintain this speed determine the fluid viscosity between the plates.

Solution →



Distance between plates, $dy = 0.025\,mm = \frac{0.025}{1000}\,m$

Velocity of upper plate, $u = 60\,cm/s$
$= 0.6\,m/s$

required force per unit area is $2\,N/m^2$

that is Shear Stress, $\tau = \frac{\text{Force}}{\text{Area}} = 2\,N/m^2$

we know that, $\tau = \mu \cdot \frac{du}{dy}$

Where, du = change in velocity

$du = u - 0 = 0.6\ m/s$

dy = Change in distance

$dy = \frac{0.025}{1000}\ m$

$\tau = \mu \cdot \frac{du}{dy} \Rightarrow 2 = \mu \times \frac{0.6 \times 1000}{0.025}$

$\Rightarrow \mu = \frac{2 \times 0.025}{0.6 \times 1000}$

$\mu = 8.33 \times 10^{-5}\ \frac{N.S}{m^2}$

$1\ \frac{N.S}{m^2} = 10$ Poise

$\Rightarrow \mu = 8.33 \times 10^{-5} \times 10$ Poise

$= 8.33 \times 10^{-4}$ Poise

Que 4 → The shear stress at a point in an oil is 0.3 Pa and the velocity gradient at the point is 0.25 m/s. Find the viscosity of the oil if the density of the oil is 970 kg/m³, also find the kinematic viscosity of the oil.

Solution →

Shear stress, $\tau = 0.3\ Pa = 0.3\ N/m^2$

Velocity gradient, $\frac{du}{dy} = 0.25\ m/s$

$\left\{1\ Pa = 1\ \frac{N}{m^2}\right\}$

Density of oil, $\rho = 970\ kg/m^3$

Shear stress, $\tau = \mu \cdot \frac{du}{dy}$

Viscosity of oil, $\mu = \frac{\tau}{\left(\frac{du}{dy}\right)}$ Pa.S or $\frac{N.S}{m^2}$

$$\mu = \frac{0.3}{0.25} \text{ Pa.S}$$

$$\boxed{\mu = 1.2 \text{ Pa.S}} \text{ or } N.S/m^2$$

Kinematic Viscosity, $\nu = \frac{\mu}{\rho}$

$$\nu = \frac{1.2}{970} = 1.237 \times 10^{-3}\ m^2/s$$

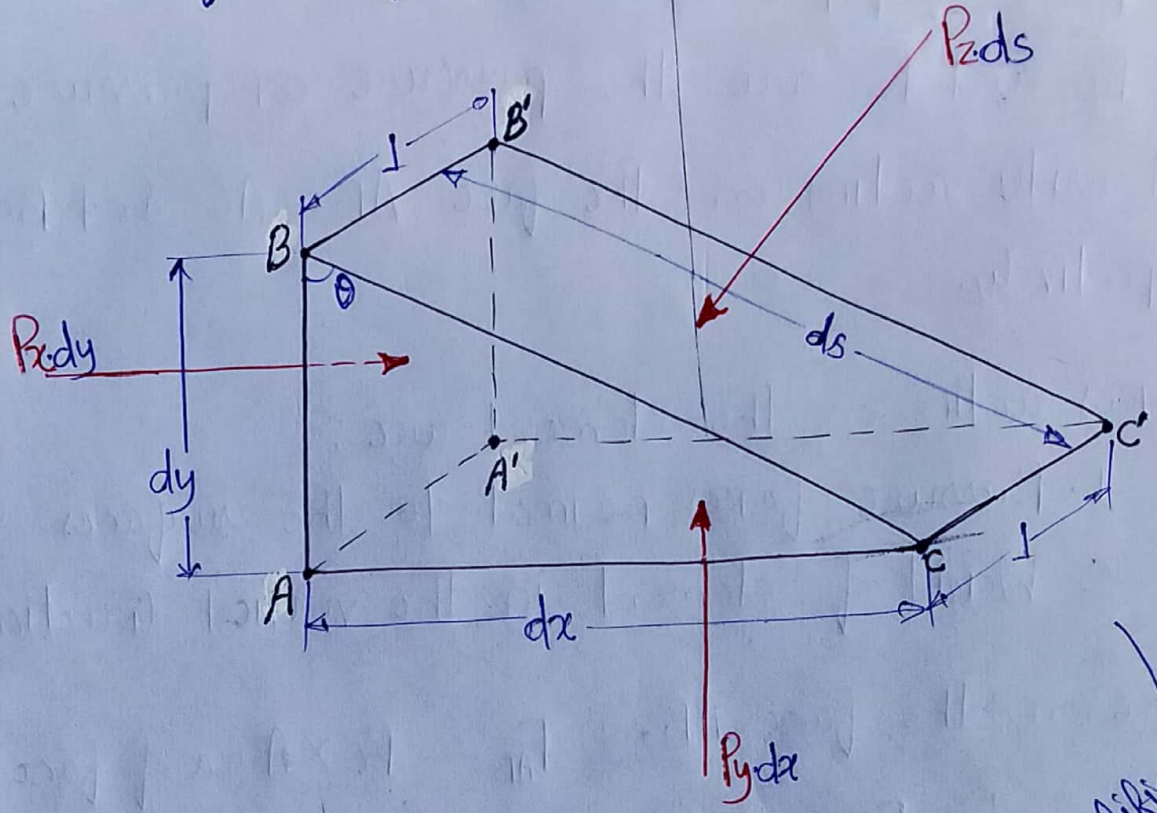
$$\boxed{\nu = 1.237 \times 10^{-3}\ m^2/s}$$

Pascal Law

The Pascal's Law states that "the pressure at a point in a fluid at rest is the same in all directions".

Consider an arbitrary fluid element of wedge shape in a fluid mass at rest and since the

fluid is at rest, there will be no shear stress on the faces of the element.



Simplified diagram

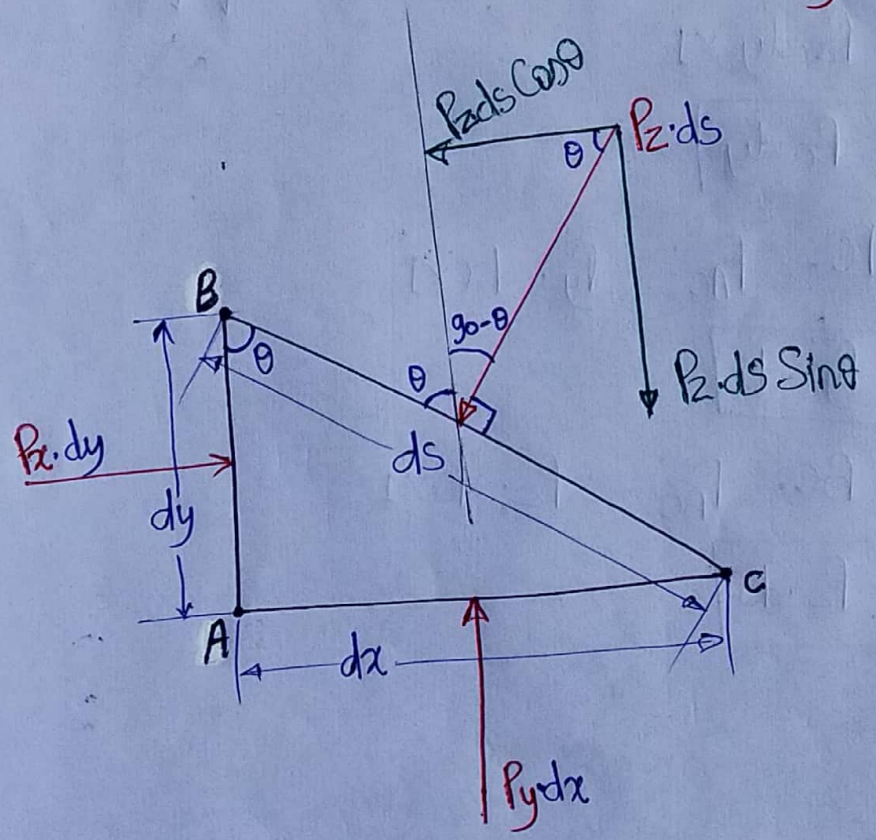


Fig:- Forces on a fluid element.

let the width of the element perpendicular to the plane of paper is unity ie 1.

P_x, P_y and P_z are the pressure or pressure intensity acting on the face AB, AC and BC respectively.

Forces acting on the element are:

1. Pressure forces normal to the surfaces
2. Weight of element in the vertical direction.

Force on the face AB, $F_{AB} = P_x \times$ Area of face AB

$$F_{AB} = P_x \cdot dy \times 1$$

$$\boxed{F_{AB} = P_x \cdot dy}$$

Force on the face AC, $F_{AC} = P_y \cdot dx \times 1$

$$\boxed{F_{AC} = P_y \cdot dx}$$

Force on the face BC, $F_{BC} = P_z \cdot ds \times 1$

$$\boxed{F_{BC} = P_z \cdot ds}$$

Weight of element,

$$W = mg$$

$$\Rightarrow W = \rho V \cdot g$$

$$\Rightarrow W = \rho\left[\left(\frac{1}{2} \times AC \times AB\right) \times 1\right] \cdot g$$

$$\Rightarrow W = \rho\left[\frac{1}{2} \cdot dx \cdot dy\right] \cdot g$$

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

$m = \rho V$

Volume, $V =$ Area $\times$ Length

$V = \left(\frac{1}{2} \times AC \times AB\right) \times 1$ }

$$\Rightarrow W = \frac{dx \cdot dy}{2} \cdot \rho \cdot g$$

The equilibrium of the fluid element implies that sum of the forces in any direction must be zero.

Resolving the forces in x-direction

$$P_x \cdot dy - P_z \cdot ds \cos\theta = 0$$

$$P_x \cdot dy - P_z \cdot dy = 0$$

$$P_x \cancel{dy} = P_z \cdot \cancel{dy}$$

$$\left\{ \cos\theta = \frac{dy}{ds} \quad ds \cdot \cos\theta = dy \right\}$$

$$\boxed{P_x = P_z} \quad \text{—— (I)}$$

Resolving the forces in y-direction

$$P_y \cdot dx - P_z \cdot ds \sin\theta - \frac{dx \cdot dy}{2} \cdot \rho \cdot g = 0$$

$$P_y \cdot dx - P_z \cdot dx - \frac{dx \cdot dy}{2} \rho \cdot g = 0$$

$$\left\{ \sin\theta = \frac{dx}{ds} \quad ds \cdot \sin\theta = dx \right\}$$

Now, since (dx) and (dy) are very small, so $(dx \times dy)$ will be very very small that is, $\left(\frac{dx \cdot dy}{2} \rho \cdot g\right)$ is neglected. so our equation becomes,

$$P_y \cdot dx - P_z \cdot dx = 0$$

$$P_y \cdot dx = P_z \cdot dx$$

$$\boxed{P_y = P_z} \quad \text{—— (II)}$$

from equation (I) and (II), we have

$$\boxed{P_x = P_y = P_z}$$

The above equation shows that the pressure at any point in x, y and z directions is equal. This is called Pascal Law.

Ideal Fluid

A fluid which is non-viscous (ie viscosity $\mu = \frac{\tau}{\left(\frac{du}{dy}\right)} = 0$) and incompressible (ie compressibility $\beta = \frac{d\rho}{\rho dP} = 0$).

Non

Types of Fluids

1. Newtonian Fluids – fluids which follow Newton's law of viscosity
2. Non-Newtonian Fluids – fluids which don't follow Newton's law of viscosity.
3. Ideal Fluid
4. Real Fluid – fluid which have viscosity, all fluids in actual practice are real fluid.

Non - Newtonian Fluid

$\Downarrow$

do not obey Newton's Law of Viscosity

Rheology → Study of non-newtonian fluids.

General relationship between shear stress (τ) and velocity gradient $\left(\frac{du}{dy}\right)$ is :-

$$\boxed{\tau = A\left(\frac{du}{dy}\right)^n + B} \Longleftarrow \text{Experimental Relationship}$$

Where, A, B, n are constants

Non - Newtonian Fluids

- Time Independent Fluids
  - Dilatant Fluids
  - Pseudoplastic Fluids
  - Bingham Plastic Fluids
- Time Dependent Fluids
  - Rheopectic Fluids
  - Thixotropic Fluids

Dilatant Fluids

$n > 1, \quad B = 0$

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

$$\Rightarrow \tau = A\left(\frac{du}{dy}\right)^n$$

$$\Rightarrow \tau = A\left(\frac{du}{dy}\right)^{n-1} \cdot \left(\frac{du}{dy}\right)$$

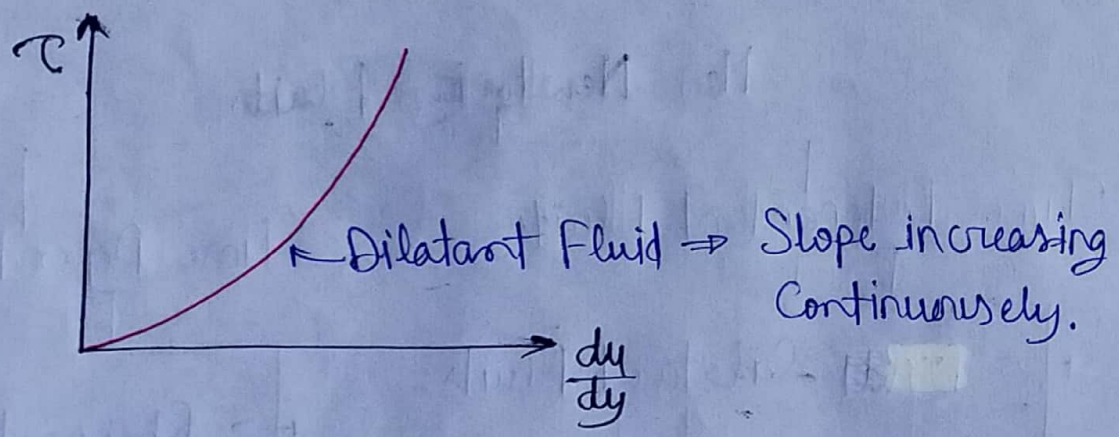
$$\boxed{\tau = \mu_{app} \cdot \frac{du}{dy}} \rightarrow \boxed{\mu_{app} = A\left(\frac{du}{dy}\right)^{n-1}}$$

$\Downarrow$

Apparent Viscosity

For these fluids, the apparent viscosity increases with rate of deformation or velocity gradient and hence these fluids are also known as Shear Thickering Fluids.

Example → sugar in water, rice starch. (माड़)

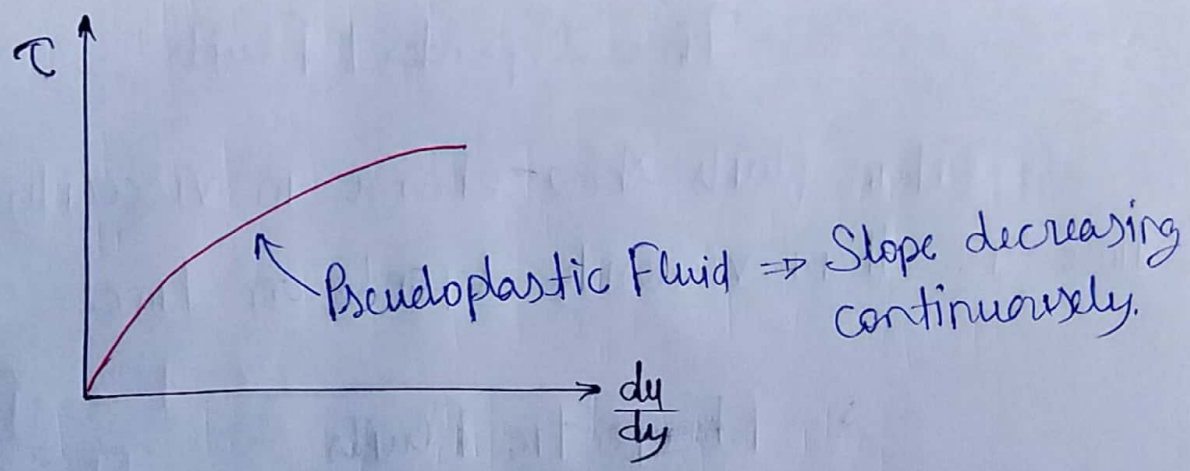


Pseudoplastic Fluids

$n < 1, \quad B = 0$

For these fluids, the apparent viscosity decreases with rate of deformation or velocity gradient and hence these fluids are also known as Shear-Thinning Fluids.

Example → Blood, milk, egg, collidal solution, ketchup.

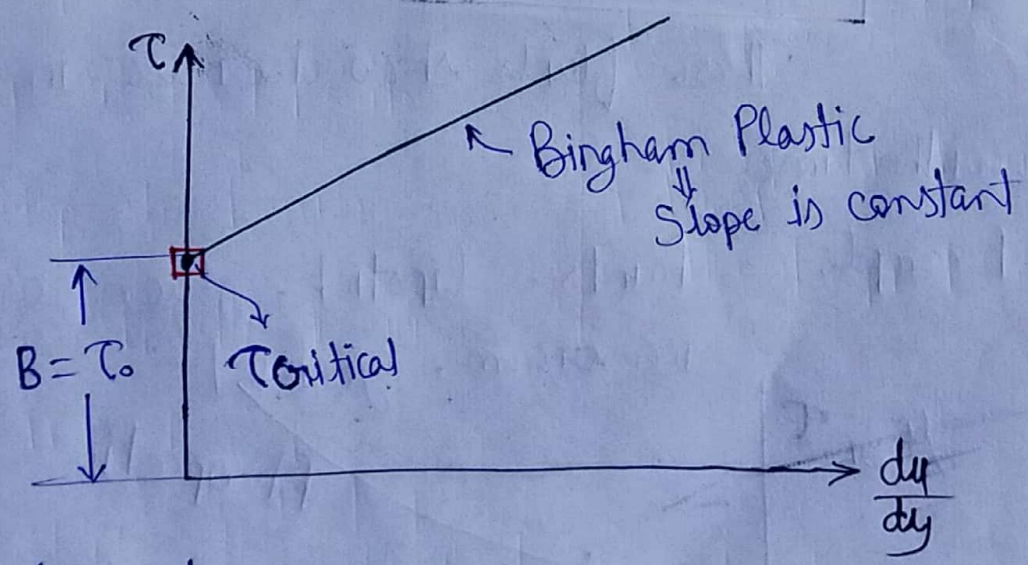


Bingham Plastic
or Ideal Plastic

$n = 1, \quad B > 0$

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

$$\boxed{\tau = A\left(\frac{du}{dy}\right) + B} \longrightarrow \text{or, } \tau = \tau_0 + \mu\left(\frac{du}{dy}\right)$$



Fluid does not start to flow until the shear stress value crosses its critical limit equal to 'B' and then viscosity remains constant.

Example → Toothpaste

Time Dependent Fluids

Certain fluids show change in viscosity with time ie their viscosity depends on time.

Rheopectic Fluids

$n > 1, \quad B > 0$

These fluids show increase in viscosity with time.

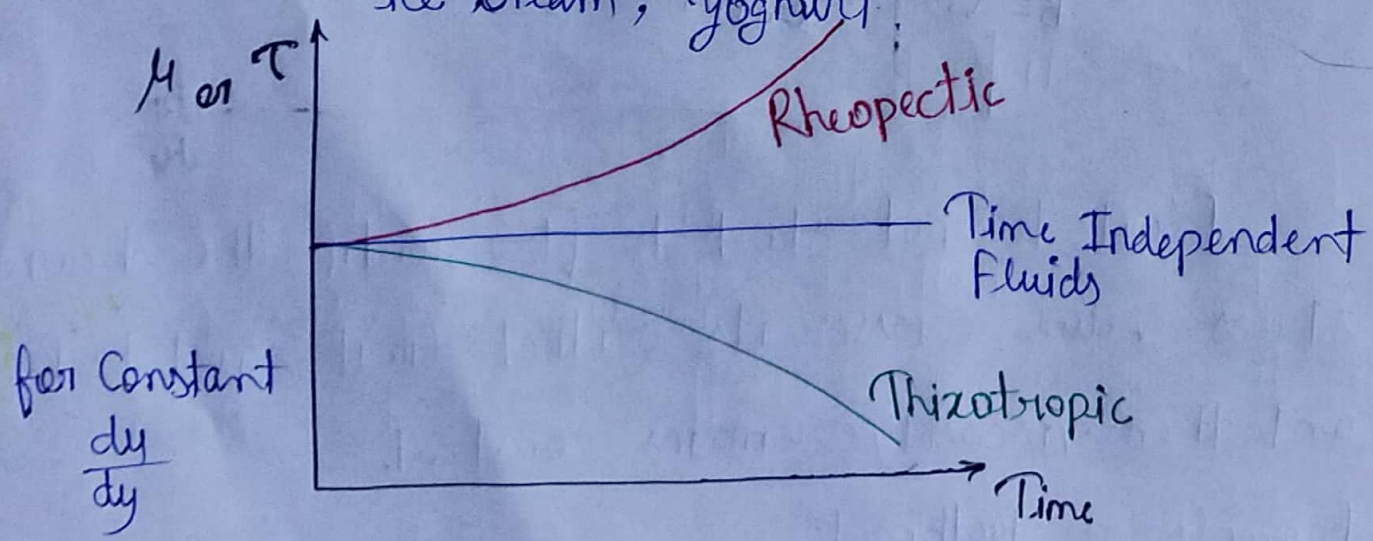
Example → Gypsum paste, Bentonite solution.

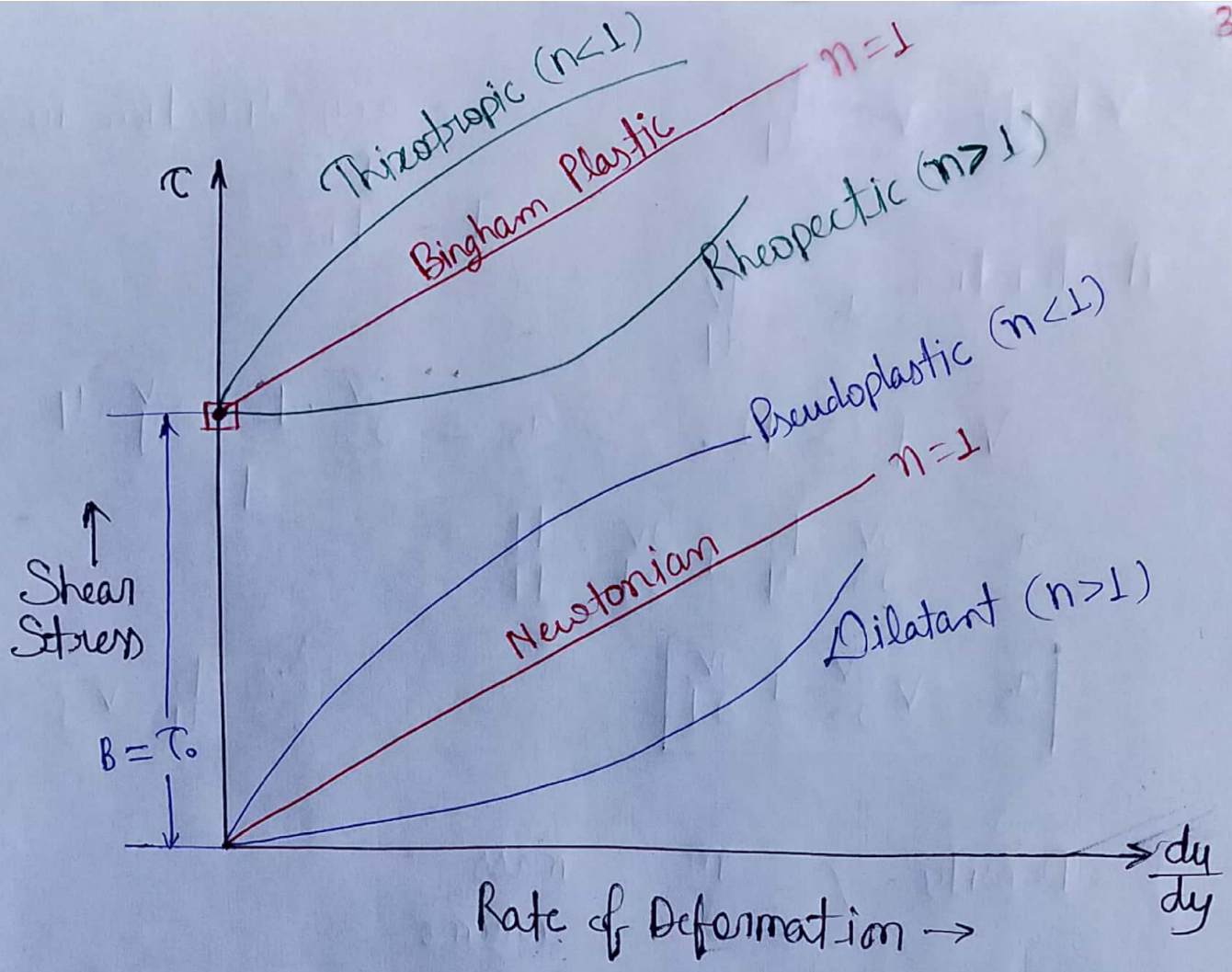
Thixotropic Fluids

$n < 1, \quad B > 0$

These fluids show decrease in viscosity with time.

Example → Paints, lipstick, glue, cosmetics, ice-cream, yoghurt.





Bernoulli's Equation

Generally forces acting on any fluid element are:

Pressure Force → F_p

Gravity Force → F_g

Viscous Force → F_v } → neglected
ie $F_v = 0 \rightarrow \mu = 0$
ie Non-Viscous Flow

Assumptions:

1. Non-Viscous Flow ($\mu = 0$)
2. Steady Flow (independent of time, no change w.r.t. time)
3. Incompressible Flow (density is constant)

Velocity, $V = \frac{ds}{dt}$

$s \rightarrow$ any direction in space

$t \rightarrow$ time

Acceleration, $a_s = \frac{dV}{dt}$

$$V = f(s, t), \Rightarrow a_s = \frac{\frac{\partial V}{\partial s} \cdot ds + \frac{\partial V}{\partial t} \cdot dt}{dt}$$

$$a_s = \frac{\partial V}{\partial s} \frac{ds}{dt} + \frac{\partial V}{\partial t} \cdot \frac{dt}{dt}$$

$$\boxed{a_s = V \frac{\partial V}{\partial s} + \frac{\partial V}{\partial t}}$$

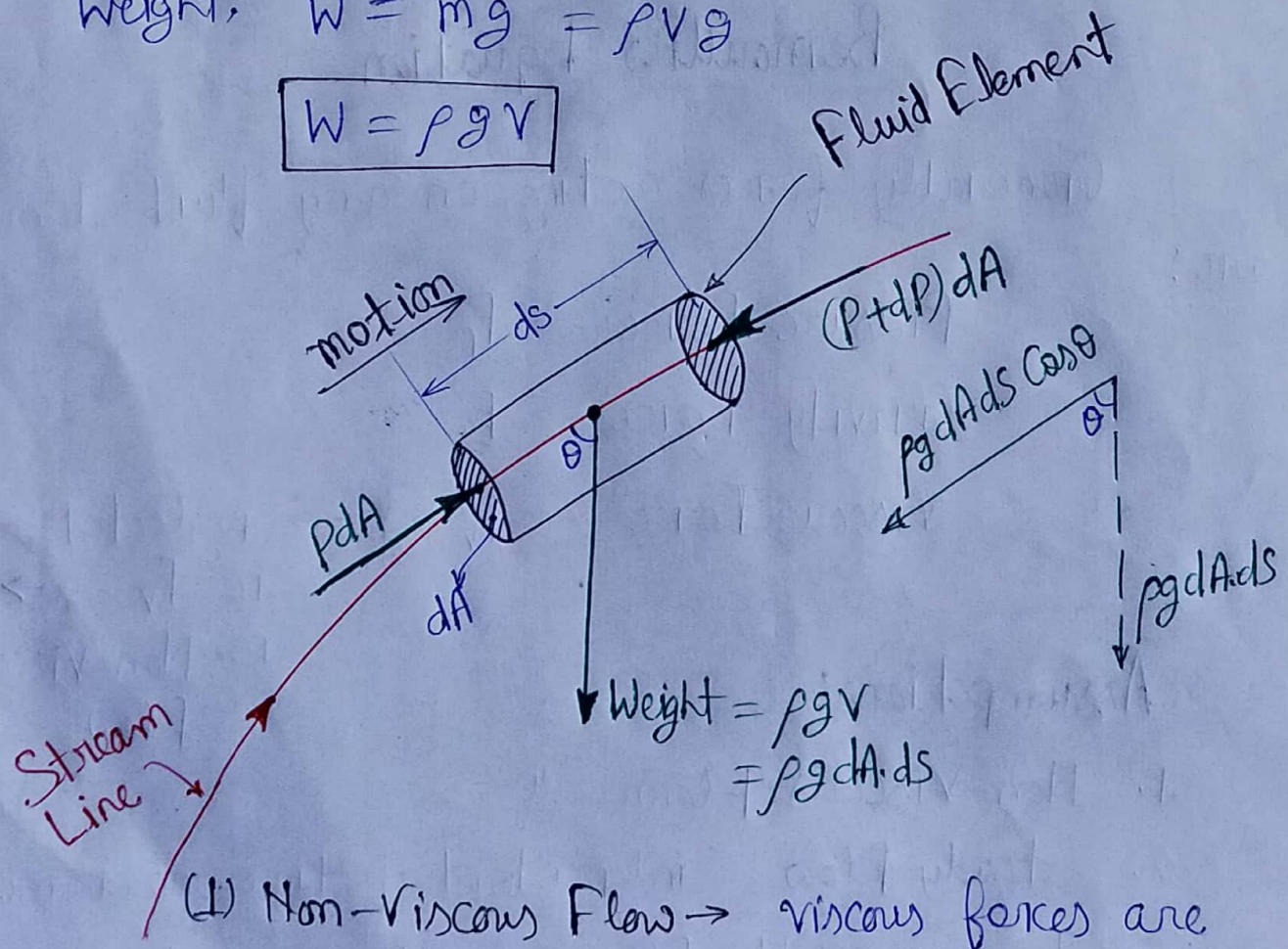
$\left\{ \because \frac{ds}{dt} = V \right\}$

Density, $\rho = \frac{m}{V} = \frac{\text{mass}}{\text{volume}}$

$m = \rho V$

Weight, $W = mg = \rho V g$

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



(1) Non-Viscous Flow → viscous forces are neglected

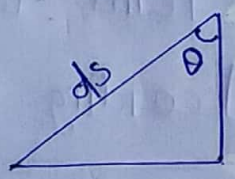
from Newton's second law

$\Sigma F = ma$ in the direction of motion

$$p\,dA - (p+dp)\,dA - \rho g\,dA\,ds\cos\theta = \rho\,dA\,ds\left[\frac{v\partial v}{\partial s} + \frac{\partial v}{\partial t}\right]$$

$$\left\{ \begin{array}{l} m = \rho V \\ m = \rho\,dA.ds \end{array} \right\}$$

$$\Rightarrow \cancel{p} - (\cancel{p}+dp) - \rho g\,dz = \rho\,ds\left[\frac{v\partial v}{\partial s} + \frac{\partial v}{\partial t}\right]$$



$dz = ds\cos\theta$ $\left\{ \cos\theta = \frac{dz}{ds} \right\}$

$$\Rightarrow \boxed{-dp - \rho g.dz = \rho\,ds\left[\frac{v\partial v}{\partial s} + \frac{\partial v}{\partial t}\right]} \quad \text{—(I)}$$

$\Downarrow$

Euler's equation for Non-Viscous Flow

(2) Steady Flow $\rightarrow$ $\frac{\partial v}{\partial t} = 0$

$$-dp - \rho g.dz = \rho.\cancel{ds}.\frac{v\,dv}{\cancel{ds}}$$

$$-dp - \rho g.dz = \rho.v\,dv$$

$$dp + \rho v.dv + \rho g.dz = 0$$

$$\boxed{\frac{dp}{\rho} + g.dz + \rho v.dv = 0} \quad \text{—(II)}$$

$\Downarrow$

Euler's equation for Steady Non-Viscous Flow

$$\int \frac{dP}{\rho} + \int g\,dz + \int V\,dV = \text{Constant}$$

(3) Incompressible Flow → ρ = Constant

$$\frac{\text{Energy}}{\text{mass}} \Rightarrow \boxed{\frac{P}{\rho} + gz + \frac{V^2}{2} = \text{Constant}}$$

⇓

Euler's equation for Steady Non-Viscous Incompressible Flow

⇓

Bernoulli's Equation.

In this equation each term represents energy of the fluid per unit mass. According to Bernoulli's Equation, in a steady non-viscous incompressible flow, the sum of pressure energy, potential energy and kinetic energy is constant. Hence Bernoulli's equation is Mechanical Energy Balance Equation.

$$\frac{\text{Energy}}{\text{mass}} \rightarrow \frac{P}{\rho} + gz + \frac{V^2}{2} = \text{Constant}$$

$$\frac{\text{Energy}}{\text{mass} \times g} \rightarrow \frac{P}{\rho g} + z + \frac{V^2}{2g} = \text{Constant}$$

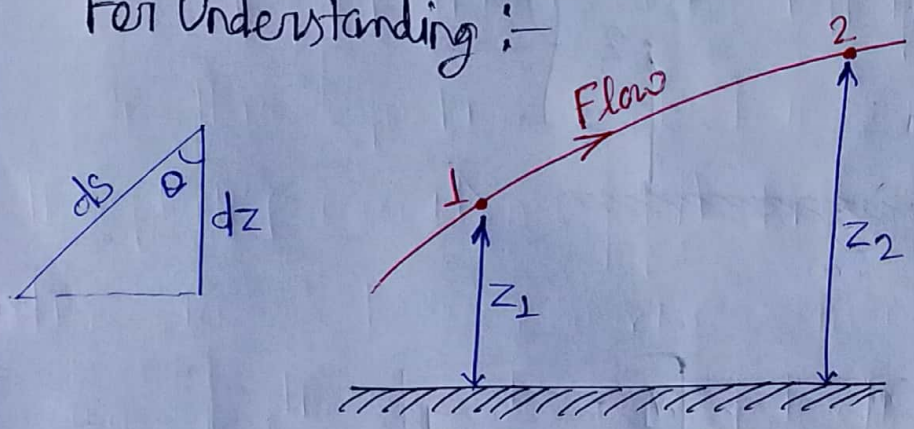
$$\frac{\text{Energy}}{\text{Weight}} \rightarrow \boxed{\frac{P}{\rho g} + \frac{V^2}{2g} + z = \text{Constant}}$$

$\frac{P}{\rho g}$ = Pressure Head [Pressure Energy per unit weight of fluid]

$\frac{V^2}{2g}$ = Kinetic Head [Kinetic Energy per unit weight of fluid]

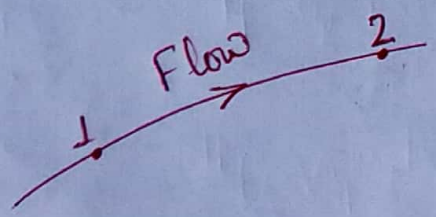
z = Potential Head [Potential Energy per unit weight of fluid]

For Understanding :-



$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

Bernoulli's Equation for Real Fluid Flow Problem :-



$$\left(\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1\right) = \left(\frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2\right) + h_L$$

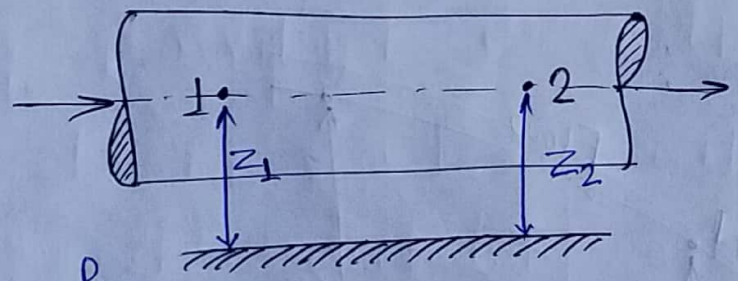
$h_L \rightarrow$ Head loss due to viscosity ie internal resistance in meter

$\Rightarrow \boxed{E_1 = E_2 + h_L}$

$E_1, E_2 \rightarrow$ Energy at 1 and energy at 2.

Que1- at a location one of a horizontal pipe, the pressure head is 32 cm and velocity head is 4 cm. the reduction in area at a location 2 is such that the pressure drops down to zero then find the ratio of velocity at section 2 to section 1.

Solution →



$$\frac{P_1}{\rho g} = \frac{P_1}{\omega} = 32 \text{ cm}$$

$$\frac{V_1^2}{2g} = 4 \text{ cm} \Rightarrow \boxed{V_1^2 = 2g \times 4}$$

$$\frac{P_2}{\rho g} = \frac{P_2}{\omega} = 0$$

from Bernoulli's Equation

$$\frac{P_1}{\omega} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\omega} + \frac{V_2^2}{2g} + Z_2$$

$$32 + 4 + \cancel{Z_1} = 0 + \frac{V_2^2}{2g} + \cancel{Z_2} \qquad \{\because Z_1 = Z_2\}$$

$$\frac{V_2^2}{2g} = 36 \text{ cm} \Rightarrow \boxed{V_2^2 = 2g \times 36}$$

hence, $\frac{V_2^2}{V_1^2} = \frac{2g \times 36}{2g \times 4} = 9$

$$\frac{V_2^2}{V_1^2} = 9 \Rightarrow \frac{V_2}{V_1} = \sqrt{9} = \sqrt{3\times3}$$

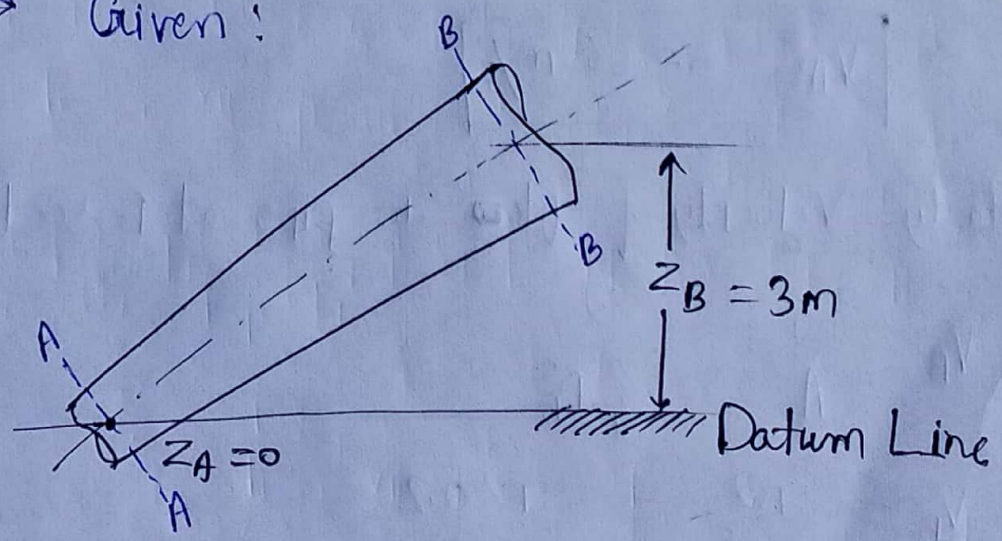
$$\boxed{\frac{V_2}{V_1} = 3}$$

Que2 → A water supply pipe line changes diameter from 20 cm at A to 50 cm at B. Pressure at A and B are 78.5 kN/m² and 58.9 kN/m² respectively with the end B being 3 m higher than A. If the flow in pipeline is 200 lit/s find:

(1) Direction of flow

(2) The head lost between A and B.

Solution → Given:



Diameter, $D_A = 20$ cm, $D_B = 50$ cm
$= 0.2$ m $= 0.5$ m

Pressure, $P_A = 78.5$ kN/m², $P_B = 58.9$ kN/m²
$= 78500$ N/m², $= 58900$ N/m²

Flow rate, $Q = 200$ litres/s

or Discharge, $Q = \frac{200}{1000}$ m³/s

$= 0.2$ m³/s

$\{\because 1\ m^3 = 1000$ litres

1 litre $= \frac{1}{1000}\ m^3\}$

Discharge, Q = Area × Velocity

$\boxed{Q = A \cdot V}$ ⇒ Velocity, $V = \frac{Q}{A} = \frac{\text{Discharge}}{\text{Area}}$

Pipe area, $A = \frac{\pi}{4} D^2$

Velocity of flow in pipe at A, section,

$$V_A = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} D_A^2}$$

$$\Rightarrow V_A = \frac{4Q}{\pi D_A^2} = \frac{4 \times 0.2}{\pi \times 0.2^2}$$

$$\Rightarrow \boxed{V_A = 6.366\ m/s}$$

Similarly, Velocity of flow in pipe at B, section,

$$V_B = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} D_B^2}$$

$$\Rightarrow V_B = \frac{4Q}{\pi D_B^2} = \frac{4 \times 0.2}{\pi \times 0.5^2}$$

$$\Rightarrow \boxed{V_B = 1.018\ m/s}$$

By using Bernoulli's equation

Energy Head at section A,

$$E_A = \frac{P_A}{\omega} + \frac{V_A^2}{2g} + Z_A$$

$$E_A = \frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A$$

$$E_A = \frac{78500}{1000 \times 9.81} + \frac{6.366^2}{2 \times 9.81} + 0$$

$$\Rightarrow \boxed{E_A = 10.065 \text{ m of water}}$$

Energy Head at section B,

$$E_B = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B$$

$$\Rightarrow E_B = \frac{58900}{1000 \times 9.81} + \frac{1.018^2}{2 \times 9.81} + 3$$

$$\Rightarrow \boxed{E_B = 9.053 \text{ m of water}}$$

(1) Direction of flow:- as 'E_A' is more than 'E_B', hence the direction of flow is from 'A' to 'B'

(2) The head lost between 'A' and 'B' = h_L

we know that,

$$E_1 = E_2 + h_L$$

or $$E_A = E_B + h_L$$

$$h_L = E_A - E_B$$

$h_L = 10.065 - 9.053$

$$\boxed{h_L = 1.012 \text{ m}}$$

Que 3 → A pipe of 200 m has a slope of 1 in 100 and tapers from 1 m diameter at the high end to 0.4 m at the lower end, rate of water flow is 4000 litres/min. If the pressure at the higher end is 50 kPa, find the pressure at the lower end.

Solution → Given,

Discharge, $Q = 4000$ litres/min

Volume, $1 \text{ m}^3 = 1000$ litres

$1 \text{ litre} = \frac{1}{1000} \text{ m}^3$

$1 \text{ min} = 60$ Seconds

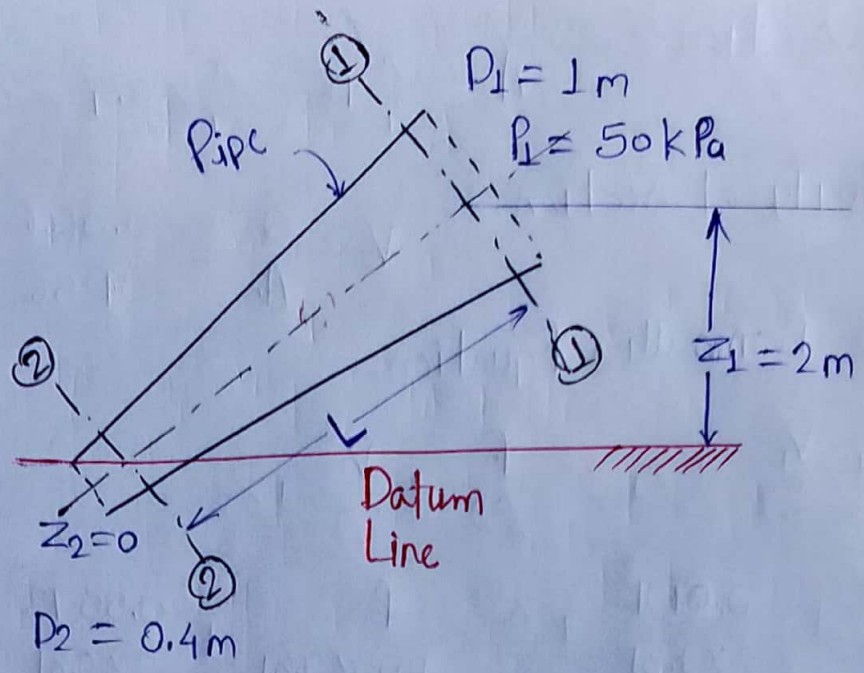
Discharge, $Q = \frac{4000}{1000 \times 60} \text{ m}^3/\text{s}$

$$\boxed{Q = 0.0666 \text{ m}^3/\text{s}}$$

Diameter at section 1, $D_1 = 1 \text{ m}$

Diameter at section 2, $D_2 = 0.4 \text{ m}$

Pressure at section 1, $P_1 = 50 \text{ kPa} = 50 \times 1000 \text{ N/m}^2$



Let the datum line passes through the centre of lower end.

then $Z_2 = 0$

Length of the pipe, $L = 200$ m

given, Slope is 1 in 100,

$$Z_1 = \text{Slope} \times L$$

$$\Rightarrow Z_1 = \frac{1}{100} \times 200$$

$$\Rightarrow Z_1 = 2m$$

Discharge through pipe;

Discharge, $Q = A_1 V_1 = A_2 V_2$

Area of section 1,

$$A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} \times 1^2 = 0.7853 \ m^2$$

Flow velocity at section 1,

$$V_1 = \frac{Q}{A_1} = \frac{0.0666}{0.7853} = 0.0891 \ m/s$$

Area of section 2, $A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} \times 0.4^2 = 0.1256\ m^2$

Flow velocity at section 2, $V_2 = \frac{Q}{A_2} = \frac{0.0666}{0.1256} = 0.5573\ m/s$

By using Bernoulli's Equation,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{50 \times 1000}{1000 \times 9.81} + \frac{0.0891^2}{2 \times 9.81} + 2 = \frac{P_2}{1000 \times 9.81} + \frac{0.5573^2}{2 \times 9.81} + 0$$

$$5.097 + 4.046 \times 10^{-4} + 2 = \frac{P_2}{9810} + 0.0158$$

$$7.0974 = \frac{P_2}{9810} + 0.0158$$

$$\frac{P_2}{9810} = 7.0974 - 0.0158$$

$$P_2 = 7.0816 \times 9810$$

$$P_2 = 69470.496\ N/m^2$$

$$P_2 = 69470.496\ Pa$$

$$\boxed{P_2 = 69.47\ kPa}$$

$\Downarrow$

Fluid pressure at section 2

Que 4 → Water flows through 200 mm diameter pipe. The point A and B are at elevation of 6m and 8m respectively along the inclined pipe. The pressure at A and B are 50kPa and 20 kPa respectively if the flow rate is 60 litres/s.

determine,

(1) Direction of flow

(2) Head loss between these points.

Solution → Given,

Diameter of pipe → $D = 200\ mm = 0.2\ m$

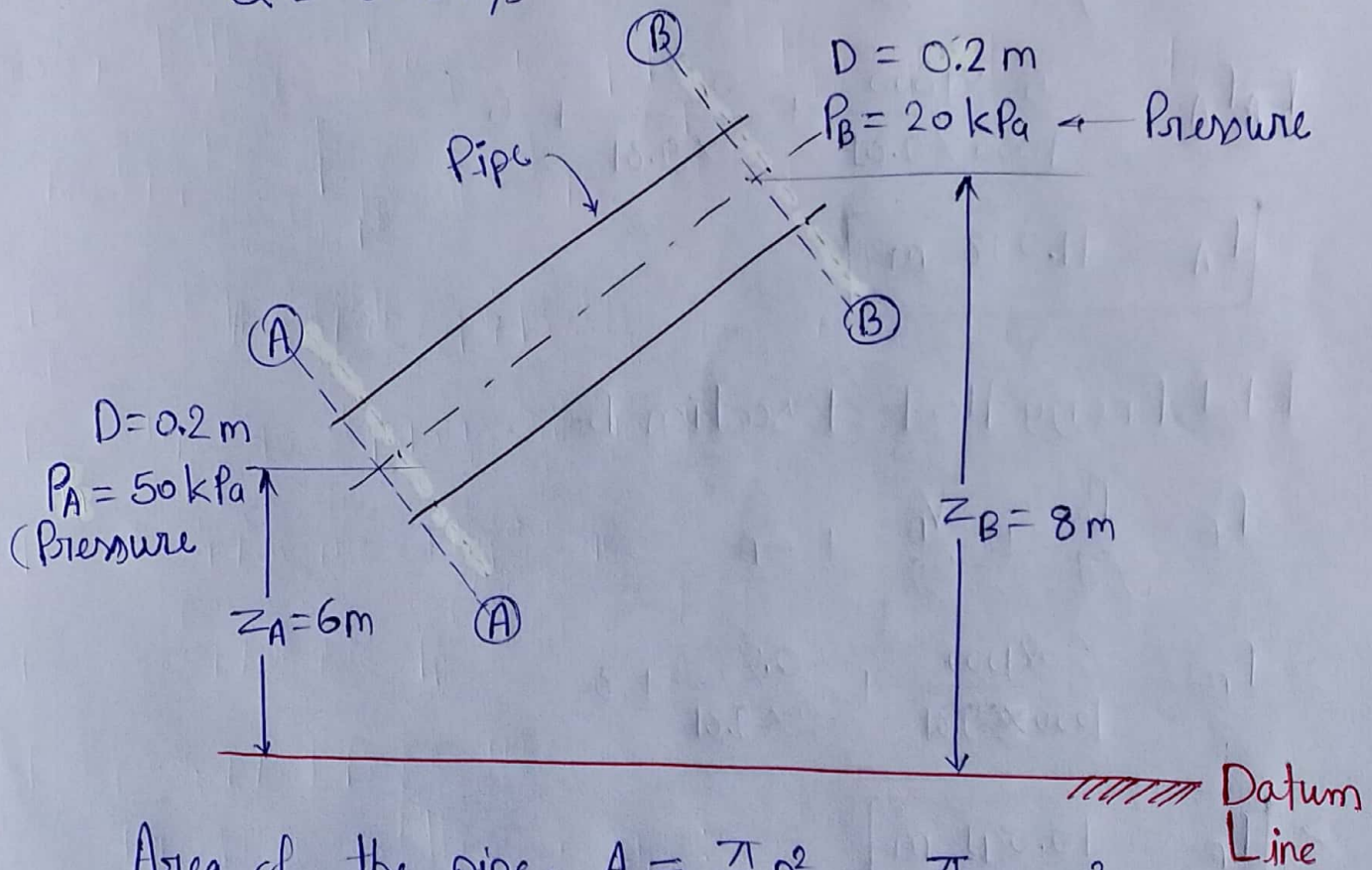
Flow rate, $Q = 60\ lit/s$

$1\ m^3 = 1000$ litres

1 litre $= \frac{1}{1000}\ m^3$

$Q = \frac{60}{1000}\ m^3/s$

$Q = 0.06\ m^3/s$



Area of the pipe, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times 0.2^2$

$A = 0.0314\ m^2$

Discharge, $Q = \text{Area} \times \text{Velocity}$

$Q = A_A V_A = A_B V_B \Rightarrow A_A V_A = A_B V_B$

$\Rightarrow \boxed{V_A = V_B}$ $\{\because A_A = A_B\}$

$\Rightarrow Q = A_A \cdot V_A$

$$V_A = \frac{Q}{A_A} = \frac{0.06}{0.0314} = 0.2 \text{ m/s}$$

$$V_A = V_B = 0.2 \text{ m/s}$$

By using Bernoulli's Equation,

Total Energy Head at section A,

$$E_A = \frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A$$

$$\Rightarrow E_A = \frac{50 \times 1000}{1000 \times 9.81} + \frac{0.2^2}{2 \times 9.81} + 6$$

$$\boxed{E_A = 11.098 \text{ m}}$$

Total Energy Head at section B,

$$E_B = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B$$

$$\Rightarrow E_B = \frac{20 \times 1000}{1000 \times 9.81} + \frac{0.2^2}{2 \times 9.81} + 8$$

$$\Rightarrow \boxed{E_B = 10.041 \text{ m}}$$

(1) Direction of flow :- as E_A is more than E_B, hence the direction of flow is from A to B.

(2) Head loss between these points.

$$E_A = E_B + h_L$$

$$h_L = E_A - E_B = 11.098 - 10.041 = 1.057 \text{ m}$$

$\boxed{h_L = 1.057 \text{ m}}$ → Head loss from A to B.

Que.5→ Water is flowing through an inclined conical pipe, 100 m long. It has 600 mm diameter at the upper end and 300 mm at the lower end the discharge rate is 50 litres/s. The pipe has a slope of 1/2:15. Find the pressure at the lower end if the pressure at the upper end is 2.5 bar.

Solution→ given,

Pipe Length, $L = 100$ m

Diameter at section 1, $D_1 = 600$ mm $= 0.6$ m

Diameter at section 2, $D_2 = 300$ mm $= 0.3$ m

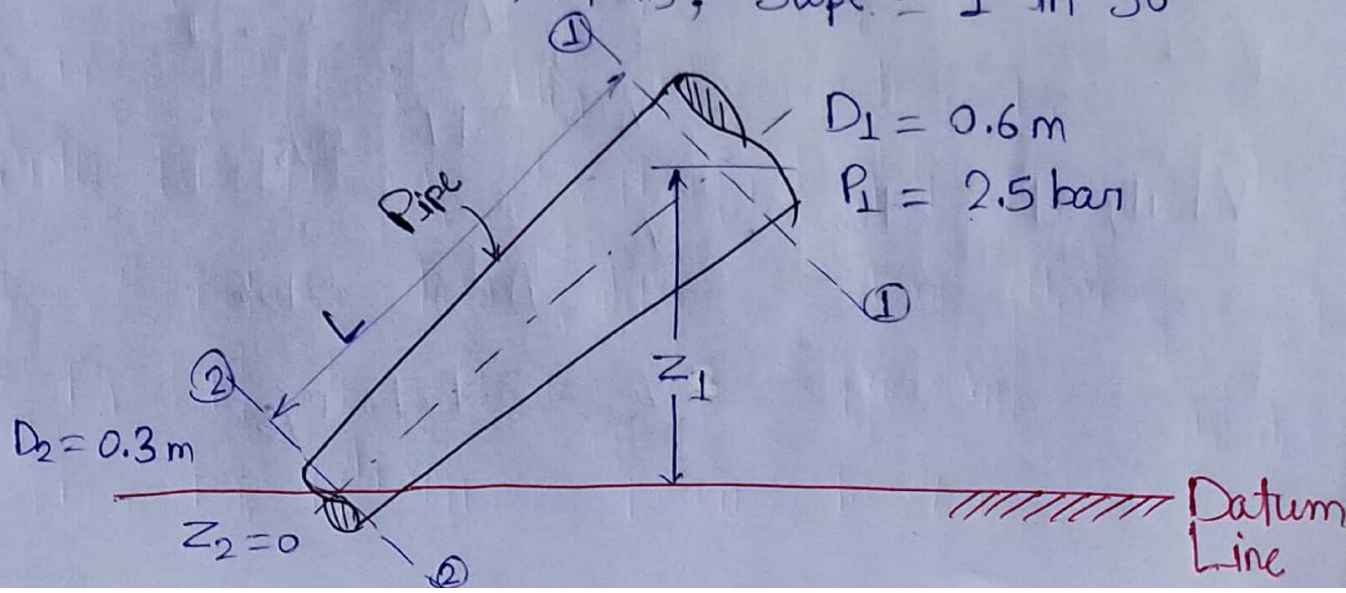
Discharge, $Q = 50$ lit/s $= \frac{50}{1000}$ m³/s

$Q = 0.05$ m³/s

{1 m³ = 1000 litre
1 litre = $\frac{1}{1000}$ m³}

Slope, $\frac{1}{2} : 15$

$= 1 : 30$ that is, Slope = 1 in 30



let the datum line passes through the centre of the lower end,

then, $Z_2 = 0$

and $Z_1 = \text{Slope} \times L$

$$Z_1 = \frac{1}{30} \times 100 \text{ m}$$

$$\Rightarrow Z_1 = \frac{10}{3} \text{ m}$$

Pressure at section 1, $P_1 = 2.5$ bar

$1 \text{ bar} = 100 \text{ kPa} = 100 \times 1000 \text{ Pa}$

$1 \text{ bar} = 10^5 \text{ Pa}$

ie $P_1 = 2.5 \times 10^5 \text{ Pa}$

Discharge through pipe, $Q = A_1 V_1 = A_2 V_2$

Area at section 1, $A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} \times 0.6^2 = 0.2827 \text{ m}^2$

Area at section 2, $A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} \times 0.3^2 = 0.0706 \text{ m}^2$

Velocity at section 1, $V_1 = \frac{Q}{A_1} = \frac{0.05}{0.2827}$

$$V_1 = 0.1768 \text{ m/s}$$

Velocity at section 2, $V_2 = \frac{Q}{A_2} = \frac{0.05}{0.0706}$

$$V_2 = 0.7073 \text{ m/s}$$

Applying Bernoulli's Equation at section ① and ②

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\Rightarrow \frac{2.5\times10^5}{1000\times9.81} + \frac{0.1768^2}{2\times9.81} + \frac{10}{3} = \frac{P_2}{1000\times9.81} + \frac{0.7073^2}{2\times9.81} + 0$$

$$\Rightarrow 25.4841 + 1.5931 + 3.3333 = \frac{P_2}{1000\times9.81} + 0.0254$$

$$\Rightarrow \frac{P_2}{1000\times9.81} = 28.7932$$

$$\Rightarrow P_2 = 28.7932\times1000\times9.81 = 282462.2 \text{ Pa}$$

$$\Rightarrow P_2 = 282.4622 \text{ kPa}$$

or $\boxed{P_2 = 2.824622 \text{ bar}}$

$\Downarrow$

Pressure at section '2'

$$\left\{ \begin{array}{l} 1 \text{ bar} = 100 \text{ kPa} \\ 1 \text{ kPa} = \frac{1}{100} \text{ bar} \end{array} \right\}$$

Hydraulic Machines

It may be defined as a device that extracts or imparts energy to a fluid flowing continuously. A turbine extracts energy and a pump imparts energy to the flowing fluid.

In other words,

Hydraulic machines are those machines which convert either hydraulic energy into mechanical energy or mechanical energy into hydraulic energy.

Mechanical Energy $\xrightarrow{\text{into}}$ Hydraulic Energy

Mechanical Energy $\xleftarrow{\text{or into}}$ Hydraulic Energy

Types of hydraulic machines:-

(1) Power Generating Machines

It is a device that is used to generate power by means of fluid in which kinetic energy, pressure energy and as well as potential energy is converted into mechanical energy.

Example → Turbine

(2) Power Absorbing Machines

Those devices which absorb energy to increase the fluid pressure energy, potential energy and kinetic energy, are called power absorbing machines.

Example → Pumps, fans, blowers, compressors

(3) Power Transmitting Machines

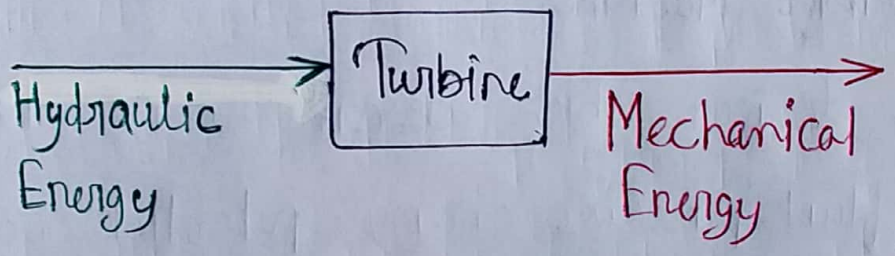
These devices are used to transmitte power from one shaft to another shaft by means of the fluid.

These are based on the principles of fluid statics and fluid kinematics which are used for either storing the hydraulic energy and then transmitting when needed.

Example → Fluid Coupling, Torque Converter.

Hydraulic Turbine
or Water Turbine

The hydraulic machines, which convert the hydraulic energy into mechanical energy are called turbine.



A hydraulic turbine or water turbine is a rotary engine used for electric power generation. It takes energy from flowing water and converts it into mechanical energy. It is used in hydraulic power plants.

Classification of hydraulic turbines :-

1. According to type of energy at inlet.

(I) Impulse Turbine → At the inlet of the turbine, only kinetic energy remains available in water.

Ex→ Pelton Turbine

(II) Reaction Turbine → At the inlet of the turbine, kinetic energy as well as pressure energy remains available in water.

Ex→ Francis Turbine

2. According to direction of flow through runner.

(I) Tangential Flow Turbine → Water flows along the tangent of the runner.

Example → Pelton Turbine

(II) Radial Flow Turbine → Water flows in the radial direction through the runner.

Example → Francis Turbine

(III) Axial Flow Turbine → Water flows along the direction parallel to the axis of rotation of the runner.

Example → Kaplan Turbine

(IV) Mixed Flow Turbine → Water enters into the turbine in radial direction and leaves in the axial direction.

Example → Modern Francis Turbine

3. According to the head at the inlet of turbine

(I) High Head Turbine → Pelton Turbine

(II) Medium Head Turbine → Francis Turbine

(III) Low Head Turbine → Kaplan Turbine

4. According to the specific speed of turbine

(I) High Specific Speed Turbine → Kaplan Turbine

(II) Medium Specific Speed Turbine → Francis Turbine

(III) Low Specific Speed Turbine → Pelton Turbine

Pelton Turbine

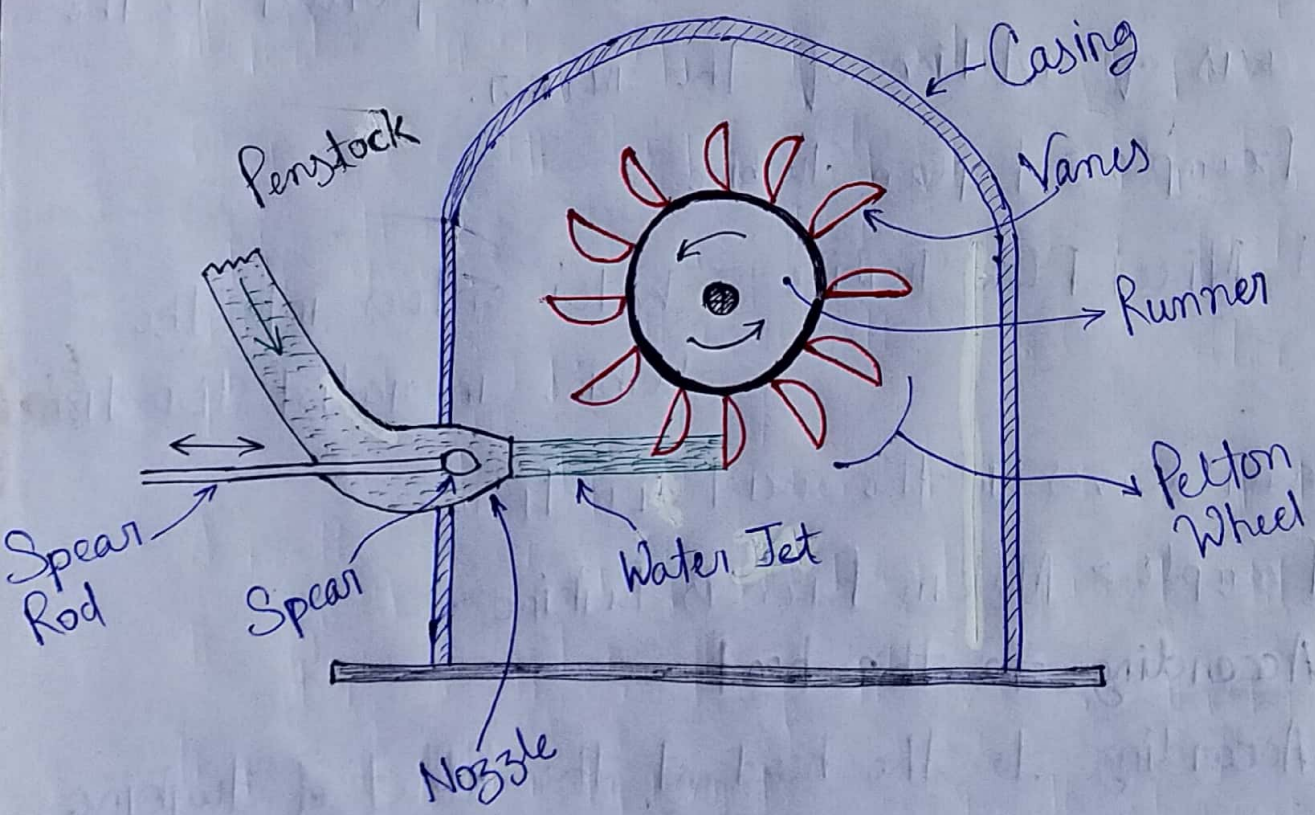


Fig:- Pelton Turbine

main parts of Pelton Turbine:-

1. Nozzle and Flow Regulating Arrangement:

The amount of water striking the buckets (vanes) of the runner is controlled by providing a spear in the nozzle.

2. Runner with Buckets or Vanes:

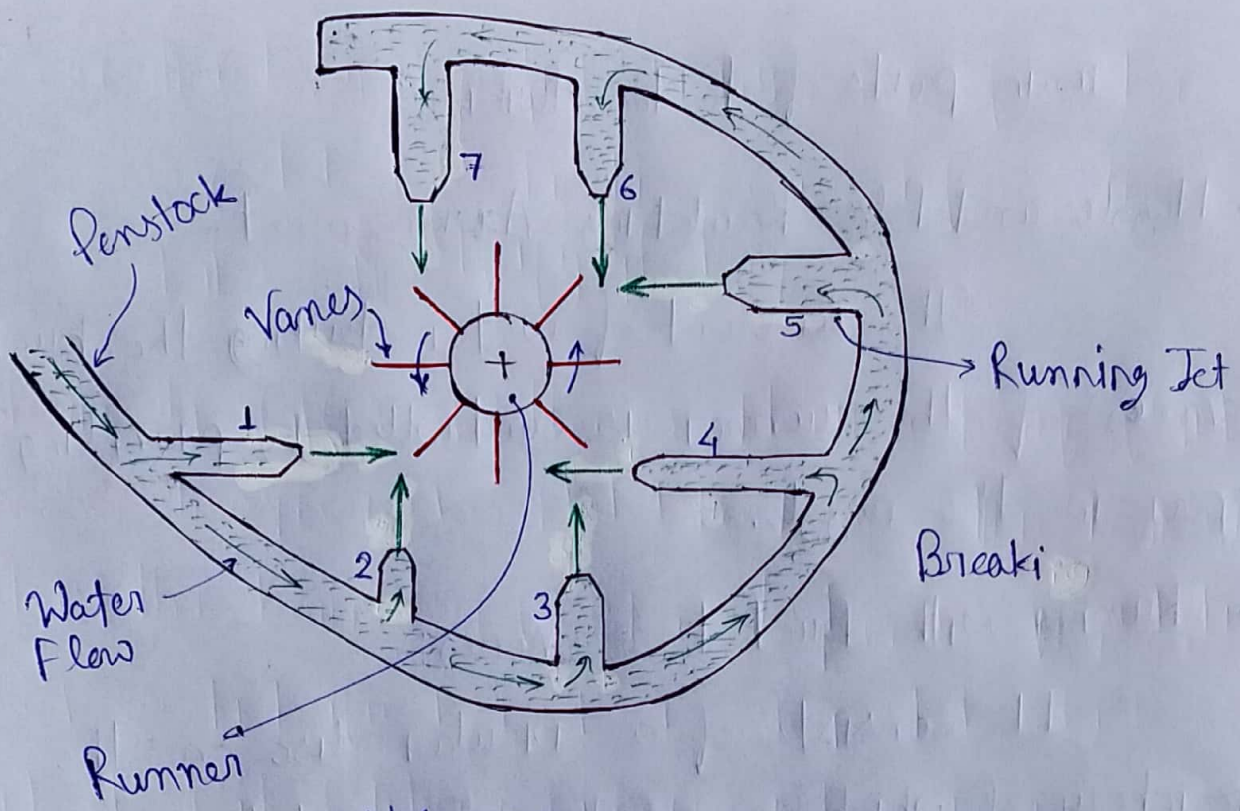
It consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed. The shape of the buckets is of a double hemispherical cup or bowl.

3. Casing:

The function of casing is to prevent the splashing of the water and to discharge water to tail race.

4. Breaking Jet:

To stop the runner in a short time a small nozzle is provided which directs the jet of water on the back of the vanes. This jet of water is called breaking jet.



Water Jet → 2, 4, 6 ⇒ Breaking Jet
Water Jet → 1, 3, 5, 7 ⇒ Running Jet

Working principle of Pelton Turbine:

- A pelton turbine is a tangential flow impulse turbine.
- When water is transferred from a high head source through the penstock which is fitted with a nozzle. Through the nozzle, water flows out as a high speed jet.
- A needle spear moving inside the nozzle controls the flow of water through the nozzle and at the same time provides a smooth flow with a negligible energy loss.

- The available potential energy of water is thus converted into kinetic energy before the water jet strikes the buckets or vanes.
- The pressure throughout the turbine is atmospheric and constant so the work is done on turbine by water is purely through impulse action.
- Speed of turbine is kept constant by a governing mechanism that automatically regulate the quantity of water flowing through the runner in accordance with variation of load.

Pumps or Hydraulic Pumps

- Centrifugal Pumps
- Reciprocating Pumps

Pumps: It is device which converts mechanical energy into hydraulic energy to increase the pressure energy, kinetic energy and potential energy of fluid ie pump converts mechanical

energy into hydraulic energy.

Centrifugal Pump

Working Principle: When a certain mass of fluid is rotated by an external source, it is thrown away from central axis of rotation and a centrifugal head is imparted which enables it to rise to a higher level.

Fluid moves in radial direction (r)

Change in pressure in radial direction is:

$$\boxed{\frac{dP}{dr} = \frac{\rho V^2}{r}}$$

Where, ρ = density = $\frac{\text{mass}}{\text{Volume}}$

r = radial distance from axis of rotation

V = linear velocity

$V = r\omega$

$\omega \rightarrow$ angular velocity

$\Rightarrow dP \propto V^2$

ie change in pressure in radial direction is directly proportional to square of the velocity.

As fluid moves away from centre of rotation tangential velocity ($V = r\omega$) increases linearly but change in pressure increases with square of tangential velocity. This is the basic principle of centrifugal pump.

Main Parts of Centrifugal Pump:

1. Impeller → The rotating part of centrifugal pump is called impeller. It consists of a series of backward curved vanes. It is mounted on a shaft.

2. Casing → It is an air tight passage surrounding the impeller and is designed in such a way that the kinetic energy of water discharge at the outlet of impeller is converted into pressure energy.

3. Suction Pipe → It is a pipe whose one end is connected to the inlet of the pump and other end is submerged into the water in a sump.

4. Delivery Pipe → It is a pipe whose one end is connected to the outlet of the pump and other end delivers the water upto the required height.

$h_s \rightarrow$ Suction Head

$h_d \rightarrow$ Delivery Head.

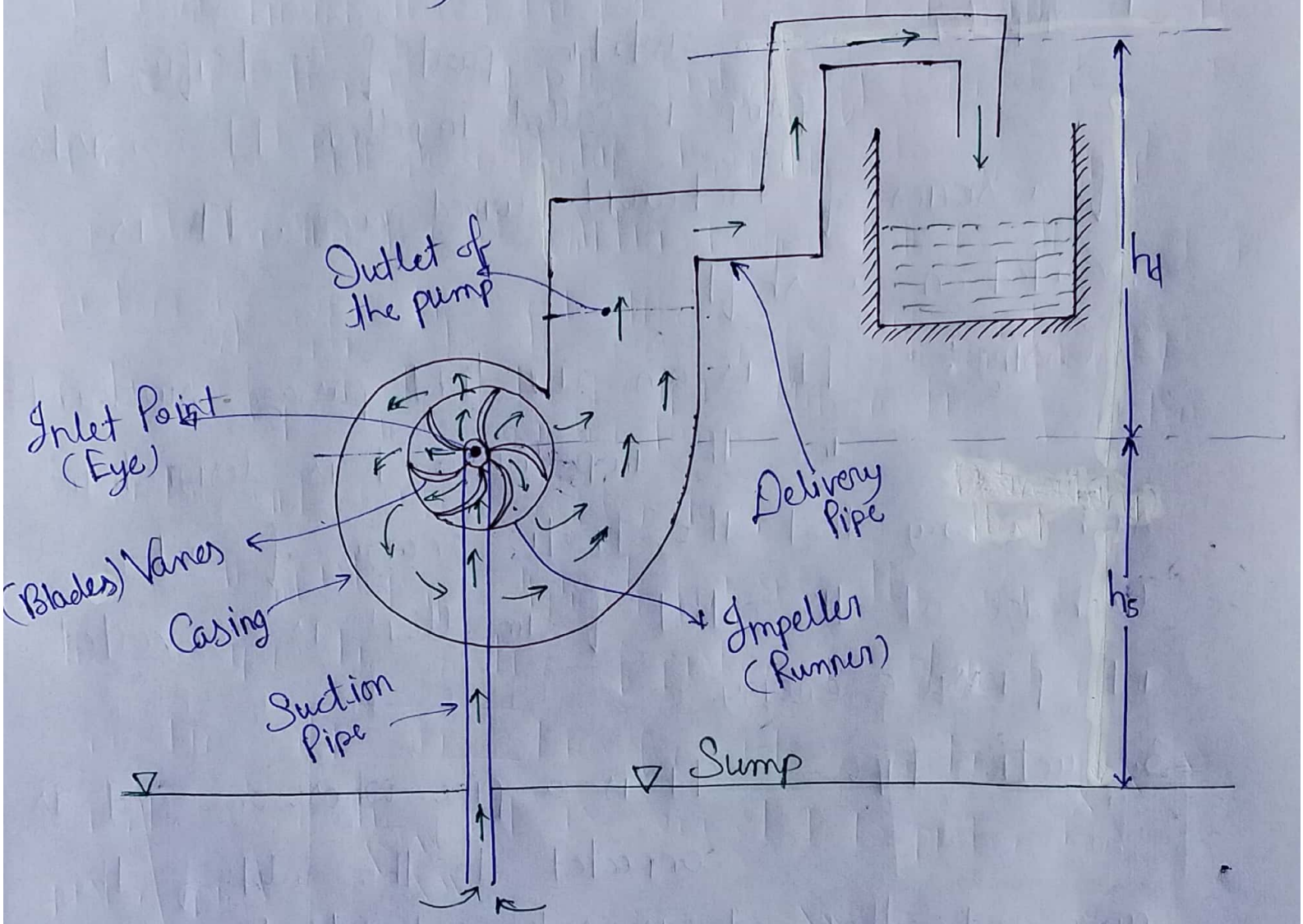


Fig: Centrifugal Pump.

Reciprocating Pump

By sucking the liquid into the cylinder in which a piston is reciprocating (moving backward and forward) which exerts the thrust on the liquid and increases the hydraulic energy (pressure energy). This pump is known as reciprocating pump.

Types of Reciprocating Pump:

1. According to water being in contact with one side or both sides of the piston.
   - (I) Single Acting Pump
   - (II) Double Acting Pump

2. According to the number of cylinder provided.
   - (I) Single Cylinder Pump
   - (II) Double Cylinder Pump
   - (III) Triple Cylinder Pump

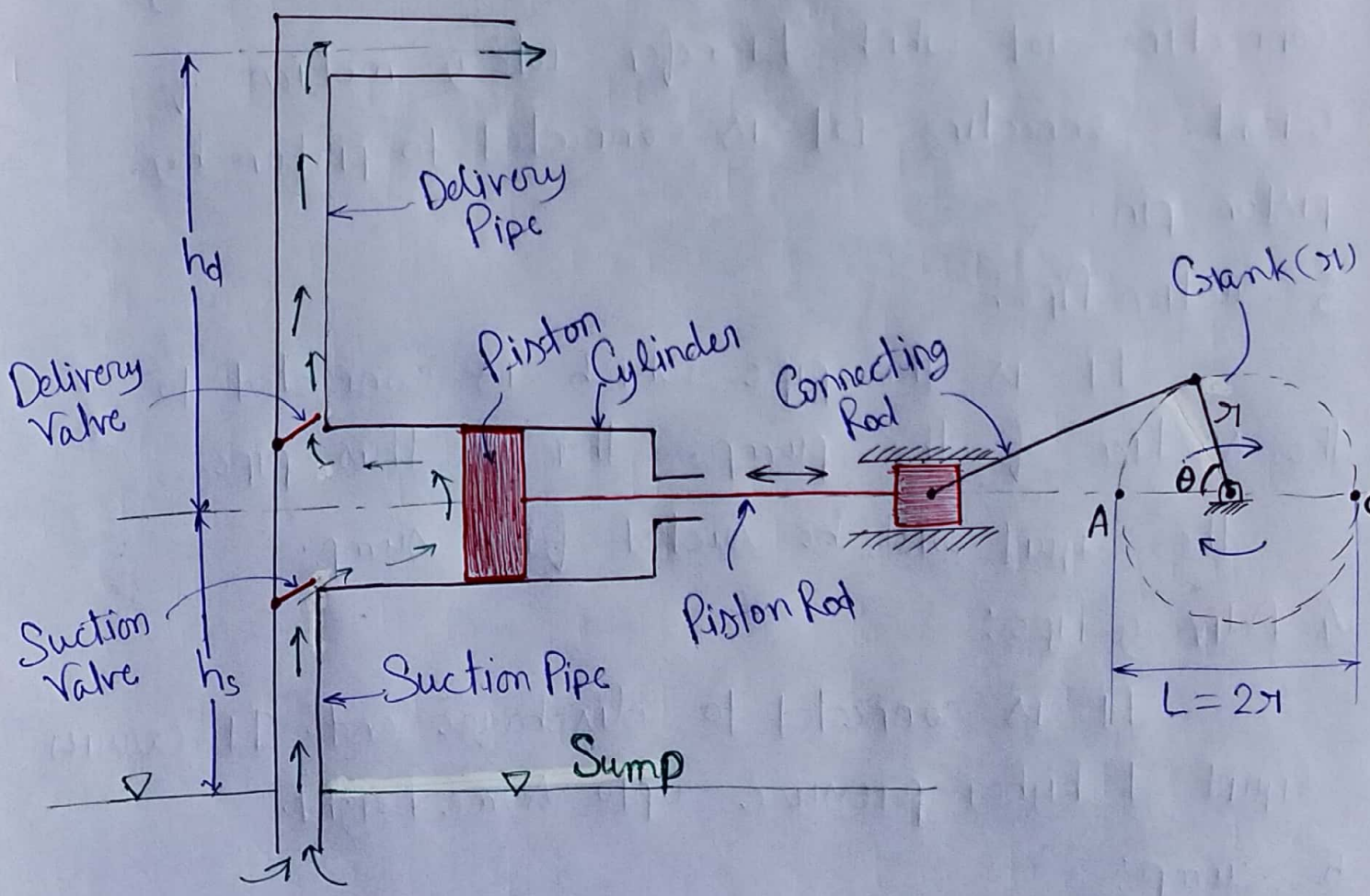


Fig:- Single Acting Reciprocating Pump

Construction of Reciprocating Pump,

1. Connecting Rod and Crank:

Crank is mounted on crankshaft which is driven by either internal combustion engine (ICE) or electric motor. Crank is connected to the piston by connecting rod thus converting rotary motion of crank into reciprocating motion of piston.

2. Piston and Cylinder:

The piston reciprocates inside the cylinder. The reciprocating motion of piston is obtained by connecting rod which transfer rotary motion of crank. Connecting rod is connected to piston by piston pin.

3. Suction Pipe:

It is the pipe which is connected to the suction of the pump, through this pipe, the liquid will be sucked from sump.

4. Delivery Pipe:

It is connected to discharge end. It carries liquid at higher pressure upto some height.

5. Sump:

It is reservoir of liquid through which water is sucked and then pumped.

When crank position is at A, the piston is at extreme left position in the cylinder.

As the crank is rotated from A to C (ie $\theta = 0°$ to $180°$), the piston moves towards right in the cylinder. Similarly crank rotates from C to A (ie $\theta = 180°$ to $360°$), and hence piston moves from extreme right to extreme left.

UNIT-3

Question Bank

1. Classified the fluids based on their properties.
2. Explain the working principle of Pelton Turbine and Centrifugal Pump.
3. What is the viscosity? Explain the Newton's law of viscosity and its significance.
4. The water is flowing through a pipe having diameters 30 and 20 cm at two sections 1 and 2 respectively. The rate of flow through pipe is 80 litre/s. The section 1 is 8 m above the datum line and section 2 is 5 m above the datum. If pressure at section 1 is 4 bar. Find the intensity of pressure at section 2.
5. What is the difference between the dynamic viscosity and kinematic viscosity?
6. Water is flowing through a pipe having diameter 300 mm and 200 mm at the bottom and upper end respectively. The intensity of pressure at the bottom end is 24.525 N/cm2 and the pressure at the upper end is 9.81 N/cm2. Determine the difference in datum head if the rate of flow through pipe is 40 litre/s.
7. State and derive the Bernoulli's equation. Explain each term with its physical significance.
8. Explain the working of the fluid couplings with suitable diagram.
9. A pipe of 200 m has a lope of 1 in 100 and tapers from 1 m diameter at the higher end and 0.4 m at the lower end and rate of flow are 4000 litre/min. If the pressure at the higher end is 50 kPa, find the pressure at the lower end.
10. Sketch the general arrangement of hydropower plant and explain the functions of its different components.

Assignment-3

1. State and explain the followings: -
    i) Pressure
    ii) Density
    iii) Viscosity
    iv) Types of fluids
2. Explain Newton's law of viscosity.
3. State and prove Bernoulli's equation for incompressible fluids. And what are the assumptions taken into considerations while proving it?
4. Explain working of Hydraulic machines.

Important Questions

1. Explain various properties of the fluid.
2. Explain Newton's law of viscosity.
3. State and prove Bernoulli's equation for incompressible fluids. And what are the assumptions taken into considerations while proving it?
4. Explain the working principal of hydraulic turbine and hydraulic pump.