M.O.S	M.O.F
1. In MOS there is a solid object ex:- bench	1. In M.O.F there is a liquid object ex:- petrol (or) water
2. IN M.O.S there is a structure with solid B.M (BM - Bending moment)	2. IN M.O.F there is a not structure because ~~[illegible]~~ it is a liquid NO B.M
3. IN MOS there less space	3. IN M.O.F there is more space.
4. There is More ~~[illegible]~~ ~~ductility~~ ductility	4. There is less ~~[illegible]~~ ductility
5. There is a particular shape	5. There is a No shape (or) shape less.

objectives of the fluid mechanics and Hydraulic ~~[illegible]~~ Mechanics.

1. understand the Basic concepts of fluid Mechanics (properties, fluid behaviour and Performance)

* Reconized the various types of fluid flow probelems encounted in practice.

* Model Emerging problems and sloved them in a systematic ~~[illegible]~~ manner.

* Have a wooking knowldge of accurasy and procedure

Fluid Mechanics

→ What is a fluid? (2M)

. This substance exist three primary phases i.e solid, liquid & guses.

→ A substance in a liquid or guse phase is settered a fluid

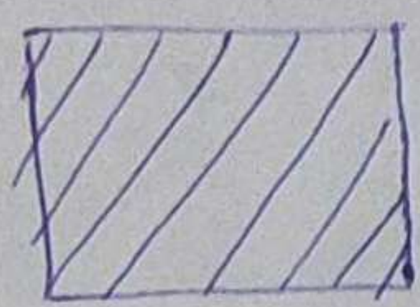
* Fluid Mechanics :- is defined as the science that deals with the behaviour of fluid ~~[illegible]~~ such as liquid & geses in motion (or) at rest. When the fluid is at rest known as fluid statistics (or) In ocean are fluid Dynamics

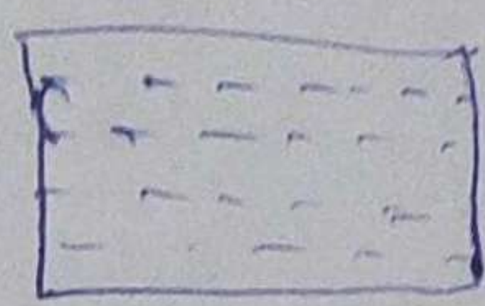
Hydralic Mechines :- are defind as this mechines which converts either hydrolic energy (energy forced by water) into mechanical energy

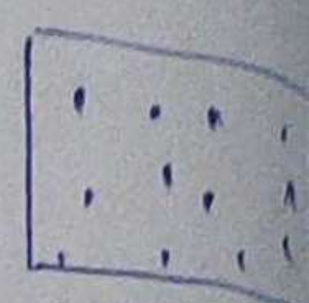
(which is further converted into electrical energy)

The Hydraulic machines which converts hydraulic energy into mechanical energy known as Turbine while the hydraulic machines which converts the mechanical energy into Hydraulic energy are called pumps.

Diagrams

solid → 

Liquid → 



Gases

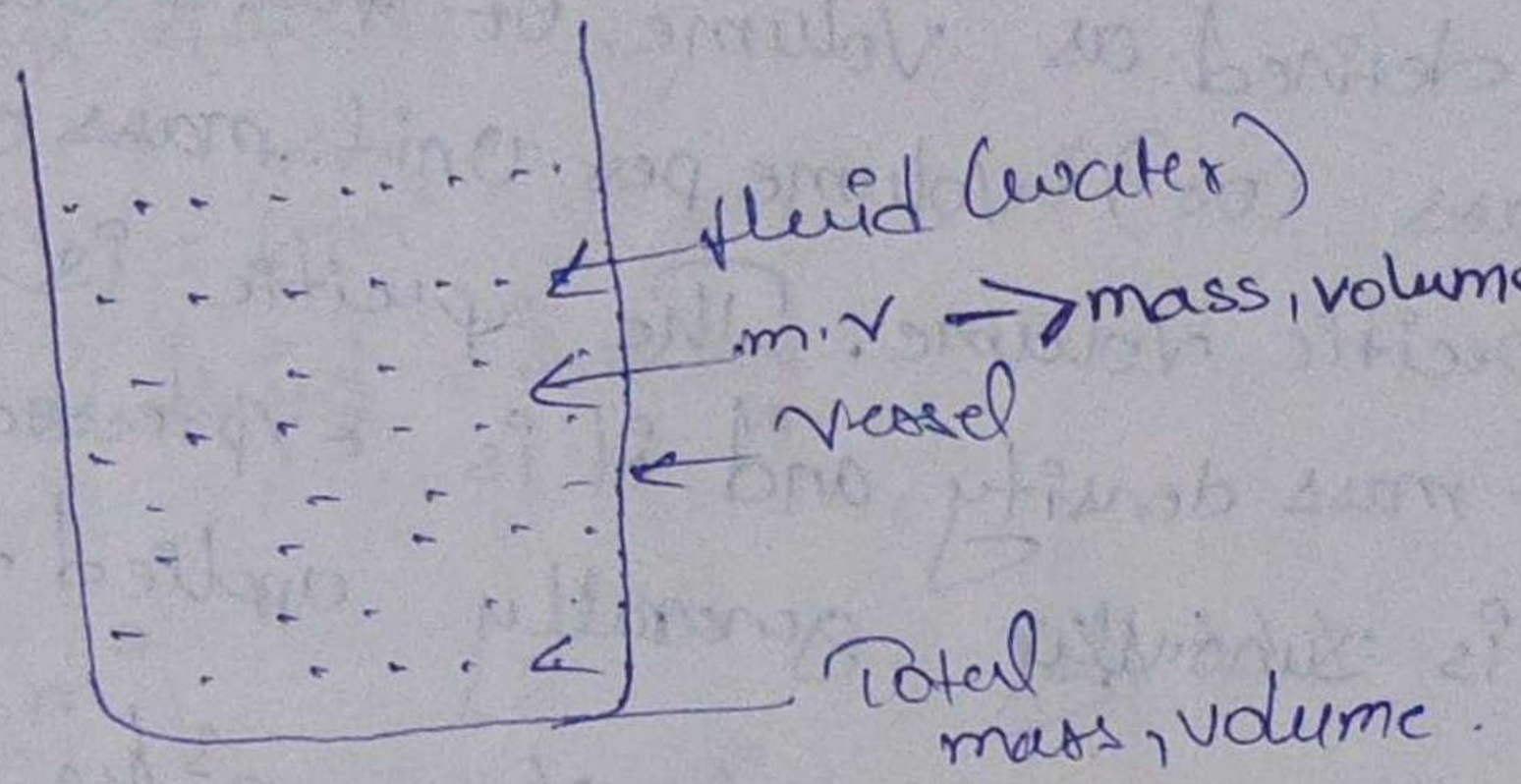
Intermolecular force	: Strong	moderate	weak
compressibility	: incompressible	incompressible	compressi
Density	: High	moderate	low
fluidity	: can't flow	can flow	can flow
space b/w particle	: Very less	more then solid less then gas	Too high

** Properties of fluids : some important properties fluid (water) which will be consider are *

1. Density
2. Weight Density
3. Specific volume
4. Specific gravity
5. viscosity
6. Surface tension

7. capillarity (∵ volume of circle $v = \frac{\pi}{4} d^2 \times l$)

Properties of fluids



1. Density :- (ρ) The density is also known as mass density (or) specific mass of liquid may be defined as the ratio of mass per unit volume it $\rho = \frac{m}{v}$ at standard temperature and pressure it is denoted by (ρ) (row)

It's units are kg/m^3.

The value of density of water is $1000 kg/m^3$

2. Weight Density (w) :- The weight density is also known as specific weight. It is defined as the weight per unit volume $\left(\frac{\text{weight of fluid}}{\text{volume of fluid}}\right)$ at standard temperature and pressure it is denoted by 'w'

This specific weight of water is taken as in S.I

→ unit $w = 9.81 kN/m^3$ → units are kN/m^3

→ in MKS, units $w = 1000 kgf/m^3$

$$w = \frac{\text{weight of fluid}}{\text{volume of fluid}} = \frac{\text{mass} \times \text{acceleration due to gravity}}{\text{volume}}$$

$= mg$

$$\boxed{w = \rho g} \quad \left[\rho = \frac{m}{v}\right]$$

3. <u>specific volume</u> (v) :- specific volume of fluid is defined as volume of fluid occupied by a unit mass (or) volume per unit mass of fluid is called specific volume. The specific is reciprocal of mass density and it is expressed as in m^3/kg it is generally applied to gases

$$v = \frac{V}{m} \cdot m^3/kg$$

$$\boxed{\frac{1}{\rho} = \frac{1}{\frac{m}{v}}} \rightarrow \text{(reciprocal mass density)}$$

4. <u>specific gravity</u> (s) : Is defined as the ratio of the weight density of fluid to the weight density of standard fluid. (or) The ratio of specific weight of liquid to the specific weight of standard liquid.

*For liquids the standard liquid fluid is take as water

→ For gases the standard fluid taken as air

→ Specific gravity is also known as <u>relative density</u>

→ It is dimensionless quantity (i.e. w = weight) and denoted by letter (s) Then $s = \frac{w_{liquid}}{w_{std\ liquid}}$ (∵ std = standed liquid)

5/ viscosity

$(\because w_{water} = 9.81 \times 10^3)$

* Calculate specific weight, mass, volume, gravity of a liquid having a volume of $6m^3$ and weight of fluid is ~~44KN~~ 44KN

volume (v) = $6m^3$

weight of fluid = 44 kN

volume (v) = $6m^3$

weight of fluid = 44kN = $44 \times 10^3 N$

1. sp weight (w) ..?
2. sp mass (ρ)
3. sp volume (v)
4. sp Gravity (s)

1. sp weight (w) = $\frac{\text{weight of fluid}}{\text{volume}}$

2. sp mass (ρ) = $\frac{w}{g}$

$= \frac{7.33 \times 10^3}{9.81}$

$\boxed{w = \rho g}$

$\boxed{g = m/s^2}$

$\rho = 747$

3. sp volume (v) = $\frac{1}{\rho} = \frac{1}{747} = 1.33 \times 10^{-3} m^3/kg$

4. sp gravity (s) = $\frac{w_{liquid}}{w_{std\ liquid}}$

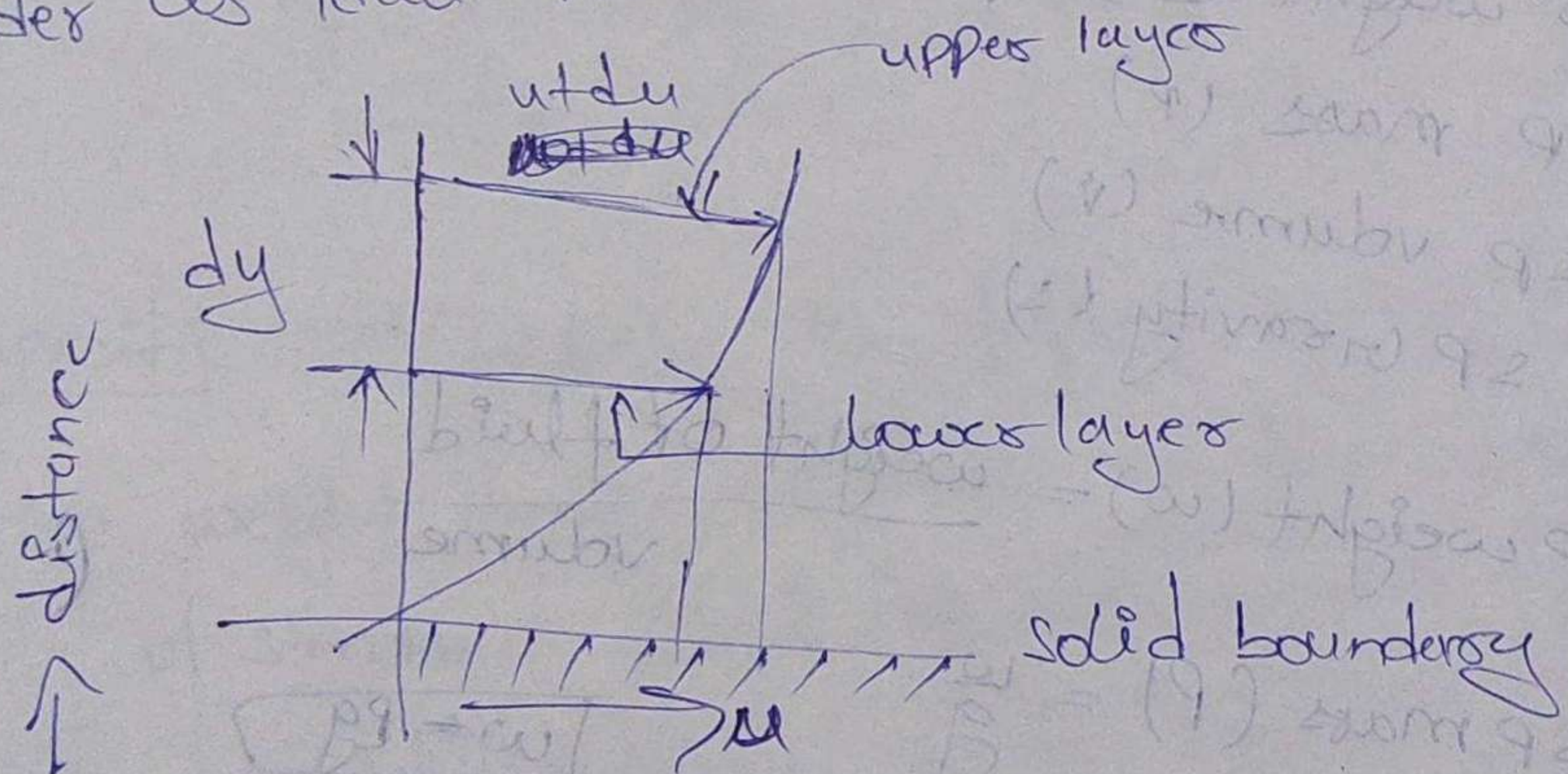
$= \frac{7.33 \times 10^3}{9.81 \times 10^3}$

$s = 0.747$

$w_{std} = 9.81 kN/m^3$

$= 9.81 \times 10^3 N/m^3$

5. Viscosity : May be defined as the property of fluid which determines its resistance to shearing tress it is Measure of the internal friction which cause resistance to fluid flow. it is due to cohesion and molecular flow occurs. these effects appear as shearing stress b/w the moving layers of fluid an ideal fluid as NO viscosity, There is no fluid which can be classified as perfectly ideal fluid. how ever the fluid with little viscosity are sometimes consider as ideal fluid



Viscosity variation

When two layers of fluid at a distance dy upon move one layer over other at different velocity that is u+du, the viscosity together with relative velocity causes a shear stress acting b/w the fluid layer. Thus shear stress is proportional to the rate of change

of velosity with respect to distance y it is denoted by τ

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

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

where μ = constant of proposnality and known as ~~rate of sheur deformation~~ (or) rate of sheur ~~strain~~ co-efficent of dinamic viscosity (or) only viscosity.

$\frac{du}{dy}$ = rate of deformation (or) Velosity gradient
or
rate of sheur strain

du = change of velocity

dy = change of distance.

τ = sheur stress in N/m^2

$$\boxed{\mu = \frac{\tau}{\frac{du}{dy}}}$$ → The units of viscosity in

M.K.S = $kgf\,sec/m^2$

SI = $N.s/m^2$ ✓

$\boxed{1\,N/m^2 = 1\,Pa}$ $\boxed{\therefore Pa \Rightarrow Pascal}$

$\boxed{1\,N.s/m^2 = Pa.s}$

$1\,kgf = 9.81\,N$

$$\boxed{1\ Poice = \frac{1}{10}\,N.s/m^2}$$

1 point.

Kinematic viscosity: It is defined as the ratio dinamic viscosity (viscosity) to the density of fluid. It is denoted Greek symbol

$$\boxed{\vartheta = \frac{\mu}{\rho}}$$

ϑ = kinematic viscosity
μ = density of viscosity

** Kinematic viscosity is also known stoke
The units of kinematic viscosity in M.K.S m^2/s
in S.I = m^2/s, C.G.S = cm^2/s

$$\boxed{1 \text{ stoke} = 10^{-4} m^2/s}$$

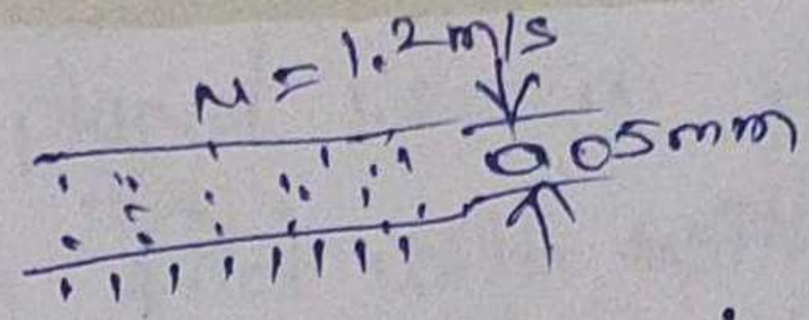
1 Types of fluids:?

2. Write a short notes surface tension and capillarity?
examples, units, formula, definition.

Pblm

A plate 0.05mm distand from a fixed plate moves at 1.2 m/sec and required at a force of 2.2 N/m2 to maintain this speed find the viscosity of fluid b/w plates

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



$\tau = 2.2 N/m^2$

$dy = 0.05mm = 0.05 \times 10^{-3} m$

$du = u - 0$

$= 1.2 - 0$

$= 1.2 m/s$

Force $= 2.2 N/m^2$

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

$= \frac{2.2}{\frac{1.2}{0.05 \times 10^{-3}}}$

$\mu = 9.16 \times 10^{-5} N.s/m^2$

$\mu = 9.16 \times 10^{-4}$ poise

Pblm

* The space b/w two square plot plate is filled with oil, each side of plate is 720 mm. The thickness oil film is 15mm. the upper plate which moves at 3 mete/sec requires a force of 10N, To mointed the speed determine

1. dinamic viscosity
2. The kinematic viscosity of oil, specific
3. gravity of oil is

Ans:- 1.16 N/m^2 0.0012 M^2/s

1. dynamic viscosity $(\mu) = \frac{\tau}{\frac{du}{dy}}$

1. kinmatic viscosity $(\nu) =$

Type of Fluid

1. Ideal Fluid
2. Real Fluid
3. Newtonian fluid
4. Non Newtonian Fluid
5. Ideal plastic fluid

→ **Ideal fluid** :

→ incompressible not having viscosity surface tension → Imaginary fluid

eg: there is no such fluid available in nature

→ **Real fluid**

→ compressible

→ having viscosity surface tension

→ All fluid in practile are real fluid

→ Example :- water, petrol, kerosene

→ **Newtonian fluid**

→ fluid in which shear stress directly propostional to shear stress corelocity gradients.

→ viscosity remains constant

→ Example :- water mineral, oil, Alcohol.

4. **Non-Newtonian fluid**

→ fluid in which shear stress is not proportional

is not proportional to shear stram

→ viscosity of fluid changes

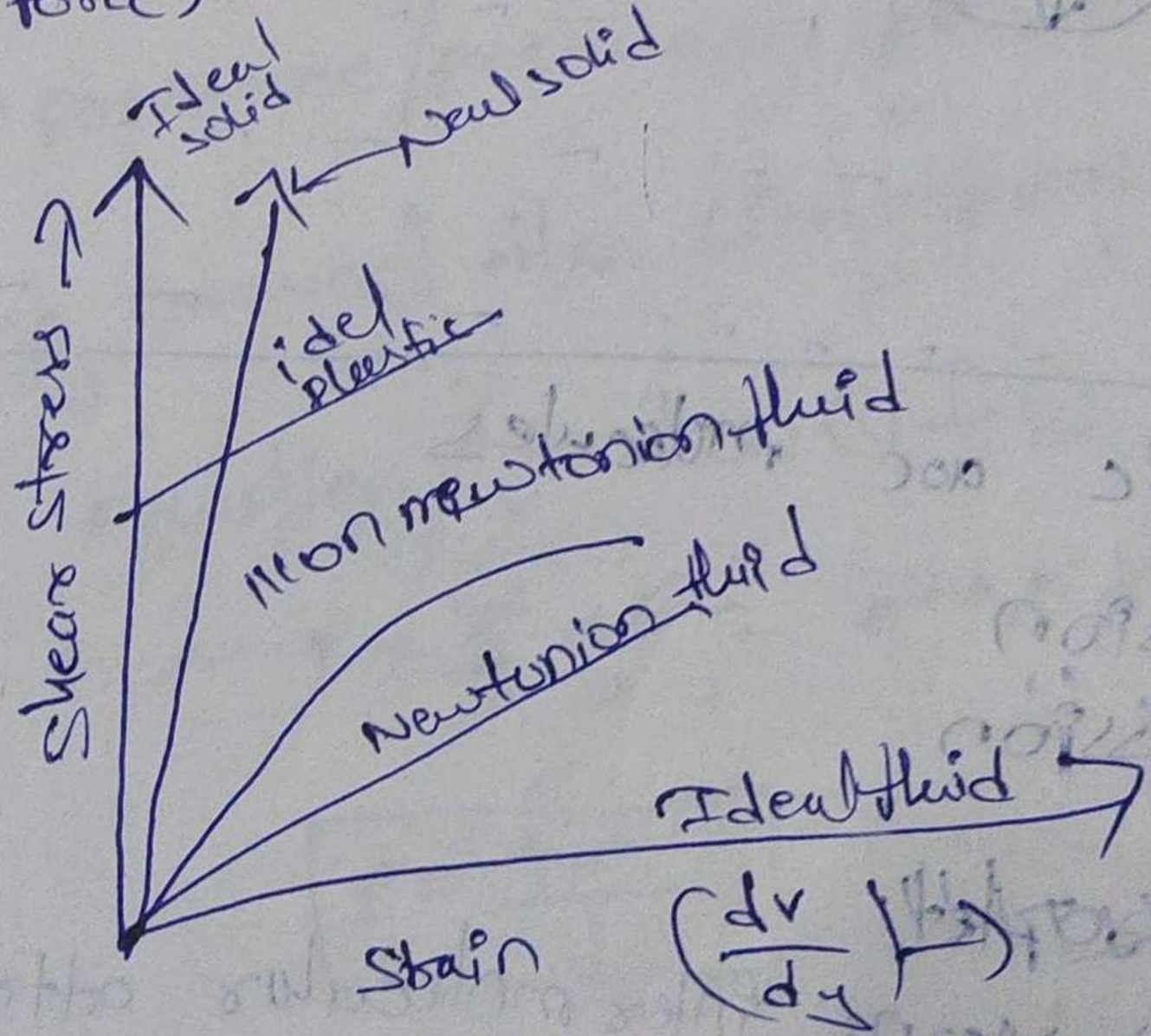
→ Examples :- cosmous silty, putty mortar.

5. Ideal plastic fluid

→ shear stress is more than yield value and shear stress is proportional to shear strain

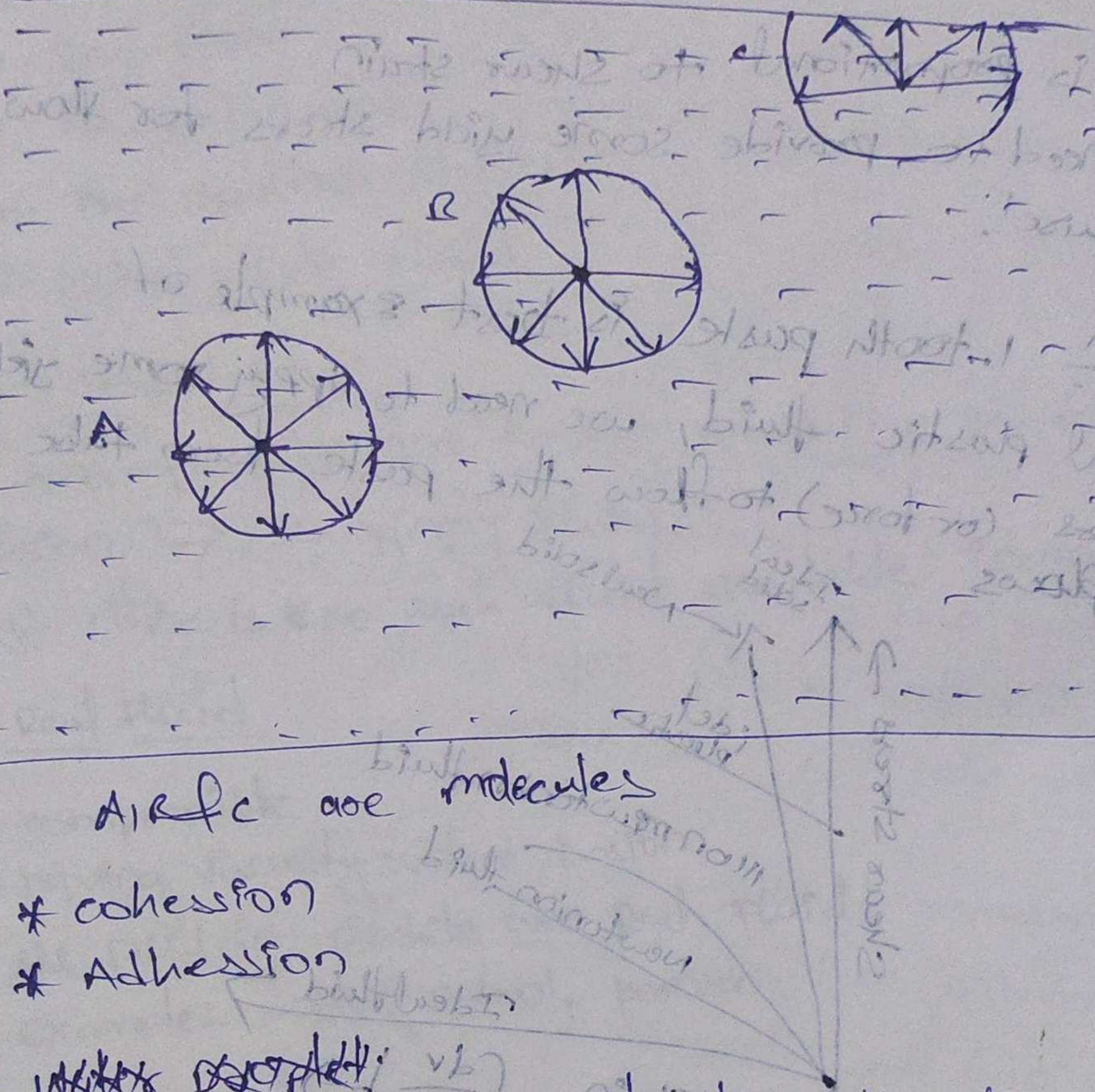
→ we need to provide some yield stress for flow of fluid.

note:- 1. tooth paste is best example of Ideal plastic fluid, we need to apply some yield stress (or force) to flow the paste from tube it flows



Surface Tension

Free surface.



Air & c are molecules

* cohession
* Adhession

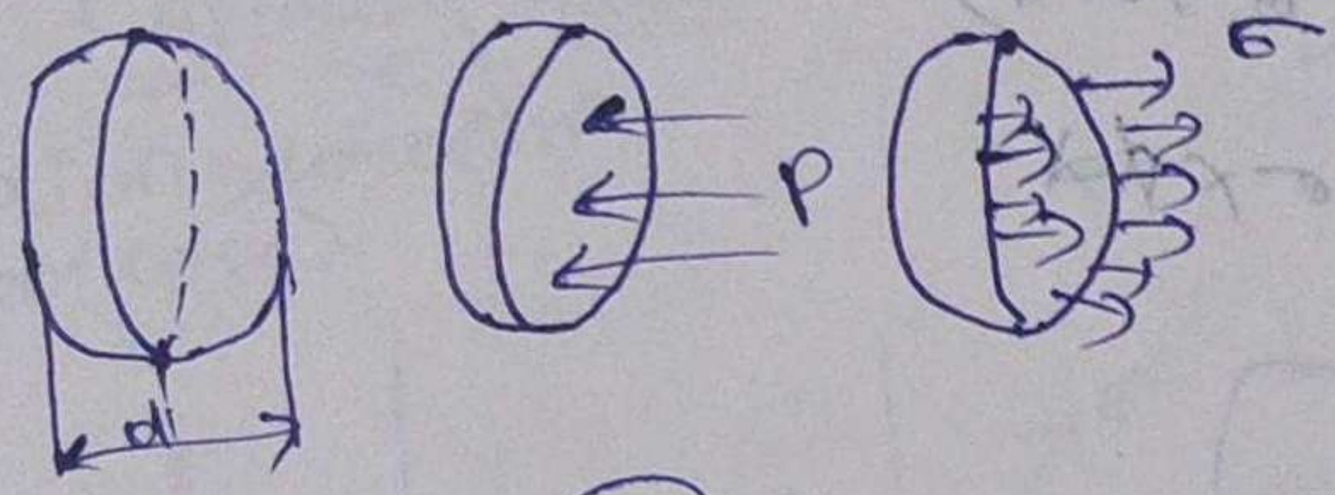
* ~~Inter molecular~~

cohession:- Means inter molecular attraction. b/w molecules of the same liquid. It is a tendency of a liquid has one Assemblage of particles. Surface tension is due to cohession b/w particles at the free surface

Adhession :- Means attraction b/w the molecules of liquid and molecules of solid boundary surface in contact with liquid this property enables liquid to stick another body.

→ as shown in fig the molecules below the surface of liquid have characteristic number of nearest neighbours, Newton second law tells as that the sum of force acting all the interface in any direction must be zero.

1. Water droplet



σ = surface Tension
P = pressure intensity
d = Diameter of droplet

Force due to pressure/pressure force $= P \times \frac{\pi}{4} d^2$ — ①

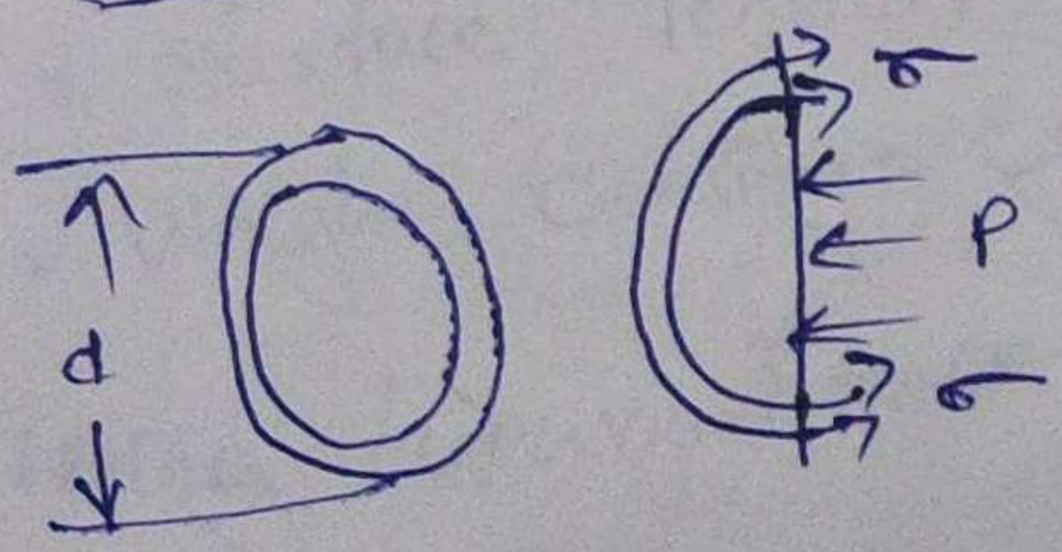
Force acting around the circumference $= \sigma \times \pi d$ — ②

equating Equation ① & ②

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

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

2. Hollow bubble



pressure force / force due to pressure $= P \times \frac{\pi}{4} d^2$ — ①

Force acting around the circumference

$= 2(\sigma \times \pi d)$ — ②

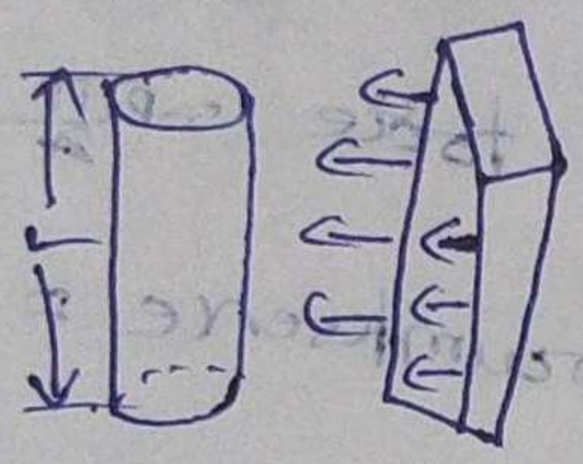
By equating equation ① & ②

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

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

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

3. Liquid Jet



Pressure force $= P \times L \times d$ — ①

Force due to surface Tension.

$= \sigma \times 2L$ — ②

By equating ① & ②

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

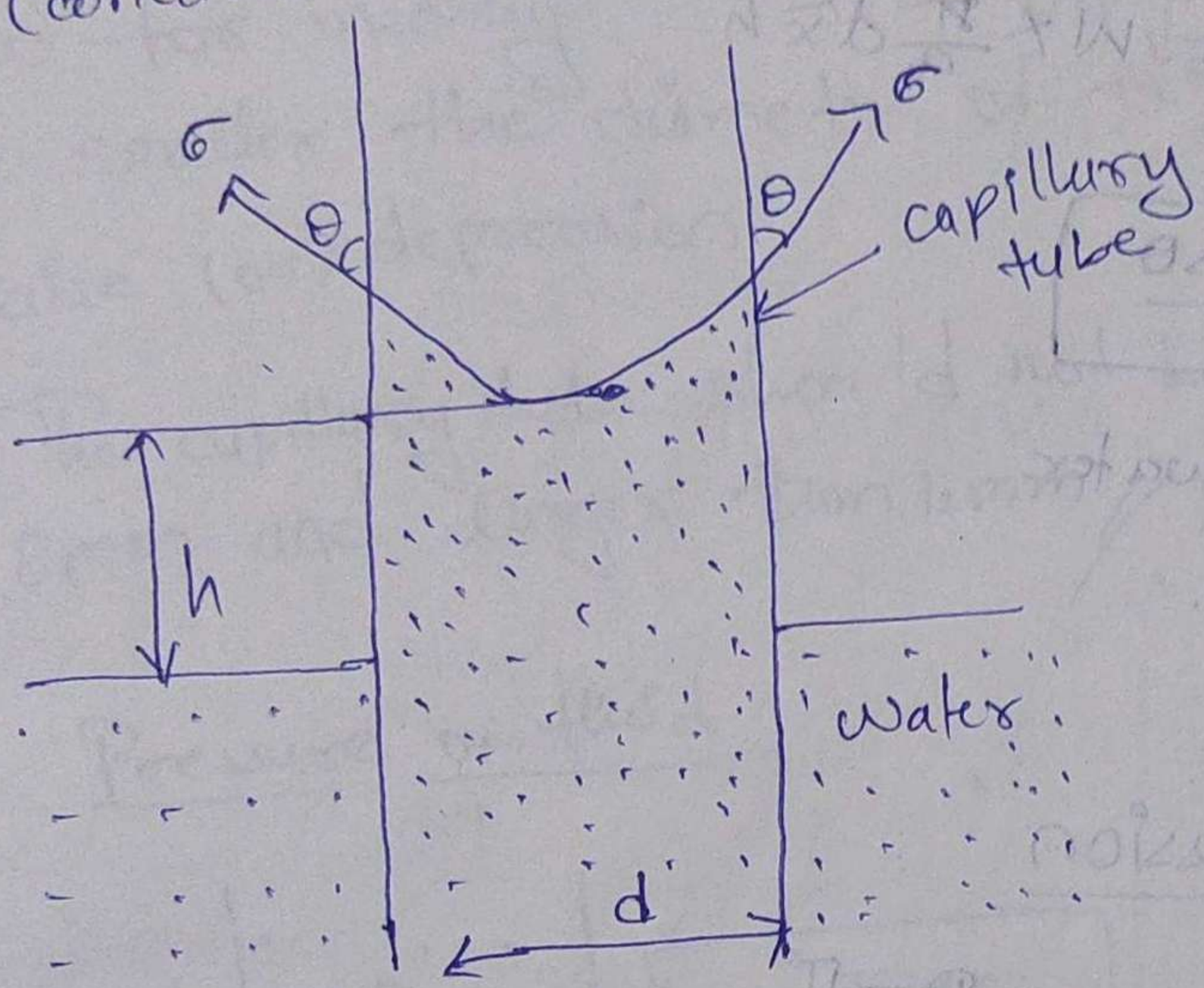
$$\boxed{P = \frac{2\sigma}{d}}$$

Capillarity

Capillary rause

Adhesion > cohesion
(concave)

$\theta < \frac{\pi}{2}$



let
d = diameter of capillary tube
θ = Angle of contact of water surface
h = capillary raise / Height of capillary raise
σ = surface Tension
w = Weight Density = ρg

* Lifting / upward force due to surface Tension = $\sigma \cos\theta \times \pi d$ — (1)

* Downward / Gravity force
= weight Density × volume of fluid.

$= w \times \text{Area} \times \text{height}$

$= w \times \frac{\pi}{4} d^2 \times h$ — ②

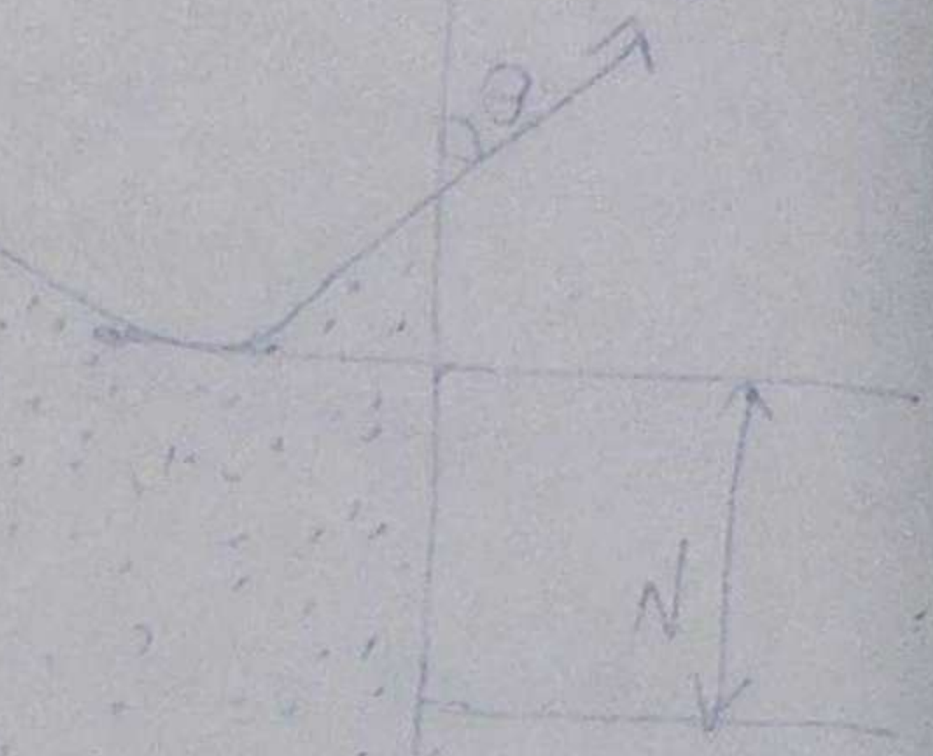
By equating equation ① & ②

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

$$\boxed{h = \frac{4\sigma\cos\theta}{wd}}$$

if $\theta = 0 \Rightarrow$ for water

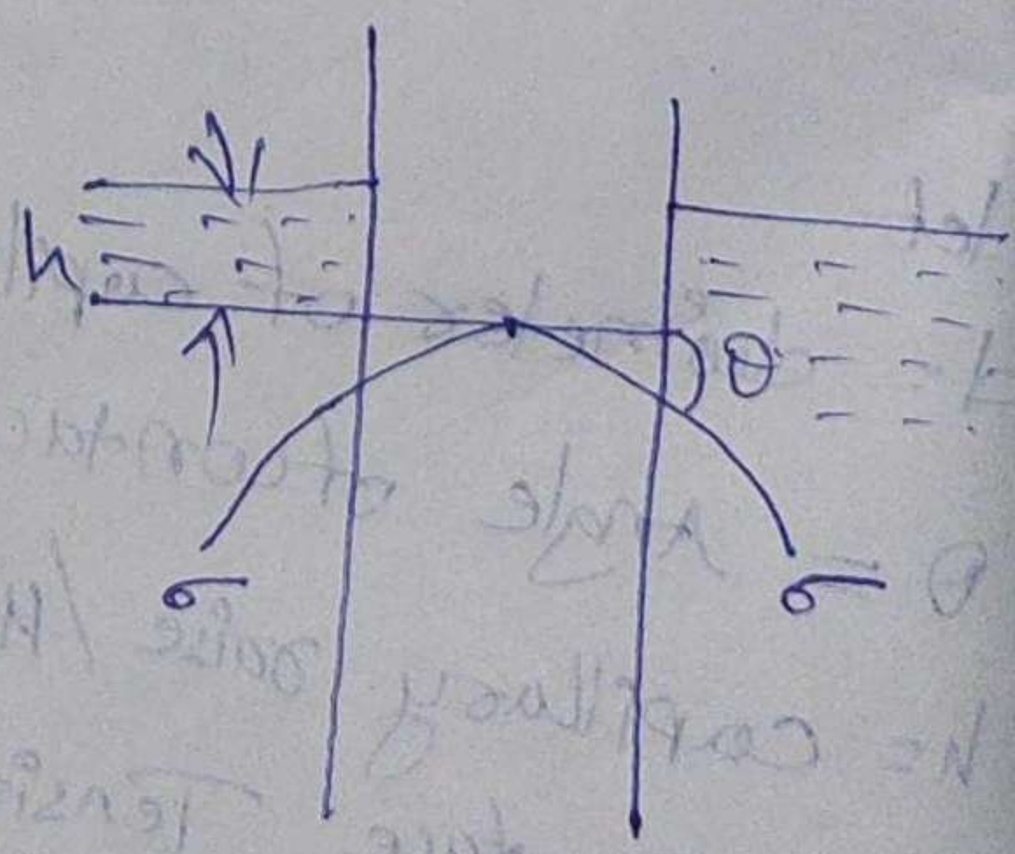
$$\boxed{h = \frac{4\sigma}{wd}}$$



Capillary depression

$\theta > \frac{\pi}{2}$

h = capillary depression



Assume Angle of depression is $\theta = 140$

$\cos\theta = \cos 140$

$= \cos(180-40)$

$= -\cos 40$

cohesion > Adhesion

(convex)

$\theta = 0$ for water

$\theta = 135$ to 150 mercury

→ It is phenomenon by which a liquid rise into a thin glass tube above or below general level. This phenomenon is due to

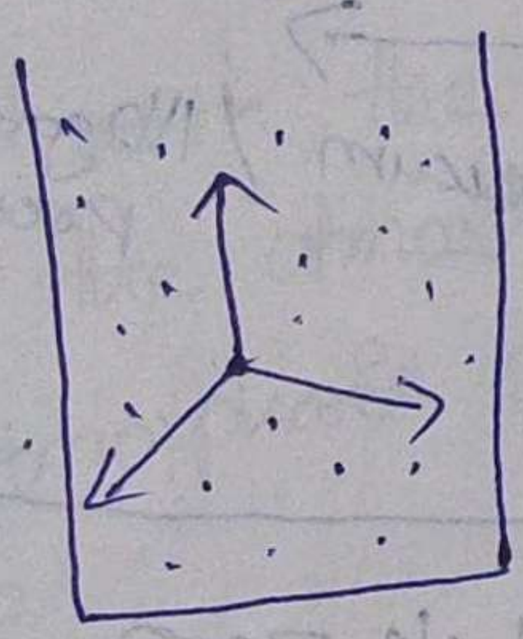
the combined effect cohesion and adhesion of liquid particles.

<u>Note</u>:- If $\theta = 0$ for water or $\theta = 130$ to 150 for mercury

→ smaller the diameter of capillary tube greater is the capillary rise (or) depression

→ The capillary tube should not be smaller than 8mm and larger than 12mm

Pressure of fluid



$$P = \frac{Force}{Area}$$

$= N/m^2$

When the fluid is contain in the vessel/container it exacts force at all points from the sides, To & and bottom of the container. The $\frac{force}{unit\ Area}$ is known as pressure.

-The intensity of pressure $\left(P = \frac{force}{Area}\right) = F/A$

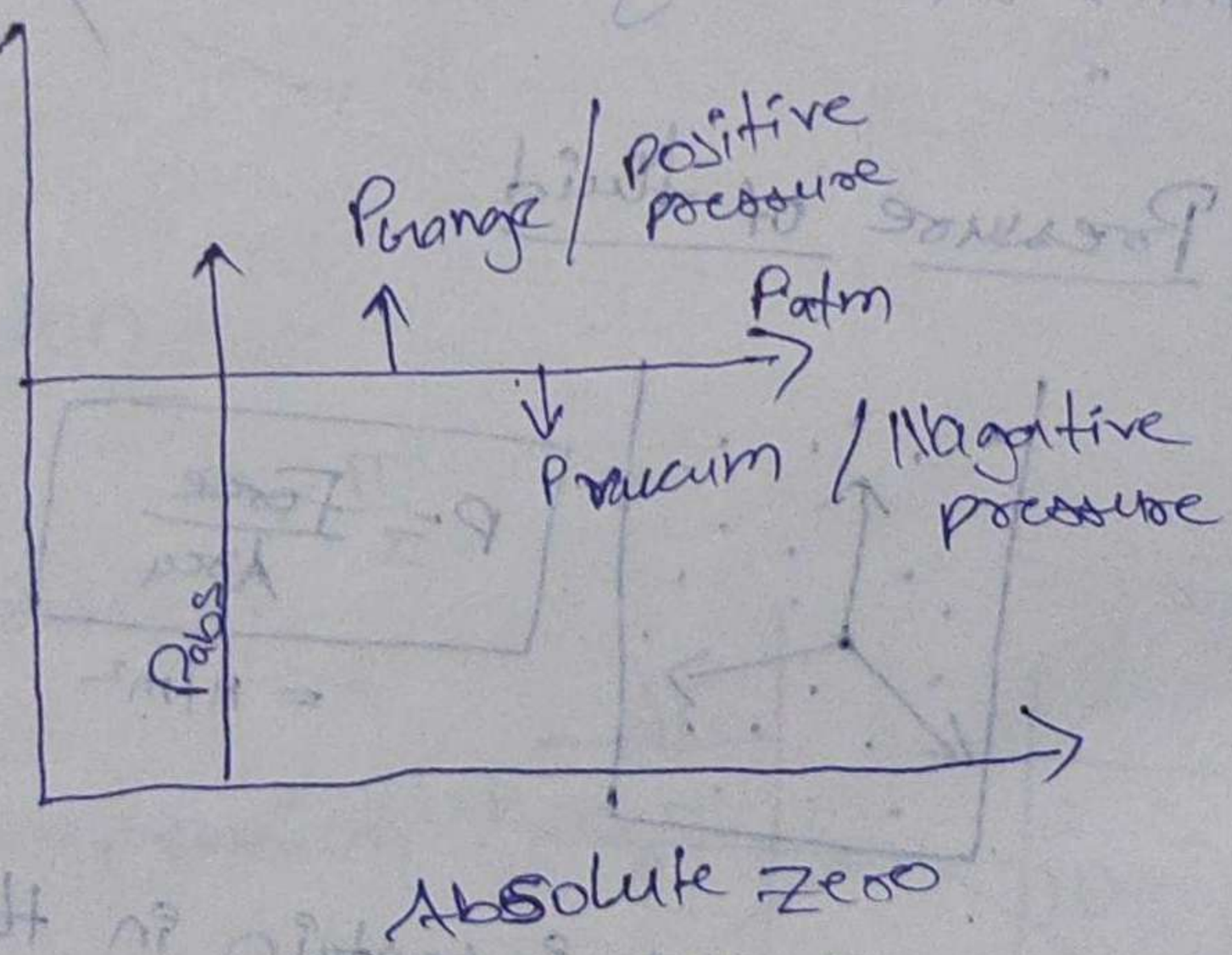
Its units are $= N/m^2$

<u>Pascals law</u>:- Its states that the pressure (or) intensity of pressure at a point in a static fluid is equal in all direction i.e $P_x = P_y = P_z$

Note:- The standard pressure at sea level is 1.01325 bar (or) 101.32 kN/m²
= 760 mm of Hg
= 10.3 M of water

The standard Temperature is 15°c
↓
atmospheric

Absolute, gauge & vaccum pressure



Absolute pressure (P_{Abs})
It is measured to establish an absolute pressure scale which is independed of the change in atmospheric pressure. A pressure absolute zero can exits only in complete vaccum. Any pressure measured above the absolute zero pressure is termed as An absolute pressure the Absolute pressure is some of atmosphere pressure and gauge pressure

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

$$\boxed{P_{ac} = P_{atm} - P_{abs}}$$

vacum atmosphere

Atmospheric pressure : The Atmospheric air exests a normal pressure upon all surface with which it is in contact and known as Atmospheric pressure. The Atmospheric pressure is also known as barometric pressure. the Atmospheric pressure at sea level is called standard atmospheric pressure.

Gauge Pressure (Pgauge) : It is the pressure measured with the help of pressure measuring instrument in which the atmosphere pressure is taken as datum. The Atmospheric pressure on scale is marked as zero

∴ $\boxed{\text{Gauge}}$: it is a instrument (or) measuring device.

* **Measurement of pressure**

*→ Measurement of fluid may be following devices.

1. manometers
2. mechanical gauges.

Nanometers: Nanometers are defined as device used for measuring pressure of fluid by balancing the column of fluid by the same (or) column of another column of fluid. These are classified as follows:

a) Simple Manometer.

i. Piezometer

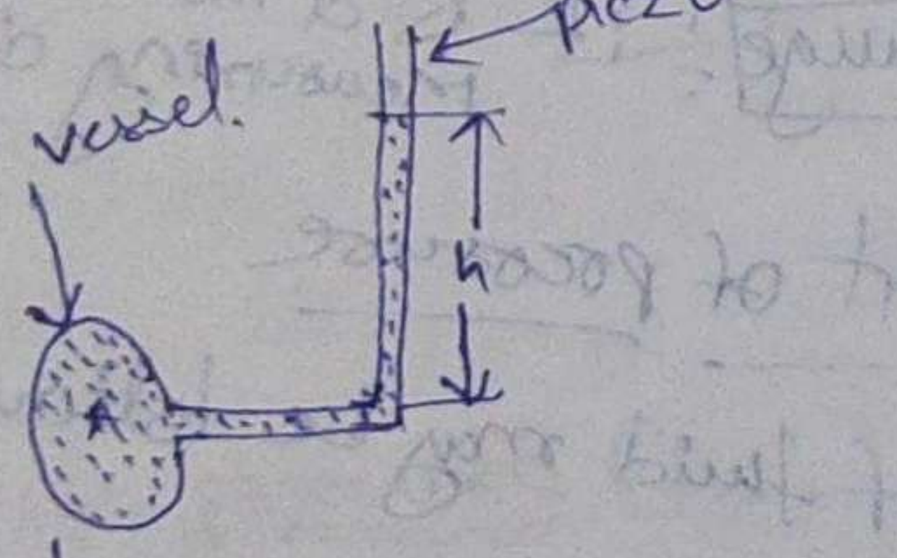
ii. U. manometer

iii. simple column manometer

b) Differential manometer.

a) simple manometer

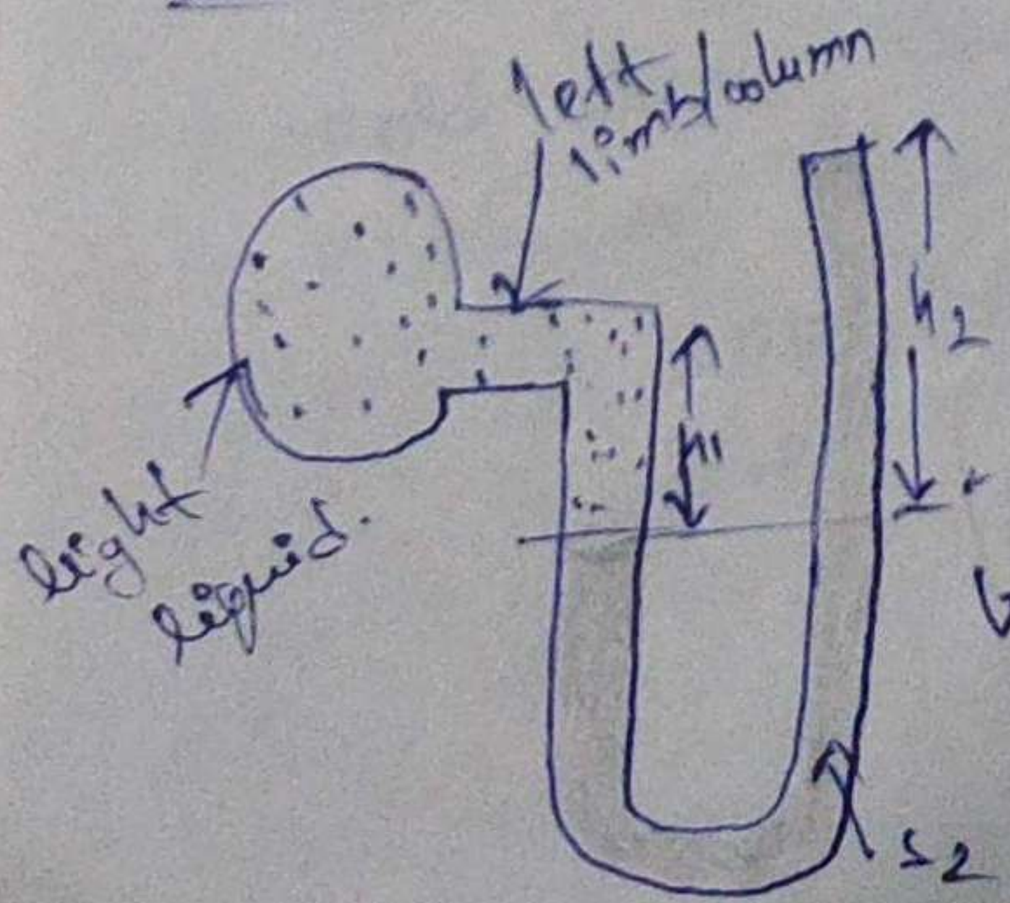
i) Piezometer



$P = wh$

$$\boxed{P = \rho g h}$$

U- Tube manometer



$w = \rho g$

$P = wh$

$= s\rho g h$

$S = \frac{w_s}{w_s}$

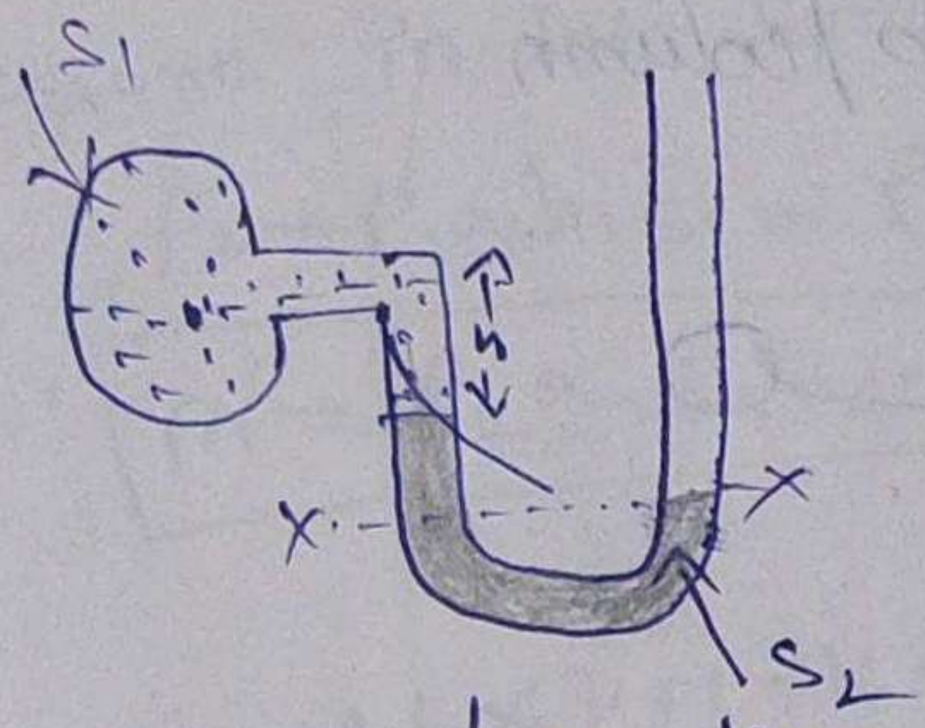
$w_s = S w_s$

$w = S\rho g$

$= 1000 \times 9.81 \times S$

$w = 9810 \times S$

Gauge /positive pressure



b. vaccum/Nagative pressure

let

A = pressure at a point (P_A)

XX = Datum line

h_1 = height of light liquid above datum line

h_2 = height of heavy liquid above datum line

s_1 = Specific Gravity of light liquid

s_2 = specific Gravity of heavy liquid

ρ_1 = Density of liquid = $1000 \times s_1$

ρ_2 = Density of Heavy liquid = $1000 \times s_2$

Pressure in left limb / column

$$P_A + \rho_1 \times s_1 \times g_1 \times h_1 \quad \text{—} (1)$$

pressure in Right limb / column

$$\rho_2 \times s_2 \times g_2 \times h_2 \quad \text{—} (2)$$

By Equation (1) & (2)

$$P_A + \rho_1 g_1 h_1 s_1 = \rho_2 s_2 g_2 h_2$$

$$\boxed{P_A = \rho_2 s_2 g_2 h_2 - \rho_1 s_1 g_1 h_1}$$

Note:- -ive sign indicates vaccum or nagtigive pres

* Pressure in Right limb / column
left

$P_A + \rho_1 s_1 g_1 h_1 + \rho_2 g_2 s_2 h_2$ — (1)

Pressure in Right limb

$= 0$ — (2)

By equating (1) & (2).

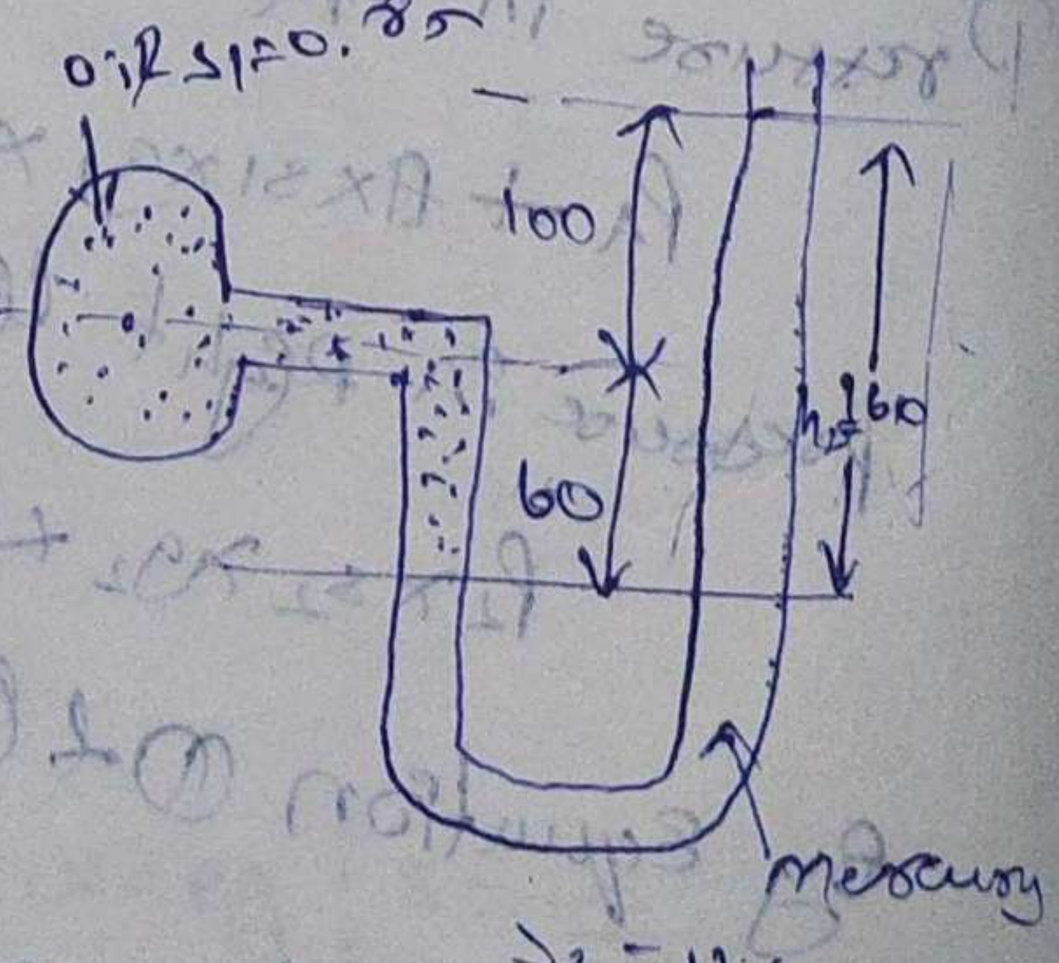
$P_A + \rho_1 s_1 g_1 h_1 + \rho_2 g_2 s_2 h_2 = 0$

$P_A = -(\rho_1 s_1 g_1 h_1 + \rho_2 s_2 g_2 h_2)$

**

(1) A U-Tube Manometer is used to measure pressure of the oil of specific gravity is 0.85 flowing in a pipe line. Its left end is connected to the pipe and Right limb is open to atmosphere. The center of pipe is 100mm below the level of mercury of the specific gravity is 13.6 in the Right limb. If the difference of mercury level in the two limb is 160mm, Determine the absolute pressure of oil in the pipe.

Sol:



oil sp gravity $s_1 = 0.85$

mercury sp Gravity $s_2 = 13.6$

Height of left limb $h_1 = 60mm = 60 \times 10^{-3} = 0.06$

Height of Right limb $h_2 = 160mm$

$= 160 \times 10^{-3} m$

$= 0.16.$

Pressure in left limb

$$P_A + \rho_1 g_1 h_1 s_1 = \rho_2 g_2 s_2 h_2$$

$$\boxed{P_A = \rho_2 g_2 s_2 h_2 - \rho_1 g_1 s_1 h_1} \quad [g_1 = g_2 = 9.81]$$

$$P_A = 1000 \times 13.6 \times 9.81 \times 160 \times 10^{-3} - 1000 \times 0.85 \times 9.81 \times 60 \times 10^{-3}$$

$$P_A = \cancel{20887.95}\ N/m^2$$

$$20886.25\ N/m^2$$

$$P_g = 20.84\ kN/m^2$$

$$\boxed{P_{abs} = P_{atm} + P_g}$$

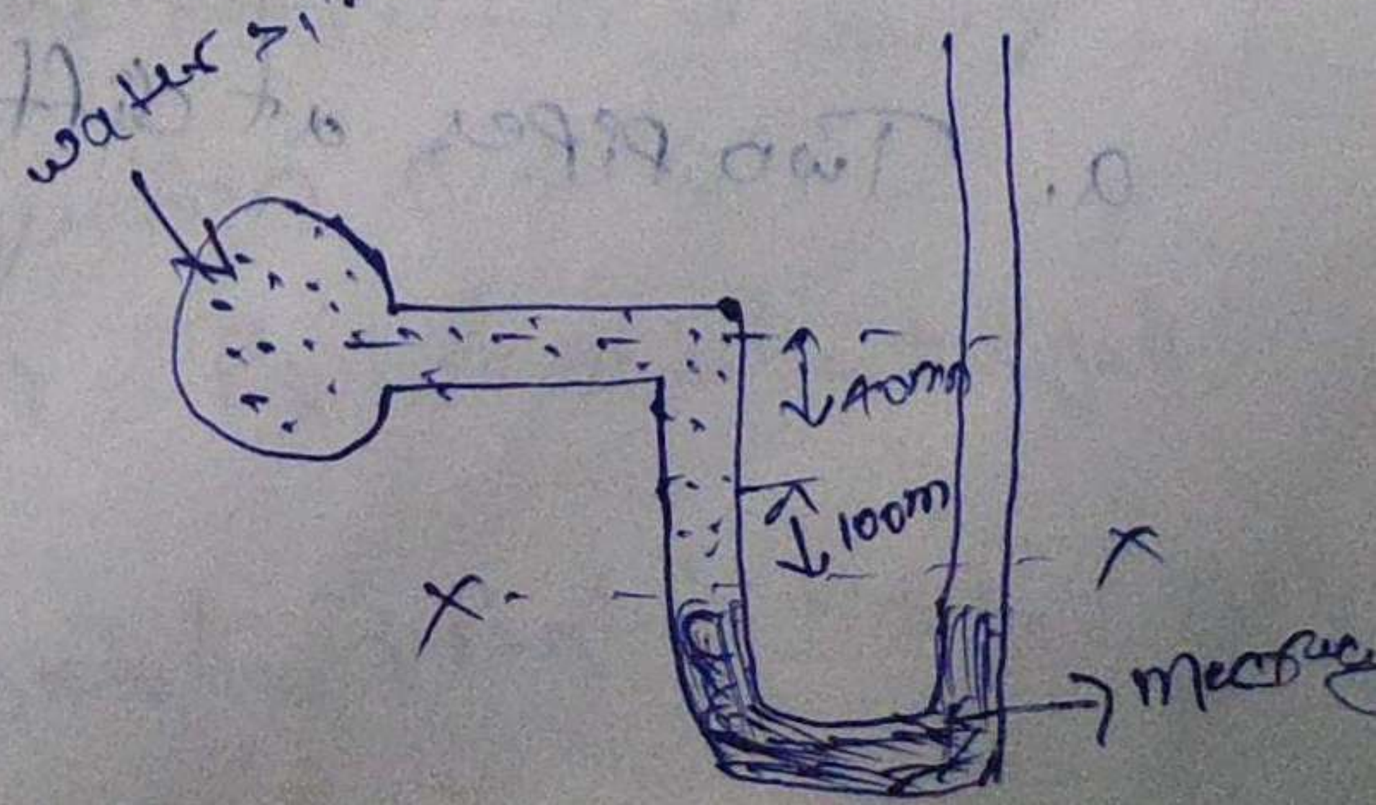
$P_{atm} = 1.0132\ bar$

$$P_{abs} = 101.32 + 20.84$$

$$= 122.16\ kN/m^2$$

$$= 122.16 \times 10^{-3}\ N/m^2.$$

2) A U-Tube manometer containing mercury was used to find negitive pressure in the pipe, containing water. The Right limb was opened to the atmosphere find the vacuum pressure in the pipe. If the difference of mercury level two limbs was 100mm and height of water in the left limb from the centre of the pipe was found to be 40mm below.



Pressure in left limb

$P_A + \rho_1 s_1 g_1 h_1 + \rho_2 s_2 g_2 h_2$ — (1)

Pressure in right limb = 0 — (2)

$P_A + \rho_1 s_1 g_1 h_1 + P_2 s_2 g_2 h_2 = 0$

$P_A = -(\rho_1 s_1 g_1 h_1 + \rho_2 s_2 g_2 h_2)$ $[g_1 = g_2 = g = 9.81]$

$P_A = -(1000 \times 1 \times 9.81 \times 40 \times 10^{-3} + 1000 \times 13.6 \times 9.81 \times 100 \times 10^{-3})$

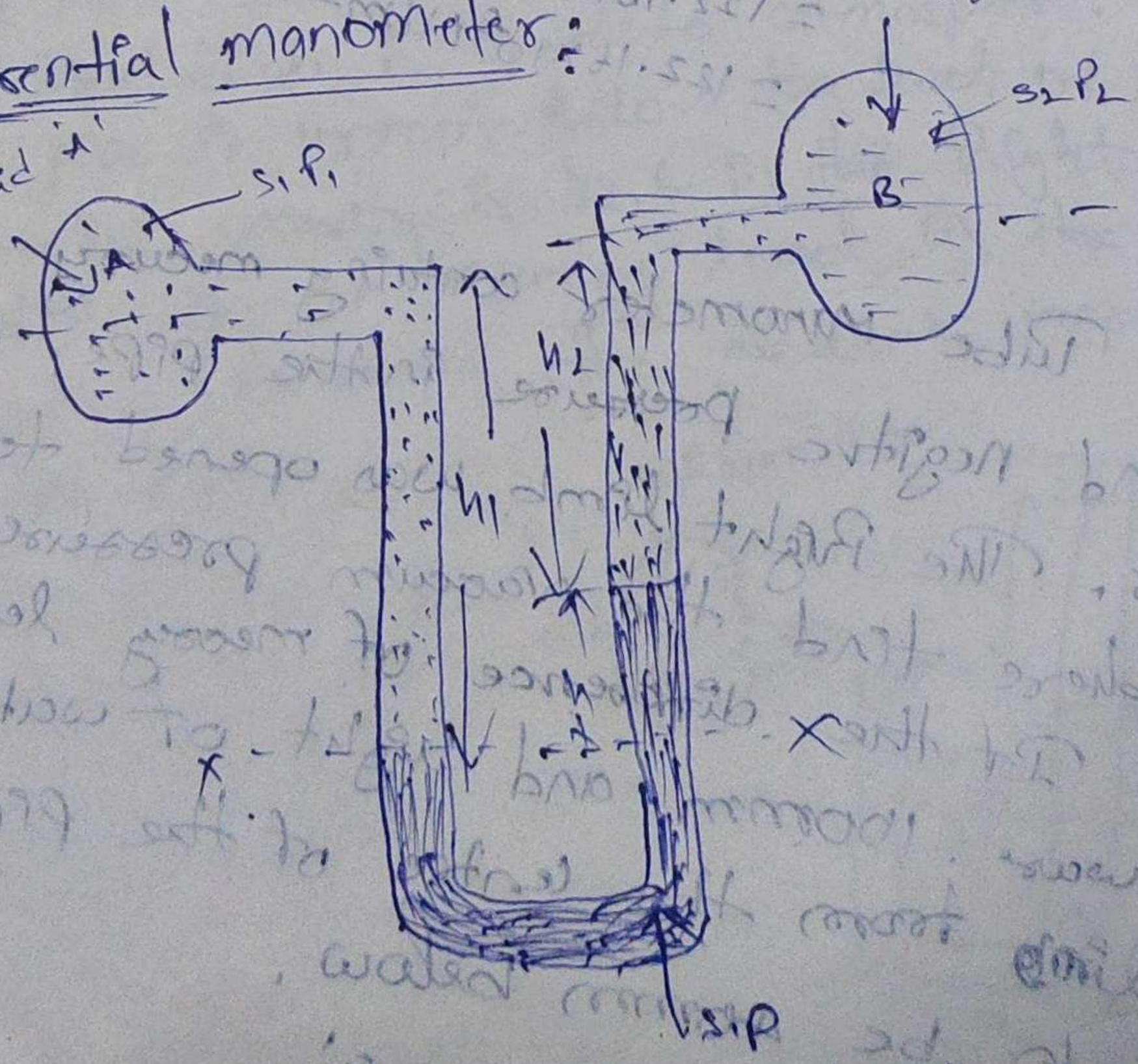
$P_A = -13734\ N/m^2$

$\therefore \rho_1 = 1000 \times s_1$

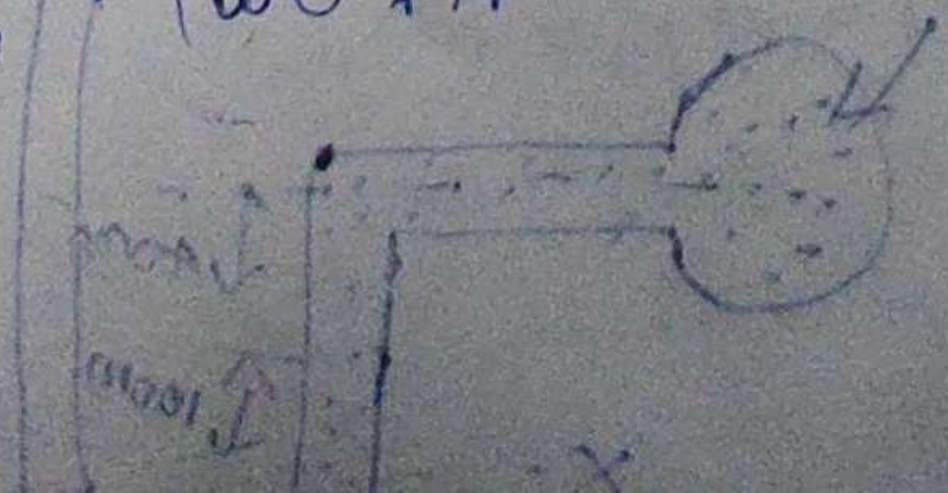
or

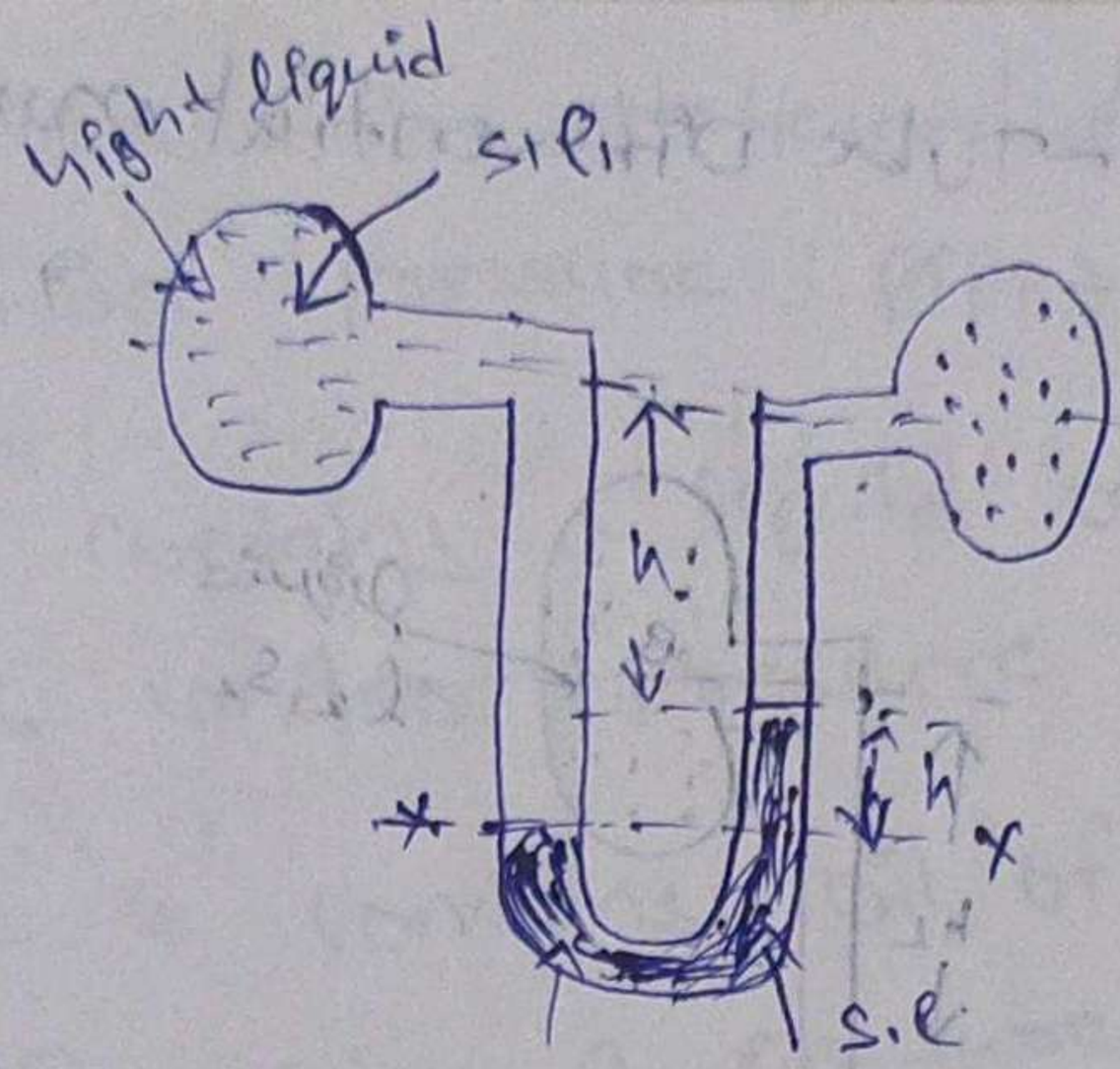
$\therefore \rho_1 = \rho_2 = \rho = 1000\ kg/m^3$

Differential manometer:



a. Two pipes at different level.





b. Two pipes at same level.

P.R.2

$$P_A + \rho_1 s_1 g h_1 = P_B + \rho_2 s_2 g_2 h_2 + \rho_s g h$$

$$P_A - P_B = \rho_2 s_2 g_2 h_2 + \rho_s g h - \rho_1 s_1 g h_1$$

Differential manometer

pressure in left limb

$$P_A + \rho_1 s_1 g h_1 \quad \text{—} (1)$$

pressure in right limb

$$P_B + \rho_2 s_2 g_2 h_2 + \rho_s g h \quad \text{—} (2)$$

(2) pressure in left limb

$$P_A + \rho_1 g_1 (h_1 + h) \quad \text{—} (1)$$

& pressure in right limb

$$P_B + \rho_2 g_2 s_2 h_2 + \rho_s g h \quad \text{—} (2)$$

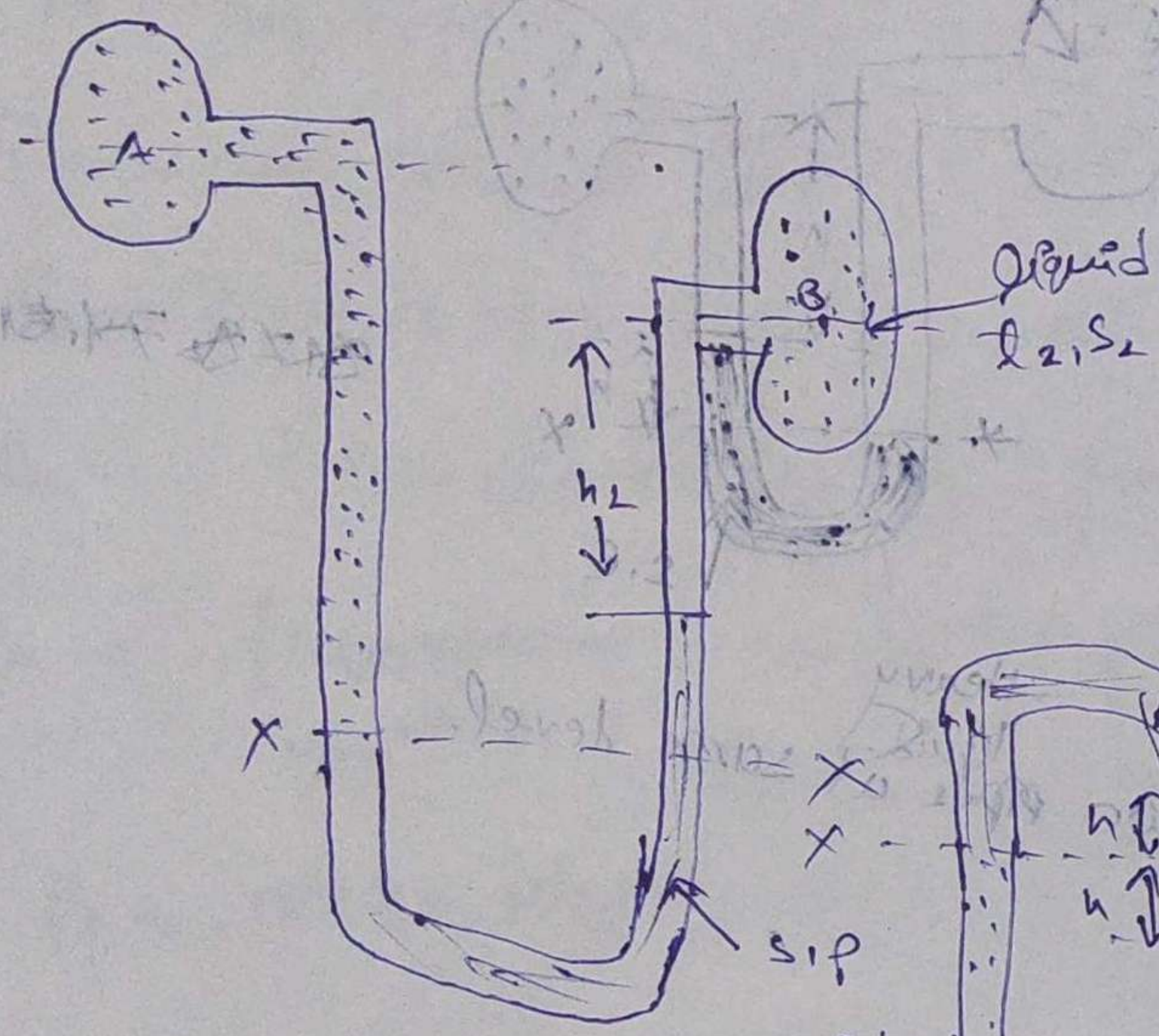
By equating equation (1) & (2)

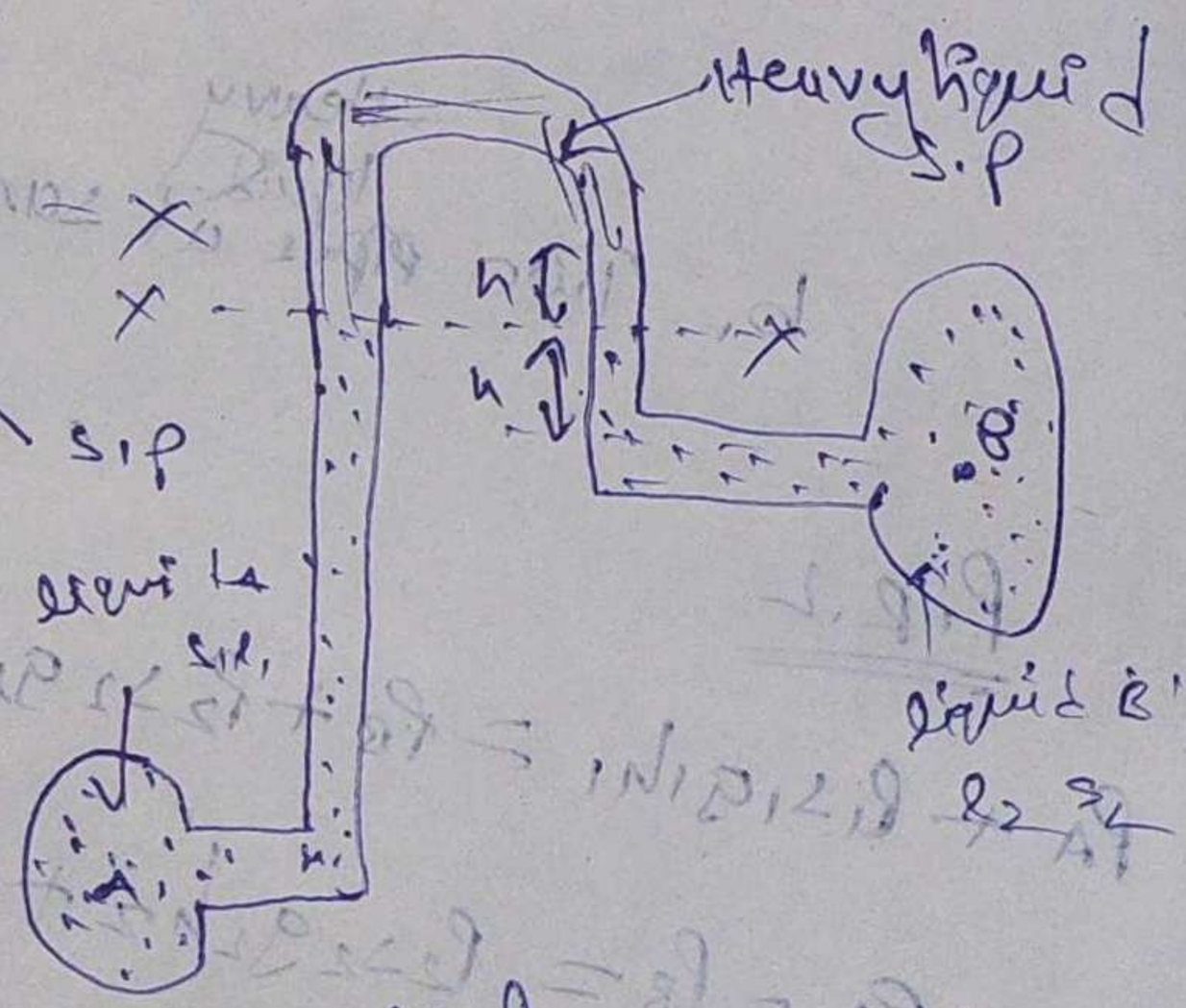
$$P_A + \rho_1 s_1 g_1 (h_1 + h) = P_B + \rho_2 g_2 s_2 h_2 + \rho_s g h$$

$$P_A - P_B = (\rho_2 g_2 s_2 h_2 + \rho_s g h) - \rho_1 s_1 g_1 (h_1 + h)$$

Inverted U-Tube Differential manometer

9 2073-6





Inverted U-Tube differential manometer.

* pressure in left limb

$$-(P_A + \rho_1 S_1 g h_1) \quad \text{--- (1)}$$

* Pressure in Right Limb

$$-(P_B + \rho_2 S_2 g_2 h_2 + \rho_s g h) \quad \text{--- (2)}$$

By equating (1) & (2)

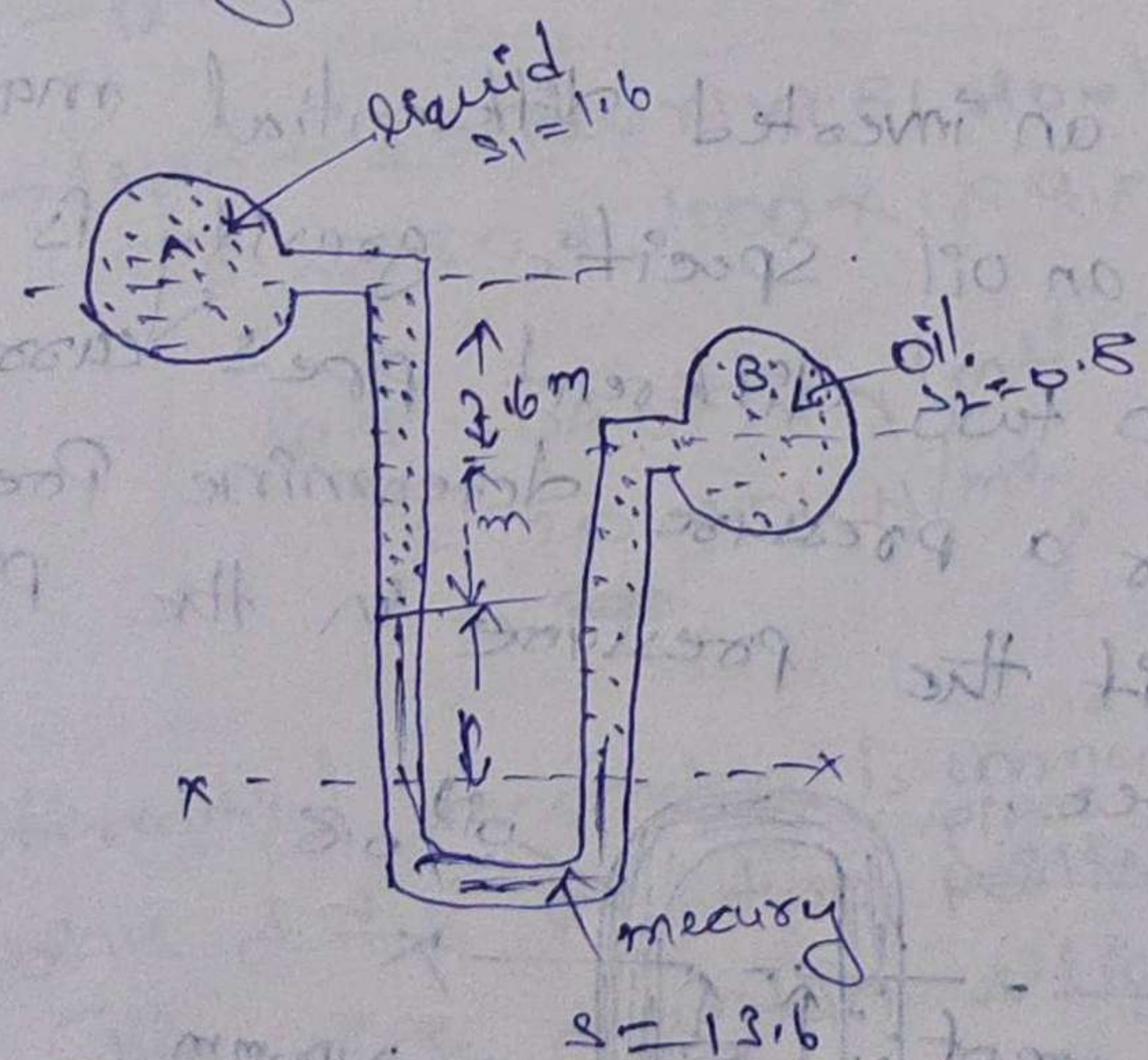
$$P_A + \rho_1 S_1 g h_1 = P_B + \rho_2 S_2 g_2 h_2 + \rho_s g h$$

* Fig shows a U-tube differential manometer contains two pressure pipes at A & B

→ The pipe "A" contains a liquid of specific gravity 1.6 under pressure of 110 kN/m²

→ The pipe "B" contains oil of specific gravity 0.8 under a pressure of 200 kN/m²

→ Find the difference of pressure measured by mercury has a fluid falling in U-Tube



* pressure in left limb

$P_A + \rho_1 S_1 g h_1 + \rho S g h$

$110 \times 10^3 + 1000 \times 1.6 \times 9.81 \times 3.6 + 1000 \times 13.6 \times 9.81 \times h =$ ↳ 29921.6

pressure in right limb

$P_B + \rho_2 S_2 g_2 h_2$ — ①

$200 \times 10^3 + 1000 \times 0.8 \times 9.81 (1+h) = 207848$

By equating ① & ②

29921.6

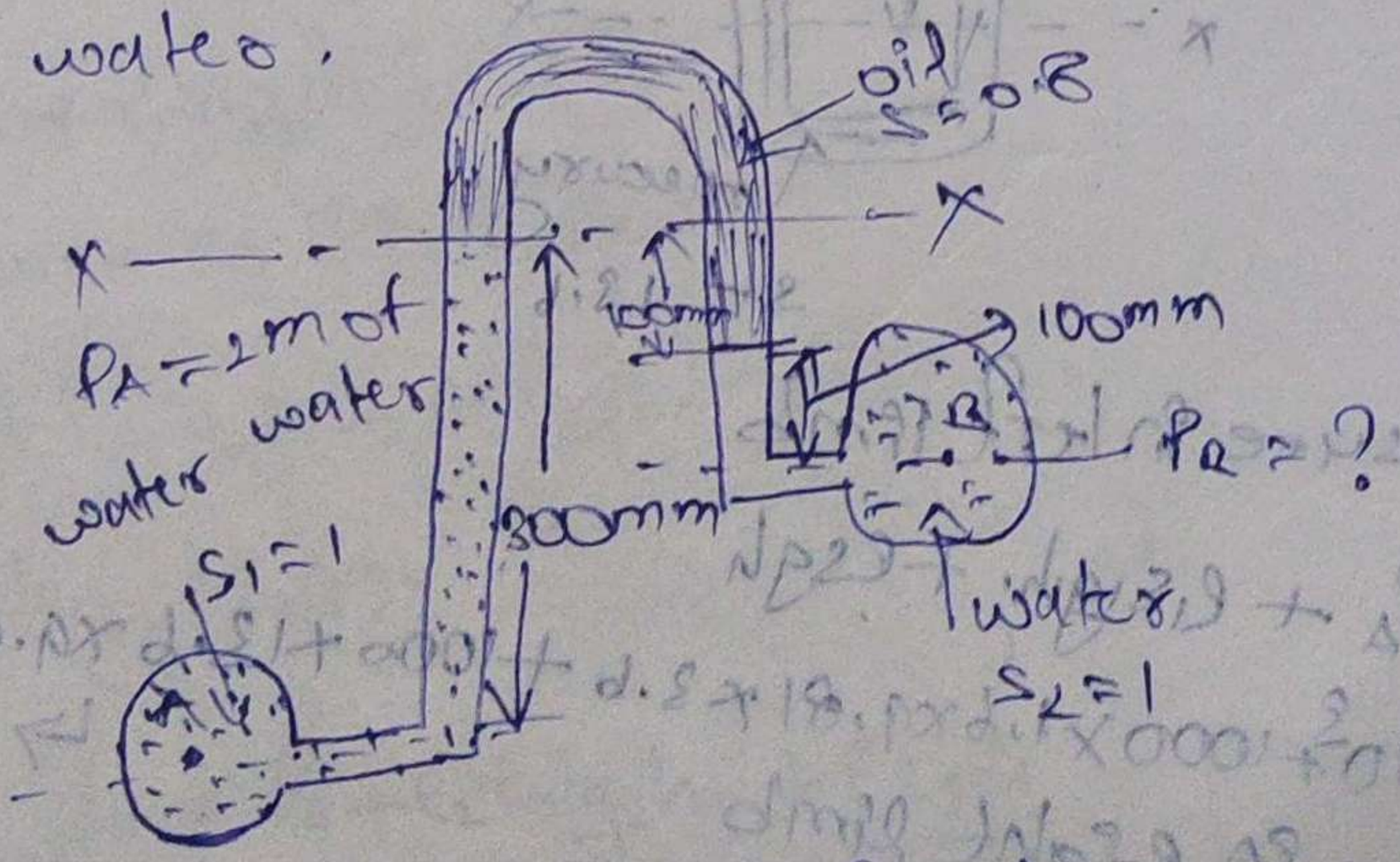
$h =$

$29992.6h = 20784B(1+h)$

$29992.6h = 20784B + 20784Bh$

$= 20784B$

Fig shows an inverted differential manometer having an oil specific gravity is 0.8 connected to two different pipes carrying water under a pressure determine Pressure in the pipe A is 2m of water.



$P = wh$

$= \rho g h$

$= 2 \times 9.81 \times 1000$

$P_A = 19620\ N/m^2$

$P_B = 17954\ N/m^2$

$P_B = 18 kN/m^2$ $h_1 = 300$
$= 0.3m$

* pressure in left limb.

$-(P_A + \rho_1 S_1 g_1 h_1)$ — ①

* pressure in right limb

$-(P_B + \rho_2 S_2 g_2 h_2 + \rho_s g h)$ — ②

Now by equating equation ① & ②

$-P_A - \rho_1 S_1 g_1 h_1 = P_B + \rho_2 S_2 g_2 h_2 + \rho_s g h$

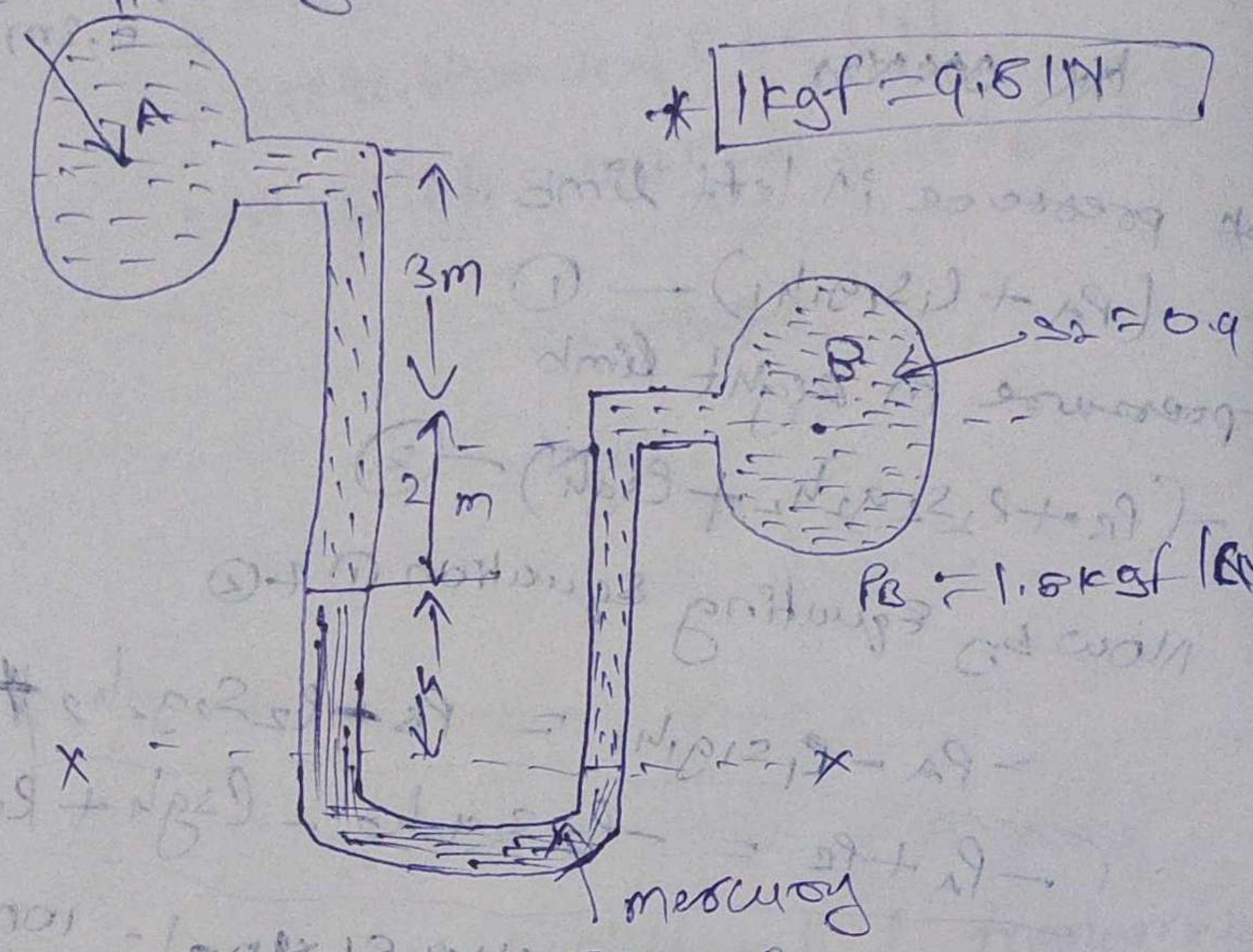
$-P_A + P_B = -\rho_2 S_2 g_2 h_2 + \rho_s g h + \rho_1 S_1 g_1 h_1$

$-19620 + P_B = 1000 \times 1 \times 9.81 \times 0.1 - 1000 \times 0.8 \times 9.81 \times 0.150 + 1000 \times 1 \times 9.81 \times 0.3$

$P_B = 20404.8 N/m^2$
$= 20.404 kN/m^2$

* A differential manometer is connected at the two points A & B of two pipes as shown in fig. The pipe A contain a liquid of specific gravity 1.5 while pipe B a liquid of specific gravity is 0.9. The pressure at A & B are 1kgf/cm² on 1.80 respectly. Find the difference in mercury level in differential mano meter

$S_1 = 1.5$ $P_A = 1 kgf/cm^2$



* $\boxed{1 kgf = 9.81 N}$

$S = 13.6$

$P_A = 1.5 \times 10^4$

$= 98100 N/m^2$

$P_B = 1.8 \times 9.81 \times 10^4$

$= 176580 N/m^2$

* pressure in left limb

$P_A + \rho_1 S_1 g h_1 + \rho g h$ — (1)

* pressure in Right limb

$P_B + \rho_2 S_2 g_B (h+2)$ — (2)

By Equating (1) & (2)

$P_A + \rho_1 S_1 g h_1 + \rho g S h = P_B + \rho_2 S_2 g_B (h+2)$

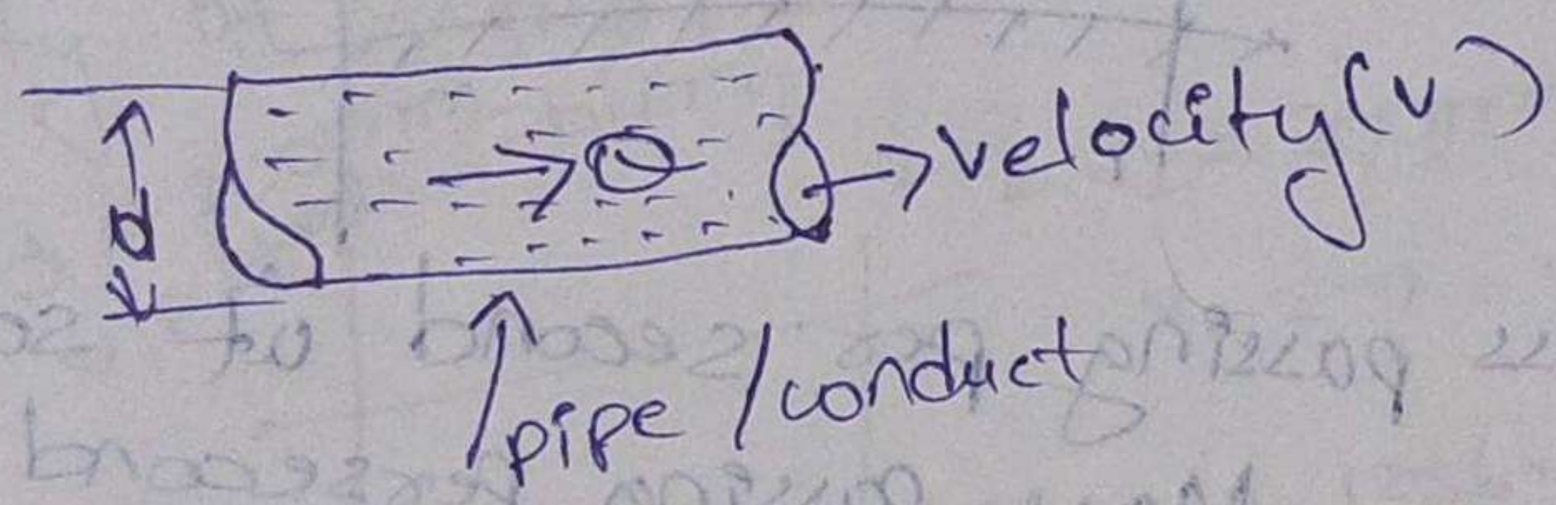
$98100 + 1000 \times 1.5 \times 9.81 \times 5 + 1000 \times 9.81 \times 13.6 h =$

$176580 + 1000 \times 0.9 \times 9.81 \times (h+2)$

$h = 0.181 M$ $\quad h = 181 MM$

* Write types of lines
** Describe the types fluid flows

Rate of flow / Discharge



Discharge (or) rate of flow is diffind as the quantity liquid flowing per second through a section pipe the quantity liquid (or) channel (or) conduct. it is generally denoted by Q

let us consider a liquid flow through pipe with area of cross-section A and average velocity of liquid (v)

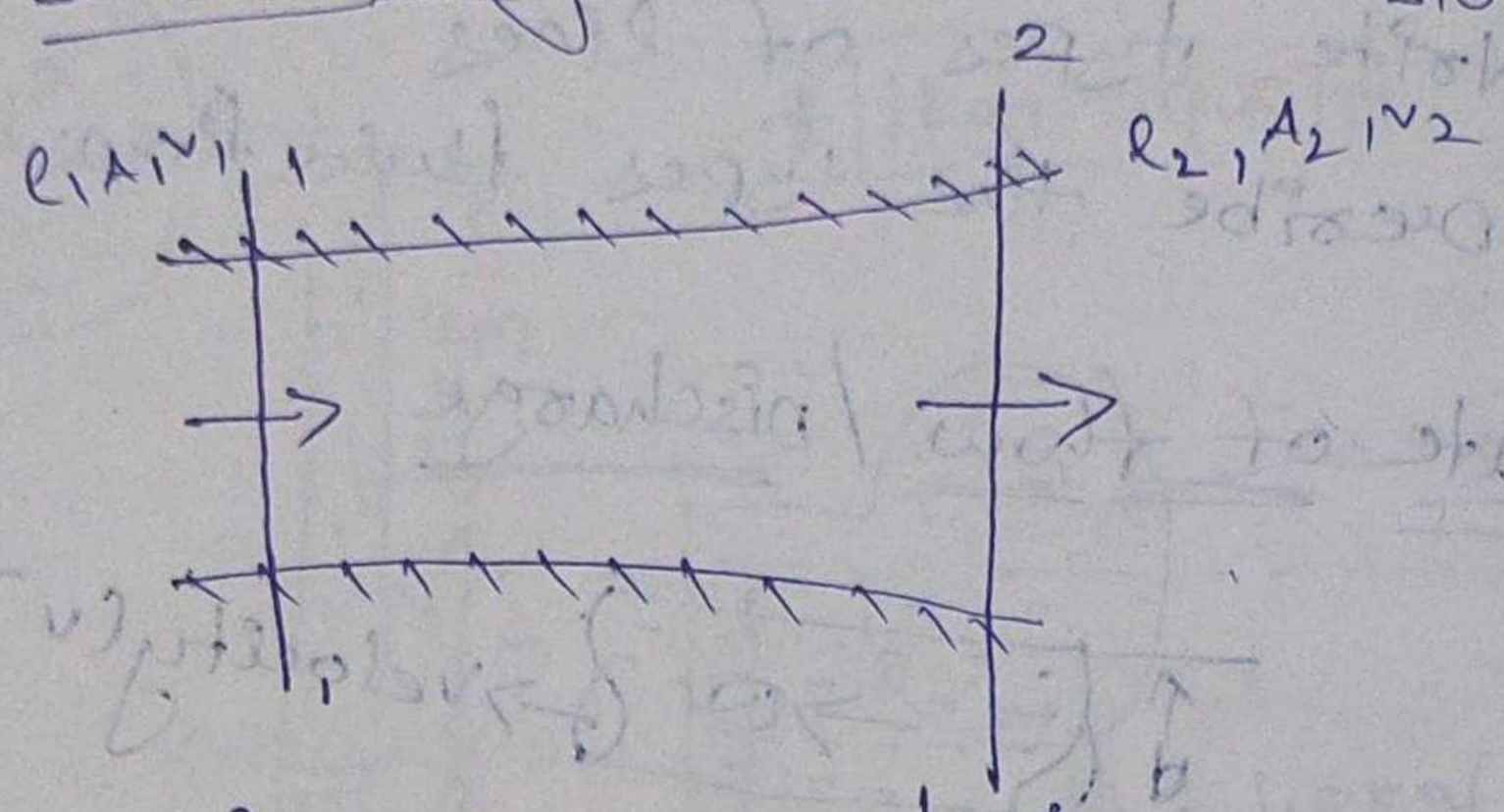
* Discharge or rate of flow = Area × Avg velocity = A × v

$$\boxed{Q = AV}$$

The units are in m^3/s

* $\boxed{1\,lpm = \frac{1}{1000 \times 60}\,m^3/s}$

Continuity Equation [one Dimen-sional



Mass passing per second at section 1-1 = Mass passing per second at section 2-2

The continuity equation is based on the principle conservation of mass its ~~takes~~ states that "If No fluid is added or removed from the pipe in any length then the mass passing per second across different section shall be same."

$$\rho_1 a_1 v_1 = \rho_2 a_2 v_2 \quad [\text{if } \rho_1 = \rho_2]$$

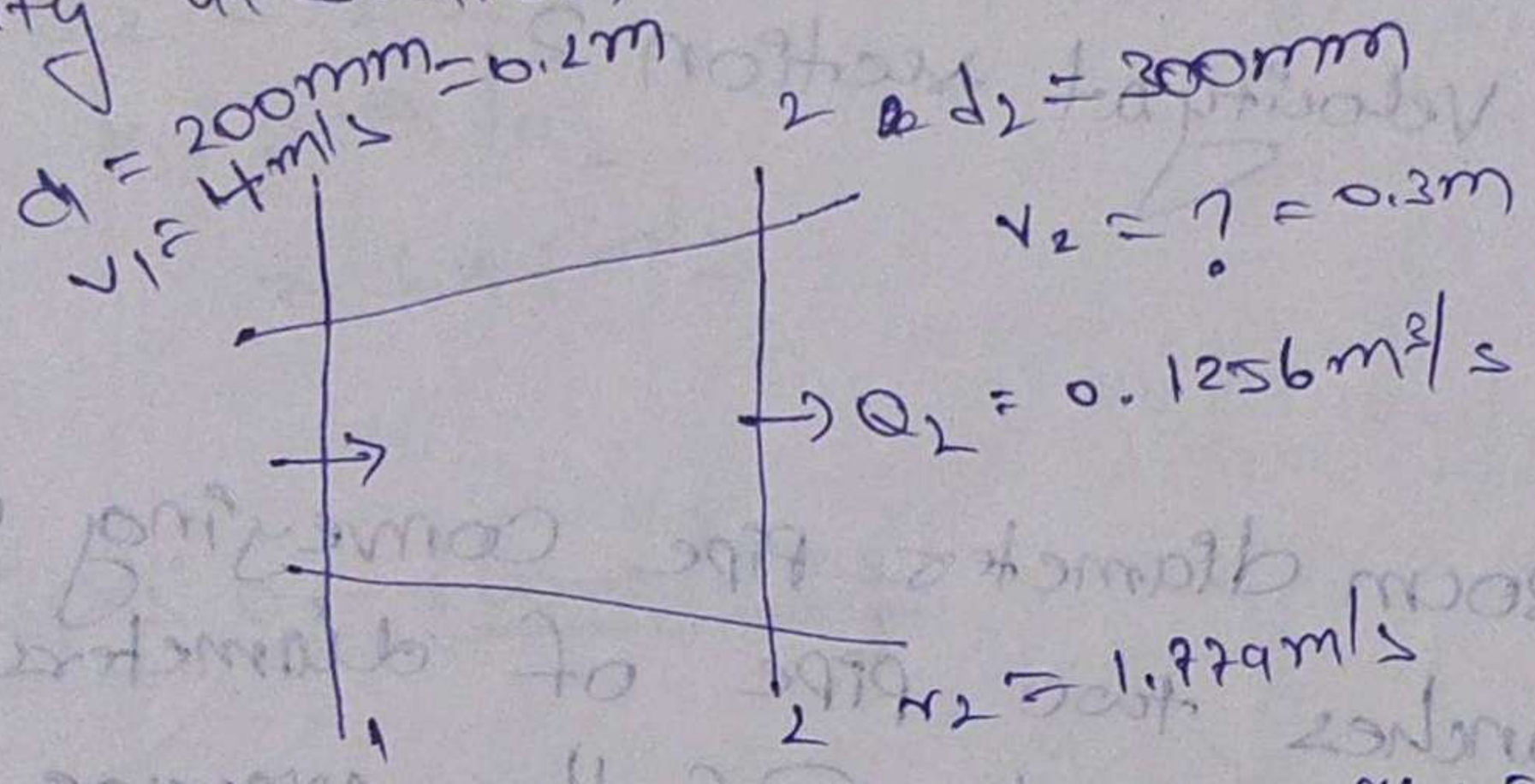
Above Equating is applicable to the compressed as well as incompressed fluids.

$$\boxed{a_1 v_1 = a_2 v_2}$$

$$\boxed{Q = a_1 v_1 = a_2 v_2}$$

This equation known as continuity equation

The diameter of the pipe at section 1-1 and 2-2 200mm and 300mm respectively the velocity of the water flow in a pipe is 4m/s Find i) discharge at section 1-1 ii) velocity at section 2-2



continuity equation $Q = a_1 v_1 = a_2 v_2$

$$a_1 = \frac{\pi}{4} d_1^2$$

$$= \frac{\pi}{4}(0.2)^2$$

$$a_1 = 0.0314 m^2$$

$$a_2 = 0.0706 m^2$$

$$Q = a_1 v_1$$

$$= 0.0314 \times 4$$

$$= 0.1256 m^3/s$$

$$Q = a_2 v_2$$

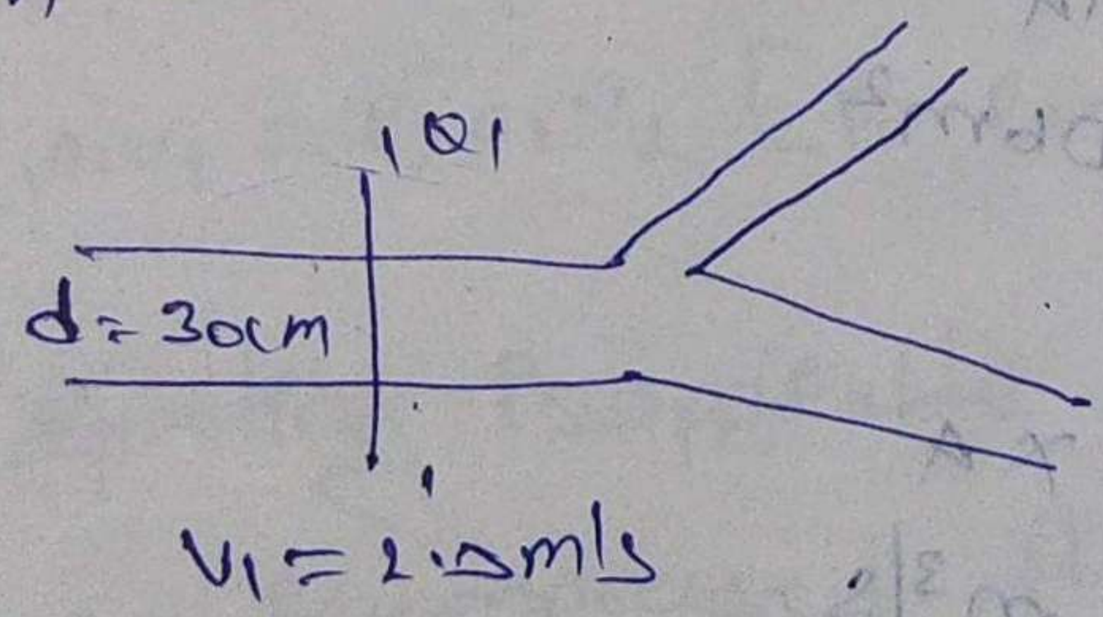
$$v_2 = Q/a_2$$

$$= \frac{0.1256}{0.0706}$$

$$v_2 = 1.779 m/s$$

* The diameter of the pipe section 1 and 2 are 10cm & 15cm respectivly find the discharge throughout the pipe if the velocity of water flowing through water pipe in section 1 is 5m/s also determine the velocity at section 2.

* A 30cm diameter pipe conveying water, branches two pipe of diameters 20cm & 15cm respectivly. If the average velocity in the 30cm diameter is 2.5m/s find the discharge in this pipe, Also determine the velocity in 15cm pipe if the average velocity in 20cm diameter pipe is 2 meter 2m/s



$$\boxed{Q_1 = Q_2 + Q_3}$$

$$Q = a_1 v_1$$

$$= \frac{\pi}{4}(0.3)^2 \times 2.5$$

$$Q_1 = 0.176 \, m^3/s$$

$$Q_3 = a_3 v_3$$

$$= \frac{\pi}{4}(0.2)^2 \times 2$$

$= 0.062\ m^3/s$

$Q_2 = Q_1 - Q_3$

$= 0.176 - 0.062$

$= 0.114\ m^3/s$

From continuity equation

$Q_2 = a_2 V_2$

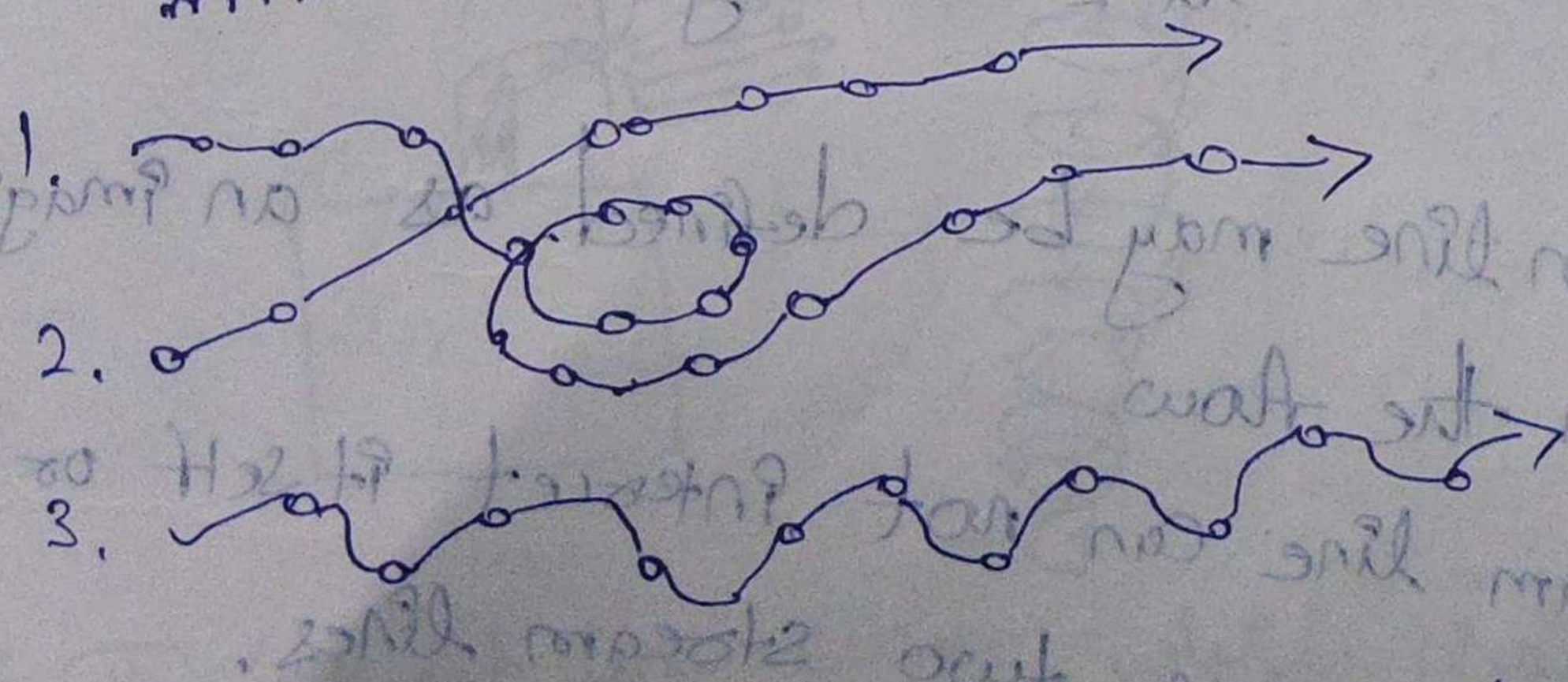
$V_2 = Q_2 / a_2$

$= 6.47\ m/s$

Types of flow lines

1. path line
2. stream line
3. stream tube
4. streak line

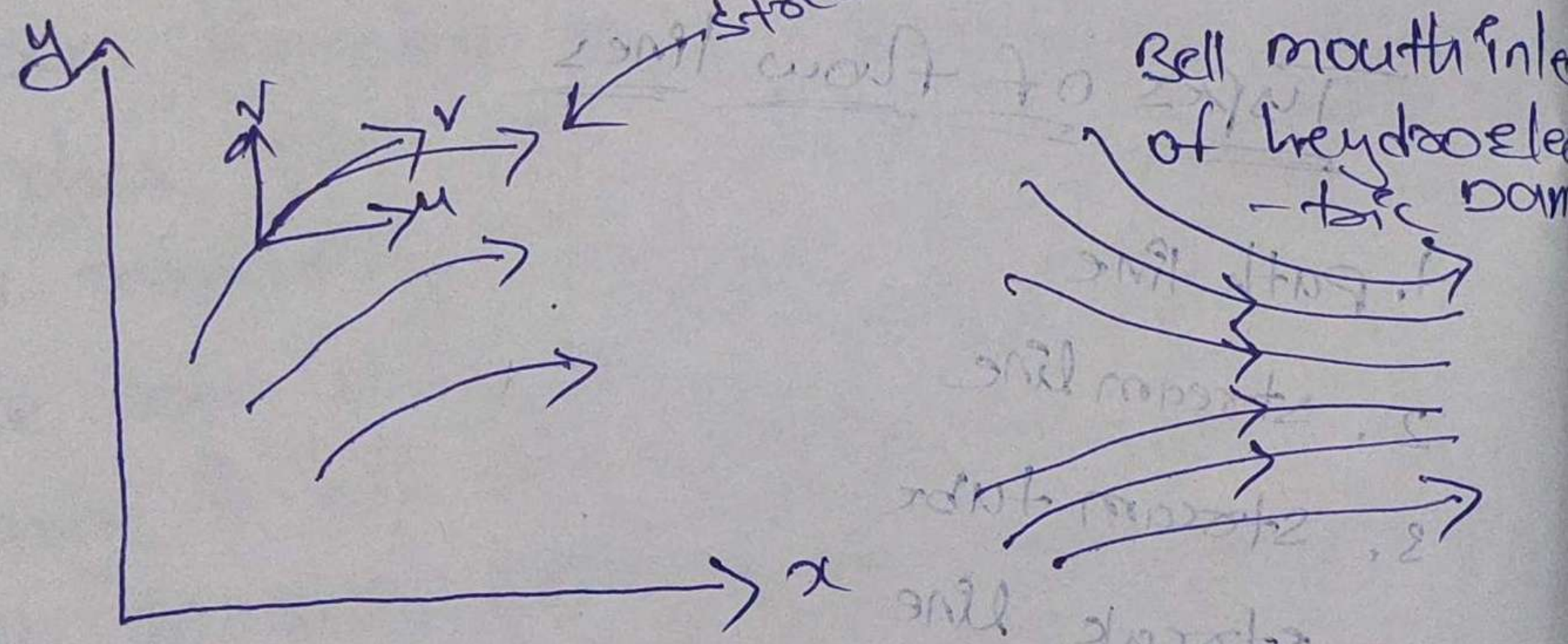
1. path Line



A path line is the path by a fluid particle in motion. A path shows the direction of particles as moves ahead

For this case the waves moving along surface of water the result is path line that are electrical in shape. you may have experince similar while rubing up and down on ocean waves at the beach.

2. Stream line



v = velocity in y direction

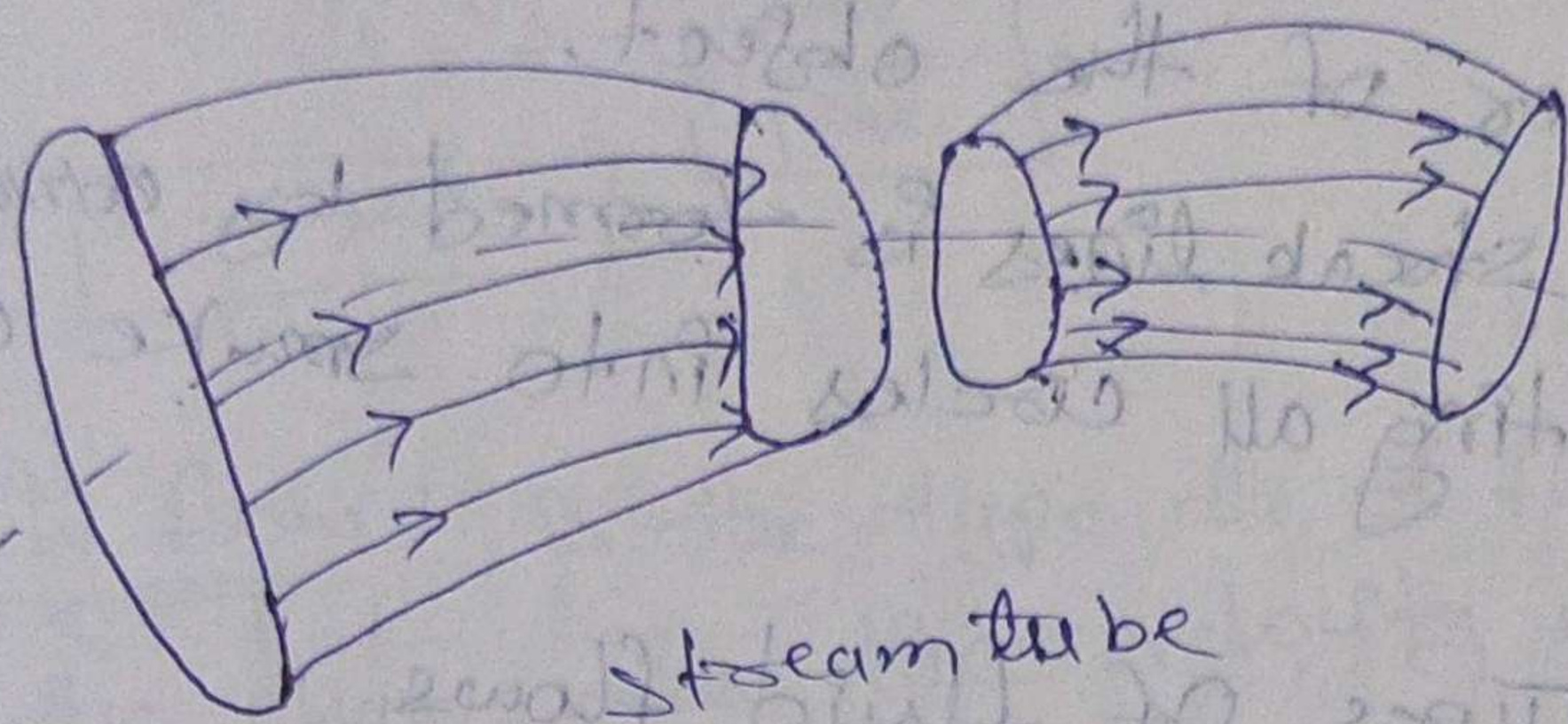
u = velocity in x direction

→ Stream line may be defined as an imagin line with in the flow

→ stream line can not intersect it self or Nor can accross two stream lines.

this type of flow line you may experince near the bellmouth of hydroelectric dam

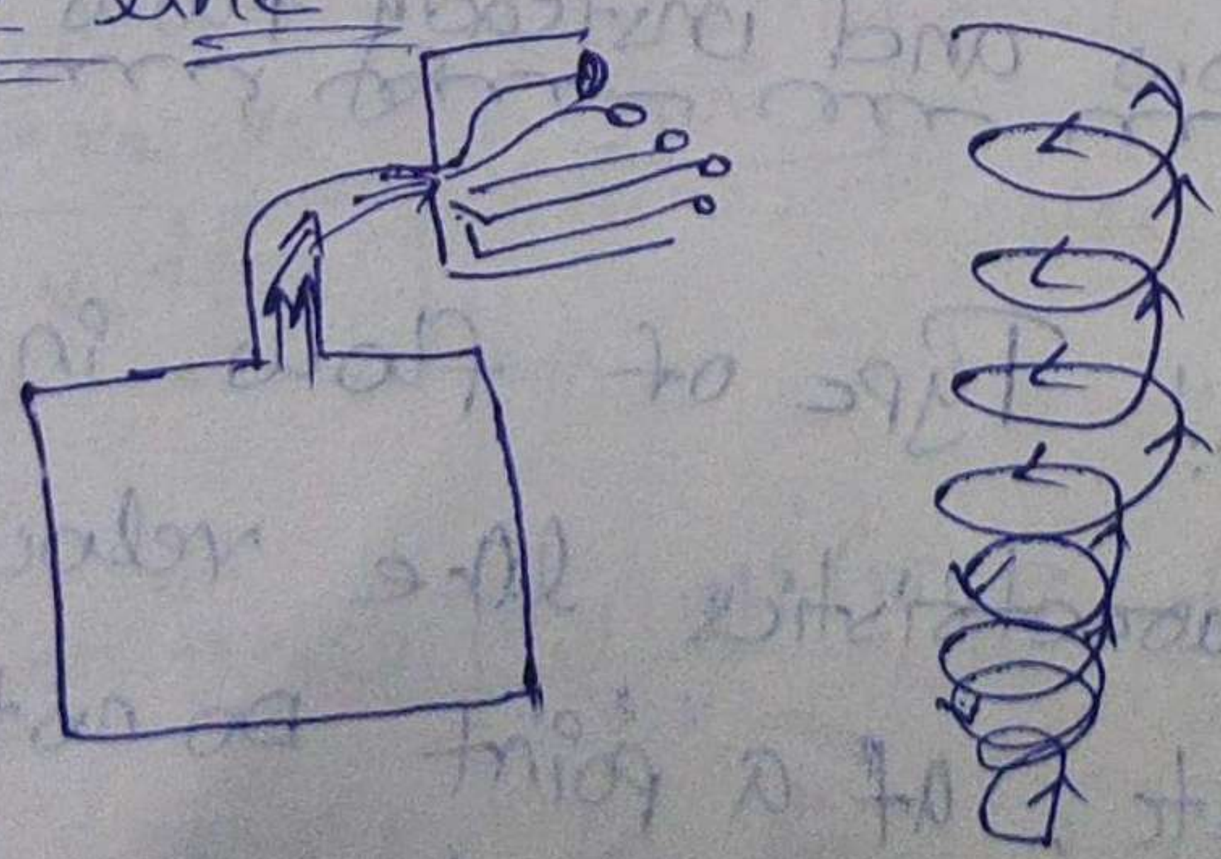
8. Stream tube :



Stream tube

→ stream tube is fluid mass bounded by a group of stream lines is known as stream tube the example is :
communication cables consists of Bundle of fire optic cable.
And the's flow we may observe in the pipes and Nozzles.

Streak line



⇒ The streak line curve which gives an instenpameous picture of the location of fluid particle which have passed through in given point.

As the particle are forced out the way by object the accelerate around the shoulder of the object.

→ The streak lines is formed by connecting all circles into smoke curve.

Types of fluid flows

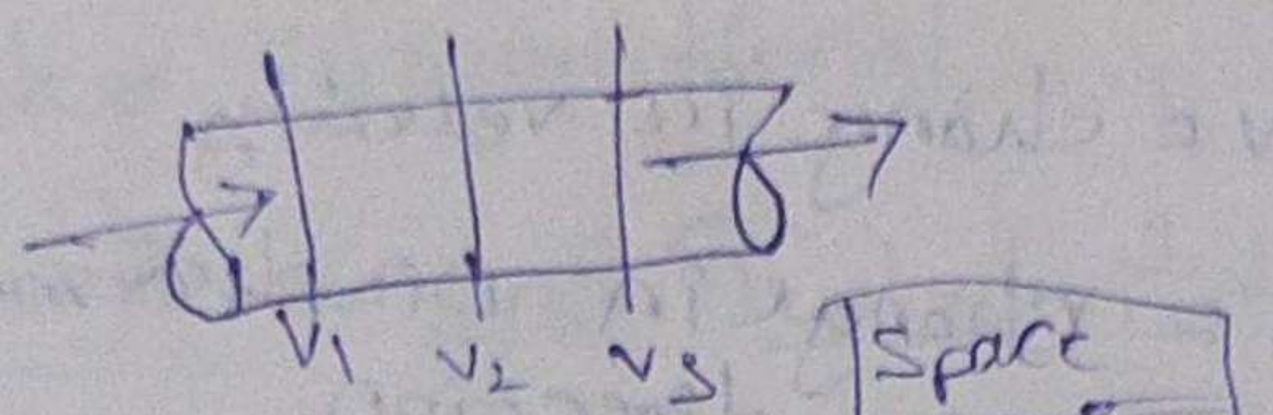
1. steady and unsteady flow.
2. uniform and nonuniform flow
3. Rotational and Irrotational flow
4. Laminar and Turbulent flow
5. compressible and Incompressible flow
6. one, Two and Three dimensional flow

1. Steady flow and unsteady flow.

Steady flow: Type of flow in which the fluid characteristics like velocity, pressure and density etc. at a point Do not change with time is called steady flow.

Mathamatically $\left[\frac{\partial u}{\partial t}\right]_{x_0,y_0,z_0} = 0$, $\left[\frac{\partial v}{\partial t}\right]_{x_0,y_0,z_0} = 0$

$\left[\frac{\partial w}{\partial t}\right]_{x_0,y_0,z_0} = 0$ $\left[\frac{\partial P}{\partial t}\right]_{x_0,y_0,z_0} = 0$



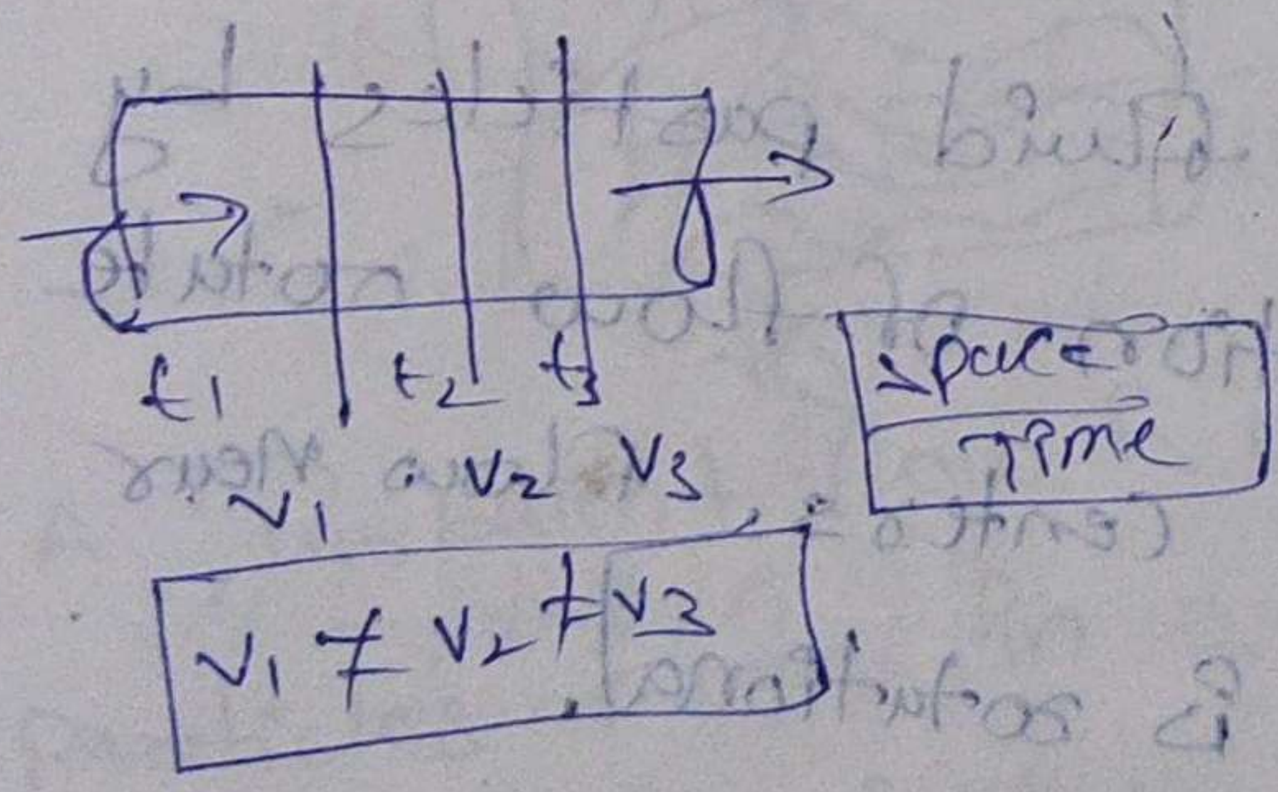
$$\boxed{V_1 = V_2 = V_3}$$

<u>Unsteady flow</u> : is the type of flow in which the characteristics like velocity, pressure and density at a point change with respect to time

Mathematically :-

$$\left[\frac{\partial u}{\partial t}\right]_{x_0, y_0, z_0} \neq 0 \quad , \quad \left[\frac{\partial v}{\partial t}\right]_{x_0, y_0, z_0} \neq 0$$

$$\left[\frac{\partial w}{\partial t}\right]_{x_0, y_0, z_0} \neq 0 \qquad \left[\frac{\partial P}{\partial t}\right]_{x_0, y_0, z_0} \neq 0$$



$$\boxed{V_1 \neq V_2 \neq V_3}$$

2. <u>Uniform and non uniform flow</u>

<u>Uniform flow</u> : is the type of flow in which the velocity at any given type does not change with the respective to space is called uniform flow.

$\left[\frac{dv}{dt}\right]_t = 0$ dv = change in velocity

ds = change in Displacement in any direction.

Non Uniform flow : is the type of flow in which the velocity given time. change with the respect to space mathamatically.

$$\left(\frac{dv}{ds}\right)_t \neq 0$$

3. Rotational and Irrotational flow.

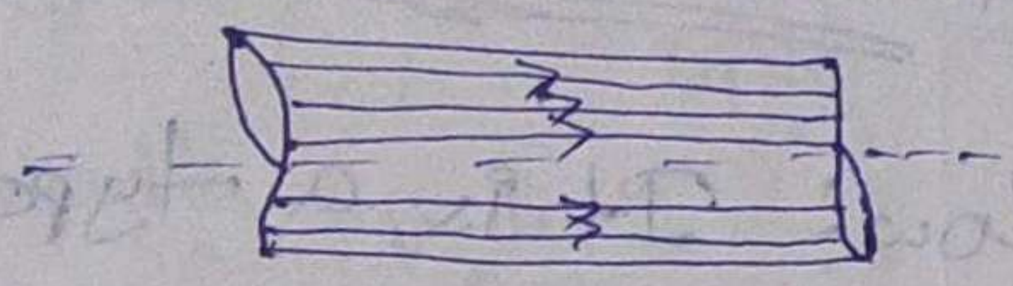
i. Rotational flow : A flow is set to be rotational if the fluid particles by moving the direction of flow rotate about their mass centers. Flow near solid boundries is rotational.

ii. Irrotational flow : A flow is set to irrotational if the fluid particle while moving in the direction of flow do not rotate about their mass centers. flow outside the boundary layer in Generally

consider irrotational.

4. Laminar and Turbulent flow

Laminar flow :



A laminar flow is one in which path's taken by dividual particals. donot cross one on other and move along with well defined path. This type of flow also called stream line.

Turbulent flow :

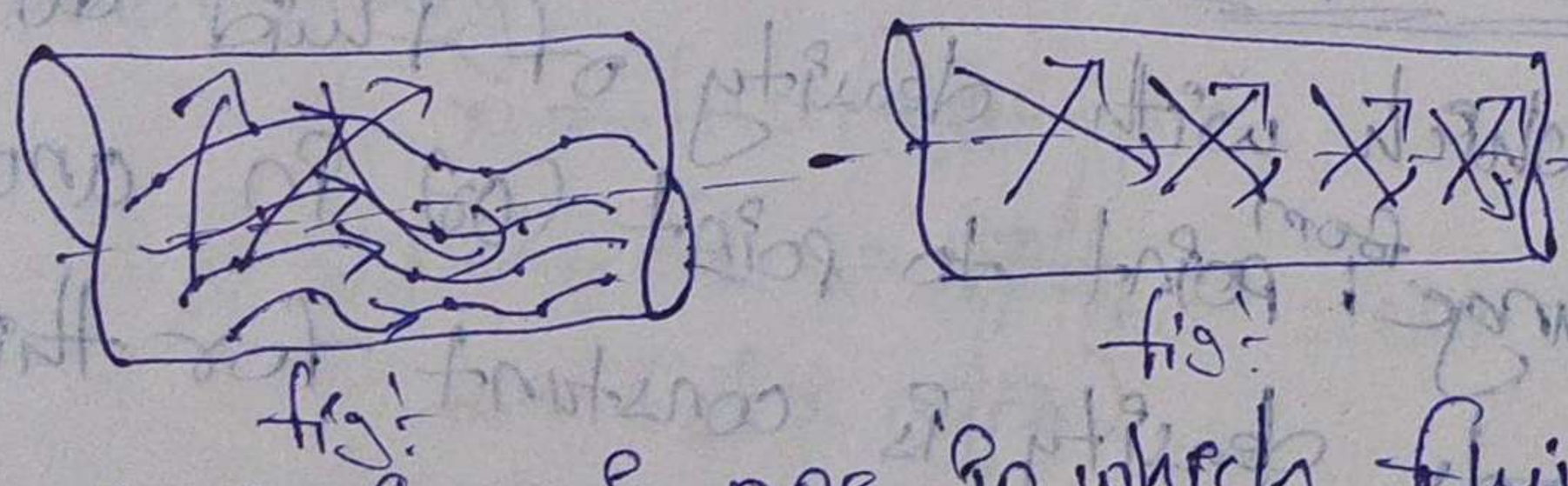


fig:

A Turbulent flow is one in which fluid particles move in a zig-zag way show in fig this is due to high velocity flow in conduite laminar and Turbulent flow are characterised on the basis laminar. number (Re) iff Re less 2000 (Re < 2000) than flow is laminar if Re > 4000 - flow is turbulent

If in between 2000 & 4000, may be laminar (or) turbulent. (Transition flow)

5. <u>Compressible and Incompressible</u>

Compressible flow: It is a type of flow in which the density (ρ) of a fluid change from point to point or in other words density is not constant for this flow.

Ex: flow of gases

$\rho \neq$ constant

<u>Incompressible flow</u>: It is a type of flow in which with density of fluid do not change from point to point (or) in another words density is constant for this flow.

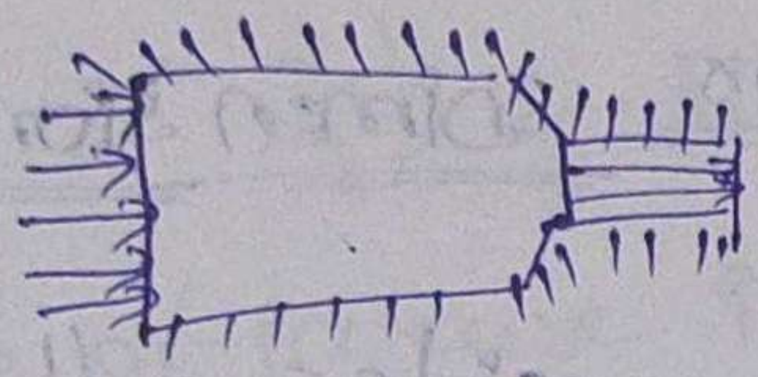
Liquids are generally considered as incompressible flow.

Ex: water

$\rho =$ constant.

6. <u>One, Two and Three dimensional flow</u>

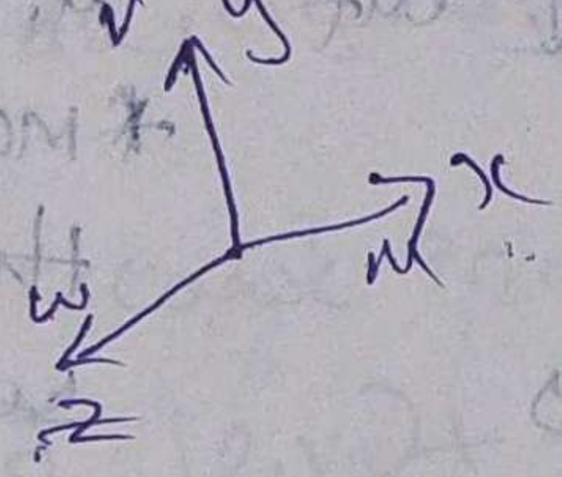
<u>One dimensional flow</u>:



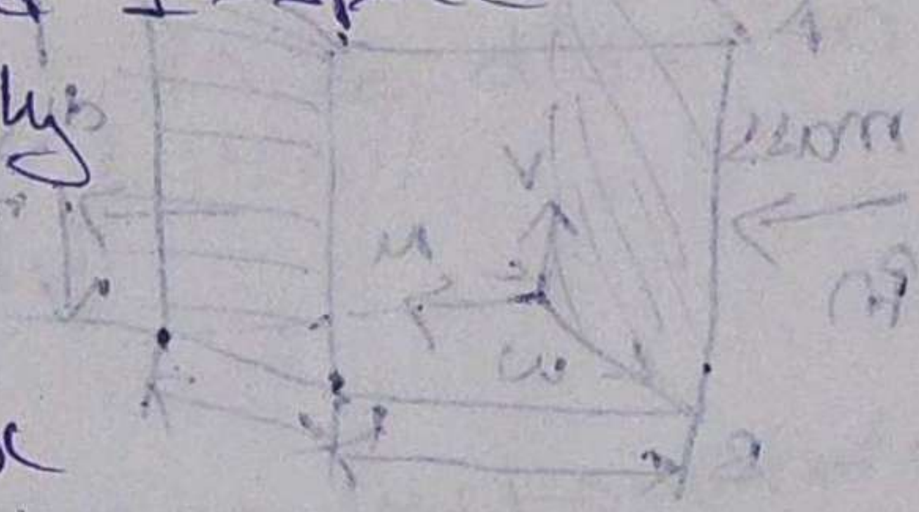
$u = f(x)$

$v = 0, w = 0$

mathematically



In which show parameter such as velocity is a function of time and 1-space co-ordinate only



* Two dimensional flow: In which show parameter such as velocity is a function of time and 2-space co-ordinate only

Mathematically

$u = f_1(x, y)$

$v = f_2(x, y)$

$w = f_3(x, y)$

* Three dimensional flow: In which show parameter such as velocity is a function of time and 3-space co-ordinate only

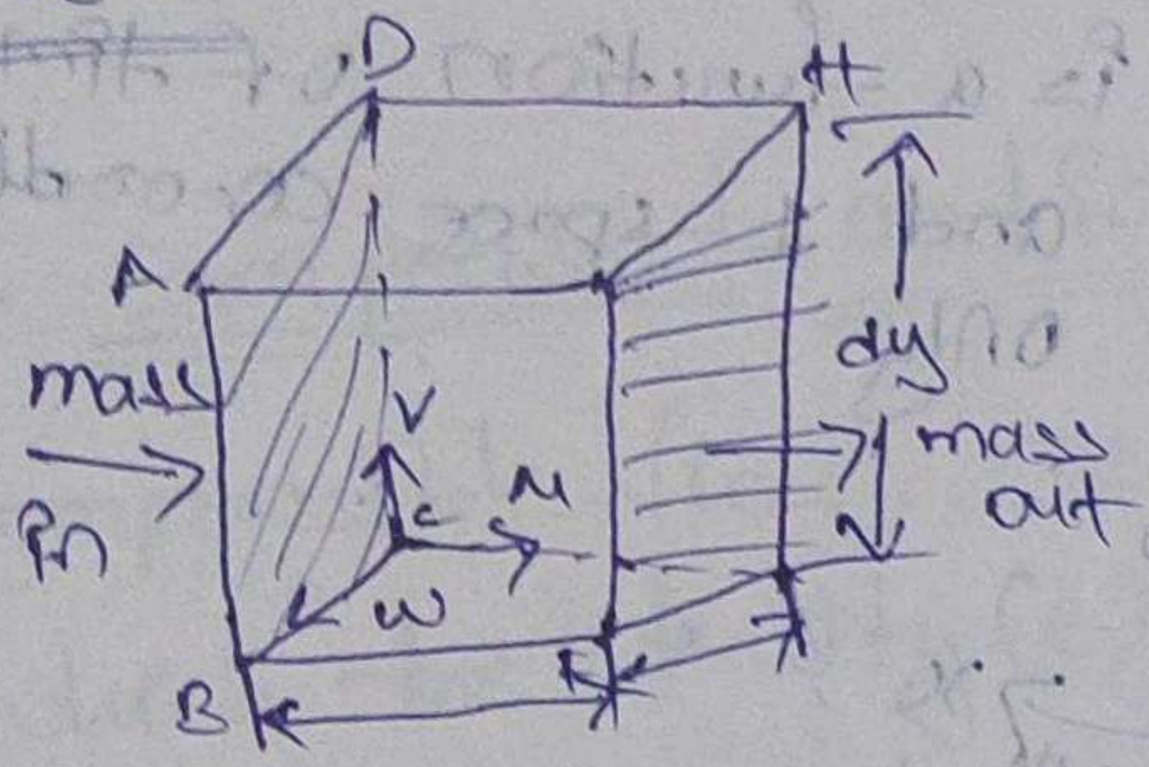
mathematically

$u = f_1(x, y, z)$

$v = f_2(x, y, z)$

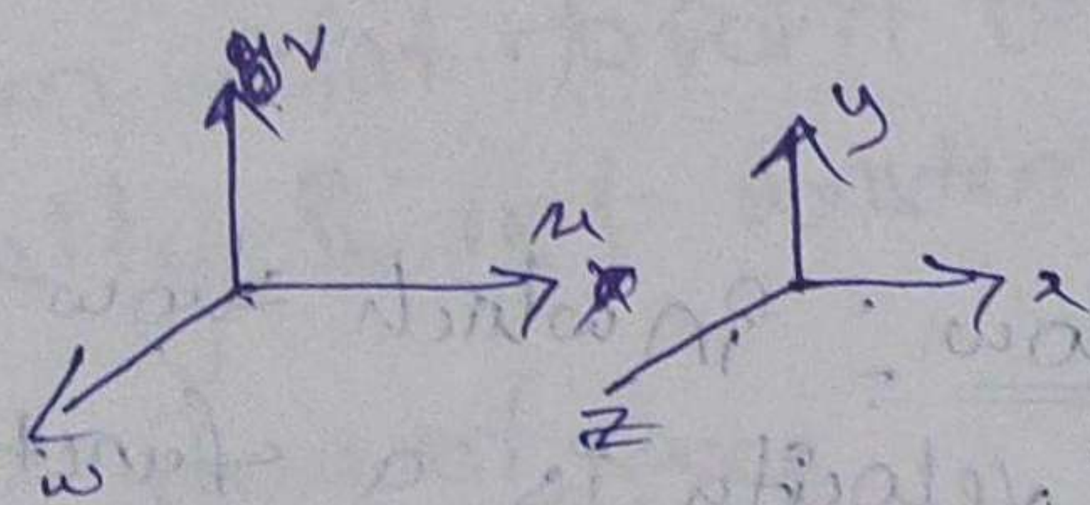
$w = f_3(x, y, z)$

Continuity Equation for 3Dimensional flow



consider a fluid element with length dx.dy.dz and velocity u, v & w.

* Mass of fluid entering the face ABCD per second



$\rho = \frac{m}{V} \Rightarrow m = \rho.V \Rightarrow \rho.\frac{A.l}{s}$

$m = \rho.A.v \quad [\because l/s = v]$

= $\rho \times$ velocity in x direction $\times$ area of face ABCD

$= \rho \times u \times dy.dz$

$\Rightarrow$ Mass of fluid leaving the face EFGH per second.

$\rho \times u \times dy.dz + \frac{\partial}{\partial x}[\rho.u\, dy.dz]dx$

* Rate of increase in mass in x-direction.

= mass entering through face ABCD

− mass leaving through face EFGH per second.

$= \rho.u\, dy.dz - (\rho.u.dy.dz + \frac{\partial}{\partial x}(\rho.u.dy.dz)dx)$

$= \rho.u.dy.dz = -\rho.u.dy.dz - \frac{\partial}{\partial x}(\rho.u.dy.dz)dx$

$= -\frac{\partial}{\partial x}(\rho.u.dy.dz)dx$

$$= -\frac{\partial}{\partial x}(\rho.u)\,dx.dy.dz$$

* Rate of increase in mass in y-direction

$$= -\frac{\partial}{\partial y}(\rho.v)\,dx.dy.dz$$

* Rate of increase in mass in z direction

$$\frac{\partial}{\partial z}(\rho.w)\,dx.dy.dz$$

Total rate of increase in mass (net gain of mass)

$$= -\left(\frac{\partial}{\partial x}(\rho.u) + \frac{\partial}{\partial y}(\rho.v) + \frac{\partial}{\partial z}(\rho.w)\right)dx.dy.dz \quad (1)$$

* mass of fluid in the elements is

$$m = \rho.v \Rightarrow \rho.(dx.dy.dz)$$

* mass of fluid element increase with time

$$= \frac{\partial}{\partial t}(\rho.dx.dy.dz)$$

$$= \frac{\partial \rho}{\partial t}(dx.dy.dz) \quad (2)$$

According to law of conservation of mass

*Net increase in mass per unit time is equal to rate of increase of mass per unit time.

Equating equation (1) & (2)

$$= -\left(\frac{\partial}{\partial x}(\rho.u) + \frac{\partial}{\partial y}(\rho.v) + \frac{\partial}{\partial z}(\rho.w)\right)dx.dy.dz$$

$$= \frac{\partial \rho}{\partial t}(dx.dy.dz)$$

$$= \left(-\frac{\partial}{\partial x}(\rho.v) - \frac{\partial}{\partial z}(\rho.w)\right)dx.\cancel{dy}.dz = \frac{\partial \rho}{\partial t}dx.dy.dz$$

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}\rho.x + \frac{\partial}{\partial y}(\rho.v) + \frac{\partial}{\partial t}(\rho.w) = 0$$

This equation known as continute equation for the dimensional flow in all application.

If A flow is steady $\frac{\partial \rho}{\partial t} = 0$

$$\frac{\partial}{\partial x}\rho.u + \frac{\partial}{\partial y}\rho.v + \frac{\partial}{\partial t}\rho.w = 0$$

If flow is in compressible (ρ = const)

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

If the flow is two dimensional. than

$$\frac{\partial w}{\partial z} = 0$$

$$\boxed{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0} \text{ — 2D}$$

Types of heads (Energies) of liquid.

1. Potential head (or) potential Energy
2. velocity head (or) kinetic Energy ($v^2/2g$)
3. pressure head (or) pressure Energy ($\frac{P}{\omega}$)

total Energy

$$= \frac{P}{\omega} + \frac{v^2}{2g} + z$$

Potential head :- this is the position above sum suitable datum line, it is denoted by letter Z.

velocity head (or) kinetic Energy :- This is due to the velocity flowing of liquid and is measured as $v^2/2g$ where velocity of flow and g assilaration due to gravity

$g = 9.81 \, m/sec^2$

3. pressure head (or) pressure Energy :- this is due pressure of liquid and is measured as $\frac{P}{\omega}$.

where P = pressure
ω = weight density of liquid

Total Head (or) Total Energy the total head of liquid particle in motion in sum of its potential energy, velocity energy, pressure energy.

Total Head $= \frac{P}{\omega} + \frac{v^2}{2g} + Z$

Its units are in meters

* In a pipe of 90mm diameter water is flowing with a main velocity of 2m/s & at a gauge pressure of 350 KN/m2

In the fluid flow there are flowing flows are present

$$\boxed{F_x = ma}$$

F_g = gravity force

F_p = pressure force.

F_γ = force due to viscosity

F_t = Force due to turblent

F_c = Force due to compressibility.

Net force (F_x) = $F_g + F_p + F_\gamma + F_t + F_c$

$$F_x = F_g + F_p + F_\gamma + F_t + F_c$$

If the force due to compressibility (F_c) is neglessible.

$$\boxed{F_x = F_g + F_p + F_v + F_t}$$

this equation known as Renold's equation of motion.

* If F_t is ~~meteorg~~ negleg ible $F_x = F_g + F_p + F_f$

→ This equation of motion called as "Navier stoke equation".

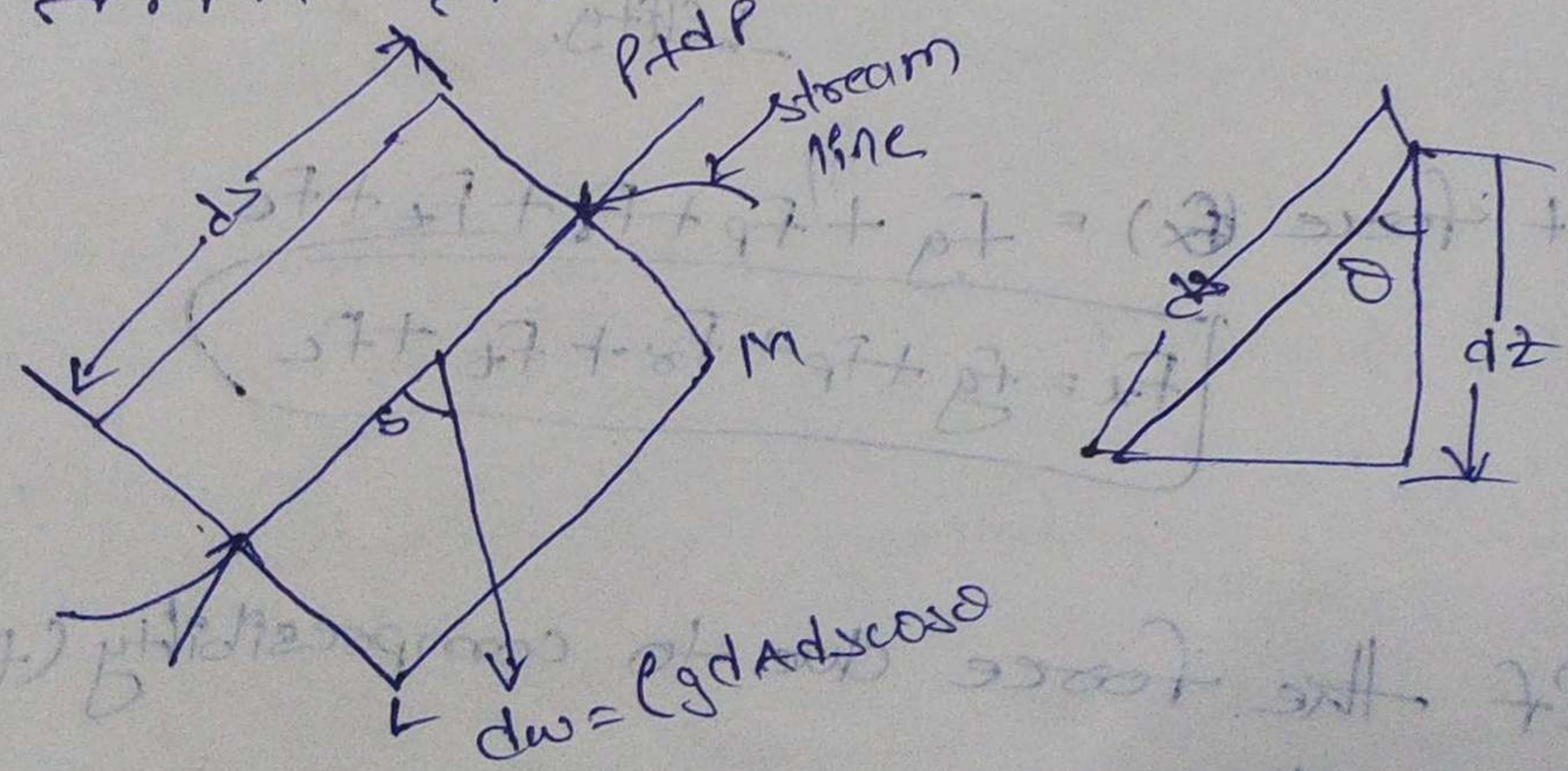
→ If the flow is assume to be ideal ($\mu = 0$) than vicos force is 0

→ The resulting Net force becomes.

$$\boxed{F_x = F_g + F_p}$$

This equation of motion known as Euler's equation of motion,

Euler's equation of motion *** Imp ***



$$\boxed{\cos\theta = \frac{dz}{ds}}$$

let

ds = length of fluid element LM

dA = cross secotional Area of fluid element L-M

P = pressure on fluid element at L

$P + dP$ = pressure on element at M

V = velocity of fluid element.

→ According to Newton's second law of motion, Net force = mass × Acceleration

$$\boxed{F_N = ma}$$

Net pressure force $= P.dA - (P + dP).dA$

$= \cancel{P.dA} - \cancel{P.dA} - dP.dA$

$= -dP.dA$

weight of fluid element

$= -\rho.g\, dA.ds.\cos\theta$

$= -\rho g\, dA\, \cancel{ds} \cdot \frac{dz}{\cancel{ds}}$

$= -\rho.g\, dA.dz$

Net force $= -dP.dA - \rho g\, dA.dz$

mass of fluid element

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

$m = \rho.V$

$= \rho.dA.ds$

W = weight of element / volume

weight of fluid element

$= W \times V$

$= \rho.g \times dA\,ds$

$= \rho.g\, dA\,ds$

Acceleration, $a = \frac{dv}{dt}$

$= \frac{dv}{ds} \times \frac{ds}{dt}$ $\left[v = \frac{ds}{dt}\right]$

$$= v \cdot \frac{dv}{ds}$$

$$-dp \cdot dA - \rho g dA \cdot dz = \rho \cdot dA \cdot ds \times v \cdot \frac{dv}{ds}$$

$$-dp - \rho g \cdot dz = \rho \cdot v \cdot dv$$

Dividing both sides with 'ρ'

$$\frac{-dp - \rho g \cdot dz}{\rho} = \frac{\rho \cdot v \cdot dv}{\rho}$$

$$-\frac{dp}{\rho} - \frac{\rho g \cdot dz}{\rho} = \frac{\rho \cdot v \cdot dv}{\rho}$$

$$-\frac{dp}{\rho} - g \cdot dz = v \cdot dv$$

$$\frac{dp}{\rho} + g \cdot dz + v \cdot dv = 0$$

$$\boxed{\frac{dp}{\rho} + v \cdot dv + g \cdot dz = 0}$$

This equation known Euler's equation of motion

Bernoulli's Equation from Euler's Equation

Assumptions :- i. Fluid is ideal.

ii. Flow is steady

iii. Flow is incompressible.

iv. Flow is ~~irrotational~~ irrotational.

Bernoullis statement:- Bernoullis equations states that in an ideal incompressable fluid when the flow is steady & continous the sum of pressure energy, kinetic energy & potential energy is constant along a steam line.

From Euler's equation

$$\frac{dP}{\rho} + v.dv + g\,dz = c$$

By Intigrating above equation

$$\int\left(\frac{dP}{\rho} + v.dv + g.dz\right) = c$$

$$\frac{P}{\rho} + \frac{v^2}{2} + gz = c$$

By dividing Both side with 'g'

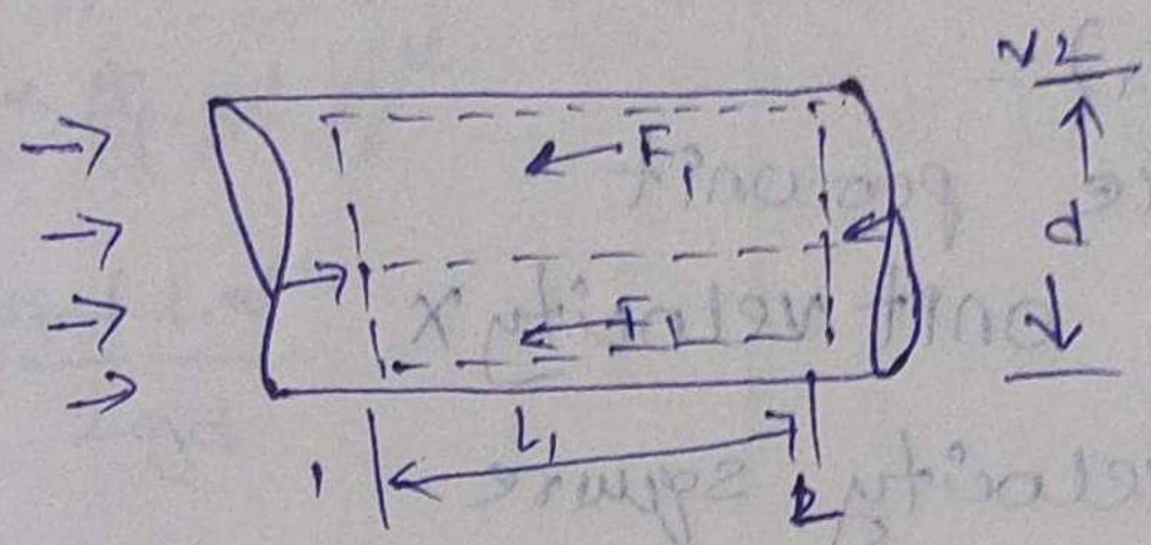
$$\frac{P}{\rho g} + \frac{v^2}{2g} + z = c$$

$$\boxed{\frac{P}{w} + \frac{v^2}{2g} + z = c}$$

This equation is known as Bernoullis ~~statement~~ equation.

Bernoullis equation at point 1 and 2 [L&M] is given as $\boxed{\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{w} + \frac{v_2^2}{2g} + z_2}$

Loss of head due to friction



let

P_1 = pressure intensity at sec 1

v_1 = velocity of flow sc

L = length of pipe sec-1-1 & 2-2

d = dia of pipe

h_f = loss of head due to friction

P_2 v_2 are the pressure intensity and velocity of flow at sec-2-2

f' = frictional Resistance per unit wetted area per unit velocity

Applying Bernoulli's equation at

section 1-1 & 2-2

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

But $Z_1 = Z_2$ [∵ Pipe is Horizontal]

$V_1 = V_2$ Dia of Pipe is same at sec 1-1 & 2-2

$$\frac{P_1}{\omega} = \frac{P_2}{\omega} + h_f$$

$$h_f = \frac{P_1}{\rho g} - \frac{P_2}{\rho g}$$

$$P_1 - P_2 = \rho g h_f$$

Frictional force (F_1) = Frictional resistance per unit wetted area per unit velocity × wetted Area × velocity square

$$F_1 = f' \times \pi d L \times V^2 \quad [\because \text{wetted Area} = \pi d L]$$
$$= f' \times P \times L \times V^2$$

Forces acting on the flow sec-1-1 & 2-2

Pressure force at sec 1-1 = $P_1 A$

Pressure force at sec 2-2 = $P_2 A$

Resolving all forces in horizontal direction

$$P_1 A - P_2 A - F_1 = 0$$

$$P_1 A - P_2 A = F_1$$

$$(P_1 - P_2) A = f' \times P \times L \times V^2$$

$$P_1 - P_2 = \frac{f' \times P \times L \times V^2}{A} \quad [\because P_1 - P_2 = \rho g h_f]$$

$$\text{eght} = \frac{f \times L \times V^2}{A}$$

$$hf = \frac{f'}{eg} \times \frac{P}{A} \times L \times V^2$$

$$\frac{P}{A} = \frac{\text{wetted perimeter}}{\text{Area}}$$

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

$$hf = \frac{f'}{eg} \times \frac{4}{d} \times L \times V^2$$

putting $\frac{f'}{e} = \frac{f}{2}$

$$hf = \frac{f}{2g} \times \frac{4}{d} \times L \times V^2$$

$$hf = \frac{4 f L V^2}{2gd}$$

loss of head / loss of energys

→ Major losses
↓
→ loss of head due to friction

→ Minnor losses
↓
- → sudden enlargment
- → contraction (sudden)
- → Bend of pipe
- → pipe fittings
- → An obstruction
- → leakage loss

This equation is known as Darcy weisbach equation and used for finding the loss of head due to friction (Hf). where Hf = loss of head due to friction

f = coefficent of friction

L = length of pipe in meters

v = velocity m/s

D = Diameter of pipe

**

power required $\boxed{P = wQh_f}$

Darcy weisbach equation

$$h_f = \frac{f'}{\rho g} \times \frac{P}{A} \times L \times v^2$$

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

$$\frac{f'}{\rho} = \frac{f}{2}$$

Hydraulic mean depth (m)

$$\boxed{m = \frac{d}{4}} \qquad \boxed{\frac{P}{A} = \frac{1}{m}}$$

Chezy's Equation

loss of head due to friction (h_f)

$$h_f = \frac{f'}{\rho g} \times \frac{P}{A} \times L \times v^2$$

Hydraulic mean depth (m)

$$m = \frac{A}{P} = \frac{\text{Area}}{\text{diameter}}$$

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

Ratio of $\frac{P}{A} = \frac{1}{m} = \frac{4}{d}$

$$h_f = \frac{f'}{\rho g} \times \frac{1}{m} \times L \times v^2$$

$$v^2 = \frac{h_f}{L} \times \frac{\rho g}{f'} \times m$$

$$v = \sqrt{\frac{h_f}{L}} \times \sqrt{\frac{\rho g}{f'}} \times \sqrt{m}$$

$\frac{h_f}{L} = i$ (loss of head per unit length)

$\sqrt{\frac{\rho g}{f'}} = c$ (chezy's constant)

$\boxed{v = c\sqrt{mi}}$ → inoff

↓ continue

$\frac{h_f}{L} = i$ (loss of head per unit length)

$\sqrt{\frac{\rho g}{f'}} = c$ (Chezy's constant)

$v = c\sqrt{mi}$ → This equation known as chezy's equation thus loss of head due to friction in pipe from chezy's formula can be obtained.

→ where v = velocity of flow m/s

c = No units

m = Hydraulic mean depth

i = loss of head for unit length of pipe

Find the head loss due to friction in pipe of d = 300mm and l = 50m through which water is flowing in v = 3 m/s using

i. Darcy formula.

ii. Chezy formula for which C = 60 and

Take ν for water ν = 0.01 stroke.

---

i. Darcy equation $h_f = \frac{4fLv^2}{2gd}$

ii. Chezy's equation $v = C\sqrt{mi}$ for which C = 60

$\nu = 0.01$ stoke

$= 0.01\ cm^2/s$

$= 0.01 \times 10^{-4}\ m^2/s$

Imp data for problem

$Re = \frac{V \times D}{\nu} = \frac{3 \times 0.30}{0.01 \times 10^{-4}}$

$Re = 9 \times 10^5$

---

1. Darcy equation $h_f = \frac{4fLv^2}{2gd}$

$f = \frac{16}{Re}$ if $Re < 2000$

$f = \frac{0.079}{(Re)^{1/4}}$ if Re in b/w 4000 to 10^6

$f = \frac{0.079}{(9 \times 10^5)^{1/4}}$

$f = 2.564 \times 10^{-3}$

$h_f = \frac{4 \times 2.564 \times 10^{-3} \times 50 \times (3)^2}{2 \times 9.81 \times 0.3}$

$\boxed{h_f = 0.784\ m}$

② Chezy's equation

$v = c\sqrt{mi}$

Hydraulic mean depth (m)

$$m = \frac{\text{Area of flow}}{\text{Perimeter}} = \frac{\frac{\pi d^2}{4}}{\pi d}$$

$$m = \frac{d}{4} = \frac{0.3}{4} = 0.075$$

$$i = \frac{h_f}{L} \quad h_f = i \times L$$

$$3 = 60 \times \sqrt{0.075 \times i}$$

$$i = 3 \times 60 \times \sqrt{0.075}$$

$$i = \left(\frac{3}{60}\right)^2 \times \frac{1}{0.075}$$

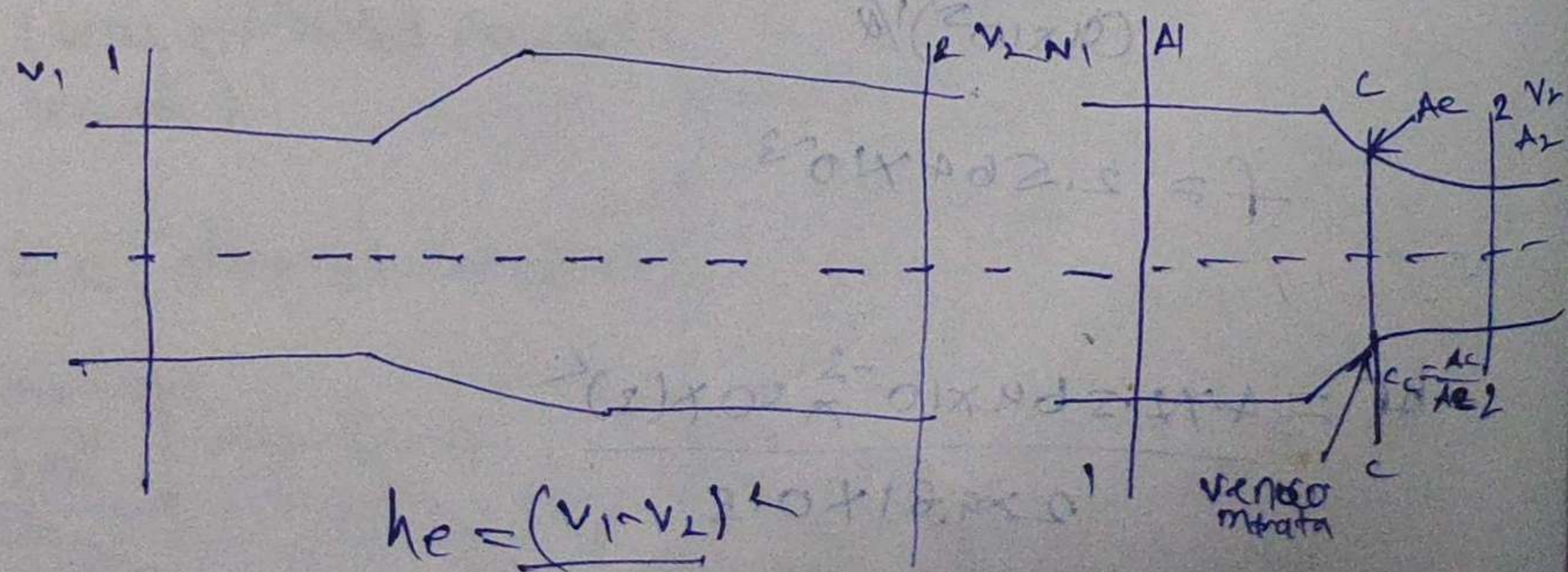
$$i = 0.0333$$

$$h_f = 0.0333 \times 50$$

$$h_f = 1.6\,m.$$

Minor loss

1. Loss of head due to sudden enlargement



$$h_e = \frac{(v_1 - v_2)^2}{2g}$$

$$= \frac{v_2^2}{2g}\left[\frac{v_c}{v_2} - 1\right]$$

From continuity equation

$$A_c v_c = A_2 v_2$$

$$\frac{v_c}{v_2} = \frac{A_2}{A_c} = \frac{1}{A_c} = \frac{1}{C_c}$$

$$= \frac{v_2^2}{2g}\left[\frac{1}{C_c} - 1\right]$$

$$\boxed{h_c = \frac{k v_2^2}{2g}}$$

where $k = \left[\frac{1}{C_c} - 1\right]$

If the value of C_c is 0.62

$$k = \left[\frac{1}{0.62} - 1\right] = 0.375$$

$$h_c = 0.375 \frac{v_2^2}{2g}$$

If value of C_c is not given

$$\boxed{h_c = 0.5 \frac{v_2^2}{2g}}$$

loss of head at entrance (Inlet of pipe)

$$\boxed{h_i = 0.5 \frac{v_1^2}{2g}}$$

loss of head at exit of pipe (outlet of pipe)

$$\boxed{h_o = \frac{v_2^2}{2g}}$$

loss of head due to bend

$$\boxed{h_b = \frac{k v_2^2}{2g}}$$

where k = co-efficient of bend and depends on angle of bend, radius of curvature & diameter of pipe.

loss of head in various fitting

$$\boxed{h_{ft} = \frac{k v^2}{2g}}$$

where k = co-efficient of fitting

Unit - 4

Impact of Jets

Introduction: A fluid jet is steam of fluid issuing from a nozzle with a high velocity and Hence a high kinetic energy. when a jet impinges on a plate or vane or blade, It exerts a force on it this force can be evalivated using imppals momentum principle. The application imppals momentum equation is for evaluting the hydrodynemic force on stationary and moving vanes.

The following cases of impacts on jets will be considred

1. force exerted by the jet on stationary plate
2. force exerted by the jet on moving plate.

1. force exerted by the jet on stationary plate.

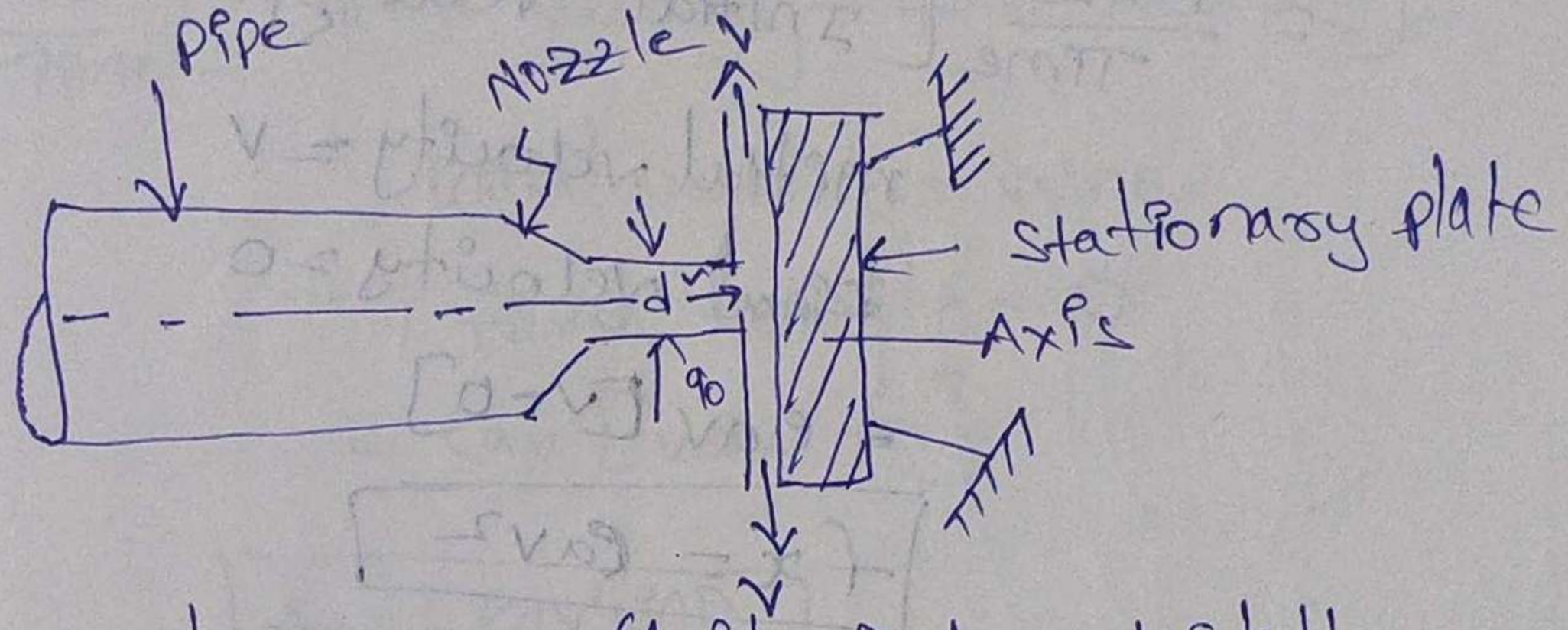
i. when flat plate is held normal to the jet
ii. when flat plate is held inclind to the jet
iii. when the plate is curved

2. force exerted by the jet on moving plate.

i. when flat plate is held normal to the jet
ii. when flat plate is held inclined to the jet
iii. when the plate is curved.

→ force exerted by the jet on stationary flat plate held normal to the jet plate

plate held Normal to Jet



→ figure shows a fluid jet strightly a stationary held perpendicular / Normal. to be flow direction (~~Jet~~ z direction).

→ Let a & V be the crossectional area and velocity of jet respectly.

→ The jet after striking this plate will get its direction change through 90°.

→ If v neglect the friction b/w jet and plate as is possible when the plate is smooth.

→ If the friction is consider the velocity of liquid coming off the plate will be slittely less than V

The force exited likely jet on the plane plate in the direction of jet (X direction)

F_x = Rate of change of momentum

$$= \frac{(\text{Initial momentum} - \text{final momentum})}{\text{Time}}$$

$$= \frac{\text{mass}}{\text{Time}} [\text{Initial velocity} - \text{final velocity}]$$

initial velocity = V

final velocity = 0

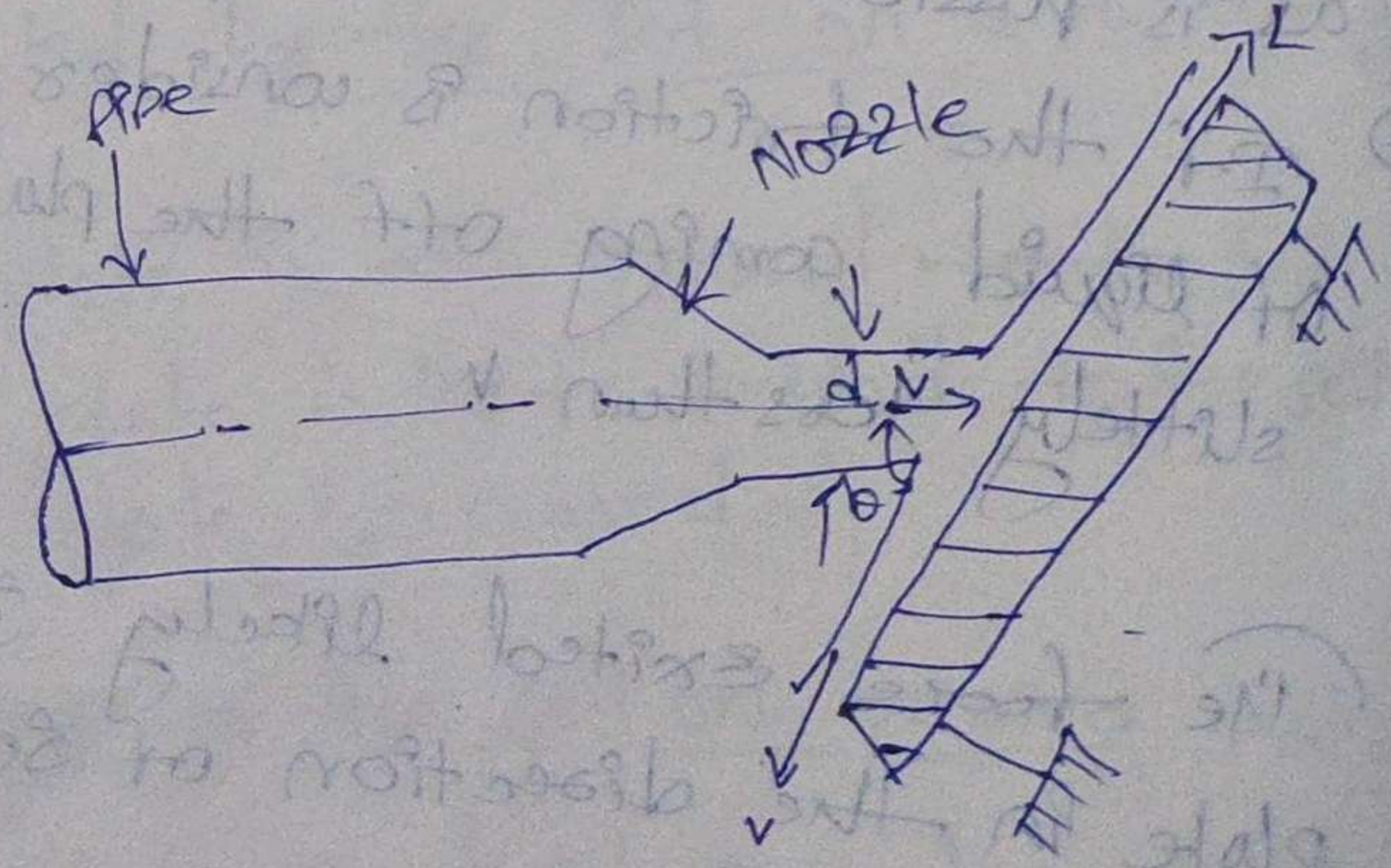
$$= aV[V-0]$$

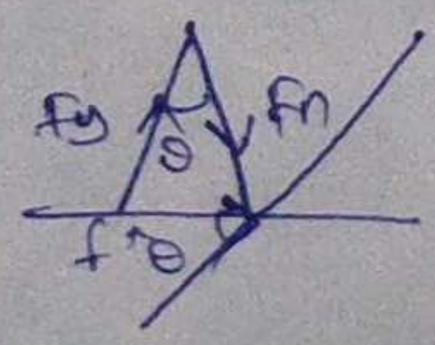
$$\boxed{F_x = aV^2}$$

where

since the plate is stationary ∴ The work done on the plate is zero

When flat plate is held inclined to the jet.





F_n = Rate of change of momentum

$$= \frac{(\text{Initial momentum} - \text{final momentum})}{\text{Time}}$$

$$= \frac{\text{mass}}{\text{Time}}[\text{Initial velocity} - \text{final velocity}]$$

Initial velocity $= v\sin\theta$

Final velocity $= 0$

$$= \rho a v[v\sin\theta - 0]$$

$$\boxed{F_n = \rho a v^2 \sin\theta}$$

Force in x - Direction (F_x)

$$F_x = F_n \sin\theta$$

$$= \rho a v^2 \sin\theta \cdot \sin\theta$$

$$\boxed{F_x = \rho a v^2 \sin^2\theta}$$

$$F_y = F_n \cos\theta$$

$$= \rho a v^2 \sin\theta \cdot \cos\theta$$

$$\boxed{F_y = \rho a v^2 \sin\theta \cdot \cos\theta}$$

$$Q_1 = \frac{Q}{2}(1 + \cos\theta)$$

$$Q_2 = \frac{Q}{2}(1 - \cos\theta)$$

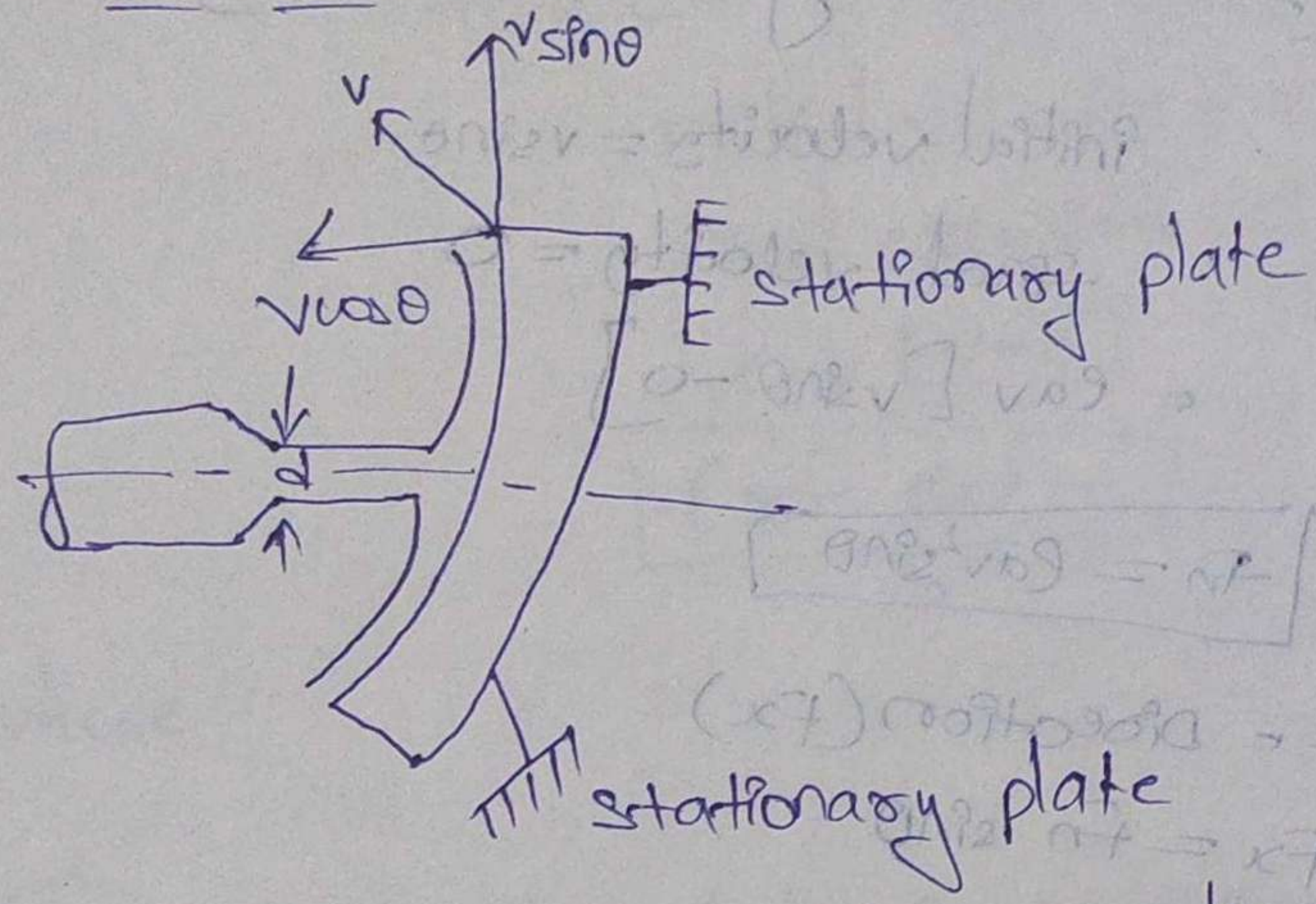
ratio of discharge

$$\frac{Q_1}{Q_2} = \frac{1 + \cos\theta}{1 - \cos\theta}$$

Stationary curved plate

Same Model on this problem

Case-I: At center



Apply Impulse momentum equation
force in x-Direction [f_x]

$$f_x = \frac{mass}{sec}\left[V_{1x} - V_{2x}\right]$$

$$f_x = \rho a V\left[V_{1x} - V_{2x}\right]$$

$V_{1x} = V$

$V_{2x} = -V\cos\theta$

$$f_x = \rho a V[V - (-V\cos\theta)]$$

$$= \rho a V[V + V\cos\theta]$$

$$\boxed{f_x = \rho a V^2[1 + \cos\theta]}$$

$f_y = \rho a V[V_{1y} - V_{2y}]$ ← force in y-Direction [f_y]

$V_{1y} = 0$

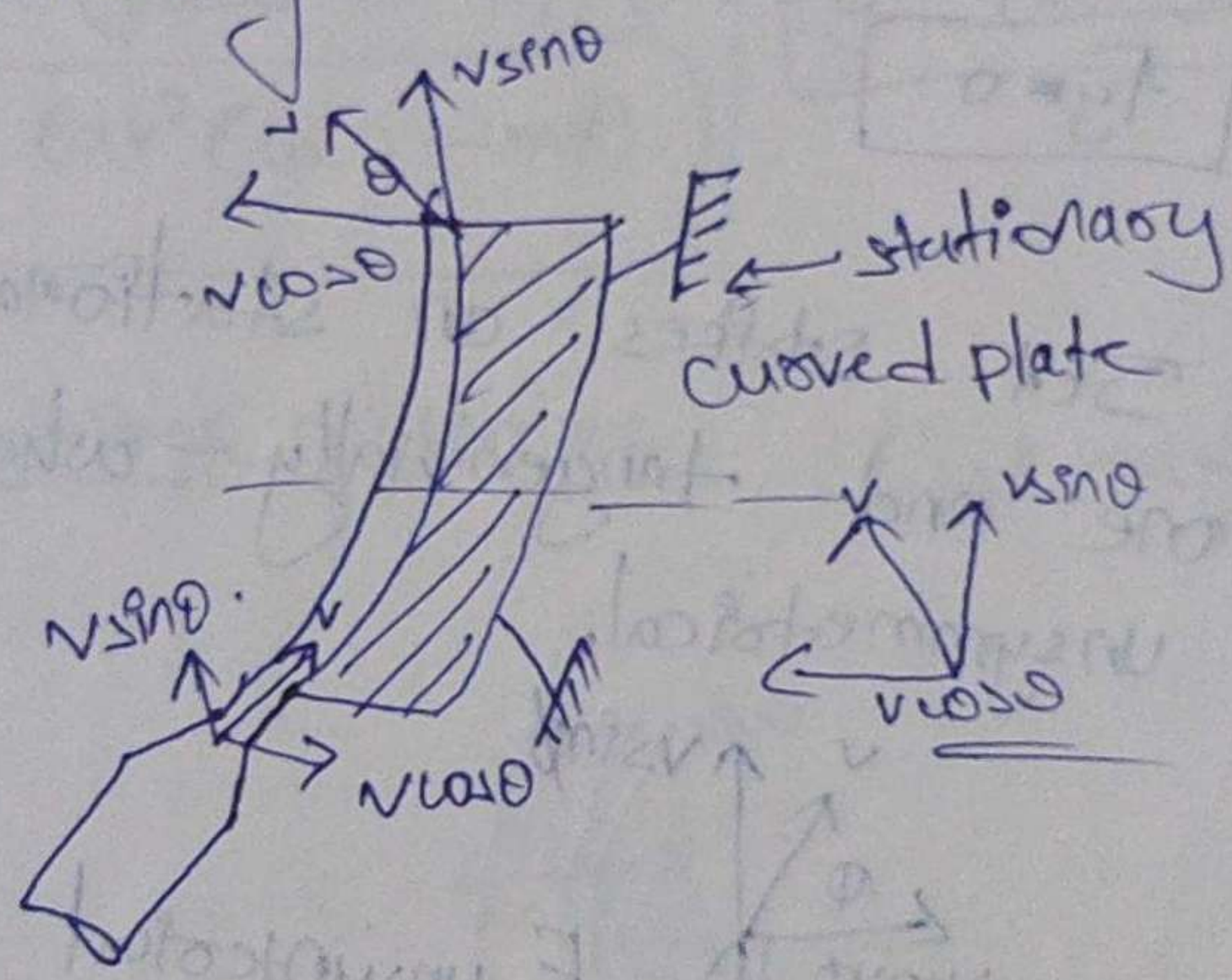
$V_{2y} = V\sin\theta$

$= \rho a v [0 - v\sin\theta]$

$$\boxed{F_y = -\rho a v^2 \sin\theta}$$

-ve sign indicates force acting in downward direction.

Case-II: Jet strikes ~~v sign~~ on stationary curved plate at one end tangentically when the plate is cimentrically



Apply Impulse momentum equation

Force in x-Direction [Fx]

$$F_x = \frac{\text{mass}}{\text{sec}} [v_{1x} - v_{2x}]$$

$$F_x = \rho a v [v_{1x} - v_{2x}]$$

$v_{1x} = v\cos\theta$

$v_{2x} = -v\cos\theta$

$$F_x = \rho a v [v\cos\theta - (-v\cos\theta)]$$

$$= \rho a v [v\cos\theta + v\cos\theta]$$

$$\boxed{F_x = 2\rho a v^2 \cos\theta}$$

force in y- Direction (F_y)

$$F_y = \rho a v [v_{1y} - v_{2y}]$$

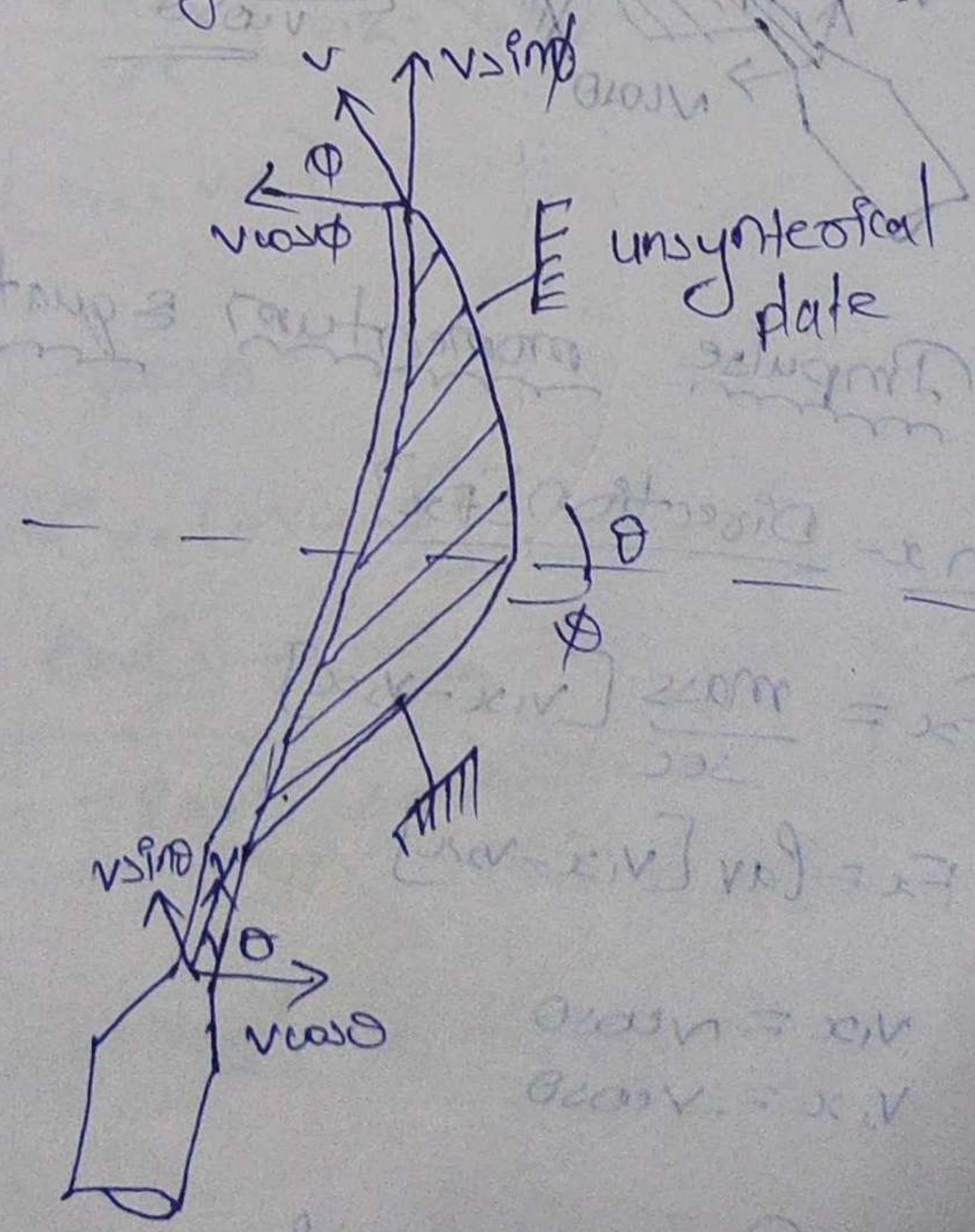
$$v_{1y} = v\sin\theta$$

$$v_{2y} = v\sin\theta$$

$$= \rho a v [v\sin\theta - v\sin\theta]$$

$$\boxed{F_y = 0}$$

Case-3 Jet strikes an stationary curved plane at one end tangentially when the plate is unsymmetrical.



Apply (Impulse momentum equation)

force in x - direction [F_x]

$$F_x = \frac{mass}{sec}[V_{1x} - V_{2x}]$$

$$F_x = \rho a V [V_{1x} - V_{2x}]$$

$$V_{1x} = V\cos\theta$$

$$V_{2x} = -V\cos\phi$$

$$F_x = \rho a V[V\cos\theta - (-V\cos\phi)]$$

$$= \rho a V[V\cos\theta + V\cos\phi]$$

$$\boxed{F_x = \rho a V^2(\cos\theta + \cos\phi)}$$

force in y - direction [F_y]

$$F_y = \rho a V[V_{1y} - V_{2y}]$$

$$V_{1y} = V\sin\theta$$

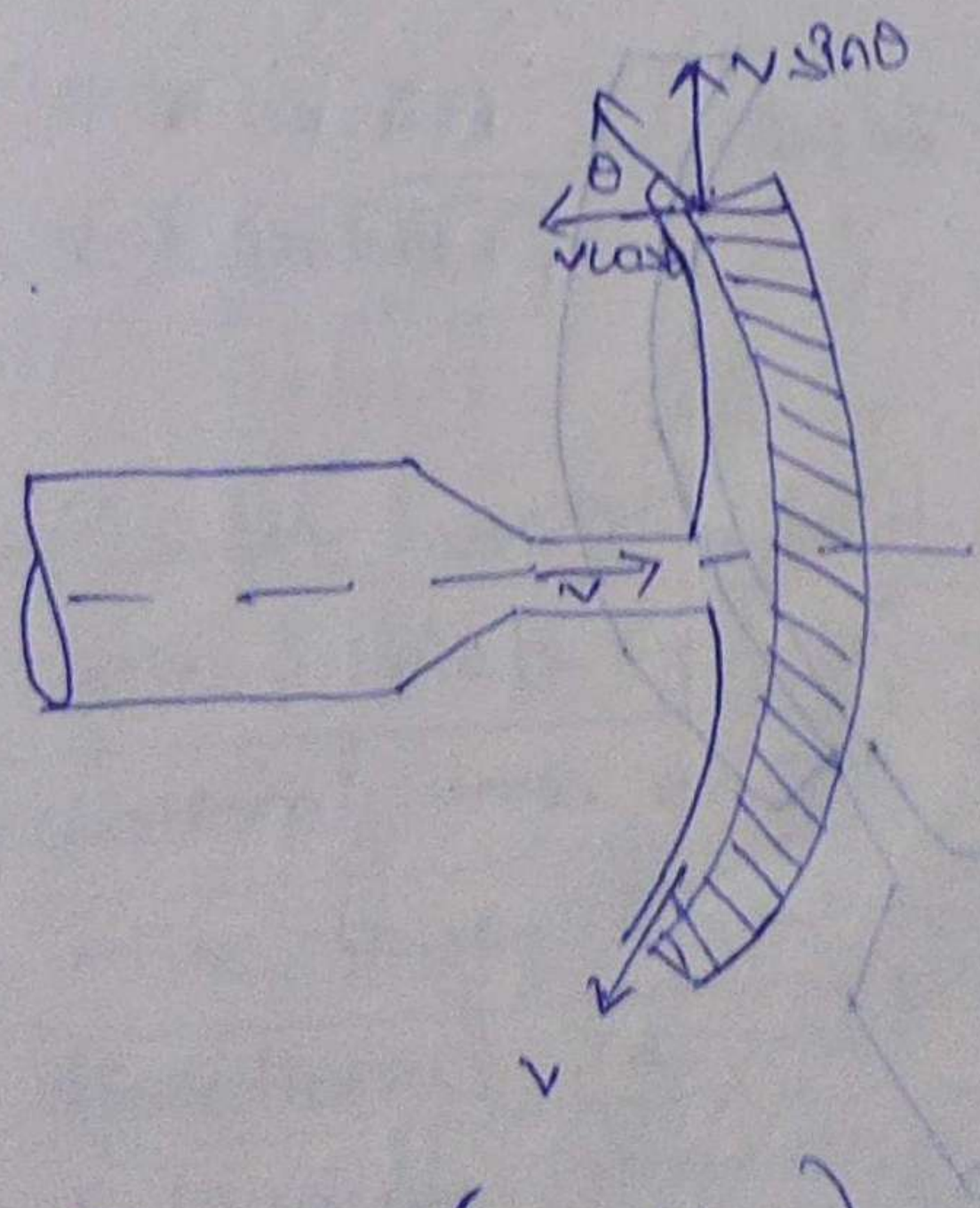
$$V_{1y} = V\sin\theta$$

$$V_{2y} = V\sin\phi$$

$$F_y = \rho a V(V\sin\theta - V\sin\phi)$$

$$\boxed{F_y = \rho a V^2(\sin\theta - \sin\phi)}$$

Jet strikes at center (Already written)



$$F_x = \rho a V(V_{1x} - V_{2x})$$

$$V_{1x} = V$$

$$V_{2x} = -V\cos\theta$$

$$F_x = \rho a V(V - (-V\cos\theta))$$

$$= \rho a V(V + V\cos\theta)$$

*A Jet of water 75mm in diameter issues with velocity of 30 m/s And impenges on a setationary flat plate which distroyes it forward motion find it force Exerted on the plate on work done.

$d = 75mm$

$= 0.075m$

$V = 30$

$a = \frac{\pi}{4} d^2$

$= \frac{\pi}{4}(0.075)^2$

$a = 4.417 \times 10^{-3} m^2$

$f_x = \rho a v^2$

$\rho = 1000 kg/m^3$

$= 1000 \times 4.417 \times 10^{-3} \times (30)^2$

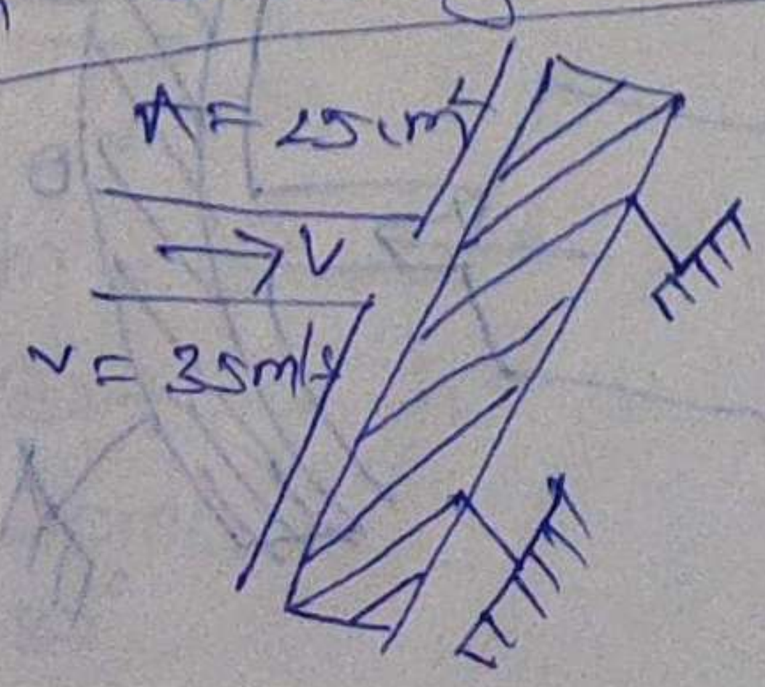
$f_x = 3975.3 N \longrightarrow 3975.3 \times 10^{-3}$

$\boxed{F_x = 3.97 kN}$

problem

*A Jet of water strikes with velocity of 35m/s on flat inclined plate at 30° with axis of z. with the crossectional area of ~~jet~~ is 25m²

determine the force exerted on the plane in the directional normal to the jet. the ratio of in which discharge is divided.



① $F_n = \rho a v^2 \sin\theta$

$F_x = 1000 \times 25 \times 10^{-4} \times (35)^2 \sin 30$

$F_n = 1531.25\,N$

② components of F_n

$F_x = F_n \sin\theta = 1531.25 \sin 30$

$F_y = F_n \cos\theta = 765.62\,N$

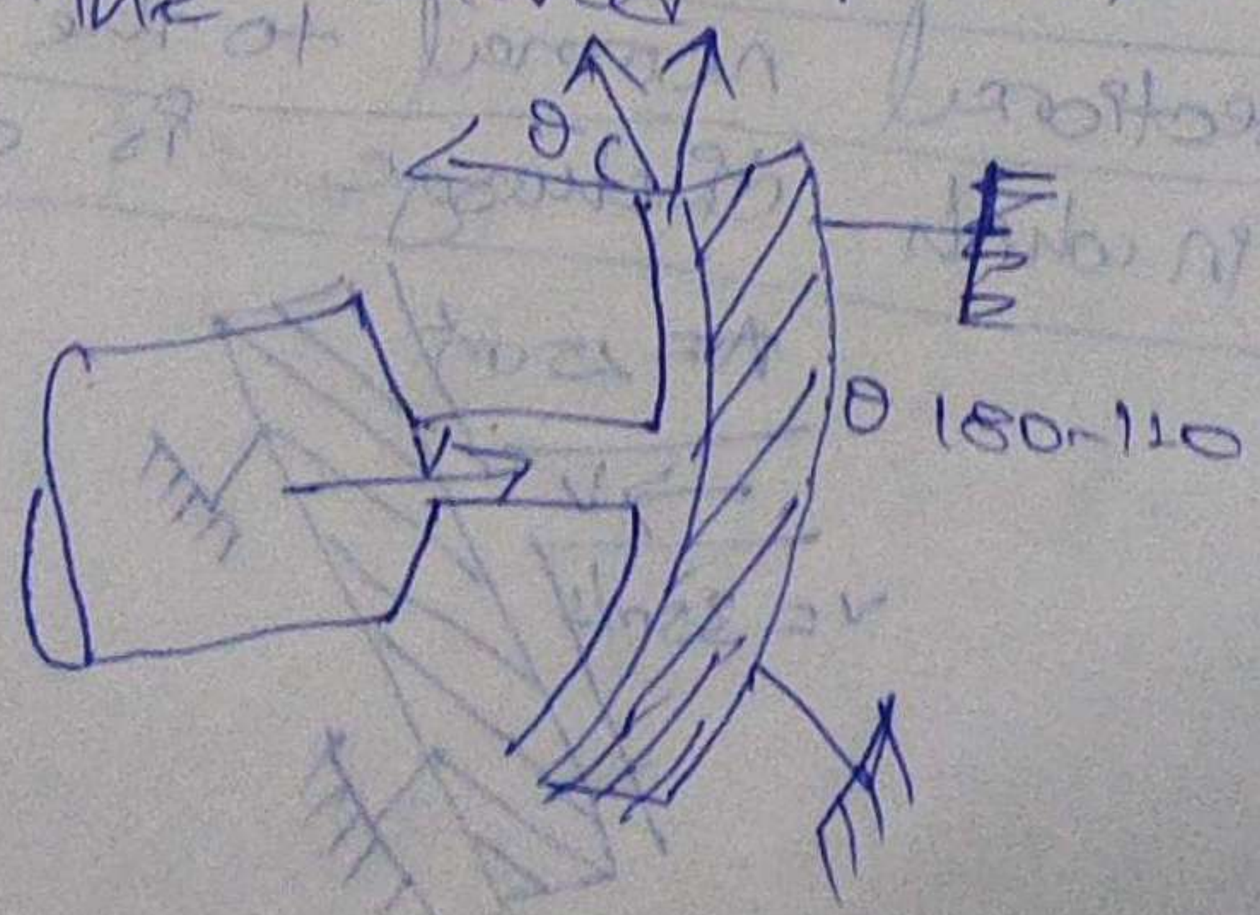
$= 1531.25 \cos 30$

$= 1326.11\,N$

Ratio of Discharge $\left(\frac{Q_1}{Q_2}\right)$

$$\frac{Q_1}{Q_2} = \frac{1+\cos\theta}{1-\cos\theta} \Rightarrow \frac{1+\cos 30}{1-\cos 30} = 13.92$$

A Jet of water diameter 40mm moving with velocity of 30 m/s strikes a curve fixed symmetrical plane at the centre find the force exerted by the jet of of water in the direction of jet if the jet is deflected through an angle of 120° at the outlet of the curved plane.



$d = 40mm$
$= 0.040 m$

$a = \frac{\pi}{4}(0.040)^2$
$= 1.25 \times 10^{-3} m^2$

$V = 20 m/s$

$\theta = 180 - 120$
$= 60°$

$-f_x = \rho a V^2 (1 + \cos\theta)$

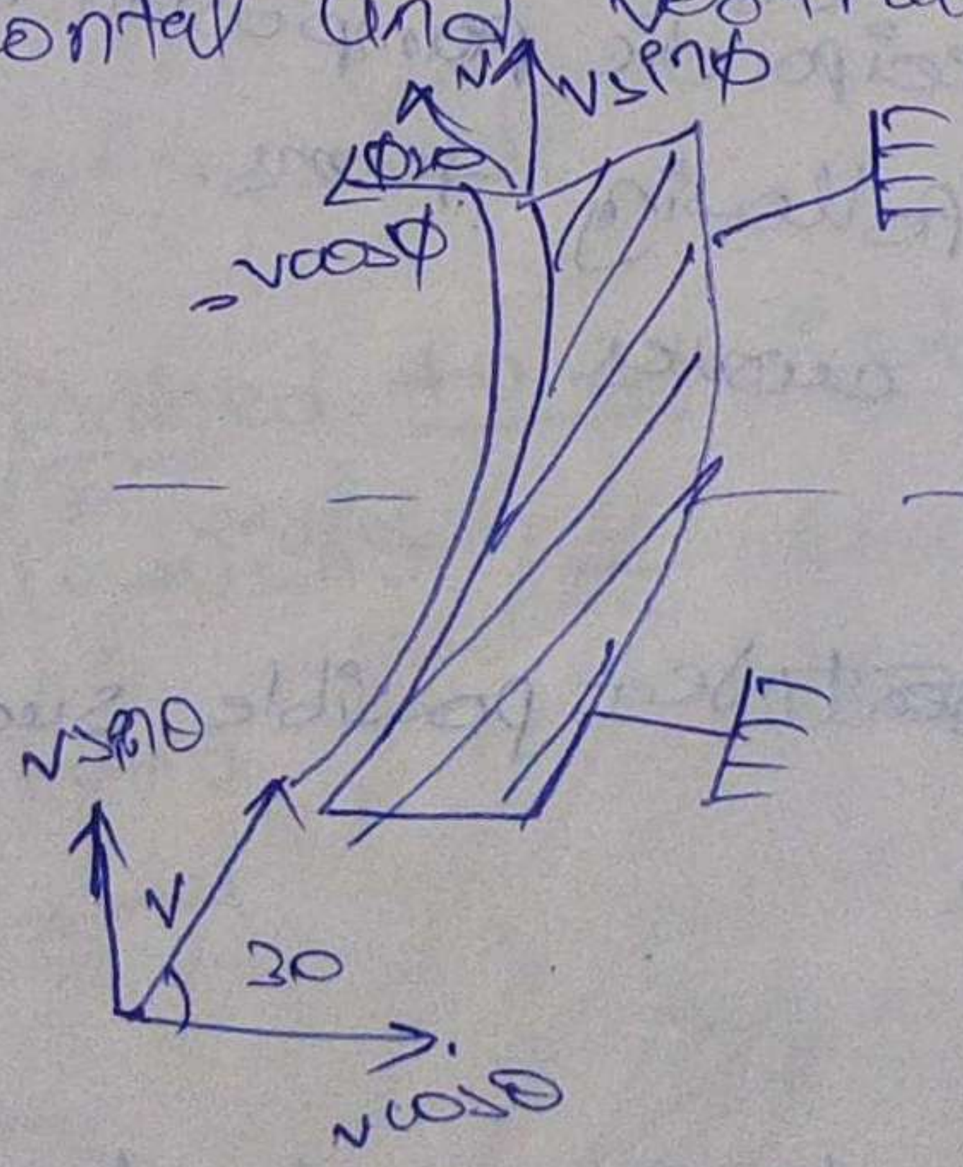
$= 1000 \times 1.25 \times 10^{-3} \times (20)^2 (1 + \cos 60)$

$f_x = 1667.5 N$

$f_y = -\rho a V^2 \sin\theta$

$f_y = 924.27 N$

(4) A Jet of water of diameter 60mm moving with velocity of 40m/s strikes at curved fixed plate tangentially at the one end at angle of 30 at horizantal A jet leaves the plane at ~~40m/s~~ angle of 20° to the horizantal find the force excerted by the jet on the plane in the horizontal and vertical directions.



$d = 60mm = 0.060 m$

$A = 2.827 \times 10^{-3} m^2$

$V = 40 m/s$

$\theta = 30°$

$\phi = 20$

$F_x = \rho a v^2 (\cos\theta + \cos\phi)$

$= 1000 \times 2.82 \times 10^{-3} \times (40)^2 (\cos 30 + \cos 20)$

$F_x = 8167.61 N$

$F_y = \rho a v^2 (\sin\theta - \sin\phi)$

$= 1000 \times 2.827 \times 10^{-3} \times (40)^2 \times (\sin 30 - \sin 20)$

$F_y = 714.57 N$

Unit - 5 Home work question

Draw and explain working principle of centrifugal pump with neat sketch.

How do you classify pumps

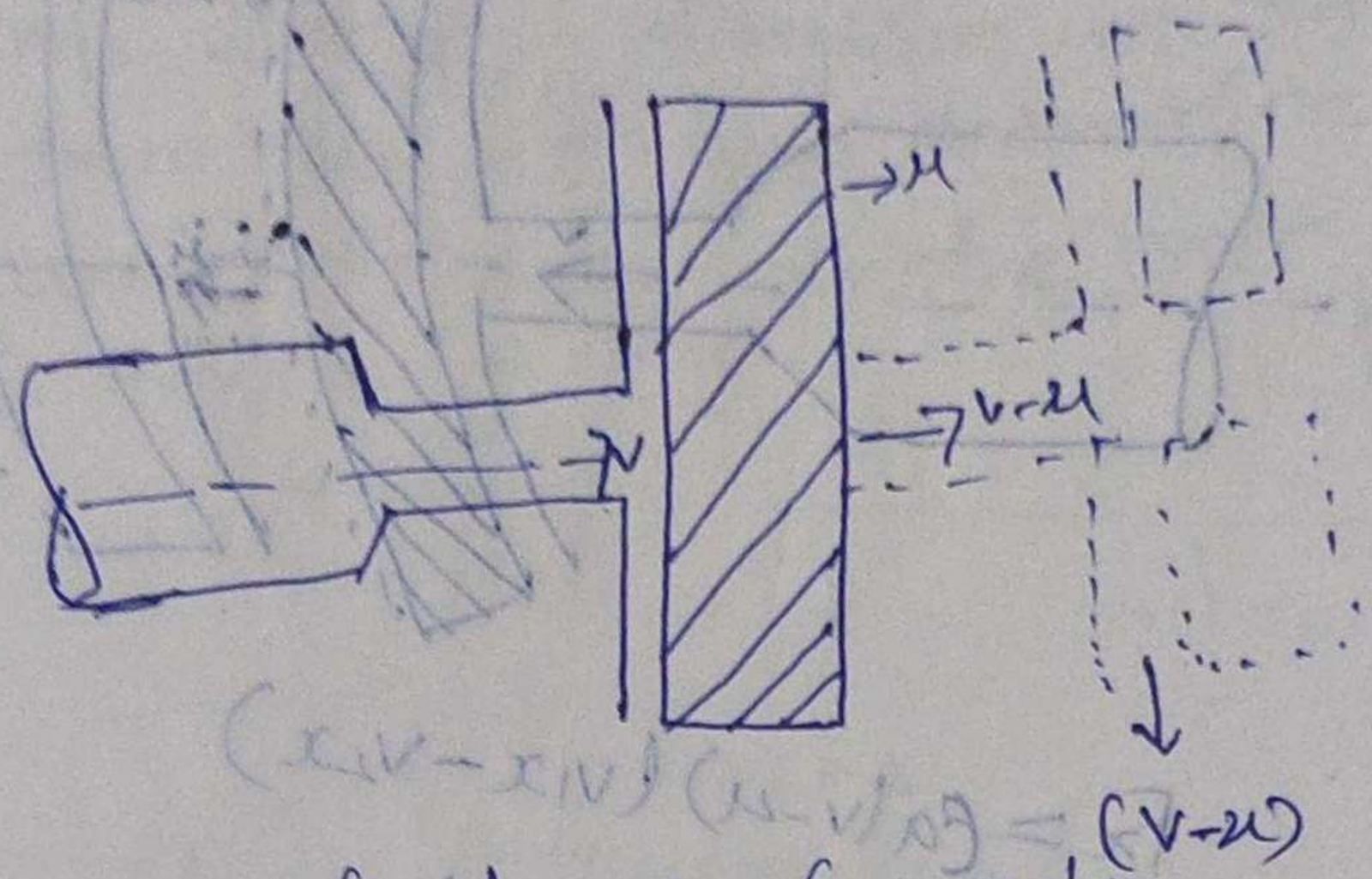
or

explain the reciprocetic pump with the neat sketch.

Briefly explain following terms.

1. characteristic curves
2. slip
3. NPSH → Net possible suction
4. surge tank
5.
6. Specific speed of centrifugal pump.

Force exerted on moving flat plate on moving normal to the set



F_x = Rate of change of momentum

$= \frac{\text{mass}}{\text{sec}}$ [Initial velocity − Final velocity]

$= \rho a(v-u)$ [(v−u) − 0] ∵ Final velocity

$$\boxed{F_x = \rho a(v-u)^2}$$

work done (w) = $F_x \times u$

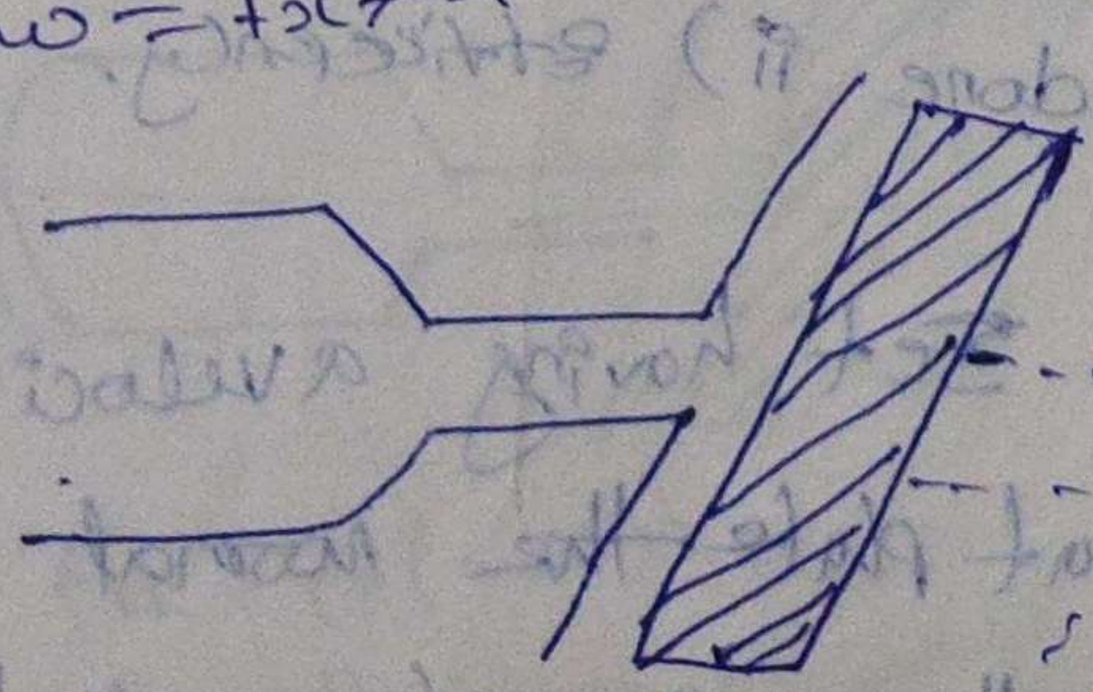
$= \rho a(v-u)^2 \times u$

<u>plate held Inclined to the jet</u>

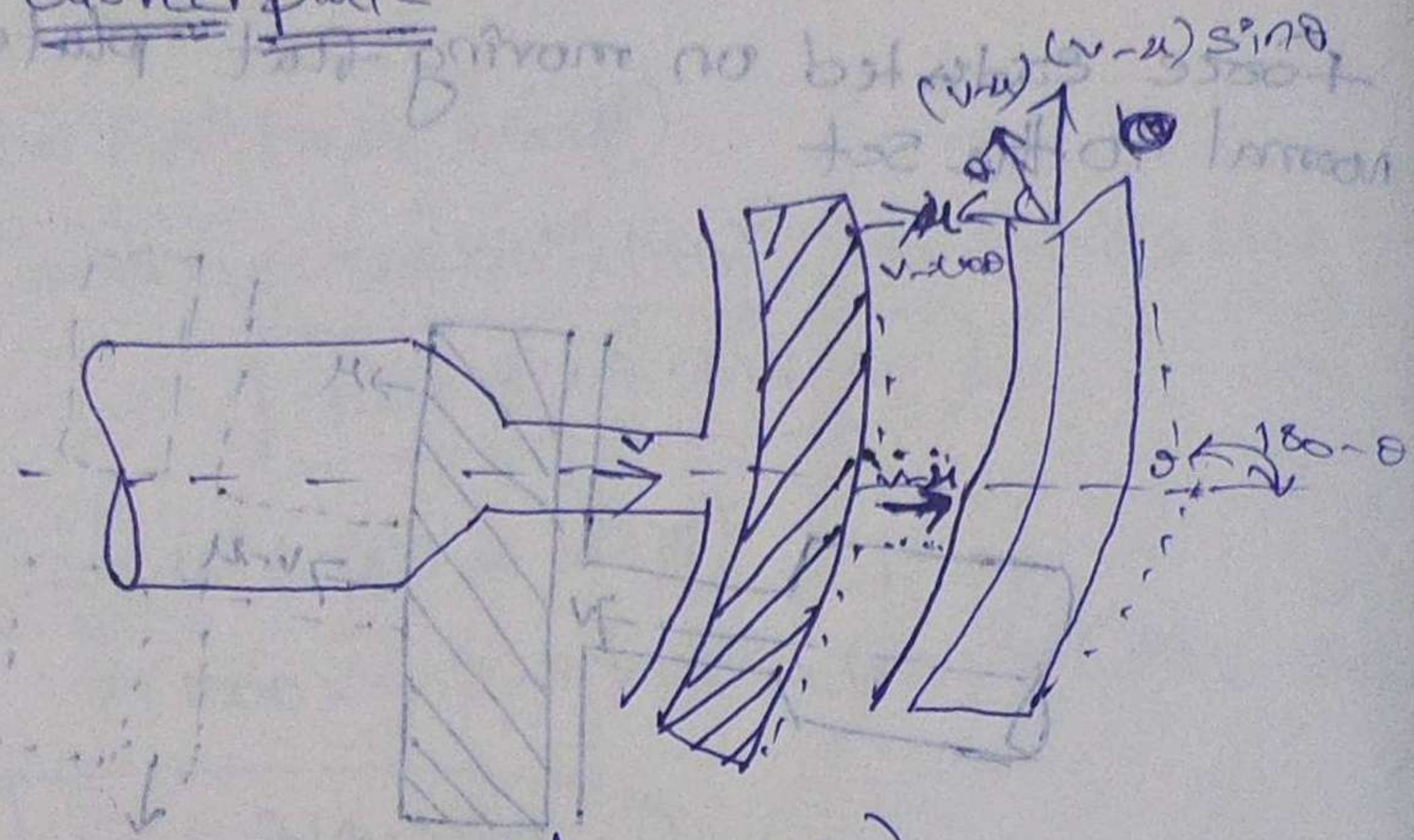
$F_n = \rho a(v-u)^2 \sin\theta$ / $F_y = F_n \cos\theta$

$F_x = F_n \sin\theta$

$w = F_x \times u$



curved plate



$$F_x = \rho a (v-u)(v_{1x} - v_{2x})$$

$$v_{1x} = (v-u)$$

$$v_{2x} = -(v-u)\cos\theta$$

$$F_x = \rho a (v-u)\left((v-u) - (-(v-u\cos\theta))\right)$$

$$\boxed{F_x = \rho a (v-u)^2 (1+\cos\theta)}$$

$$\text{work done} = F_x \times u$$

$$= \rho a (v-u)^2 (1+\cos\theta) \times u$$

~~Afew~~ problems

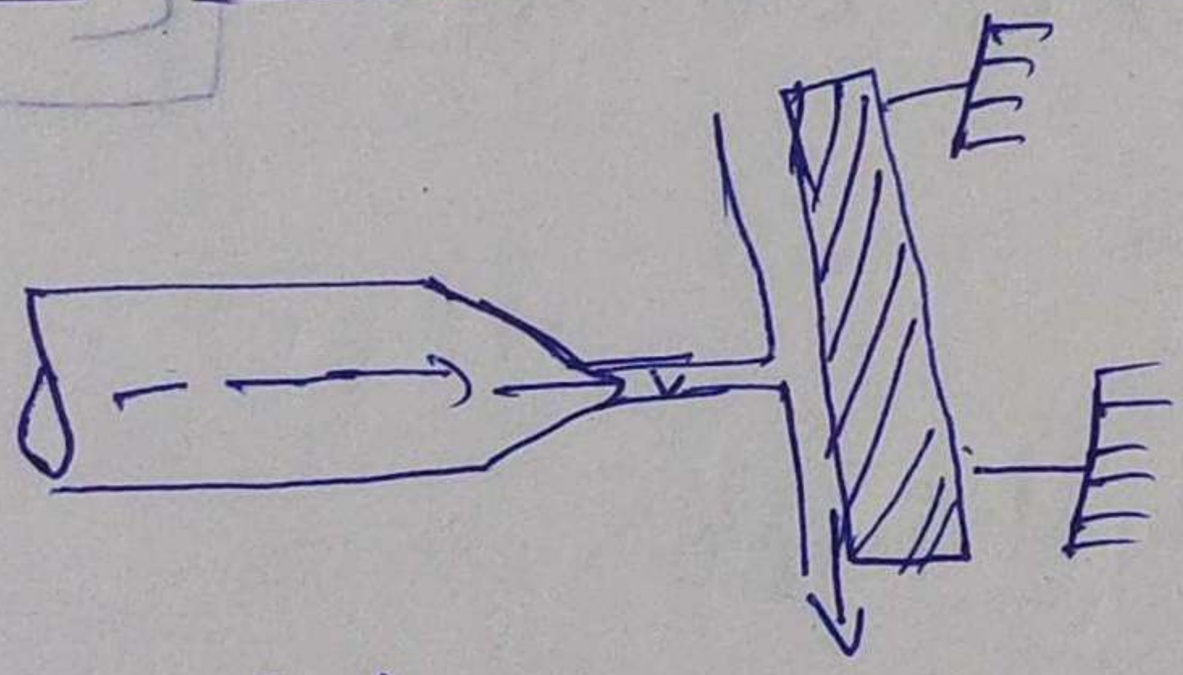
① A Nozzle of 60mm diameter delivers steam of water at 24 m/s ⊥r to a plane that moves away from the jet out 6 m/s find force on the plane i) work done ii) efficiency.

② 75mm diameter jet having a velocity of 30 m/s strikes flat plate the normal of which inclid at 45° the axes of z find the

Normal force on the jet (i) when the plate is stationary

ii. when the plate is moving with velocity of jet 15m/s with the direction of jet and away from the jet also determine the power and efficency of the jet when the plate is moving.

① Normal to jet

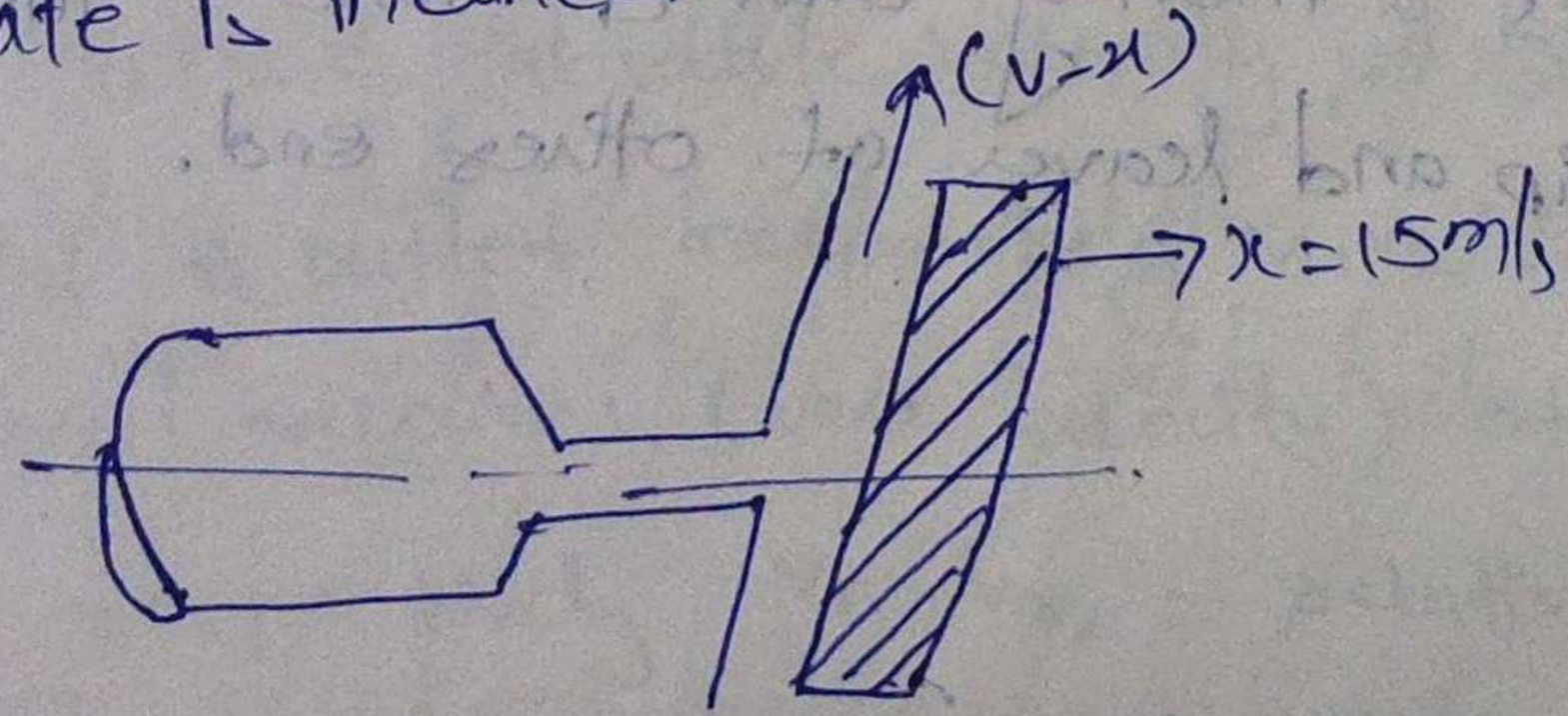


$F_x = \rho a v^2$

$= 1000 \times \frac{\pi}{4} (0.075)^2 \times 30$

$F_x =$

② plate is inclined & in motion



$F_x = \rho a (v-x)^2 \sin\theta$

$F_n = 702.87N$

θ, π = tip angles at inlet & outlet respectively

α, β = angles which the absolute velocities at inlet & outlet respectively.

The triangle ΔABD is called inlet velocity of Δ triangle $\Delta B'D'C'$ is called out let velocity of triangle.

V_{f_1}, V_{f_2} = velocity of flow ~~(or)~~ flow velocity is inlet & outlet velocities.

Inlet velocity triangle.

1. Take any point A & draw a line $AB = V_1$ making an angle α with the ~~horizontal~~ horizontal line A_1D
2. Draw a line $AC = u_1$ and join C to B, CB which represents relative velocity (V_{r1}) of the jet at inlet. If the loss of energy at inlet due to impact zero than CB must be tangential direction to the vane at inlet
3. From B draw a perpendular line BD meeting horizontal line AC produced at D

than BD represents the velocity of flow (V_{f_1}) at inlet & AD represents the velocity of whirl (V_{w_1}) at inlet.

4. The triangle BCD = θ which represents vane angle at inlet ΔABD = α which represents Δ of absolute velocity made by jet

Out let velocity Triangle

i. If the vane is surface assume with smooth the energy loss due friction will be zero and thus $V_{r_1} = V_{r_2}$ will be in tangensial direction to the vane at out let

ii. Draw B', C' in the tangensial direction of the vane at outlet and cut $B'C' = V_{o2}$

iii. From C' draw a line C'A' in the direction of vane ~~and~~ at outlet and equal to u_2, u_2 represents velocity of vane and outlet and join A'B' which represents absolute velocity of jet (V_2) at outlet in magnitude and direction.

iv. from B' draw a perpendular B'D' to meet the A'C' produced at D then B'D' represents velocity of flow (V_{f_2}) and A'D' represents Vewill velocity (V_{w_2}) at outlet respectively.

FINAL