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UPA

Fluid : A fluid is a substance which is capable of flowing and deforming under the action of shear, no matter how small force may be.

In solids, deformation almost constant with time but in liquids deformation changes with time so in fluids rate of deformation is more important than deformation.

- fluid cannot resist shear force under static ~~consider~~. condition.
- fluid deforms continuously under the action of shear force.
- fluid can never regain its original shape, when the shear force is applied.
- Fluids are called as zero memory substance.
- Liquids and gases are example of fluids.

Classification of fluids :-

fluids may be classified into five types:-

(i) Ideal fluid
(ii) Real fluid
(iii) Newtonian fluid
(iv) Non-newtonian fluid
(v) Ideal plastic fluid

(1) Ideal fluid.

→ incompressible, no viscousity, No Surface tension, steady flow, irrotational flow.
↳ Imaginary fluid.
↳ Ex- not available in nature.

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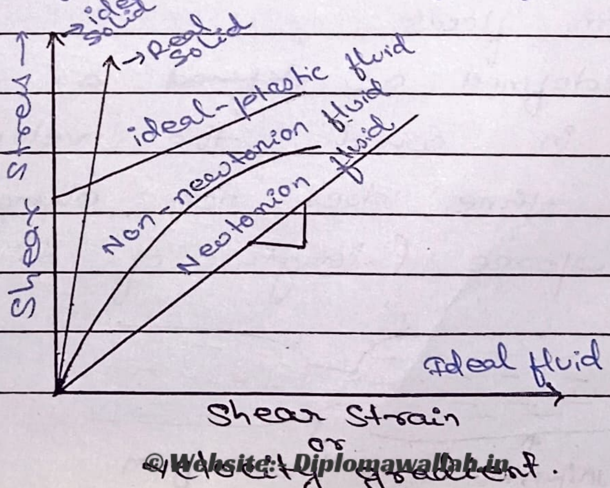
2) Real fluid
↳ compressible, having viscousity, surface tension.
↳ all fluid present in nature are real.
↳ Ex :- water, oil, petrol

3). Newtonian fluid
↳ type of real fluid, shear stress ∝ shear strain.
↳ follows newton's law of viscosity
↳ Ex - water, air, alcohol, Benzene etc
↳ viscosity remains constant.

4). Non-newtonian fluid
↳ type of real fluid, shear stress ∝ shear strain
↳ viscousity of fluid changes
↳ doesn't follow newton's law of viscosity.
Ex - motor oil, blood, shampoo, food sauces paints etc

5) Ideal plastic fluid
↳ Shear stress is more than yeild value.
↳ Shear Stress ∝ Shear strain
↳ we need to ~~produce~~ provide some yeild stress for flow of fluid.



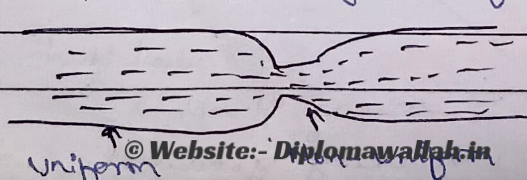
Types of fluid flow :-

- ↳ steady & unsteady
- ↳ laminar and turbulent
- ↳ Uniform and non-uniform
- ↳ compressible and incompressible
- ↳ rotational and irrotational.

1). • Steady flow
- ↳ all conditions ~~ate~~ any point in a stream remains constant with respect to time.
- ↳ the quantity of liquid flowing / sec through any section is constant.
- ↳ velocity, density, pressure etc, does not changes at a point with time
- ↳ Ex :- flow through a pipe with constant $\frac{dv}{dt} = 0$

• Unsteady flow
- ↳ doesnot remain constant
- ↳ is not constant $\frac{\partial v}{\partial t} = 0.$
- ↳ changes
- ↳ Ex :- turbulent flow in a river, blood flow in artics.

2). • Uniform flows
- → is defined as ~~defined as~~ that type of flow in which the velocity at any given time does not change with respect to space (length of direction of flow).



• Non-uniform flows

↳ the velocity at any given time change with respect to space (-).

(3) • Laminar flows

→ the fluid particles move along well defind path or stream line & all the streamline are straight and ||.

Reynolds no helps to predict the flow pattern of fluid

$$Re = \frac{\rho V L}{\mu}$$

density, velocity, length

dynamic viscousity

Re < 2000

• Turbulent flows

↳ fluid particles move in random motion or zig-zag way

↳ High losses occurs in this

Re > 4000

(4) • Compressible flows

↳ flow density of the fluid changes point to point.

↳ density is not constant.

• Incompressible flows

↳ flow density = constant.

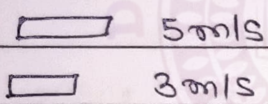
5.) • Rotational flows

↳ In this flow, fluid particles rotates about their on axis while moving along the stream line.

• Irrotational flows

↳ does not rotates.

* Viscousity - It is the property of fluid ~~with~~ which offer's resistance to one layer of fluid by another layer.

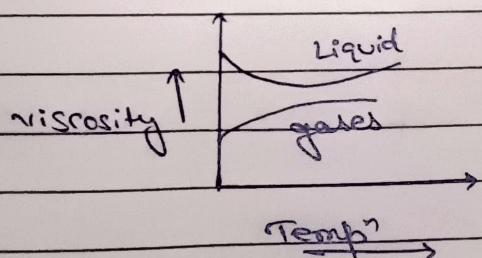


thickness of fluid ∝ viscousity

Newton's law of viscosity = $\dfrac{\text{shear stress}}{\text{shear strain}}$

viscousity of the fluid is independent of rate of deformation.

e.g.- water, air.



Properties of Fluid :-

(i) Density or mass density
(ii) Specific weight or weight density
(iii) Specific volume
(iv) Specific gravity
(v) Viscosity
(vi) Temperature
(vii) Surface tension
(viii) vapour pressure
(ix) pressure

(i) Density/mass density :- It is defined as the ratio of the mass of a fluid to its volume.

$$= \frac{mass}{Vol.} \quad kg/m^3$$

→ It is denoted by symbol ρ (rho).
→ S.I. Unit :- kg per cubic metre (kg/m^3)
→ Density of water : $1 g/cm^3$ or $1000 kg/m^3$
→ Air (ρ_{air}) = $1.23 kg/m^3$

(ii) Specific weight (w) : N/m^3

→ $w = \frac{\text{weight of fluid}}{\text{volume of fluid}} = \frac{(\text{mass of fluids}) \times \text{acc}^n \text{ due to gravity}}{\text{Vol}^m \text{ of Liq.}}$

$$= \frac{\text{mass of fluid} \times g}{\text{Vol}^m \text{ of Liquid}} = \frac{mg}{V}$$

$$\boxed{w = \rho g} \quad \left\{ \because \frac{mass}{Vol^m} = \rho \right\}$$

→ weight density (w) for water = $9.81 \times 1000\ N/m^3 = 9810 N/m^3$

1 kgf = 9.81 N

(iii) **Specific volume** = Vol/mass

$= \frac{1}{\text{density}}$

$$\boxed{\text{specific vol}^m = \frac{1}{\rho}}$$

- The specific volume is the reciprocal of mass density and commonly applied to gases.
- S.I. unit :- m^3/kg

(iv) **Specific gravity or relative density** = $\frac{\text{specific weight of given fluid}}{\text{specific " " standard fluid}}$ (water = 1000 kg/m^3)

→ for Liquids : standard fluid is water [1000 kg/m^3]
→ for gases : standard fluid is air. [1.27 kg/m^3]
→ It is denoted by 'S'.
→ It is also called relative density of it is dimensionless quantity.

$$\boxed{R.D = \frac{\rho_1}{\rho_2}}, \quad (S.G)_f = \frac{\rho_{f(\text{given fluid})}}{\rho_{f}(\text{standard fluid})}.$$

$$\boxed{(S.G)_f = \frac{\rho_F}{\rho_w} = \frac{\rho_F g}{\rho_w g} = \frac{w_F}{w_w}} \rightarrow \text{Liquid.}$$

(5) **viscosity** :- viscosity is the property of the fluid that determines the amount of resistance offered by the fluid to shear stress.

OR

The property of fluids which offers internal resistance betn two adjacement layer is known as viscosity.

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- viscosity is due to (i) cohesive forces (in liquid)
  (ii) Molecular momentum transfer in perpendicular direction betn two adjacent layer.

- In a liquid, viscosity decreases with increases in temperature
  In a gas, viscosity increases with temperature.

Unit of viscosity : Viscosity / Dynamic viscosity / Absolute viscocity (μ).

→ S.I unit $= \mu = \frac{Ns}{m^2}$ or $\frac{kg}{ms}$

→ C.G.S $= \frac{g}{cms}$, $\mu =$ poise

Unit : • Pascal-second (Pa.s) or Poise (P)   1 P = 0.1 Pa-sec

(6) **Temperature** :- The degree of hotness or coldness of the body is determined by the temperature. The temperature of the fluid is measured using kelvin or celsius or fahrenheit.
Unit :- kelin (K), celsius (°C), or fahrenheit (°F).

(7) **Pressure** :- Pressure of a fluid is the force per unit area of the fluid. In other words, it is the ratio of force on a fluid to the area of the fluid held perpendicular to the direction of the force

- Pressure is denoted by the letter 'p'.
- S.I. unit is N/m^2 or pascal.

8). **Surface Tension**: Surface tension is a property of a liquid surface tends to occupy a minimum surface area behaves like a stretched membrane

OR

Surface tension as the force acting per unit length or energy per unit of area at the surface of a liquid.

→ S.I. unit of square tension is N/m or Nm^{-1}

$$\boxed{\gamma = \frac{F}{L} \; N/m} \quad \text{or } Nm^{-1}$$

9) **vapour pressure**: The vapour pressure of a liquid is the equilibrium pressure of a vapour above its liquid. The vapour pressure of the liquid varies with temperature, As the temperature increases, the vapour pressure ~~does~~ ~~not~~ also increases.

Units and its conversion.

1. $1 m^3 = 1000 L$
2. $1 m^3 = 264.172$ gallons
3. $1 L = 0.264$ gallons
4. $1 TMC = 28316.8 m^3$
5. 1 TMC = 2831 crore litres.
6. 1 TMC = 6.22×10^9 imperial gallons

Unit & conversions

1) cubic meter (m^3) = volume
$1 m^3 = 1000 L$

2) Liter (L):
1 Liter = 1000 ml
= $0.001 m^3$

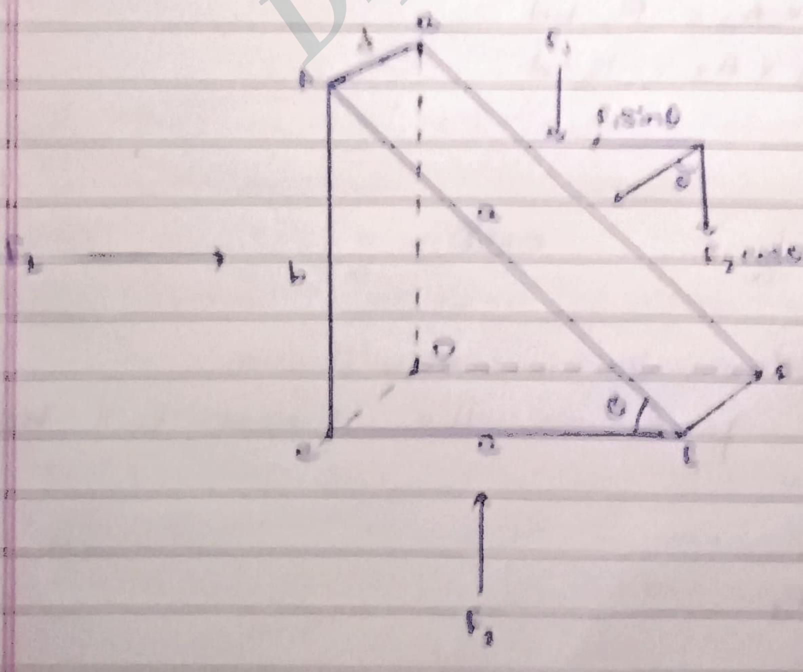
3) gallons:
1 gallon = 3.78541 L

4) TMC (thousand million cubic feet)
used in water resource management, mostly in India
1 TMC = 10^9 cubic feet (ft^3)

Pascal's law : It states that pressure applied to an enclosed fluid will be transmitted without a change in magnitude to every point of the fluid and to the walls of the container.

OR

Pascal's law states that the pressure or intensity of pressure at a point in a static fluid is equal in all direction.



Consider an arbitrary right angled prismatic A in the liquid of density rho.

Let ad, bd, and cd be the area of the faces ABFE, ABDC and CDFE, respectively.

Let P_1, P_2 and P_3 be the pressure on the faces ABFE, ABDC and CDFE.

Pressure exerts a force which is normal to the surface

Let,

P_1 exerts force F_1 on the surface ABFE,
P_2 exerts force F_2 on the surface ABDC,
P_3 " " F_3 " " " CDFE,

$\therefore$

$$F_1 = P_1 \times A_1 = P_1\, ad$$
$$F_2 = P_2 \times A_2 = P_2\, bd$$
$$F_3 = P_3 \times A_3 = P_3\, cd$$

Also,

$$\sin\theta = \frac{b}{a} \qquad \cos\theta = \frac{c}{a}$$

$\because$ The prism is in equilibrium
$\therefore$ The net force on the prism will be 0.

$$F_1 \sin\theta = F_2$$
$$F_1 \cos\theta = F_3$$

$$P_1 ad \times \frac{b}{a} = P_2 bd \quad \text{—— (i)}$$

$$P_1 ad \times \frac{c}{a} = P_3 cd \quad \text{—— (ii)}$$

considering width (d) = 1
Putting d = 1 in (i) & (ii)

$$P_1 a.1 \times \frac{b}{a} = P_2 b \times 1$$

$$\Rightarrow P_1 = P_2 \quad \text{—— (iii)}$$

$$\Rightarrow P_1 \cancel{a} \times 1 \times \frac{c}{\cancel{a}} = P_3 \times \cancel{c} \times 1$$

$$P_1 = P_3 \quad \text{—— (iv)}$$

From (iii) & (iv)

$$\boxed{P_1 = P_2 = P_3}$$

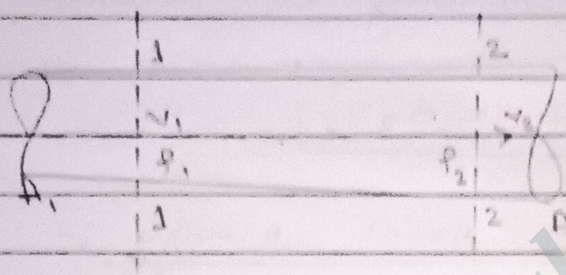
- **Assumptions :-**

1) The fluid is incompressible, at rest (static), homogeneous, enclosed.

2) External forces like gravity are either negligible or accounted for.

3) Pressure is transmitted equally in all directions within the fluid.

* **Continuity equation :-** The equation based on the principle of conservation of mass is called continuity eqⁿ. Thus, for a fluid flowing through the pipe at all the cross-section, the quantity of fluid per second is constant.



consider, a pipe having two cross-section :-
Let,

V_1 = average velocity at cross-section 1-1.
ρ_1 = density of section 1-1.
A_1 = Area of pipe at section 1-1.
V_2 = average velocity at section 2-2.
ρ_2 = density at section 2-2.
A_2 = Area of pipe at section 2-2.

The quantity of fluid per second is constant at all the cross-section of pipe.

- The rate of flow at section 1-1 = $\rho_1 A_1 V_1$
- The rate of flow at section 2-2 = $\rho_2 A_2 V_2$

According to law of conservation of Mass,

Rate of flow at section 1-1 = Rate of flow at section 2-2

$$\boxed{\rho_1 A_1 V_1 = \rho_1 A_2 V_2}$$

→ continuity equation.

- Continuity eqⁿ is applicable to the compressible as well as Incompressible fluid

- If the fluid is incompressible,

$$\rho_1 = \rho_2$$

So, the continuity eqⁿ becomes.

$$\boxed{A_1 v_1 = A_2 v_2}$$

Concept of Total Energy :-

- In fluids, total energy refers to the sum of different forms of energy ~~posed~~ possessed by the fluid at a given point per unit mass or per unit volume of a fluid.
These forms of energy can be divided into three primary components :

1) Kinetic Energy (K.E) :- The energy possessed by a liquid particle by virtue of its velocity or motion is known as kinetic energy.

or

- This is the energy due to the motion of the fluid.

- K.E per unit mass $= \frac{1}{2} \frac{\cancel{m} v^2}{\cancel{m}}$

$$= \frac{v^2}{2}$$

where, v is velocity of fluid.

2. **Potential energy (P.E):-** • The energy possesse by a liquid particle by virtue of its position is called potential energy.

OR

This is the energy due to the position of the fluid in a gravitational field.

• Potential energy per unit mass $= \frac{\cancel{m}gh}{\cancel{m}}$ $\{\because h=z$

$= gz$

where, g = acc. due to gravity (m/s^2)
h = height of fluid above reference point.

3). **Pressure energy:-** • The energy possessed by a liquid particle by virtue of its existing pressure is known as pressure energy.

or

• This is the energy due to the fluid's pressure and is associated with the work done by the fluid when its moves or is compressed

• Pressure energy per unit mass $= \frac{P}{\rho}$

where, P = Pressure (Pa. or N/m^2)
ρ = density of the fluid (kg/m^3)

- **Total Energy Equation :-**

for a steady, incompressible and inviscid flow, the total energy per unit mass is given by the bernoulli's equation :-

$$\boxed{\frac{p}{\rho} + \frac{v^2}{2} + gz = \text{constant}}$$

Where, $\frac{P}{\rho}$ = Pressure energy

$\frac{v^2}{2}$ = kinetic energy

gz = potential energy

Bernoulli's equation :-

It states that in a steady ideal flow of an incompressible fluid, the total energy at any point of the fluid is constant.

The total energy consists of pressure energy, kinetic energy and potential energy or datum energy. These energies per unit mass of the fluid are :-

Pressure energy = $\frac{P}{\rho g}$

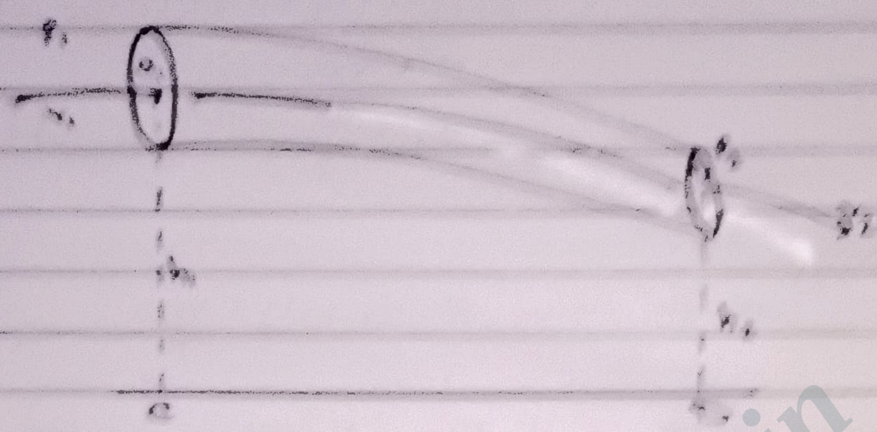
kinetic energy = $\frac{v^2}{2g}$

Potential energy or datum energy = Z

Thus, mathematically Bernolli's eq^n is written as-

$$\boxed{\frac{P}{\rho g} + \frac{v^2}{2g} + Z = \text{constant}}$$

Derivation of Bernoulli's equation :-



* Assumptions :-

(i) The liquid is ideal and incompressible

(ii) The velocity is uniform over the section and is equal to mean velocity.

(iii) The flow is steady and continuous

(iv) The flow is non-viscous.

K.E + P.E + P.E = const.

keywords • $KE = \frac{1}{2} mv^2$

• $PE = mgh$

• work = $F \times d$

• considering loss of energy

Derivation :

$$v_2 > v_1$$

Increase in K.E $= \frac{1}{2} m(v_2)^2 - \frac{1}{2} m(v_1)^2$ —— (i)

Decrease in P.E $= mgh_1 - mgh_2$ —— (ii) work done at C $= F \times d$

$= P_1 \times a_1 \times v_1 \times t$

$= P_1 \times (a_1 \times v_1 \times t)$

$= P_1 \times \text{vol.}$

$= P_1 \times \frac{m}{\rho}$

$v_1 t = L$

$\boxed{\rho = \frac{m}{\text{Vol}^m}}$

Similarly

work done at D $= P_2 \times \frac{m}{\rho}$

Net work done $= P_1 \frac{m}{\rho} - P_2 \frac{m}{\rho}$ —— (iii)

* By conservation of energy

Increase in K.E = Decrease in P.E + work done

$\Rightarrow \frac{1}{2} m (v_2)^2 - \frac{1}{2} m (v_1)^2 = mgh_1 - mgh_2 + P_1 \frac{m}{\rho} - P_2 \frac{m}{\rho}$

$\Rightarrow \frac{1}{2} m (v_2)^2 + mgh_2 + P_2 \frac{m}{\rho} = \frac{1}{2} m (v_1)^2 + mgh_1 + P_1 \frac{m}{\rho}$

$\Rightarrow \frac{1}{2} (v_2)^2 + gh_2 + \frac{P_2}{\rho} = \frac{1}{2} (v_1)^2 + gh_1 + \frac{P_1}{\rho}$

$$\Rightarrow \boxed{\frac{\rho (v_2)^2}{2} + \rho g h_2 + P_2 = \frac{\rho}{2} (v_1)^2 + \rho g h_1 + P_1}$$

Hence Proved

where, P = pressure energy

$\frac{1}{2} \rho v^2$ = kinetic energy per unit volume

$\rho g h$ = potential energy per unit volume

ρ = fluid density (kg/m³)

v = fluid velocity (m/s)

g = Acc^n. due to gravity (m/s²)

h = height above a reference point (m).

Applications of Bernoulli's eqn :-

(i) venturimeter
(ii) orific meter
(iii) pitot tube

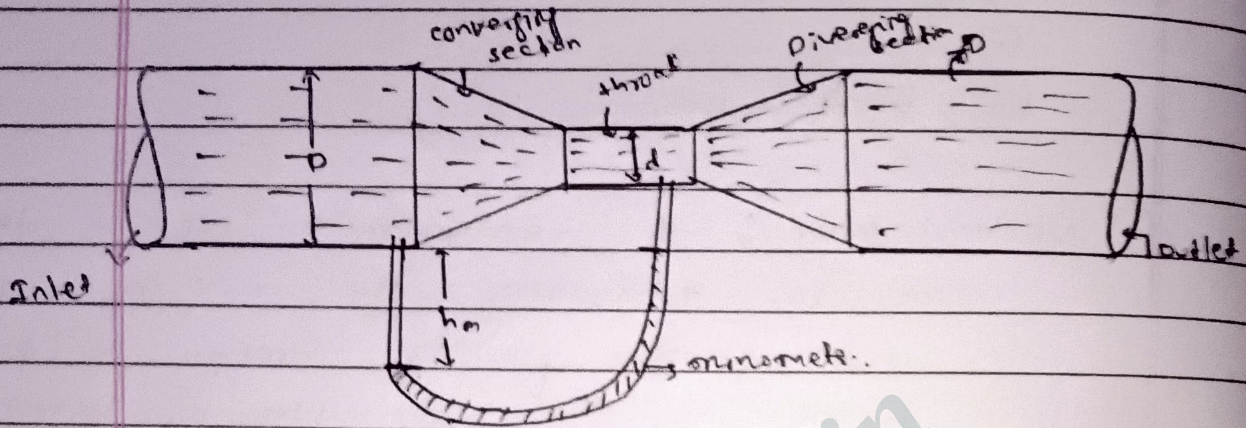
(i) venturimeter : A venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe. It is based on the principle of bernoulli's eqn.

Principle :- The venturimeter operates on the principle of bernoulli's eqn, which states in a steady, incompressible flow, the sum of the pressure energy, kinetic energy and potential energy per unit vol. or mass is constant.

construction :-
A venturimeter consists of three parts are following :-

(i) converging section :- A gradually narrowing section of the pipe where the fluid velocity increases and pressure decreases.
(ii) Throat :- The narrowest section of the venturimeter where the velocity is maximum and pressure is minimum.
(iii) Diverging section :- A gradually expanding section where the fluid slows down.

and pressure recovers to avoid energy losses.



works on the principle of continuity eqⁿ and Bernoulli's Theorem.

<u>Working</u> :- The fluids enters the venturimeter through the converging section. As the cross-sectional area decreases, the velocity of the fluid increases causing a drop in pressure at the throat due to bernoulli's principle, the throat, where the velocity is at its maximum and the pressure is at its minimum.

In the diverging section, the fluid slows down and pressure partially recovers. The pressure difference betⁿ the inlet and throat is measured and the flow rate is calculated using the continuity eqⁿ and Bernoulli's eqⁿ.

$P_1 - P_2 = \frac{\rho}{2}(v_2^2 - v_1^2)$

$$\boxed{Q_{act} = C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}}$$

C_d = co-efficient of venturimeter and value less than 1

(2) Orifice meter or orifice plate :-

It is device used for measuring the rate of flow of a fluid passing through a pipe. It works on the same principle as that of venturimeter. It is cheaper than venturimeter but does not give accurate discharge values as given by venturimeter because of more loss of energy during flow.

Principle :- It is based on the principle of Bernoulli's eqn.

Construction :-

It consists of a flat circular part which has a circular sharp edged hole called as orifice. and the diameter of orifice is 1/2 to 3/4 that of diameter of pipe.

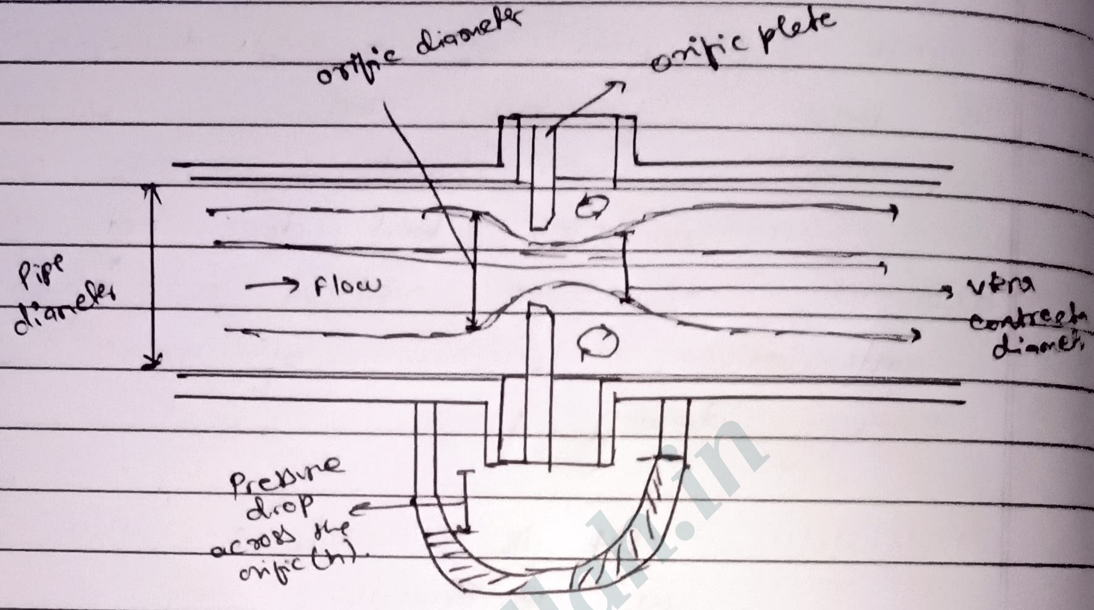
It consists of four parts are below :-

(i) Inlet section : The name inlet section means the fluid will entre into the orifice meter through inlet section.

(ii) Orifice plate : The orifice plate is situated betn the inlet and outlet. It is thin size having one hole from that the water will pass.

(iii) Flow conditioner : The flow conditioner is used to increase the linear flow in the inlet section of the meter ~~section tube~~

(iv) Outlet section : In the outlet section, the pressure of the fluid is being discharged and determined.



pressure diffⁿ betⁿ sections ① & ② is measured.

Actual discharge, $Q_{act} = \frac{C_d\, a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$

where, a_1 = cross-sectional area of pipe $\frac{\pi}{4} d_1^2$

a_2 = area of circular hole $= \frac{\pi}{4} d_2^2$

C_d = co-efficient of discharge for orific meter.

→ It is simple in construction and hence cost of replacement is cheaper as compared to a venturimeter.

→ It requires less space to install.

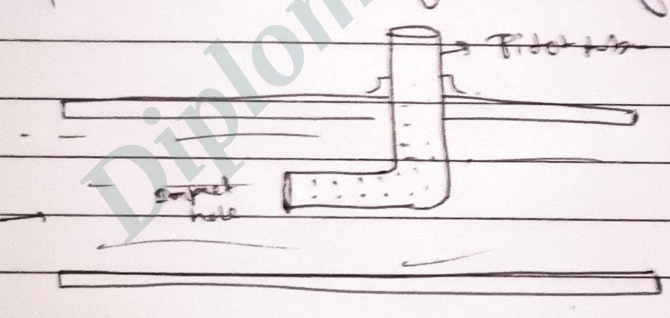
③ Pitot tube :- It is a device used for measuring the velocity of flow at any point in a pipe or a channel.

- It is based on the principle that if the velocity of flow at a point became zero, there is increased in the pressure.

due to conversion of kinetic energy into pressure energy.

- The pitot tube consists of a glass tube, bent at right angle
- The lower end which is bent through 90° is directed in the up-stream direction and the liquid rises up in the tube due to the conversion of kinetic energy into pressure.
- The velocity is determined by measuring the rise of liquid in the tube.

Consider two points ① and ② at the same level in such a way that point ② is just as the inlet of the pitot tube and point ① is far away from the tube.



- Actual velocity is given by :-

$$(V_1)_{act} = C_v\sqrt{2gh}$$

h = rise of liquid in the tube above the free surface.

where, C_v = Co-efficient of Pitot tube

∴ velocity at any point $\boxed{V = C_v\sqrt{2gh}}$