Jharsuguda Engineering School, Jharsuguda

Department of Civil Engineering

Lecture Notes

on

Hydraulics & Irrigation Engineering(Th-2)

(Only Hydraulics Part: A)

(Exclusively for 4th Semester Civil Engineering Diploma Students

under SCTE&VT,Odisha,Bhubaneswar)

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Hydrostatics :-

Hydrostatic pressure is that breach of science which relating to fluids at rest or to the pressures they exert or transmit Hydrostatic pressure.

Fluid :-

=> Fluid is a substance that continuously deforms (flow) under an applied shear stress.

=> Fluids are a subset of the phase of matter and include liquids, gases, plasma and to some extent, plastic solids.

=> Fluid is a substance which is capable of following

=> Conform the shape of the containing vessel.

=> Deform continously under application of small shear force.

=> Both liquid & gas comes under fluid ~~org~~ categories.

Types of Fluid :-

There are basically two types of fluid

(i) Ideal Fluid

(ii) Real Fluid

* Mass Density :-

=) The mass density of fluid ρ, is the mass of the fluid per unit volume.

=) In SI unit is kg/m^3

=) In CGS unit is gm/cm^3

* Weight Density (γ) :-

=) Weight Density is define as the ratio between weight per unit volume.

=) SI unit is N/m^3 / KN/m^3

=) CGS unit is $dyne/cm^3$ or $dyne/cc$

* Specific Gravity :- (G)

=) The Specific Gravity of any fluid is define as the ratio of the density of that fluid to the density of the standard fluid at a given temperature.

$$G = \frac{\text{Weight density of the Substance}}{\text{Weight density of standard fluid at a given temperature.}}$$

standard of fluid taken as water at $4^\circ c$ for water

$$\boxed{\gamma_w = 9.8 \ N/m^3 \text{ or } 1 \ gm/cc}$$

$$\boxed{G = \frac{\rho_s}{\rho_\omega} \text{ or } \frac{\gamma_s}{\gamma_\omega}}$$

$\rho_\omega = 1000 \ kg/m^3$ or $1 \ gm/cc$

$\gamma_\omega = 1000 \times 9.81 = 10000 = 9.81 \ kN/m^3$

Unit Weight of R.C.C.

$\rho_s = 2500 \ kg/m^3$

$\gamma_\omega = 25 \ kN/m^3$

Specific gravity of R.C.C (G)

$$= \frac{2500}{1000}$$

$$= 2.5$$

=> Specific gravity has no unit.

Specific gravity of Mercury is 13.6.

Specific Volume :-

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

$$\boxed{\text{Specific volume} :- \frac{\text{Volume of fluid}}{\text{Mass of fluid}}}$$

$$= \frac{m^3}{kg} \text{ or } \frac{cm^3}{gm}$$

Specific volume is reciprocal of mass density.

★ Viscosity :-

Viscosity is defined as the property of fluid by virtue of which there is a resistance to flow of liquid layers one over another. is called viscosity.

Mathematically :-

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

Where,

$\tau \rightarrow$ Shear stress

$\frac{du}{dy} \rightarrow$ is called velocity gradient.

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$\mu \rightarrow$ Proportionality constant called coefficient of dynamic viscocity.

$u \rightarrow$ Velocity of flow of liquid layers.

$y \rightarrow$ The distance of the layer from a solid boundary.

Newton's Law of viscocity :-

It state that the sheare stress develop in a fluid layer is directly propotional to the rate of change of velocity with respect to distance.

(i) Newtonion fluid (obey's Netwton's law)

(ii) Non Newtonion fluid (dosen't obey Newton's law)

Mathematically :-

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

Unit of Dynamic viscocity :-

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

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$$\mu = \frac{\tau}{\frac{du}{dy}} = \frac{\text{Shear stress}}{\frac{\text{Change of velocity}}{\text{Change of distance}}} = \frac{\text{Force/Area}}{\frac{\text{Length}}{\text{time}} \times \frac{1}{\text{Length}}} = \frac{\text{Force/(Length)}^2}{1/\text{time}}$$

$$= \frac{\text{Force} \times \text{time}}{(\text{Length})^2}$$

- MKS System $\mu = \dfrac{\frac{kgf}{m^2}}{\frac{m/sec}{m}} = \dfrac{kgf\ sec}{m^2}$

$$\boxed{\mu = \frac{kgf\ sec}{m^2}}$$

CGS System $= \dfrac{gmf\ sec}{cm^2} = \boxed{\dfrac{dyne \cdot sec}{cm^2}}$

$$\boxed{SI = \frac{N\ sec}{m^2}}$$

$1\ kgf = 9.81\ N$

$$1\ \frac{dyne\ sec}{cm^2} = 1\ \text{poise}$$

$$= \frac{1\ kgf\ sec}{m^2} = \text{poise}$$

$$= \frac{9.81\ N\ sec}{m^2}$$

$$= \frac{9.81 \times 10^5}{(10^2)^2\ cm^2}$$

$$= \cancel{9.81}\ 98.1 \ \frac{dyne\ sec}{cm^2}$$

$= 98.1$ poise

$$\boxed{\frac{1\ kgf\ sec}{m^2} = 98.1\ Poise}$$

$$1 \ \frac{N\ sec}{m^2}$$

$$= \frac{10^5\ sec}{(10^2)^2}$$

$$= 10 \ \frac{dyne\ sec}{cm^2}$$

$= 10$ poise

$$\boxed{\frac{1\ N\ sec}{m^2} = 10\ Poise}$$

$$\boxed{1\ Poise = \frac{1}{10}\ \frac{N\ sec}{m^2}}$$

Kinamatic viscocity :— ν (nu)

it is the ratio between dynamic viscocity and the density of a fluid.

$$\nu = \frac{\mu}{\rho} \qquad \frac{N/sec\ /\ m^2}{kg/m^3}$$

$$= \frac{\frac{kg.m \times sec}{sec^2 \times m^2}}{kg/m^2}$$

$$= \boxed{\frac{kg.m \times sec}{sec^2 \times m^2} \times \frac{m^2}{kg}}$$ (1)

$$= \frac{m^2}{sec}$$

Units :-

MKS / SI. MKS. $\boxed{\nu = \frac{m^2}{sec}}$

CGS $= \frac{cm^2}{sec}$ $\boxed{\nu = \frac{cm^2}{sec}}$

1 stoke $= \frac{1\ cm^2}{sec}$

$= 10^{-4}\ m^2/sec$

Variation of viscocity with temperature

For Liquid, viscocity is inversely propotional to temperature

$$\text{viscocity} \propto \frac{1}{\text{temperature}}$$

For gas, viscocity is directly propotional to temperecture

viscocity α temperatuce

(1) Calculate the specific weight, density and specific Gravity of 1 Liter of a Liquid is weight 7 N.

given:-

Volume of Liquid $= 1 l.$

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

wt of the Liquid $= 7 N$

Specific weight $= \frac{7 N}{10^{-3}}$

$= 7000 \ N/m^3$

Density $= \rho = \frac{M}{V} = \frac{\gamma}{g}$

$= \frac{7000}{9.81} = 713.5$

Specific gravity of (G)

$$= \frac{\rho_s}{\rho_w}$$

$$= \frac{713.5}{1000}$$

$$= 0.713$$

Ans

2 Calculate Density, Specific Weight and Weight of 1l of Petrol of Specific gravity 0.7.

Given:-

G = 0.7

volume = 1l

$= 10^{-3} m^3$

Density =

$$G = \frac{\rho_s}{\rho_w}$$

$$\rho_s = G \rho_w$$

$= 0.7 \times 1000$

$= 700$

Specific weight :-

$$\gamma = \rho g$$

$$= 700 \times 9.81$$

$$= 6867 \ N/m^3$$

$$wt = \frac{6867}{1000}$$

$$= 6.86 \ kg$$

3 The velocity Profile of a Fluid is given by

$$u = \frac{2}{3}y - y^2$$

Where u = velocity of the Fluid in m/sec at a distance y m. above the plate Calculate the Shear Stress develop at the Surface of the plate and at a distance 0.15 m above the plate. take the dynamic viscosity of a Fluid as 8.63 poise.

$$\frac{du}{dy} = \frac{d}{dy}\left(\frac{2}{3}y - y^2\right) = \frac{2}{3} - 2y$$

τ = sheare stress at the Surface of the Plate

$y=0$ $\mu \frac{du}{dy} \Big]_{y=0}$

$= 8.63 \left(\frac{2}{3} - 2\times 0\right)$

$= 8.63 \times \frac{2}{3}$

$= 5.75 \frac{dyne}{cm^2}$

$\tau_{y=0.15}$

$= 8.63 \left(\frac{2}{3} - 2\times 0.0015\right)$

$= 5.72$ dyne/cm^2

Assignment :-

Q Two horizontal plates are plased 1.25 cm apart the Space between them being filled with oil of viscocity 14 poises. Calculate the shear stress in oil if upper plate is moved with a vilocity of 2.5 m/s.

Ans Given:-

Plate distance (dy) = 1.25 cm

$= 0.0125$ m.

viscocity (μ) = 14 poise

$= \frac{14}{10} \frac{N\ sec}{m^2}$

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velocity = 2.5 m/sec

We know that

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

$$du = u_1 - u_2$$

$$= 2.5 - 0$$

$$= 2.5 \text{ m/sec}$$

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

$$= \frac{14}{10} \times \frac{2.5}{0.0125}$$

$$= 280 \text{ N/m}^2$$

Surface Tension :- (σ)

⇒ Surface tension is define as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two ~~immiscible~~ immiscible liquids such that the contact surface behaves like a membreane under tension.

⇒ The magnitude of this force per unit length of the free surface will have the same value as the surface energy per unit area.

⇒ It is denoted by greek letter sigma (σ).

Units of Surface tension :-

MKS Units $= \frac{kgf}{m}$

SI Units $= N/m$

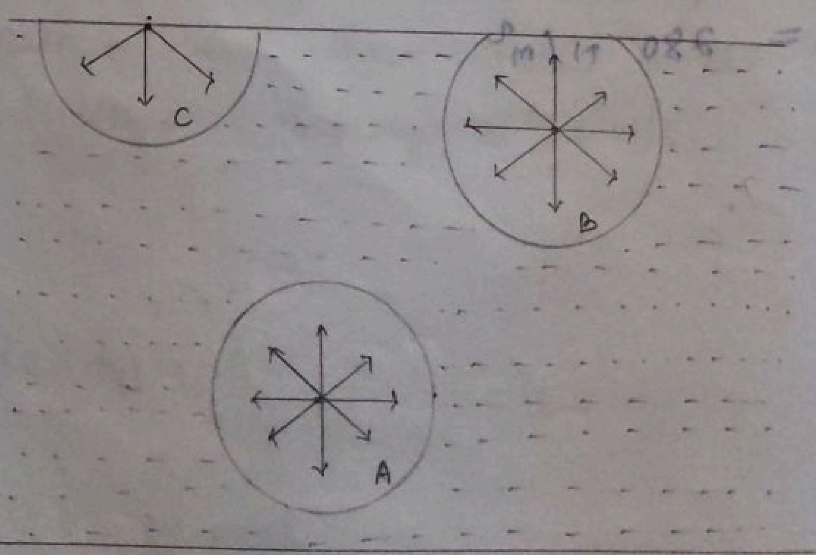
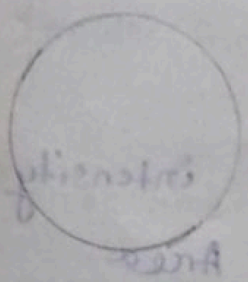
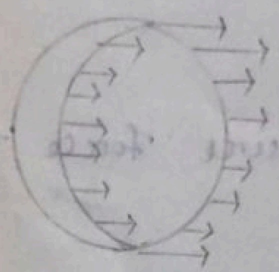


Fig Surface Tension

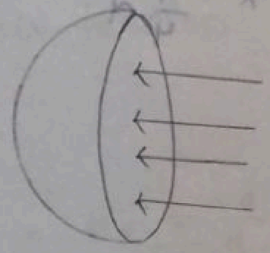
* Surface Tension on Liquid Droplet :-



Droplet



Surface tension



Consider a small spherical droplet of a liquid of radius 'r'. on the entire surface of the droplet, the tensile force into the surface temperature will be acting.

Let σ = Surface tension of Liquid

p = Pressure intensity inside the droplet

d = Diameter of droplet.

Let the droplet is cut into two halves
The tensile force due to surface tension acting around the circumference of the cut portion.

$T = \sigma \times \text{Circumference}$

$= \sigma \times \pi d$ —— (i)

Pressure force = Pressure intensity inside the droplet × Area

$= p \times \frac{\pi}{4} d^2$ —— (ii)

A equilibrium

From equation (i) & (ii)

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

$\Rightarrow \boxed{p = \frac{4\sigma}{d}}$

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* Surface Tension in Bubble :-

(out side) ~~Sub~~ Surface tension developed $= 2 \times \sigma \times \pi d$

Inside Pressure $= P$

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

At equilibrium

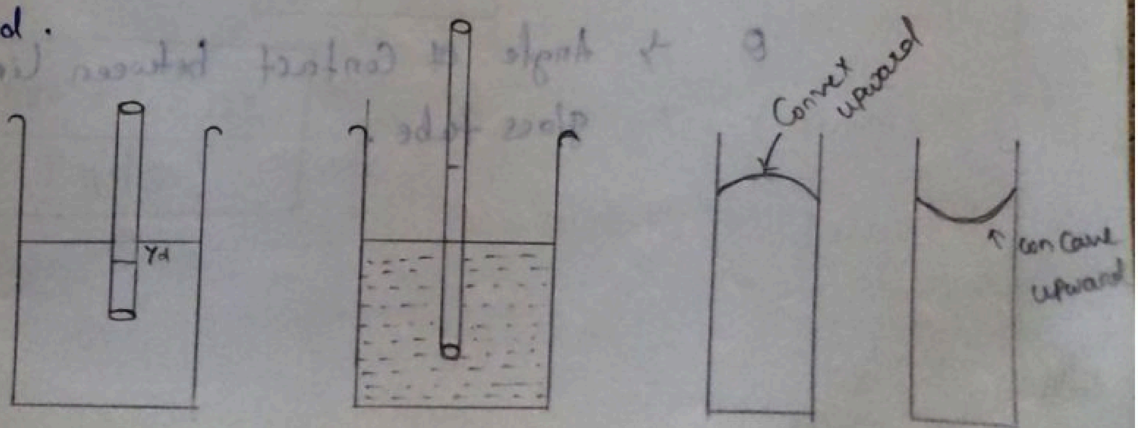
Surface tension developed = Inside Pressure force.

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

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

* Capillarity :-

Capillari is a property of fluid by virtue of which it rises or dipress when a pipe is inserted inside the fluid.



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⇒ Capillarcity can be measured in two ways

(i) Capillary Rise

(ii) Capillary depression

→ Rising of fluid inside the tube.

→ Lowering of the fluid inside the tube.

⇒ It is measured in mm, cm, m.

Mathematically

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

Where,

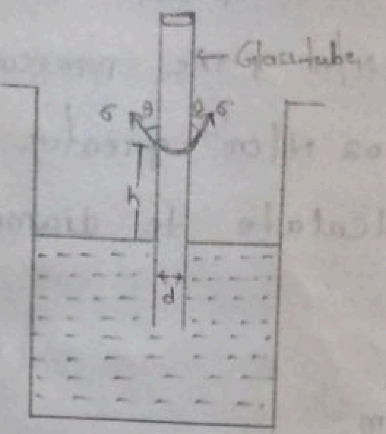
σ → Surface tension

ρ → density

g → acceleration due to gravity

d → diameter of pipe

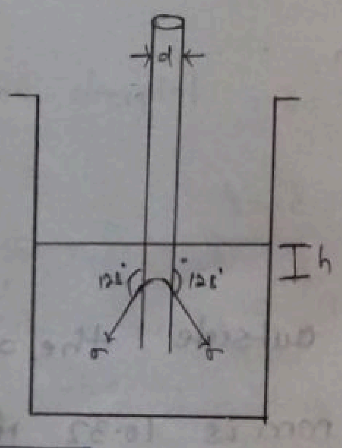
θ → Angle of Contact between liquid and glass tube.



For water, $\theta = 0°$

so = $\boxed{h = \dfrac{4\sigma}{\rho g d}}$

=> For mercury $\theta = 128°$



$$\boxed{h = \frac{4 \times \sigma \times \cos 128°}{\rho g d}}$$

1Q The Surface tension of water in contact with air at $20^\circ C$ is 0.0725 N/m. The pressure inside the droplet of water is 0.02 N/cm^2 greater then the outside Pressure. Calculate te diameter of the droplet of water.

Ans:-

$\sigma = 0.0725\ N/m$

$P = 0.02\ N/cm^2$

$= 0.02 \times 10^4\ m.$

$P = \dfrac{4\sigma}{d}$ $\quad d = \dfrac{4\sigma}{P}$

$= \dfrac{4 \times 0.0725}{0.02 \times 10^4}$

$= 1.45 \times 10^{-3}\ m$

$= 1.45\ mm.$

Q-2 The Pressure outside the droplet of water of diameter 0.04 mm is 10.32 N/cm^2 (atmospheric Pressure). Calculate the pressure with in the droplet if Surface tension is 0.0725 N/m of water

Given

$d = 0.04\ mm = 0.04 \times 10^{-3} m.$

$P = 10.32\ N/cm^2$

$= 10.32 \times 10^{3}$

$\sigma = 0.0725\ N/m$

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

$$= \frac{4 \times 0.0725}{0.04 \times 10^{-3}}$$

$$= 0.725\ N/cm^2$$

Pressure inside the droplet $= 0.0725 +$ outside pressure

$= 0.725 + 10.32$

$= 11.045\ N/cm^2$

Dt:- 30/08/2022

Q- Calculate the capillary rise in a glass tube of 2.5 mm diameter when immerged vertically in (a) water
(b) mercury

Take $\sigma = 0.0725$ N/m For water &
0.52 N/m For mercury in Contact with air.

The Specific gravity of mercury is 13.6 & the angle of Contact is 130°.

Given:-

$d = 2.5$ mm
$= 2.5 \times 10^{-3}$ m.

σ for water $= 0.0725$

$\rho = 1000$ kg/m^3

$\theta = 0$

For water

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

$$= \frac{4 \times 0.0725 \times \cos(0)}{1000 \times 9.81 \times 2.5 \times 10^{-3}}$$

$$= 0.01182 \text{ m.}$$

$$= 11.82 \text{ mm.}$$

For mercury

$\sigma = 0.52$

$\rho = 13.6$

$\theta = 130'$

$d = 2.5$ m.

$\rho_s = \rho_w \times G$

$= 1000 \times 13.6$

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

$$= \frac{4 \times 0.52 \times \cos 130'}{1000 \times 13.6 \times 9.81 \times 2.5 \times 10^{-3}}$$

$= -0.004008$ m.

$= -4.008$ mm

Q Findout the minimum size of glass tube that can be used to measure water level, the capillary rise in the tube is to be restricted to 2mm. Consider the surface tension of water in conctact with air as 0.073575 N/m.

Given :-

$h = 2$ mm

$= 2 \times 10^{-3}$

$\sigma = 0.073575$

$\theta = 0$

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

$$\Rightarrow 2\times10^{-3} = \frac{4\times 0.073575\times\cos(0)}{1000\times 9.81\times d}$$

$$\Rightarrow 2\times10^{-3} = \frac{0.2943}{9810\times d}$$

$$\Rightarrow \cancel{2\times10^{-3}\times 9810}$$

$$19.62d = 0.2943$$

$$\Rightarrow d = \frac{0.2943}{19.62}$$

$$\Rightarrow d = 0.015\ m.$$

$$d = 15\ mm$$

Fluid Pressure & Its Measurement

Fluid Pressure At a Point :-

Considere a Small area dA. in a large mass of fluid, then the force exterted by the Surrounding ~~area~~ fluid on the area dA will always be perpendicular to the Surface of dA.

Let dF is the force acting on the Area dA in normal direction then the intensity of Pressure or pressure.

$$\boxed{P = \frac{dF}{dA}}$$

If the force is uniformly distributed over the area A then the pressure at any point is given by,

$$P = \frac{F}{A}$$

$$\boxed{F = P \times A}$$

Units of Pressure :-

In MKS → kgF/m^2 or kgf/cm^2

In SI → N/m^2 or N/mm^2

$1\ N/m^2 = 1$ Pascal

$= 1 Pa$

[1 kPa = 10^3 Pa
1 MPa = 10^6 Pa]

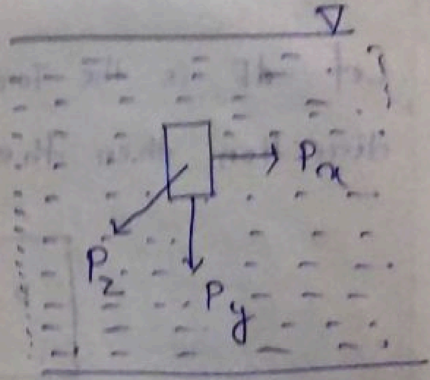
[1 bar = 100 KPa
$= 100 \times 10^3$ Pa
1 bar = 10^5 Pa]

* Pascal's Law :-

It states that, "the pressure or intensity of pressure at a point in a static fluid is equal in all direction".

mathematically.

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

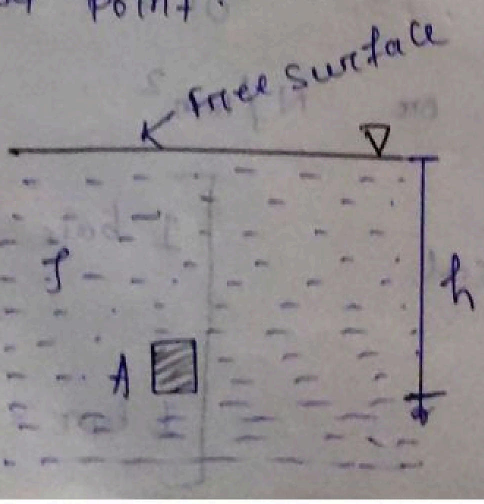


* Variation of pressure in a fluid at rest :-

The pressure at any point in a fluid at rest is obtained by hydrostatic law

* Hydrostatic Law :-

It states that, the rate of increases of pressure in a vertically downward direction most be equal to the specific weight or weight density of the fluid at that point.



Mathematically,

$$\boxed{P = \rho g h} \rightarrow \text{Hydrostatic Pressure}$$

Hydrostatic force $= P \times A$

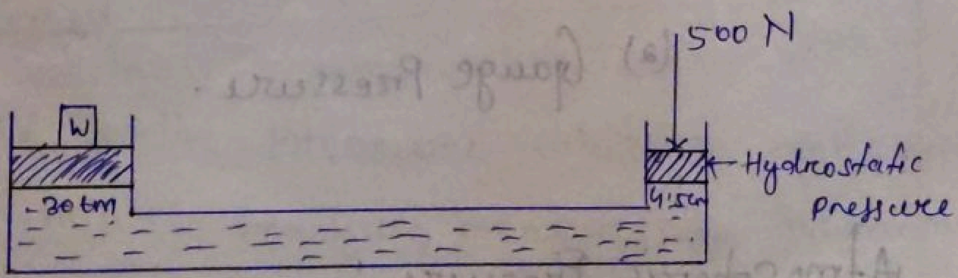
Where p is the pressure above the atmospheric pressure.

g = Accelaration due to gravity

h = Pressure head.

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

Q- A hydrolic press as a RAM of 30 cm diameter and a plunger of 4.5 cm diameter find the weight lifted by the hydrolic press when the force applied at the plunger is 500 N.



$d_1 = 30\,cm$

$d_2 = 4.5\,cm$

$F_2 = 500\,N$

$$P = \frac{F}{A} = \frac{500}{\frac{\pi}{4} \times (0.045)^2}$$

$$= 314380.13 \ N/m^2$$

$$wt = P \times \text{Area of RAM}$$

$$= 314380.13 \times \frac{\pi}{4} \times (0.3)^2$$

$$= \cancel{22} \ 22222.22 \ kN$$

Types of Fluid Pressure :-

Two type of Pressure measurement systems.

(1) Absolute Pressure / absolute zero / Complete vaccume Pressure

(2) Gauge Pressure.

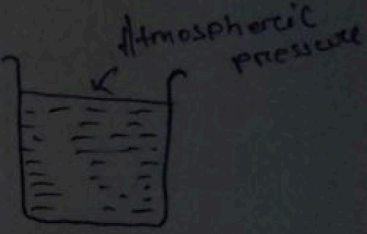
Atmospheric Pressure :-

The pressure at the sea level at ~~0~~ 15°C is 101.3 kN/m^2 or ~~10.15~~ 10.13 N/cm^2 (SI System)

1.033 kgf/cm^2 (MKS)

Pressure head - 760 mm Hg

10.33 m of water.



Vacuum Pressure :-

It is the Pressure below atmospheric Pressure.

Absolute Pressure :-

It is defined as the pressure which is measured with respect to absolute vaccume Pressure.

Gauge Pressure :-

It is defined as the pressure which is measured ~~to~~ with the help of pressure measuring instrument in ~~ab~~ which ~~at~~ atmospheric pressure which is taken as datum.

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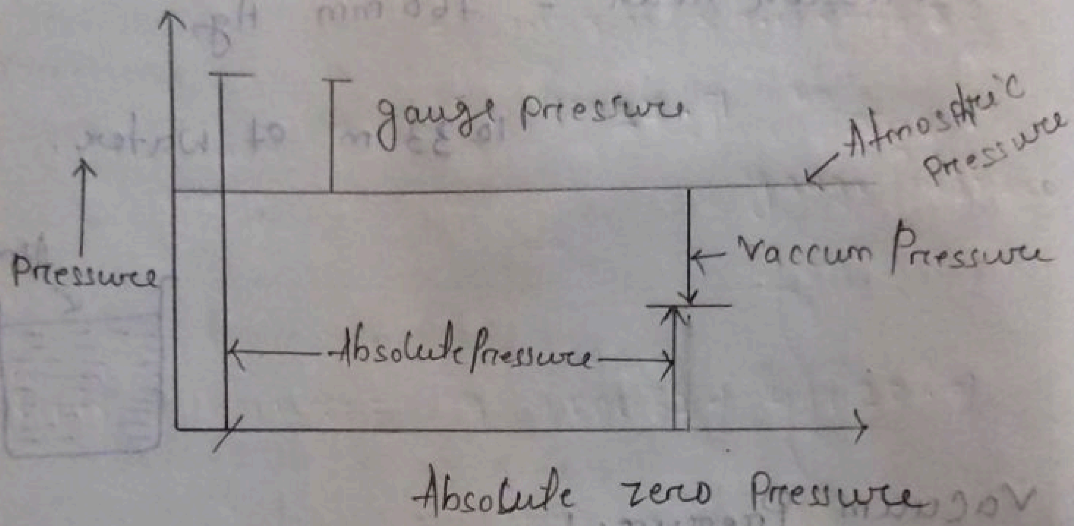
The atmospheric pressure the scale is Iaang mark as zero.



Mathematically,

$$\boxed{\text{Absolute Pressure} = \text{Gauge Pressure} + \text{Atmospheric Pressure}}$$

$$\boxed{\text{Vaccume Pressure} = \text{Atmospheric Pressure} - \text{Absolute Pressure}}$$

Q What are the gauge Pressure and absolute pressure at a Point 3 m. below the free Surface of liquid having density 1.53×10^3 kg/m³, if atmospheric pressure is equivelent to 750 mm of murcury. the Specific gravity of murcury is 13.6 and density of water 1000 kg/m³.

given data,

Depth of point from free Surface of liquid = 3 m.

Density of liquid = $\rho = 1.53 \times 10^3$ kg/m³

Atmospheric pressure head = 750 mm Hg

Specific gravity (g) Hg = 13.6

Density of water = 1000 kg/m³

Atmospheric pressure = $\rho g h$

$= \cancel{\ldots}$

$= 13.6 \times 1000 \times 9.81 \times 0.75$

$= 100062$ kg/m³

Pressure at 3m depth of liquid

$= \rho g h$

$= 1.53 \times 10^3 \times 9.81 \times 3$

$= 45027.9$ kg/m²

gauge Pressure

Absolute Pressure = $100062 + 45027.9$

$= 145089.9$

Pressure Measurement :-

There are two type of Pressure measuring instrument

(i) Manometer

(ii) Mechanical gauge

1) Manometer :-

Manometer are the devices used for measuring Pressure at a point in a fluid by balancing the Colum of fluid of the same fluid or another fluid.

Manometer are of two types

(i) Simple manometer
(ii) Differential manometer

Simple manometer :-

=> It is a pressure measuring instrument in which a glass tube having one end connected to a point where the pressure is to be measured and other end is open to atmosphere

=> These are of three type

(i) piezo meter
(ii) U-tube meter
(iii) single column manometer

2. Mechanical Gauge

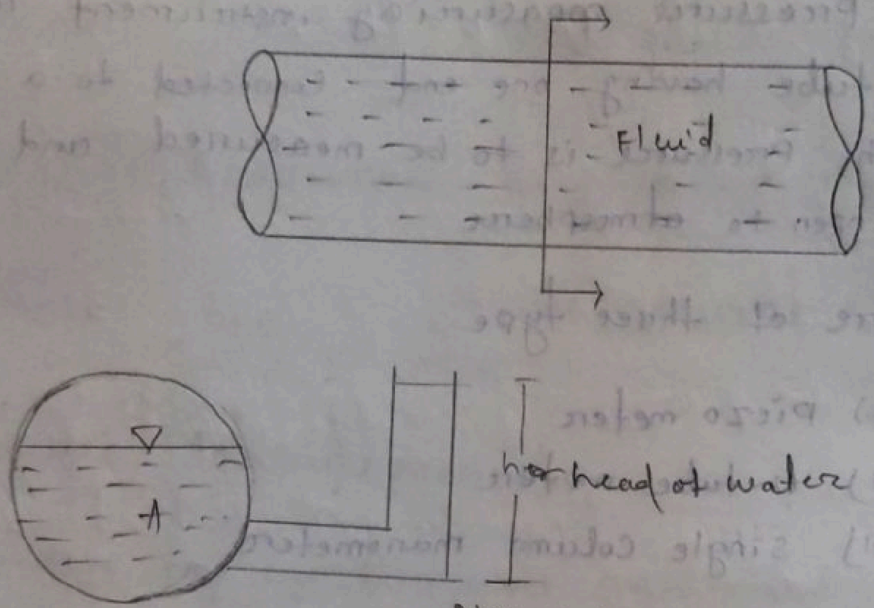
=> These are the devices used for measuring pressuring at a point in a fluid by balancing the column of fluid by a spring or dead weight.

=> These are 4 type :-

(i) Diapharagm pressure gauge
(ii) Bourdon tube pressure gauge
(iii) Dead weight pressure gauge
(iv) Bellows pressure gauge

(i) Piezo meter :-

These are the Simplest type of simple manometer in which a glass tube is connected to a point where the pressure is to be measured and other end of the glass tube is open to atmosphere.

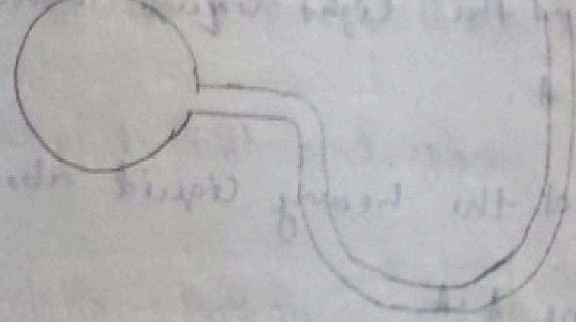


Piezo meter.

section X-X

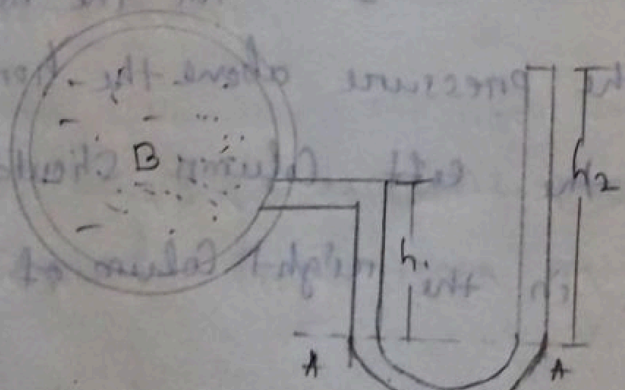
(ii) U- tube manometer

It Consists of a glass tube ~~wh~~ bent in U-shape, ~~and~~ one end of which is Connected to a point at which pressure is to be measured. of the other end remains open to the atmosphere.



U tube manometere.

=> The tube genercaly contents merrcury orr any othere Fluid whose Specific gravity is ~~gred~~ greatere than the Specific gravity of liquid whose Pressurre is to be measurre.



P is the point at which pressure is to be measure whose value is P.

let h_1 = height of the light liquid above the dotted line A A.

h_2 = height of the heavy liquid above the dotted line A·A.

S_1 = Specific gravity of light liquid

S_2 = Specific gravity of heavy liquid

ρ_1 = Density of light liquid = $1000 \times S_1$

ρ_2 = Density of heavy liquid = $1000 \times S_2$

as the pressure is same for the horizontal surface, the pressure above the horizontal line A A. in the left column should be equal to the pressure in the right colum of U-tube manometer.

Pressure above A A the left column =

$$= P + \rho_1 g h_1$$

Pressure above AA the right column -

$$= \rho_2 g h_2$$

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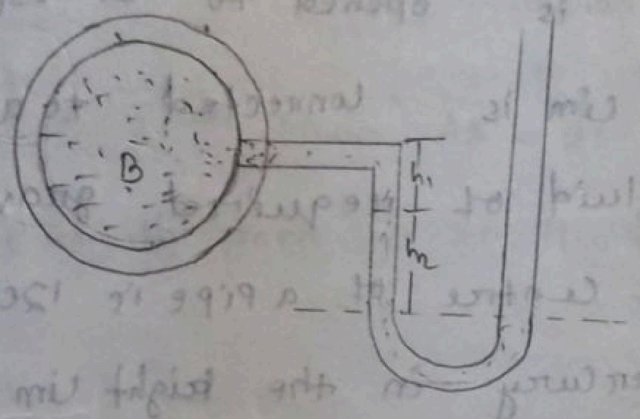
Now, equation both column we have

$$P + \rho_1 g h_1 = \rho_2 g h_2$$

$$\boxed{P = \rho_2 g h_2 - \rho_1 g h_1}$$

Vaccume Pressure :-



For measuring the vaccume pressure, the level of heavy liquid in the mano meter will be as shown in figure.

Pressure above a A A in the left column

$$= P + \rho_1 g h_1 + \rho_2 g h_2$$

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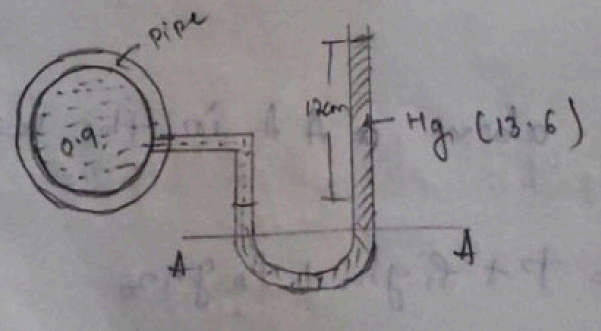
Pressure above A-A in right column above AA = 0

Now

$$P + \rho_1 g h_1 + \rho_2 g h_2 = 0$$

$$\boxed{P = -(\rho_1 g h_1 + \rho_2 g h_2)}$$

The right link of of a simple U-tube manometer contains is opened to atmosphere while the left lim is connected to a pipe in which a fluid of required gravity 0.9 is following centre of a pipe is 12cm below the level of mercury in the right lim. Find the pressure of the fluid in the pipe if the difference of mercury level in the two lims is 20 cm.



Difference in mercury level in two limbs of

U- tube manometer = 20 cm.

Specific gravity of fluid = $S_1 = 0.9$

Density of fluid = $\rho_1 = 0.9 \times 1000 = 900 \ kg/m^3$

Specific gravity of Hg = ~~900~~ 13.6.

Density of mercury = $13.6 \times 1000 \ kg/m^3$

Ht of fluid from AA = 20 - 12 - 8 cm = 0.08 m.

Let P is the pressure of fluid inside the pipe.

Left side pressure = Right side pressure

$$P + \rho_1 g h_1 = \rho_2 g h_2$$

$$P = \rho_2 g h_2 - \rho_1 g h_1$$

$$= (13.6 \times 1000 \times 9.8 \times 0.2) - (900 \times 9.8 \times 0.08)$$

$$= 25976.88 \ N/m^2$$

Q A simple U-tube manometer containing mercury is Connected to a pipe with fluid of specific gravity 0.8 and having vaccume pressure is flowing the other end of the manometer is open to atmosphere. Find the vaccume pressure in the pipe. if the difference of mercury level in the two pipe is 40 cm. and height of the fluid in the left limb from the centre of the pipe is 15 cm below

Hydrostatic Force on Surfaces :- 08/04/202

-> When we Submerged any plane object in a Fluid mass the forces that are exerted on the ~~Fluid~~ Plane ~~on the object~~ due to the fluid is called Hydrostatic force.

-> This is due to the pressure of the fluid.
The self rate of fluid particle

-> The Fluid pressure will act normal to the surface on the plane.

Total Pressure :-

It is defined as the force exerted by a static fluid on a surface either plane ~~or~~ Curve when the fluid Comes in Contact ~~to~~ with the surfaces

-> This force alway acts normal to the surface.

Centre of Pressure :-

-> It is define as the point of application of the total Pressure on the surface.

Conditions of Submerged Surfaced :-

The Submerged Surfaces are of foure type

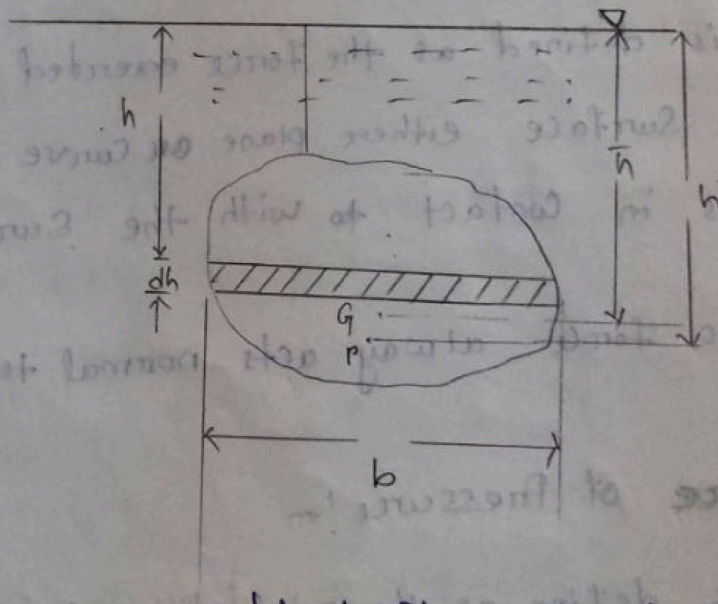
(i) vertical plane Surfaces.

(ii) Horizontal plane Surfaces.

(iii) Inclined plane surfaces.

(iv) Curve Surfaces.

(1) Vertical Plane Surfaces ~~on~~ Submerged in Liquid :-



Let us consider a vertical plane surface of arbitary shape submerged in a liquid as shown in figure.

Let,

⇒ A = Total Area of the surface

⇒ $\bar{h}$ = Distance of CG of the Area from the free Surface of Liquid.

⇒ G = It is the centre of gravity of the plane Surface.

⇒ P. = It is the centre of pressure

⇒ h^* = It is the Distance of centre of pressure form free surface of Liquid

(a) Calculation of total Pressure :- (F)

The total pressure on the surface can be determine by dividing the entire surface into No of small parallel strips.

The force on the small strip is then calculated and the total pressure on the whole area is calculated by intigrating the force on small strip.

Let the thickness of the strip is dh and width is b.

which is at a depth of h. from free surface of the liquid.

Pressure intensity on the small strip

$$= \rho g h$$

Area of the strip $= dA = b \times dh$

The total pressure force on the strip $= \rho g h \, dA$

$$dF = \rho g h \times b \times dh$$

Total pressure on the plane =

$$\int dF = \int \rho g h \, b \, dh$$

Again $\int b h \, dh = \int h \, dA$

= moment of surface area about the free surface of liquid.

= Area of the surface × Distance of the CG from the free surface.

$$= A \times \bar{h}$$

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$$\boxed{F = \rho g A \bar{h}}$$

Calculation of centre of pressure :- (F^*)

The centre of pressure is calculated using the principle of moments. which states that the moment of the resultant force about an axis is equal to the sum of moment components about the same axis.

The resultant force F is acting at P which is at a distance h^* from the free surface of liquid as shown in figure.

So the moment of force F about free surface

$$= F \times h^* \quad \text{——} \ (1)$$

The moment of force dF about free surface

$$= dF \times h$$

$$= \rho g h \times b \times dh \times h$$

$$= \cancel{\rho g h^2 \times} \ \rho g b h^2 \times dh$$

$$= \rho g h^2 dA$$

Sum of the moment of all ~~surface~~ such forces about the free surface of liquid

$$= \int \rho g h^2 \, dA$$

$$= \rho g \int h^2 \, dA$$

But $\int h^2 \, dA$ = moment of inertia of the surface about the free surface of liquid

$$= I_0$$

Sum of moment about free surface

$$= \rho g I_0 \quad \text{—} \quad (2)$$

Now equating equation (1) and (2) we have

$$F \times h^* = \rho g I_0$$

Again = $F = \rho g \bar{h} A$

$$\cancel{\rho} \cancel{g} \bar{h} A \times h^* = \cancel{\rho} \cancel{g} I_0$$

$$\boxed{h^* = \frac{I_0}{A\bar{h}}}$$

applying parallel axis theorem we have

$$I_0 = I_G + A\bar{h}^2$$

Substituting I_0 in eqn (3)

$$h^* = \frac{I_G + A\bar{h}^2}{A\bar{h}}$$

$$\boxed{h^* = \frac{I_G}{A\bar{h}} + \bar{h}}$$

From the above equation it is clear that the centre of pressure lies below the centre of gravity of the vertical surface.

The distance of centre of pressure from the free surface of liquid is indipandent of the density of the liquid.

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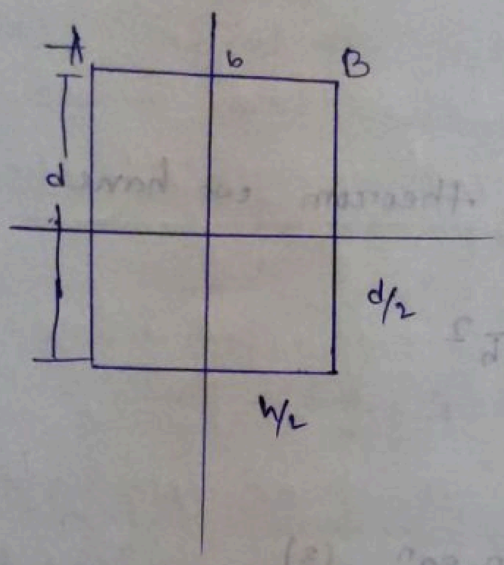
Location of CG Some common Surface:-



$$I_{xx} = \frac{bd^3}{12}$$

$$I_{CD} = I_{cg} + Ad^2$$

$$= \frac{bd^3}{12} + bd \times \left(\frac{d}{2}\right)^2$$

$$= \frac{bd^3}{12} + bd \times \frac{d^2}{4}$$

$$= \frac{bd^3}{12} + \frac{bd^3}{4}$$

$$= \frac{bd^3 + 3bd^3}{12}$$

$$= \frac{4bd^3}{12}$$

$$= \frac{bd^3}{3}$$

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$$\bar{y} = \left(\frac{2a+b}{a+b}\right) \times \frac{h}{3} \text{ from b side.}$$

$$\bar{y} = \left(\frac{2b+a}{a+b}\right) \times \frac{h}{3} \text{ from a side.}$$

A rectangular plane surface of 2m wide and 3m. deep lies in the vartical plane in water. determine the total pressure and position of centre of pressure on the plane surface. with the upward edge horizontal

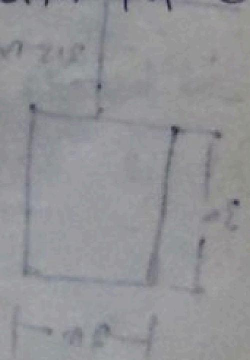
(a) and coinside with water surface.

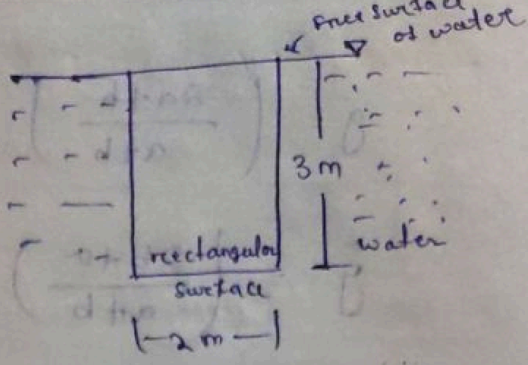
(b) 2.5m. below the free water surface.

Rectangulare surface having width (b) = 2m.

Depth (d) = 3m.

→ kept in the vertical plane with top edge horizontal in water.





(a) Top edge coinside with free surface of water :-

total pressure force (F) = $\rho g \bar{h} A$

$$= 1000 \times 9.81 \times \frac{3}{2} \times 3 \times 2$$

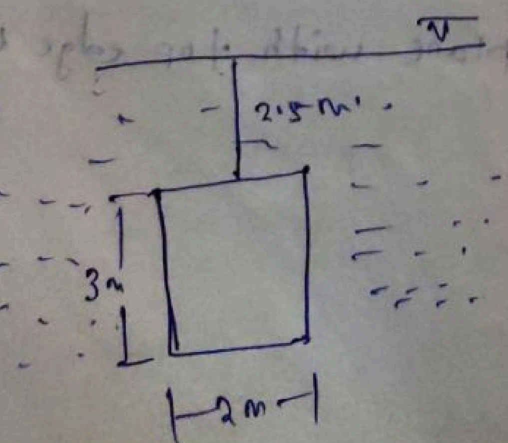
$$= 88290 \text{ N} \quad \text{---} \ (1)$$

Position of Centre of pressure from free surface :-

$$h^* = \frac{I_{CG}}{A\bar{h}} + \bar{h} = \frac{\frac{2 \times 3^3}{12}}{2 \times 3 \times \frac{3}{2}} + \frac{3}{2}$$

$$= 2 \text{ m.} \quad \text{---} \ (2)$$

(b)



$$\text{Total pressure} = \rho g \bar{h} A$$

$$= 1000 \times 9.81 \times 2.5 + \frac{3}{2} \times 3 \times 2$$

$$= 235440 \text{ N} \quad \text{— ①}$$

Position of Centre of pressure from free surface :-

$$h^* = \frac{I_{CG}}{A\bar{h}} + \bar{h} = \frac{\frac{2 \times 3^3}{12}}{2 \times 3 \times \left(2.5 + \frac{3}{2}\right)} + \left(2.5 + \frac{3}{2}\right)$$

$$= 4.187 \text{ m} \quad \text{— ②}$$

* Total Pressure horizontal surface in submerged Condition :-

→ when the Surface Submerged in the liquid with horizontal position, every point on the Surface is ~~area~~ at Same depth from free surface of the liquid.

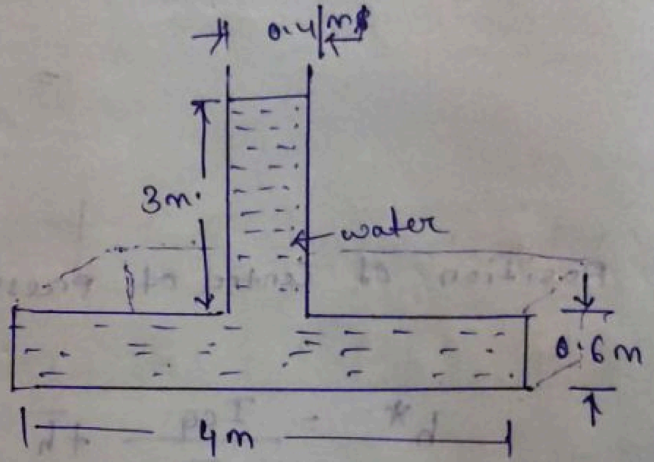
→ So the pressure intensity ~~should~~ will be equal to through out the entire Surface & will be equal to

$$p = \rho g h$$

and the pressure force $F = \rho g A \bar{h}$

and $\boxed{\bar{h} = h^*}$

Q



Calculate

(a) total pressure force at the bottom of the dam.

(b) Weight of the water inside the dam.

(c) if the width of the dam is 2m, calculate the hydrostatic paradox. between the results of a & b.

Total pressure force at the bottom of tank / container.

$$F = \rho g A \bar{h}$$

$$= 1000 \times 9.81 \times 4 \times 2 \times (3 + 0.6)$$

$$= 282528 \text{ N}$$

(b) wt of water inside the container

$$= \rho \times g \times volume$$

$$= 1000 \times 9.81 \times (3 \times 0.4 \times 2 + 4 \times 0.6 \times 2)$$

$$= 70632 \ N$$

(c) Hydrostatic paradox

the total pressure force at the bottom of the dam is much more then the weight of water in side the ~~dam~~ tank. this is called as Hydrostatic paradox.

$$= 282528 - 70632$$

$$= 211896 \ N.$$

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-! Kinematics of Flow!-

Kinematics!-

study of motion of body without knowing | Considering the force Causing the motion.

Dinamics!-

Study of motion of body with knowing the force Causing the motion.

Types of Fluid Flow!-

① steady and unsteady Flow!-

Steady!-

The Flow of Fluid in which the Flow parameter like velocity, density etc. remain Constant wrt time is called steady flow.

unsteady!-

The Flow in which the flow parameters like velocity, density etc. Changes with time is Called unsteady Flow.

(2) (b) Uniform and non uniform :-

Uniform flow :-

The flow in which the velocity remains constant w.r.t space that is called uniform flow.

Non uniform flow :-

The flow in which the velocity of flow changes w.r.t space or distance is called non-uniform flow.

(3) Lamina & turbulant flow

Lamina flow :-

The flow in which the fluid layer slides one above another layer without developing any restriction to flow is called lamina fluid. In this case the fluid particle just rolls over one another.

For lamina flow the value of Reynold's Number (Re) < 2000

turbulant flow :-

the flow ~~flo~~ of the fluid in which the fluid particle moves in zigzag fashion or random fashion without following a specified path. is called turbulant flow.

The value of Reynold's Number is > 4000.

If the value of Reynold's Number is between 2000 to 4000 then the flow canbe either lamina or turbulant.

$$\boxed{R_e = \frac{\rho v}{\gamma}}$$

where,

ρ = density of fluid

v = velocity of flow

γ = Coefficient of dynamic viscocity.

(4) Compressable and ~~Non~~ ~~Co~~ Non Compressable:

Compressable :-

The flow of fluid in which the density is changing ~~w.i.t~~ w.r.t space or distance during its travel ~~is called~~ at point to point is called compressable flow.

~~No~~ The flow of gasses this are example of Compressable flow.

Non Compressable flow:-

The flow of fluid in which the density remains Constant throughout the sections of flow is called non compressable flow.

the flow of liquid is an example o Non compressable flow.

(5) Rotational and Irrotational

Rotational flow:-

The flow of liquid in which the fluid particles moves in the direction of flow along with rotates about there own axis is called rotational flow.

Irrotational flow:-

The flow of liquid in which the fluid particles moves along the direction of flow with out any rotation about their own axis is called Irrotational flow.

One Dimensional flow:-

The flow of fluid particle in which the flow parameters can be expressed as a function of one dimension only by x axis or y axis or z axis then the flow is called one dimensional flow.

mathematicaly :-

$$\boxed{V = f(x) \text{ or } f(y) \text{ or } f(z)}$$

Two dimensional flow :-

The flow of fluid particles in which the flow parameter can be expressed as the function of two axis is called two dimensional flow.

mathematically,

$$\boxed{V = f(x, y) \text{ or } f(y.z) \text{ or } f(z, x)}$$

Three dimensional flow :-

The flow of fluid in which the flow parameteres can be expressed as functions of three axis then it is called three dimensional flow.

mathematically,

$$\boxed{V = f(x, y, z)}$$

Equation of Continuity :-

Rate of Flow / Discharge of Flow :-

The rate of flow of discharge is defined as a quantity of liquid flowing per second of a section of pipe or channel. is called discharge or rate of flow.

It is denoted by Q.

Mathematically,

$$\boxed{Q = Av}$$

where

A = Area of Crossection of flow

v = velocity of flow.

The unit of discharge = m^3/sec in SI unit.

Continuity Equation :-

It is based on the principle of Coservation of mass.

It states that the amound of liquid flowing or the discharge of a section remains Constant at different section of flow.

mathematically,

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

where,

⇒ ρ_1 & ρ_2 are the density of fluid before and after a perticular section or at two different section.

⇒ A_1 & A_2 Area of cross section of flow at two different section.

⇒ v_1 & v_2 velocity of flow at two different section. (1)

If the density is same for the liquid passing through the section ~~that~~ i.e. $\rho_1 = \rho_2 = \rho_3$

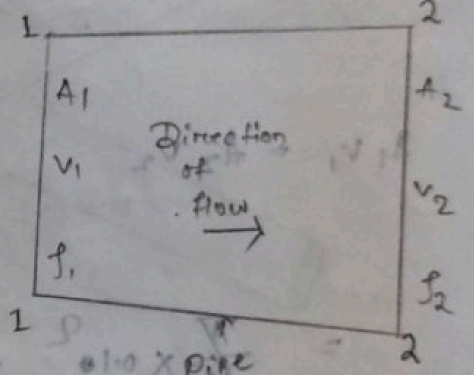
the above equation become $\cancel{\rho} A_1 v_1 = \cancel{\rho} A_2 v_2$

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

$$\Rightarrow Q = Q$$

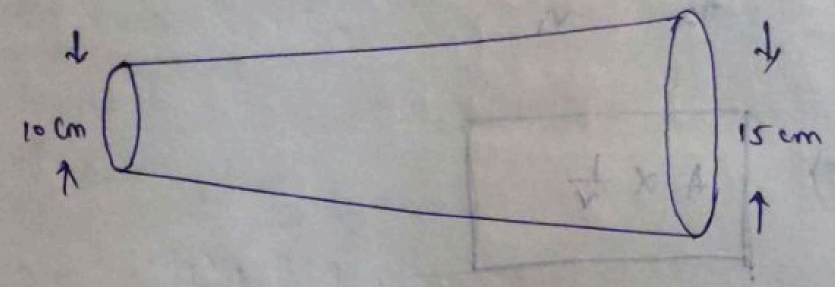
$$\frac{A_1}{A_2} = \frac{V_2}{V_1}$$

$$\Rightarrow \boxed{A \propto \frac{1}{V}}$$



(1) The Diameter of the Pipe of the Section 1 & 2 10 cm & 15 cm respectively.

Find the discharge to the pipe. if the velocity of water flowing through the pipe at section 1 is 5m/sec determine the velocity of at section 2.



$D_1 = 10\ cm$ $\qquad$ $D_2 = 15\ cm$

$v_1 = 5\ m/sec$

$A_1 v_1 = A_2 v_2$

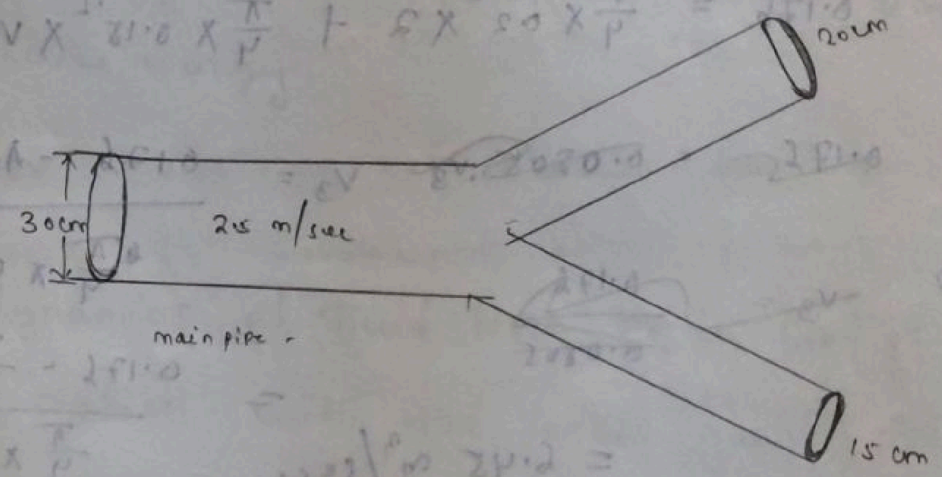
$= \cancel{\frac{\pi}{4}} \times 0.10^2 \times 5 = \cancel{\frac{\pi}{4}}\ 0.15^2 \times v_2$

$= 0.05 = 0.0225 \times v_2$

$= v_2 = \dfrac{0.05}{0.0225}$

$= v_2 = 2.22\ m/sec$

A 30 cm diameter pipe conveying water branches into 2 pipes of diameter 20 cm and 15 cm respectively if the average velocity is 30 cm diameter pipe is 2.5 m/sec. Find the discharge in this pipe also determine the velocity in 15 cm pipe if the average velocity in 20 cm pipe is 2 m/sec.



$d_1 = 30$ cm $\quad d_2 = 20$ cm $\quad d_3 = 15$ cm

$v_1 = 2.5$ m/sec

$\Rightarrow \frac{\pi}{4} \times d^2 \times 2.5$

$\Rightarrow \frac{\pi}{4} \times 0.3^2 \times 2.5$

$\Rightarrow 0.176 \; m^3/sec$

$Q_1 = Q_2$

$Q = Q_1 + Q_2$

$\Rightarrow$ ~~0.1765~~.

$\Rightarrow 0.176 = A_2 v_2 + A_3 v_3$

$\Rightarrow 0.176 = \frac{\pi}{4} \times 0.2^2 \times 2 + \frac{\pi}{4} \times 0.15^2 \times v_3$

$\Rightarrow$ ~~0.1765 = 0.0805. v3~~ $\quad v_3 = \dfrac{0.176 - A_2 v_2}{\frac{\pi}{4} \times 0.15^2}$

$\Rightarrow$ ~~v3 = 0.176 / 0.0805~~

$= \dfrac{0.176 - \frac{\pi}{4} \times 0.2^2 \times 2}{\frac{\pi}{4} \times 0.15^2}$

$= 6.45\ m^3/sec.$

Water flow to a pipe AB 1.2 m. diameter at 3 m. per / sec and ~~then passes through~~ then passes through a pipe 1.5 m. diameter at C, the pipe branchy CD is 0.8 in diameter and carries on 1/3 of the flow in AB. The flow velocity in Branch CE is 2.5 m/sec Find the volume rate of flow and velocity in BC, velocity in CD & Diameter of CE.

Dynamics of fluid flow :-

→ Euler's equation of motion.

→ Bernoulli's equation.

→ Application of Bernowli's equation.

→ Total energy of fluid , potential / daton , kinematic & Pressure energy.

The dynamics of fluid flow ~~the~~ is the study of fluid motion with the forces gauging the motion.

Forces Acting on fluid element

In case of fluid flow the following forces are present.

(i) gravity force

(ii) Pressure force

(iii) forces due to viscocity

(iv) forces due to turbulence

(v) forces due to Compressibility

→ If the forces due to Compressibility is eligible then the equation of motion resulting from the above four forces are called reynold's eqn of forces.

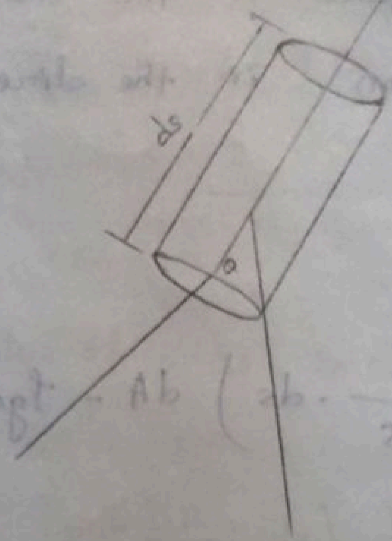
→ If the forces due to tubulance is negligible then the resulting equation of motion is called Naviere - stoke's equation.

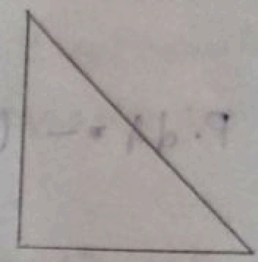
→ If the flow is assume in idea, viscous force is zero & the equation of motion is called Euler's equation of motion.

Euler's equation of motion:-

This equation of motion in which the forces due to gravity and pressure dare taken into Consideration.

This is derived by Considering the motion of fluid element along a stream line.





Consider a stream line in which the flow is taking place in a s direction.

Consider a cylindrical element of cross section dA and length ds.

The forces acting on the cylidrical element are

(i) The Pressure force $p \times dA$ in the direction of flow.

(ii) Pressure force $\left(p + \frac{\partial p}{\partial s} ds\right) dA$.

(iii) Wheight of the fleuide element $\rho g\, dA\, ds$

Let θ be the angle between the direction of flow and the line of action of the weight of the element.

The resultant force ~~on~~ the fluid element in the direction of s must be equal to the mass of the element × ~~accel~~ accelaration in the direction of s

mathematicaly,

$$P \cdot dA - \left(P + \frac{\partial p}{\partial s} \cdot ds\right) dA - \rho g \, ds \, dA \cos\theta = \rho \, dA \, ds \cdot a_s$$

where a_s is the accelaration in the direction of s.

Now $a_s = \frac{dv}{dt}$

where

v is the velocity of the fluid element which is a function of s and t.

$$\cancel{\frac{\partial x}{\partial s}} \quad \cancel{a_s = \frac{dv}{dt} = \frac{\partial x}{\partial s}}$$

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

$$= v \cdot \frac{\partial v}{\partial s} + \frac{dv}{dt}$$

If the flow is steady then $\frac{\partial v}{\partial t} = 0$

$$a_s = v \cdot \frac{\partial v}{\partial s}$$

Putting the value of a_s in ~~case of~~ equation (1) we get

$$\Rightarrow p\,dA - \left(p + \frac{\partial p}{\partial s} \cdot ds\right) dA - \rho g\, ds\, dA \cos\theta$$
$$= \rho\, dA \cdot ds \cdot a_s$$

$$\Rightarrow p \cdot dA - p\,dA - \frac{\partial p}{\partial s}\, ds\, dA - \rho g\, ds\, dA \cos\theta$$
$$= \rho\, dA \cdot ds \cdot v \cdot \frac{\partial v}{\partial s}$$

$$\Rightarrow \frac{\partial p}{\partial s} \cdot ds \cdot dA - \rho g \cdot ds \cdot dA \cdot \cos\theta$$
$$= \rho \cdot dA \cdot ds \cdot v \cdot \frac{\partial v}{\partial s}$$

dividing the equation by $\rho \cdot ds \cdot dA$ we get

$$\frac{\frac{\partial p}{\partial s} \cdot \cancel{ds \cdot dA}}{\rho\, \cancel{ds} \cdot dA} - \frac{\cancel{\rho} g \cdot \cancel{ds} \cdot \cancel{dA} \cdot \cos\theta}{\cancel{\rho} \cdot \cancel{ds} \cdot dA} = \frac{\rho \cdot \cancel{dA} \cdot ds \cdot v \cdot \frac{\partial v}{\partial s}}{\rho \cdot \cancel{ds} \cdot dA}$$

$$\Rightarrow \frac{\frac{\partial p}{\partial s}}{\cancel{\partial}\rho} - g\cos\theta = v \cdot \frac{\partial v}{\partial s}$$

$$\Rightarrow \frac{\partial p}{\rho\,\partial s} - g\cos\theta = v \cdot \frac{\partial v}{\partial s}$$

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

$$\Rightarrow \frac{\partial p}{\rho\,\partial s} + g\frac{dz}{ds} + v \cdot \frac{\partial v}{\partial s} = 0$$

$$\Rightarrow \frac{dp}{\rho\,ds} + g\frac{dz}{ds} + \frac{v\,dv}{ds} = 0$$

$$\Rightarrow \boxed{\frac{dp}{\rho} + g\,dz + v\,dv = 0} \quad \text{—— (2)}$$

Euler's equation of motion.

~~derivation~~

* Derivation of Berenoulli's eq^n from Euleres eq^n

The Euleres eq^n is as follow

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

intigrating the arobe equation..

$$\int \frac{dp}{\rho} + \int g\,dz + \int v\,dv = \text{Constant}:$$

The ~~Flow~~ fluid is incompressible then ρ is constant.

Then the equation become

$$\frac{p}{\rho} + g.z + \frac{v^2}{2} = \text{Constant}.$$

$$\Rightarrow \frac{p}{\rho} + g.z + \frac{v^2}{2} = \text{Constant}$$

$$\Rightarrow \frac{p}{\rho g} + \frac{g.z}{g} + \frac{v^2}{2g} = \text{Constant}$$

$$\boxed{\frac{P}{\rho g} + \frac{v^2}{2g} + z = \text{Constant}}$$

This is Bernoullie's equation of motion.

where

$\frac{P}{\rho g}$ is the Pressure energy or unit weight of fluid or pressure head.

$\frac{v^2}{2g}$ kinetic energy per unit weight or kinetic head.

z potential energy per unit or Potential head.

The sum of pressure head, kinetic head and Potential head is called the total head or total energy per unit weight of fluid element.

Assumption made in the derivation of Bernoullie's equation.

(i) The fluid is ideal (viscocity is zero)
(ii) The flow is steady.
(iii) The flow is incompressible.
(iv) The flow is irrotational.

Dt:- 19/04/2022

Q Water is flowing through a pipe of 5cm diameter under a pressure of 29.43 N/cm² and with a mean velocity of 2m/sec Find the total head or total energy per unit weight of the water at a crossection, which is 5m above the datum line.

Given:-

$\frac{P}{\rho g}$ = ~~29.43 N/cm²~~

diameter of pipe = 5cm = 0.05m.
velocity of water in pipe = 2m/sec = v
Pressure in the pipe = 29.43 N/cm²

$= 29.43 \times 10^4 \ N/m^2$

Pressure head :-

$$\frac{p}{\rho g} = \frac{29.43 \times 10^4}{1000 \times 9.81}$$

$$= 30\,m.$$

velocity head :-

$$\frac{v^2}{2g} = \frac{2^2}{2 \times 9.81} = 0.20\,m.$$

Daton head :- (Z) = 5m.

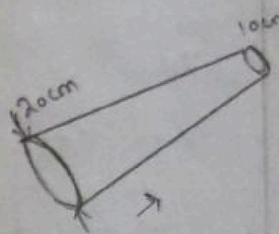
* Total head :

$$= 30 + 0.2 + 5$$

$$= 35.2\,m.$$ **Ans.**

Q. A pipe through which water is flowing, is having diameters 20 cm and 10 cm at crossection one and two respectively the velocity of water at section one is given 4 m/sec. find the velocity head at section one and two and also the discharge.

Given:-



Diameter of one section = 20 cm

Diameter of two section = 10cm.

Section - I

$v_1 = 4 \, m/sec$

$d = 20 \, cm = 0.2 \, m.$

$A_1 = \frac{\pi}{4} \times d_1^2$

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

$= 0.03 \, m^2$

Section - 2

$v_2 =$

$d_2 = 0.1 \, m.$

$A_2 = \frac{\pi}{4} \times d_2^2 = \frac{\pi}{4} \times 0.1^2 = 0.00785 \, m$

Applying equation of Continuity we have

$$A_1 v_1 = A_2 v_2$$

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

$$= \frac{0.03 \times 4}{0.00785}$$

$$= 15.28 \text{ m/sec}$$

$$\simeq 16 \text{ m/sec}$$

velocity head at section (1)

$$\frac{v_1^2}{2g} = \frac{4^2}{2 \times 9.81}$$

$$= 0.8154$$

velocity head at section (2)

$$\frac{v_2^2}{2g} = \frac{16^2}{2 \times 9.81} = 13.04 \text{ m.}$$

Discharge

$= A_1 V_1$

$= 0.03 \times 4$

$= 0.12 \, m^2/sec$

Bernoullies equation for real fluid :-

The bernoullies equation for real fluid between point one 1 and 2 is given by $\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_l$

where

where

h_L = loss of energy or head between point one and two.

Real fluid :-

The real fluids are viscous and offers resistance to flow giving rise to some losses of energy in fluid flow.

* Practical applications of Bernoullies equation

Bernoullies theorem is applicable in all problem of incompressable fluid flow where the energy consideration are involve.

It is applicable in the following measuring devices.

(i) venturimeter

(ii) Orifice meter

(iii) pitot-tube

Venturi meter :-

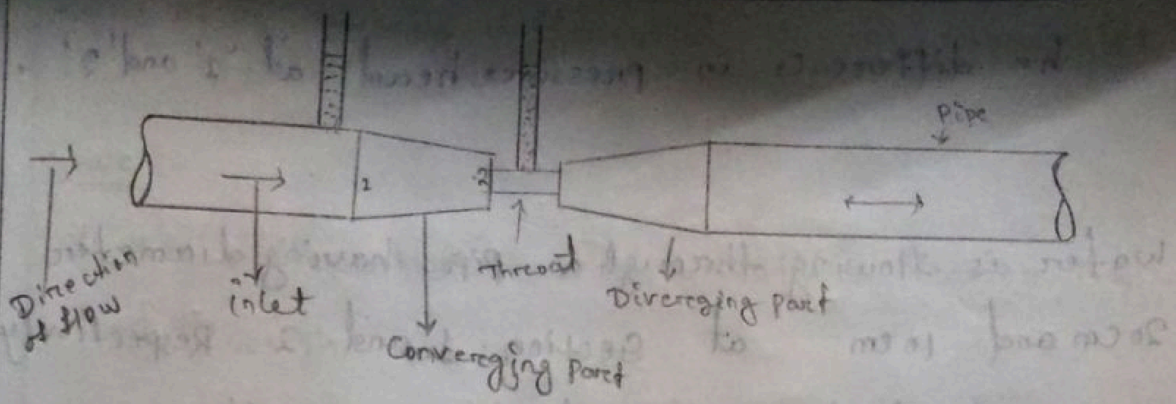
A venturi meter is a device which is used for measuring the rate of flow of a fluid flowing through a pipe

It consist of three parts :-

(a) A short converging part

(b) Throat.

(c) A diverging part



The Theorytical Discharge Q_{th}:

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

This equation gives the discharg under ideal condition and is called theorytical discharge. but actual discharge will be less than the theoritical discharge.

$$\boxed{Q_{Act} = cd \cdot \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}}$$ (actual discharge)

where

Cd is Coefficient of venturi meter and its value is less than 1.

a_1, a_2 = area of crossection of section 1 and 2

~~h = differening~~ :

h = difference in pressure head at '1' and '2'.

water is flowing through a pipe having diameter 20 cm and 10 cm at section 1 and 2 Respectively. the rate of flow through pipe is 35 l/sec. the section 1 is 6 m above datum and section 2 is 4 m above datum.

if the pressure at section 1 is 39.24 N/cm^2, find the intensity of pressure at section 2.

Value of h given by differential U-tube manometer :-

Case I :-

If the differential manometer contains heavier liquid than that through the pipe

$$h = x\left(\frac{S_h}{S_a} - 1\right)$$

Sh - Specific gravity of hevier liquid.

S_a = Specific gravity of liquid flowing through pipe.

x = Difference of heavier liquid column in U-tube.

Case II :-

If the differential manometer contains a liquid lighter than the liquid flowing through the pipe.

$$h = \left(1 - \frac{S_l}{S_a}\right) x$$

S_l = Specific gravity of lighter liquid in U-tube

Q. A horizontal venturimeter with inlate and throat diameter 30 cm and 15 cm respectively.

It is used to measure the flow of water. the reeding of a differential manometer connected to the inlate & at the throat is 20 cm of mercury. determine the rate of flow. take Cd is 0.98.

<u>Solve:-</u>

<u>Given:-</u>

for the horizontal venturimeter

d_1 = at inlate = 30 cm = 0.3 m

d_2 = at inlate = 15 cm = 0.15 m.

$a_1 = \frac{\pi}{4} \times 0.3^2$

$= 0.0706\ m^2$

$a_2 = \frac{\pi}{4} \times 0.15^2$

$= 0.0176\ m^2$

$Cd = 0.98$

$x = 20$ cm.

$$h = x\left(\frac{S_h}{S_a} - 1\right)$$

$$= 0.2\left(\frac{13.6}{1} - 1\right)$$

$$= 2.52 \text{ m.}$$

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

$$= 0.98 \; \frac{0.0706 \times 0.0176}{\sqrt{(0.0706)^2 - (0.0176)^2}} \times \sqrt{2 \times 9.81 \times 2.52}$$

$$= 0.125 \text{ m}^3/\text{sec}$$

(2) In a 100 mm diameter horizontal pipe a venturimeter of 0.5 contraction ratio has been fixed. the head of water on the meter when there is no flow is 3m. (gauge) find the rate of flow for which the throat pressure will be 2m. of water absolute. Cd is 0.97. Take atmospheric pressure head = 10.3 m of water.

given :-

diameter of pipe = 100 mm

$= 0.1\,m$

Contraction ratio = 0.5 $\frac{a_1}{a_2}$ or $\frac{a_2}{a_1}$

$= a_2 = 0.5\,a_1$

~~head of water~~

gauge pressure = 3m.

$a_1 = \frac{\pi}{4} \times 0.1^2$

$= 0.00785\ m^2$

$a_2 = 0.5 \times 0.00785$

$= 0.00392\ m^2$

P_1

~~absolute pressure~~ = Atmospheric pressure + gauge pressure

$= 10.3 + 3$

$= 13.3\ m$

$h = P_1 - P_2$

$= 13.3 - 2$

$= 11.3\ m.$

$$= Cd.\ \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

$$= 0.97 \cdot \frac{0.00785 \times 0.00392}{\sqrt{0.00785^2 \times 0.00392^2}} \times \sqrt{2 \times 9.81 \times 11.3}$$

$$= 0.065\ m^3/sec$$

Orifice Meter :-

→ It is a device used for measuring the rate of flow of a fluid through a pipe.

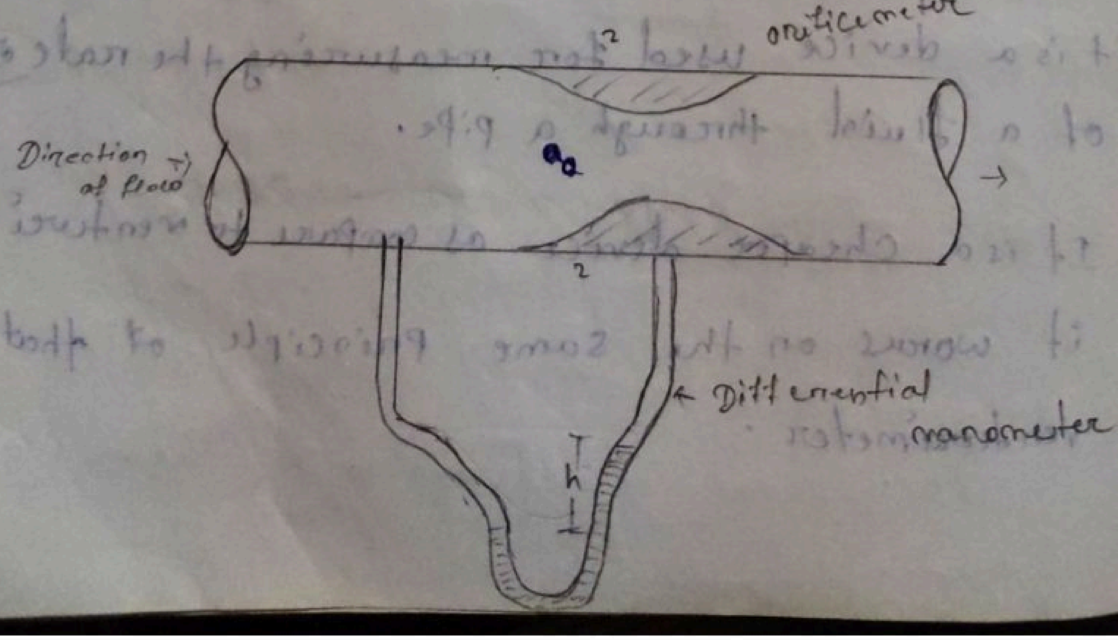
→ It is a cheaper device as compare to venturi meter.

→ it works on the same principle of that of venturimeter.

→ It Consist of a ~~thick~~ flat circular plate which has a circular sarf edge ~~w~~hole called orifice, which is concentric with the pipe.

⇒ The orifice diameter is kept generally 0.5 times the diameter of the pipe, though it may vary from 0.4 to 0.8 time the pipe diameter,

⇒ ~~The~~ A differential manometer is connected as section one which is at a distance of 1.5 to 2 times the diameter the string for the orifice plate and at section-2 which is at a distance of about half the diameter of ~~the~~ the orifice on the down stream side from the orifice plate.



a_0 = Area of orifice meter

a_1 = Area of c/s of pipe at section 1-1.

a_2 = Area ~~of~~ ~~c/s~~ at vena contracta.

$$\boxed{\text{Coefficient of Contraction } (C_c) = \frac{a_2}{a_0}}$$

The discharge of orifice meter = Q = ~~cd~~

$$Q = \frac{C_d \; a_0 \, a_1 \sqrt{2gh}}{\sqrt{a_1^2 - a_0^2}}$$

Cd = Coefficient of discharge of orifice meter having ~~also~~ value is less than that the venturi meter.

An orifice meter with orifice diameter 10 cm is inserted in a pipe of diameter 20 cm. the pressure gauges fitted ~~on~~ up stream and down stream of orifice meter give reading of 19.62 N/cm² and 9.81 N/cm² respectively. Cd = 0.6. Find the discharge through the pipe.

Given :-

$d_0 = 10\ cm = 0.1\ m.$

$d_1 = 20\ cm = 0.2\ m.$

$a_0 = \frac{\pi}{4} \times 0.1^2$

$= \cancel{7085}\ 0.00785\ m^2$

$a_1 = \frac{\pi}{4} \times 0.2^2$

$= 0.0314 m^2$

$P_1 =$

~~up side pressure~~

up stream pressure = 19.62 m.

down stream pressure = 9.81

$P = \rho g h$

$19.62 = 1000 \times 9.81 \times h$

$19.62 = 9810 h$

$h_1 = \frac{19.62}{9810}$

$= 0.002$

$$h_1 = \frac{P}{\rho g}$$

$$= \frac{19.62 \times 10^4}{1000 \times 9.81}$$

$$= 20$$

$$h_2 = \frac{P}{\rho g}$$

$$= \frac{9.81 \times 10^4}{1000 \times 9.81}$$

$$= 10$$

$$h = h_1 - h_2$$

$$= 20 - 10$$

$$= 10m.$$

$$Q = \frac{Cd.\ a_0 a_1 \sqrt{2gh}}{\sqrt{a_0^2 - a_2^2}}$$

$$= \frac{0.6 \times 0.00785 \times 0.0314 \times \sqrt{2 \times 9.81 \times 10}}{\sqrt{0.00785^2 \times 0.0314^2}}$$

$= 0.068\ m^3/sec$

Assumption

2 An orifice meter with orific diameter 15 cm is inserted with a pipe of 30 cm diameter. the Pressure difference measured by a mercury oil differential manometer on the two side of orifice meter gives a reading ~~gives a reading~~ 50 cm of mercury find the rate of flow of oil of specific gravity 0.9. if cd of orific meter is 0.64.

Ans

$d_0 = 15cm$

$d_1 = 30cm$

~~$a_0 = \frac{\pi}{4} \times$~~ $a_0 = \frac{\pi}{4} \times 0.15^2$

~~$= 1.76\ m^2$~~ $= 0.0176\ m^2$

~~$a_1 = \frac{\pi}{4} \times 0.3$~~ $a_1 = \frac{\pi}{4} \times 0.3^2$

$= 0.0706\ m^2$

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$h = 15cm.$

$= 0.15m.$

$Cd = 0.64$

$g = 0.9$

is
the
urcy
e of
reading
c'
meter

$$Q = \frac{Cd \; a_0 a_1 \sqrt{2gh}}{\sqrt{a_0 - a_0}}$$

$$= \frac{0.64 \times 0.0176 \times 0.0706 \sqrt{2 \times 0.9 \times 0.15}}{\sqrt{(0.0706)^2 - (0.0176)^2}}$$

$= 0.00604 \; m^3/sec$

Q Find the velocity of flow of an oil through a pipe when the difference of mercury level in a differen U tube manometer connected to two tappins of the pitted tube is 100 mm take coefficient of pitted tube 0.08. the specific gravity of oil is 0.8.

Sol^n A. differential manometer is inserted to the pipe. It contains Hg mercury having Sg = 13.6

$C_v = 0.08$

$g = 0.8$

Difference in the level of u-tube manometer

$= 100\,mm$

$= 0.1\,m = x$.

$h =$

*

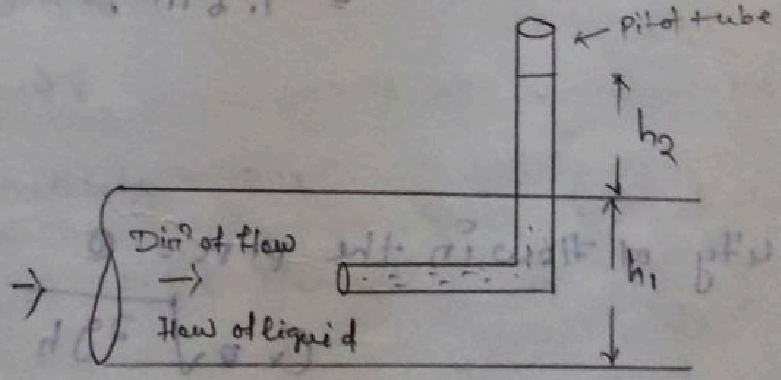
Pitot-tube :-

It is a device used for measuring the velocity of flow at any point in a pipe or channel.

→ It is based on the principle that if the velocity of flow at a point becomes 0 at a point, the

→ Pressure at that point is increased due to conversion of kinetic energy in to pressure energy.

→ In the simplest form the pitot tube consist of a glass tube bend at right angle to the direction of flow.



h_1 - Depth of pitot tube in liquid.

h_2 Rise of liquid above free surface

$$\boxed{V_{th} = \sqrt{2gh_2}}$$

$$\boxed{V_{act} = C_v\sqrt{2gh_2}}$$

where,

C_v is the Coefficient of pitot tube.

Soln * $h = x\left(\frac{S_g}{S_0} - 1\right) = 0.1\left(\frac{13.6}{6.8} - 1\right)$

$= 1.6 \text{ m}.$

velocity of flow in the pipe = $C_v \sqrt{2gh}$

$= 0.98\sqrt{2 \times 9.81 \times 1.6}$

$= 5.49 \text{ m/sec}$

2 A pitot static tube is placed in the centre of a 300 mm pipe line has one orifice point of stream and other perpendicular to it. the mean velocity in the pipe is 0.8 of the central velocity. Find the discharge through the pipe, if pressure difference between the two orifices is 60 mm of water take coefficient of pitot-tube $C_v = 0.98$.

Difference in pressure = 60 mm

= 0.06 m.

= h.

$C_v = 0.98$

Mean velocity = 0.8

$v_{mean} = 0.8 \times v_{central}$

$V_{central} = C_v \sqrt{2gh}$

$= 0.98 \sqrt{2 \times 9.8 \times 0.06}$

$= 1.06$ m/s.

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$V_{mean} = 0.8 \times 1.06$

$= 0.85\ m/s.$

$\text{discharge} = V_{mean} \times \text{Area}$

$Q = 0.85 \times \frac{\pi}{4} \times 0.3^2$

$= 0.06\ m^3/s.$

discharge of the pipe.

A pitot tube is used to measure the velocity of water in a pipe. the stagnation pressure head is 6m, and static pressure head is 5m. calculate the velocity of flow, assuming $C_v = 0.98$.

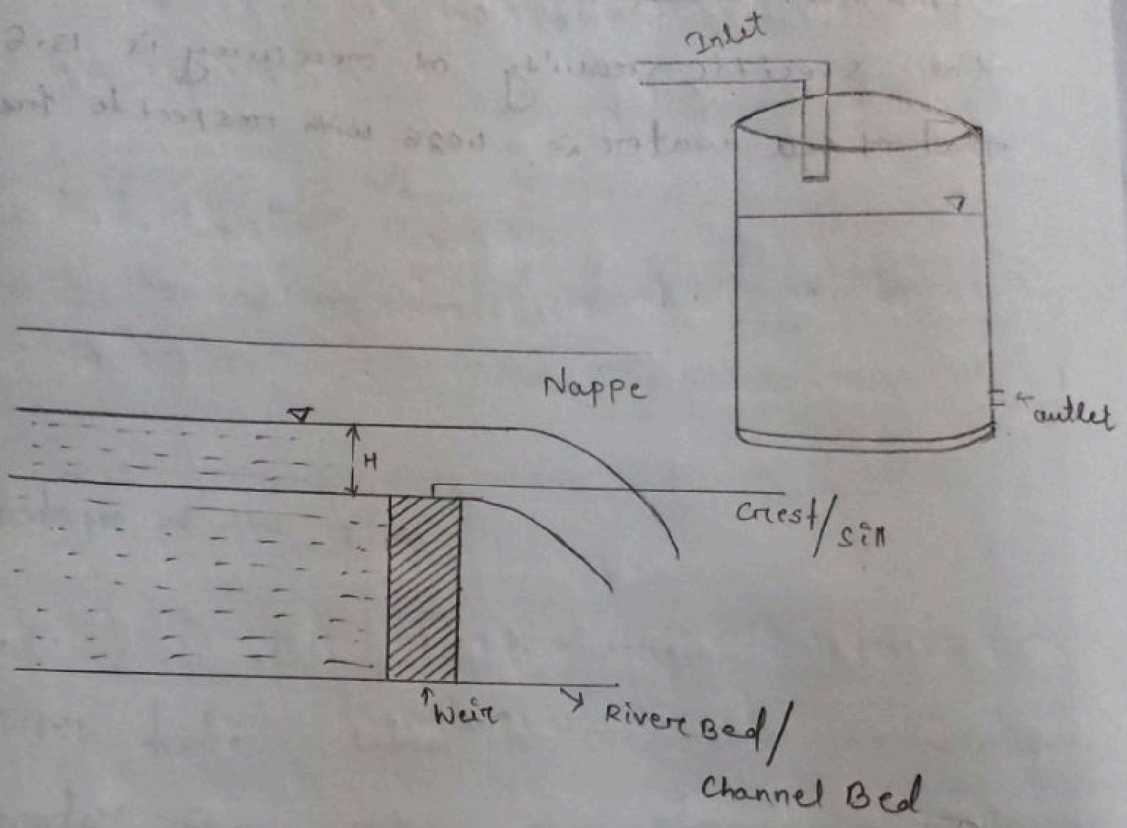
A submarine moves horizontaly in a sea and has it axis is ~~some~~ 15m below the surface of water. a pitot tube properly placed just infront of the submarine and along its axis is connected to the two limbs of a u-tube manometer containing mercury.

the difference of mercury level is found to be 170 mm Find the speed of the Submarine knowing that the specific gravity of mercury is 13.6 and that of sea water is 1.026 with respect to fresh water.

CP:- 2.2

Flow Through Notches & Weirs,

Notch :-



It is a device, for measuring the rate of flow of liquid to a small channel or a tank.

It may be defined as a small opening in the side of a tank ~~&~~ or a small channel in such a way that the liquid surface in the tank is below the top edge of the opening.

It is made up of metalic plate of smaller size.

Classification of Notch :-

(a) according to the shape of the opening

(i) rectangular Notch.

(ii) Triangular Notch.

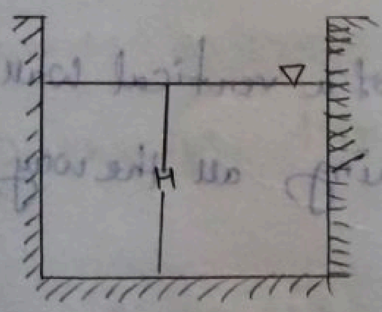
(iii) Trapizoidal Notch.

(iv) stepped Notch.

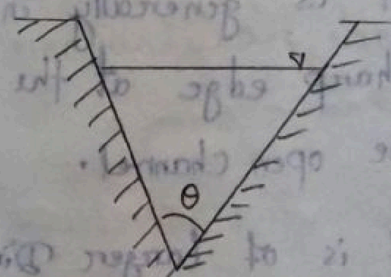
(b) According to the effect of sides of Nappe

(i) Notch with end Contraction.

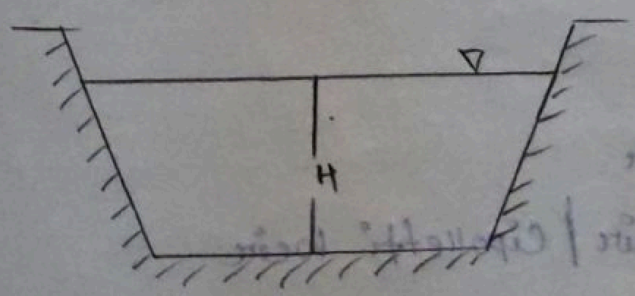
(ii) Notch without end Contraction. (Suppressed Notch)



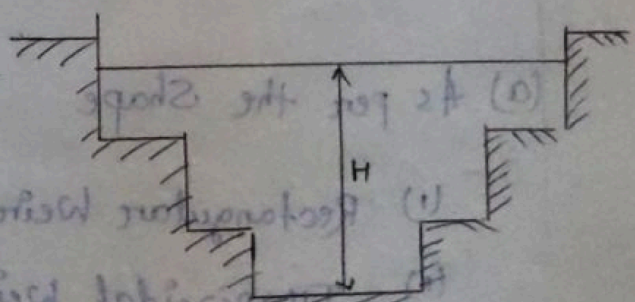
Rectangular Notch



Triangular Notch



Trapizoidal Notch



Stepped Notch

Nappe / Vein :-

It is the sheet of water flowing through the Notch or over the weir.

Crest / Sill :-

It is the Bottom edge of the Notch or top of the weir in which water flows.

Weir :-

It is a Concrete of Masonary structure placed in an open Channel over which the flow occurs.

It is generally in the form of a vertical wall with a Sharp edge at the top running all the way across the open channel.

It is of larger Dimension.

Classification of Weirs :-

(a) As per the Shape

(i) Rectangular Weir

(ii) Trapizoidal Weir / Cipolletti weir

(iii) Triangular weir

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(b) As per the shape of Crest

(i) Sharp Crested weir.

(ii) Broad Crested weir.

(iii) Narrow Crested weir.

(iv) ~~Ogee~~ Ogee shaped weir.

(c) Effect of side on the Emerging Napee.

(i) Weir with end Contraction.

(ii) Weir without end Contraction.

Discharge through a rectangular weir:—

$$Q = \frac{2}{3} C_d \cdot L \sqrt{2g} \, (H)^{3/2}$$

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$$\boxed{Q = \frac{8}{15} C_d \tan\frac{\theta}{2} \cdot \sqrt{2g}\, H^{5/2}}$$

h- head of water of v notch

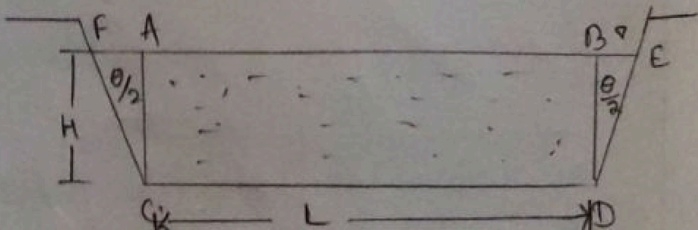
θ = angle of notch

IF $\theta = 90°$ called right angled v notch.

$$\boxed{Q = 1.417 \times h^{5/2}}$$

~~Discharge over a~~ :

Discharge through a trapezoidal notch/weir :-



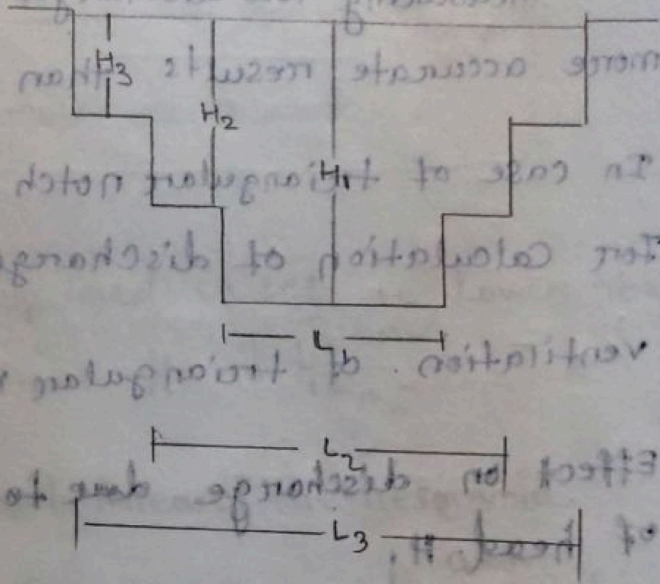
$Q = Q_1 + Q_2$

(ABCD) FAC & BED

$\Rightarrow$ ~~Q~~ Q_{2}

$$\Rightarrow Q = \frac{2}{3} C_{d_1} L\sqrt{2g}\, H^{3/2} + \frac{8}{15} C_{d_2} \tan\frac{\theta}{2} \sqrt{2g}\, H^{5/2}$$

Discharge over a Stepped Notch :-



$$Q = Q_1 + Q_2 + Q_3$$

$$Q = \frac{2}{3} c_d L_1 \sqrt{2g} \left(H_1^{3/2} - H_2^{3/2}\right) + \frac{2}{3} c_d L_2 \sqrt{2g} \left(H_2^{3/2} - H_3^{3/2}\right) + \frac{2}{3} c_d L_3 \sqrt{2g}\, H_3^{3/2}$$

2 mark

Advantages of triangular notch or weir over rectangular notch or weir :-

Expression for discharge for a right angle v notch is very simple.

For measuring low discharges, a triangular notch gives more accurate results than rectangular notch.

In case of triangular notch, only h is required for calculation of discharge.

ventilation of triangular notch is not necessery.

Effect on discharge due to error in measurement of head H.

For rectangular weir :-

An error of one % a measuring H will produce 1.5% error in discharge over a rectangular weir or notch.

For triangular weir or Notch :-

An error of 1% in measuring H will produce 2.5% error is discharge over a triangular weir or notch.

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Application :- (Application of ~~[illegible]~~ weir or Notch)

(a) The time required to empty a reservoir or tank with rectangular weir or notch.

$$\boxed{T = \frac{3A}{C_d L \sqrt{2g}} \left(\frac{1}{\sqrt{H_2}} - \frac{1}{\sqrt{H_1}} \right)}$$

where,

T = the time required in sec to lower the height of liquid from H_1 to H_2

A = Crossectional Area of the reservoir.

H_1 = Initial height of liquid above the crest.

H_2 = Final height of Liquid above the crest or notch.

(b) Time required to empty reservoir with a triangular notch or weir.

$$\boxed{T = \frac{5A}{4 C_d \tan\frac{\theta}{2} \sqrt{2g}} \left(\frac{1}{H_2^{3/2}} - \frac{1}{H_1^{3/2}} \right)}$$

Velocity of approach (V_a) :-

It is defined as the velocity with which the water approaches the weir or notch before it close over it.

$$\boxed{V_a = \frac{Q}{\text{Area of the Channel}}}$$

$$\boxed{h_a = \frac{V_a^2}{2g}}$$

again $Q = \frac{2}{3} C_d \times L \times \sqrt{2g} \left((H_1 + h_a)^{3/2} - h_a^{3/2}\right)$

Discharge equation with velocity of approach.

(1) Find the discharge of water flowing over a rectangular notch of 2m length when the crest head over the notch is 300 mm. take Cd = 0.6.

$Cd = 0.6$

$L = 2m.$

$H = 300 mm$

$= 0.3 m.$

$$Q = \frac{2}{3} cd \, L \sqrt{2g} \, H^{3/2}$$

$$= \frac{2}{3} \times 0.6 \times 2m. \times \sqrt{2 \times 9.81} \times 0.3^{3/2}$$

$$= 0.58 \, m^3/sec.$$

(2) Determine the height of a rectangular weir of length 6m. to be built across a rectangular channel. the maximum depth of water on the up stream side of the weir is 1.8 m. and discharge is 2000 l/sec. take cd = 0.6 and neglect end contraction.

Find the discharge over a triangular notch of angle 60° when the head over the v notch is 0.3m take Cd = 0.6

$$Q = \frac{8}{15} Cd \tan\frac{\theta}{2} \sqrt{2g}\, H^{5/2}$$

2)

Soln

Given data:-

For the rectangular weir, to be built across a rectangular channel.

length (l) = 6m.

maximum depth of water on the up stream side of weir = 1.8 m.

Discharge in Q = 2000 lit/s

= 1.8 m. = 2 m³/s

Cd = 0.6

H = ?

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we have discharge equation

$$Q = \frac{2}{3} C_d \, L \sqrt{2g} \, h^{3/2}$$

$$\Rightarrow Q = \frac{2}{3} \times 0.6 \times 6 \sqrt{2 \times 9.81} \, (1.8 - h)^{3/2}$$

$$\Rightarrow Q = 10.63 \, (1.8 - h)^{3/2}$$

$$\Rightarrow 4 = 112.99 \, (1.8 - h)^{3/2}$$

$$\Rightarrow (1.8 - h)^{3/2} = \frac{4}{112.99}$$

$$\Rightarrow (1.8 - h)^{3/2} = 0.035$$

$$\Rightarrow 1.8 - h = (0.035)^{1/3}$$

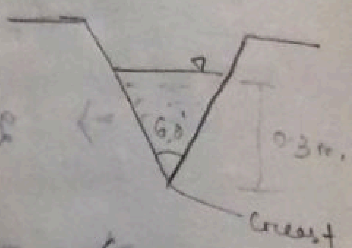
$$\Rightarrow h = 1.8 - (0.035)^{1/3}$$

$$h = 1.47 \text{ m}.$$

3 Given data, For the triangulare notch

$$\theta = 60^\circ$$

head over the v notch = 0.3m.



(Triangular Notch)

$$H = .3\text{ m.}$$

$$Q = \frac{8}{15}\, C_d + \tan\frac{\theta}{2} \times \sqrt{2g}\, (H)^{5/2}$$

$$= \frac{8}{15} \times 0.6 \times \tan\frac{60}{2} \sqrt{2 \times 9.81}\, (.3)^{5/2}$$

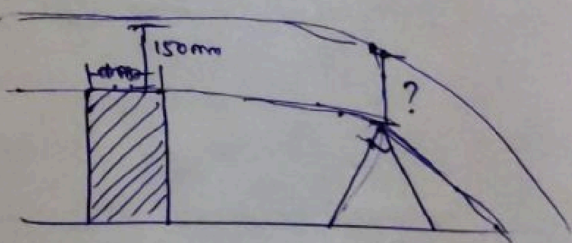
$= 0.04$ m^3/s Ans

(4) water flows over a rectangular weir 1m. length and at a depth of 150 mm and after wards passes through a triangular right angle weir. take cd for the rectangular and triangular weir as 0.62 and 0.59 respectively find the depth of water over the triangular weir

(5) find the time required to lower the water level from 3m. to 2m. in a reservoir of diameter 80m x 20m. by a rectangular notch of length 1.5 m. take $C_d = 0.62$.

(6) find the discharge over a rectangular weir of length 100 m. the head of water over the weir is 1.5 m. the velocity of approach is given as 0.5 m/s. take $C_d = 0.6$.

4



$L = 1m.$

$C_{d_1} = 0.62$ $\quad$ $C_{d_2} = 0.59$

$$Q_{Rec} = \frac{2}{3} C_{d_1} L \sqrt{2g} H^{3/2}$$

$$= \frac{2}{3} \times 0.62 \times 1 \times \sqrt{2 \times 9.81} (0.15)^{3/2}$$

$$= 0.106$$

$H^{5/2} = 0.076$

$H = 0.3565$

$$0.106 = \frac{8}{15} C_{d_2} \tan\frac{\theta}{2} \sqrt{2g} H^{5/2}$$

$$0.106 = \frac{8}{15} \times 0.59 \times 1 \times \sqrt{2 \times 9.81} \times H^{5/2}$$

$$0.106 = 1.393 H^{5/2}$$

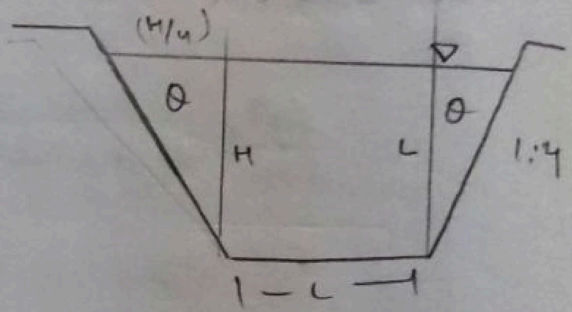
Cipolletti Weir / Notch :-

It is a type of trapezoidal weir in which the side slope horizontal to vertical is 1:4.

The discharge

$$\boxed{Q = \frac{2}{3} C_d \, L \sqrt{2g} \, (H)^{3/2}}$$

H : V = 1:4



Q

$2 \times 3 = 6$

$4 \times 1 = 4$

10 marks

5 Given :-

$h_1 = 3m.$

$h_2 = 2m.$

diameter = 80m x 80m.

Area = 6400

$L = 1.5 m.$

$C_d = 0.62$

$$t = \frac{3A}{C_d L \sqrt{2g}} \left(\frac{1}{\sqrt{H_2}} - \frac{1}{\sqrt{H_1}} \right)$$

$$= \frac{3 \times 6400}{0.62 \times 1.5 \times \sqrt{2 \times 9.81}} \left(\frac{1}{\sqrt{.2}} - \frac{1}{\sqrt{3}} \right)$$

$$= 604.780 \text{ Sec.}$$

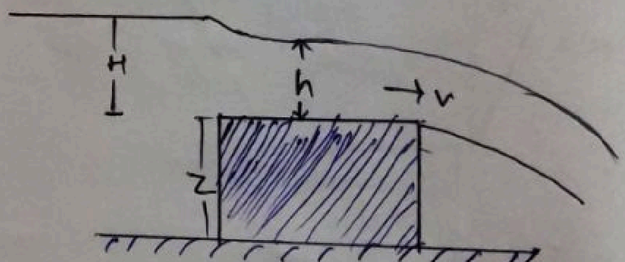
Discharge over a broad creasted weir :-

$$\boxed{Q = C_d\, L \times \sqrt{2g}\, (Hh^2 - h^3)}$$

If $2L > H$ broad creasted weir

$2L < H$ Narrow ~~weir~~ creasted weir

h = head of water at the needle of weir with in creast



v = velocity of flow over the water

$$\boxed{Q_{max} = 1.705\, C_d\, L \times H^{3/2}} \quad \text{if } \boxed{h = \frac{2}{3}H}$$

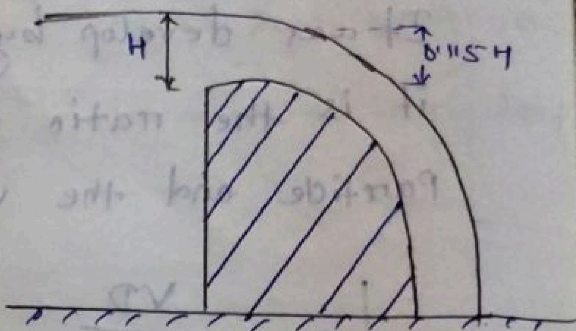
Discharge over a narrow creasted weir :-

$$\boxed{Q = \frac{2}{3} C_d\, L \times \sqrt{2g}\, H^{3/2}}$$

Discharge over a Ogee weir :-

Here creast of the weire rises upto to 0.115 H and falls as shown in figure

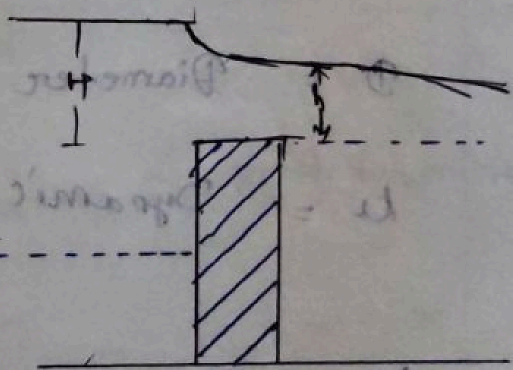
$$\boxed{Q = \frac{2}{3} C_d L \times \sqrt{2g}\, H^{3/2}}$$



Discharge over a Submerged/ weire

when water level on the d/s sid of weir is above the creast level of weire, it is called submerged drowned weir.

$$\boxed{Q = \frac{2}{3} C_{d_1} \cdot L \times \sqrt{2g}\,(H-h)^{3/2} + C_{d_2} L \cdot h \sqrt{2g(H-h)}}$$



C_{d_1} = Coefficient of discharge for force portion.

C_{d_2} = Coefficient of discharge for drowned portion.

~~A broad crested weir ...~~

Reynold's Numbere (R_e) :-

It was develop by Reynold in 1883
it is the ratio of inertial force of flowing particle and the viscous force of fluid particle.

$$R_e = \frac{VD}{\nu}$$

$$\boxed{R_e = \frac{\rho V D}{\mu}}$$

Where,

ρ = Density of the fluid through pipe

V = Average velocity of the fluid

D = Diameter of the pipe.

μ = Dynamic viscocity of the fluid.

ν = ~~...~~ Kinematic viscocity.

If $Re < 2000$ the flow is called lamina flow.

If $Re > 4000$ the flow is called turbulent flow

if the value of Re is in between 2000 to 4000 then the flow changes from lamina to turbulent flow.

ele.

Energy losses in pipe flow :-

(I) Major Energy losses (Energy loss due to friction)

(II) Minor Energy losses

Energy loss due to friction :-

The energy loss due to the friction between the fluid and walls of the pipe contributes the major loss in energy of the fluid.

The energy loss due to friction can be determined by two equations.

(a) Darcy - Weisbach's formula

(b) Chezy's formula.

Darcy - weisbach's Formula :-

Mathematically :-

$$\boxed{h_f = \frac{4fLv^2}{2gd}}$$

where,

h_f = the head loss due to friction

f = Coefficient of friction

$= \frac{16}{R_e}$ if $R_e < 2000$

$= \frac{0.079}{R_e^{1/4}}$ if $R_e >$ 4000 to 10^6

Chezy's Formula :-

$$\boxed{H_f = \frac{F'}{\rho g} \cdot \frac{P}{A} L \times v^2}$$

where,

F' = the friction factor

P = weted Perimeter

A = Area of crossection of pipe

v = Mean velocity of flow.

$$\frac{A}{P} = m \qquad \frac{d}{4} \text{ (For circular pipe)}$$

m = hydrolic mean depth / hydrolic radius.

$$\frac{h_f}{L} = i = \text{loss of head per meter length of the pipe.}$$

$$\boxed{C = \sqrt{\frac{\rho g}{f'}}}$$ = Chezy's Constant

$$\boxed{V = C\sqrt{mi}}$$

Q Find the head loss due to friction in a pipe ~~from~~ of diameter 300mm and length 50 m. velocity of flow is 3 m/sec use darcy formula and chezy's formula take C = 60 and ν of water is 0.01 stoke

Sol^n ① use darcy, weisbach's formula

$$h_f = \frac{4fLv^2}{2gd}$$

$$R_e = \frac{VD}{\nu}$$

$\nu = 0.01$ stoke

$= 0.01\ cm^2/s$

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

$$R_e = \frac{3 \times 0.3}{0.01 \times 10^{-4}}$$

$$= 900000$$

$$f = \frac{0.079}{R_e^{1/4}}$$

$$= \frac{0.079}{900000^{1/4}}$$

$$= 2.56 \times 10^{-3}$$

$$h_f = \frac{4 \times 2.56 \times 10^{-3} \times 50 \times 3^2}{2 \times 9.81 \times 0.3}$$

$= 0.78 \; m.$

use Chezy's formula :-

$v = 60\sqrt{\frac{0.3}{4} \times \frac{h_f}{l}}$

$3 = 60\sqrt{\frac{0.3}{4} \times \frac{h_f}{50}}$

$q = 3600 \left(\frac{0.3}{4} \times \frac{h_f}{50} \right)$

$$h_f = \frac{9 \times 4 \times 50}{3600 \times 0.3}$$

$$= \frac{36 \times 50}{3600 \times 0.3}$$

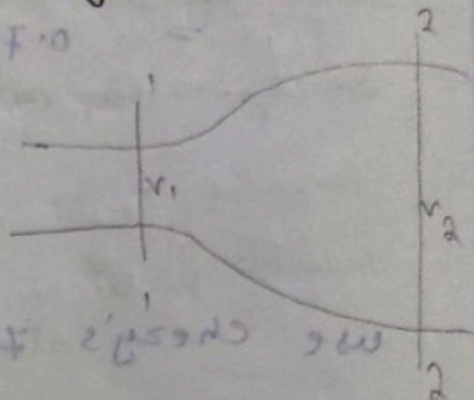
$$= \frac{1}{0.6} = \frac{10}{6}$$

$= 1.66.$

Minor losses in Pipe flow :-

(I) loss of head due to Sudden enlargement :-

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

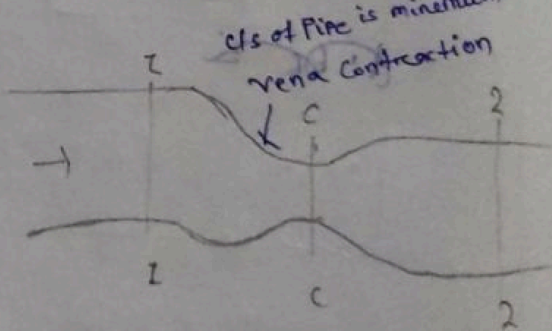


v_1 = velocity of flow at section 1,1

v_2 = velocity of flow at section 2,2

(II) Loss of head due to sudden Contraction :-

$$\boxed{h_c = \left(\frac{1}{C_c} - 1\right)^2 \frac{v_2^2}{2g}}$$



$C_c = \frac{A_c}{A_2}$ → = Coefficient of Contraction

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

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

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Loss of head at entrance of pipe :-

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

Loss of head at exit of the pipe :-

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

Loss of head due to obstruction in pipe :-

$$\boxed{h_e = \frac{v^2}{2g}\left(\frac{A}{C_c(A-a)}-1\right)^2}$$

where,

a = maximum area of obstruction

A = Area of Crossection of the pipe

v = velocity of flow in pipe.

C_c = Coefficient of Contraction.

Loss of head due to bend in pipe :-

$$h_b = \frac{kv^2}{2g}$$

k = Coefficient of bent which depends upon angle of the bend, Radius of Curvature of the bent and diameter of the pipe.

Loss of head due to pipe fittings :-

$$h_p = \frac{kv^2}{2g}$$

where,

k = Coefficient of pipe fittings

Loss of head due to valves, pipe fitting, and Couplings.

Hydraulic Gradient ~~pipe~~ line :- (HGL)

i) It is the line form by joining the datum head and pressure head along the direction of flow of fluid at various locations.

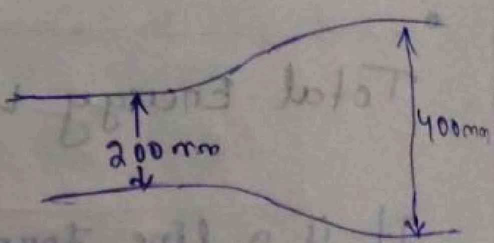
(ii) It is also formed by joining the ordinates of the sum of datum head and pressure head from the centre line of the pipe or a reference datum.

Total Energy Line (TEL) :-

It is a line formed by joining the datum head, pressure head and kinetic head from the centre line of the pipe along the direction of flow of fluid.

(1) Find the loss of head of pipe of diameter 200 mm is Suddenly enlarged to a diameter of 400 mm the rate of flow through the pipe is 250 l/sec

(11) At a Sudden enlargement of a water main from 240 mm to 480 mm diameter, the hydraulic gradient rises by 10 mm. Estimate the rate of flow.



Sol^n $h_e = \dfrac{k v^2}{2g}$

$Q = 250$ ltr/sec $= 0.25\ m^3/se$

discharge is constant

applying equation of Continuity

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

$$a_1 v_1 = a_2 v_2$$

$$a_1 = 0.0314$$

$$a_2 = 0.1256$$

$$v_1 = \frac{0.25}{0.0314}$$

$$= 7.96 \text{ m/sec}$$

$$v_2 = \frac{0.25}{0.1256}$$

$$= 1.99$$

$$h_e = \frac{(7.96 - 1.99)^2}{2 \times 9.81}$$

$$= \cancel{0.3044}\ 1.81 \text{ m}^2$$

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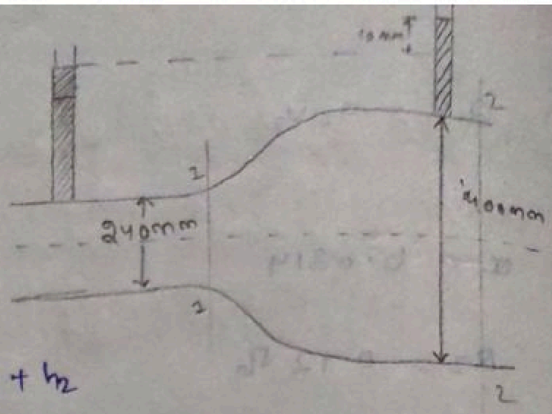
(1) Ans



Apply Berenoulli's equation

$$\cancel{\frac{P_1}{\rho g}} + \frac{v_1^2}{2g} + \cancel{z_1} = \cancel{\frac{P_2}{\rho g}} + \cancel{z_2} + \frac{v_2}{2g} + h_2$$

$$\frac{v_1^2}{2g} - \frac{v_2^2}{2g} = h_2 = 10mm = (0.01\,m)$$

$$v_1^2 - v_2^2 = 2g\ (0.01).$$

$$v_1^2 - v_2^2 = 2 \times 9.81 \times 0.01 = 0$$

$$v_1^2 = 0.196 + v_2^2$$ ~~we have~~

We have $a_1 v_1 = a_2 v_2$

$$\Rightarrow \cancel{\frac{\pi}{4}} \times 0.24^2 \times v_1 = \cancel{\frac{\pi}{4}} \times 0.48^2 \times \sqrt{(v_1^2 - 0.196)}$$

$\Rightarrow$ ~~$v_1\ 0.24^2\ 0.2083$~~

$$\Rightarrow v_1^2 (0.24^2)^2 = 0.48^2 (v_1^2 - 0.196)$$

$$\Rightarrow v_1^2\, 0.0033 = 0.2304\, (v_1^2 - 0.196)$$

$$\Rightarrow v_1^2$$

water is flowing through a pipe diameter 200 mm at a velocity of 3 m/sec a circular solid plate of diameter 150 mm is placed in the pipe to obstructed the flow find the loss of head due to obstruction in the pipe take $C_c = 0.62$

$A = 0.000314$

$a = 0.0176$

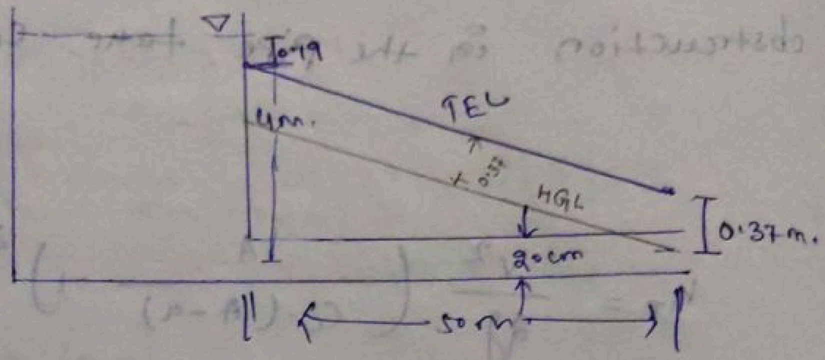
$$h_e = \frac{V^2}{2g}\left(\frac{A}{C_c \cdot (A-a)} - 1\right)^2$$

$$= \frac{3^2}{2 \times 9.81}\left(\frac{\frac{\pi}{4} \times (0.02)^2}{0.62\left(\frac{\pi}{4} \times 0.02^2 - \frac{\pi}{4} \times 0.15^2\right)} - 1\right)^2$$

$$= 3.311$$

Determine the rate of flow of water through a pipe of diameter 20 cm and length 50 m. when one end of the pipe is connected to a tank and the other end of the pipe is open to atmosphere. the pipe is horizontal at the height of the water tank is 4 m. above the centre of the pipe. Consider all minor losses and take $f = 0.009$ in the formula

$$h_f = \frac{4 f L v^2}{2 g d}$$ Also draw the HGL and TEL



Given data:-

length of pipe = 50 m = L

Diameter of Pipe = 20 cm

d = 200 mm = 0.2 m.

Hf of water in the tank from the centre line of pipe = 4 m.

Apply Bernoullis theorem at top surface of water and at the exit of pipe with respect to

$$\frac{\cancel{p_1}}{\cancel{\rho g}} + \cancel{\frac{v_1^2}{2g}} + h_1 = \frac{\cancel{p_2}}{\cancel{\rho g}} + \frac{v_2^2}{2g} + h_2 + \text{losses}$$

$$0+0+4 = \frac{v_2^2}{2g} + 0 + h_e + h_f$$

$$4 = \frac{v^2}{2g} + 0.5\frac{v^2}{2g} + \frac{4flv^2}{2gd}$$

$$4 = \frac{v^2}{2g}\left(1+0.5+\frac{4fl}{d}\right)$$

$$= \frac{v^2}{2\times 9.81}\left(1+0.5+\frac{4\times 0.009\times 50}{0.2}\right)$$

$$4 = 0.535v^2$$

$$v^2 = 7.47$$

$$v = 2.73 \text{ m/s}$$

Rate of flow $= Q = A\,v$

$$= \frac{\pi}{4}\times 0.2^2 \times (2.73)$$

$$= 0.085 \quad m^3/s$$

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Consider A, B, C are the points at top of water Surface ~~ent~~ of pipes & at the entrance of pipe with the tank respectively.

Total energy at A = 0 + 0 + 4
= 4m.

Total energy at C = Total energy at A − he

$$= 4 - 0.5 \frac{v^2}{2g}$$

$$= 4 - \frac{0.5 \times 2.7^2}{2 \times 9.81}$$

$$\simeq 3.81 \text{ m.}$$

Total energy at B = $0 + \frac{v^2}{2g} + 0$

$$= \frac{2.7^2}{2 \times 9.81}$$

$$\simeq 0.37$$

hydreolic gradient line (HGL)

If we deduct the kinetic head of TEL. we will get HGL

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

$= 0.37$ m

2.5

Open Channel Flow

→ Watere surrface will be exposed to atm pressurre.

→ Flow occurrs due to grravity / slope of channel

→ In case pipe, if water flows half / not full

~~for~~ Re < 500-600

Re > 2000 -- turrbulant flow

Re = 500 - 2000

Transition state.

Critical flow $F_e = 1$

Subcritical flow $F_e < 1$

super critical flow $F_e > 1$

Forrade's Number (F_e)

$$F_e = \frac{V_E}{\sqrt{G D}}$$

Discharge through Open Channel :

(a) Chezy's Formula :-

$$\boxed{Q = A\sqrt{mi}}$$

where, $C = \sqrt{\frac{w}{f}}$

$m = \frac{A}{P}$

c = Bed slope

w = ~~w~~ unit weight of water/liquid

f = frictional resistance per unit velocity per unit area

A = Area of flow ~~Hydraulic~~

m = Hydrolic mean depth

P = wetted perimeter

(b) Mannings Formula :-

$$\boxed{C = \frac{1}{N} m^{1/6}}$$

N = manning's Constant

Q. Find the velocity of flow and rate of flow to a rectangulare channel, having 6m. width and 3m depth and it is running full the bed slop of the channel is 1 : 2000 and C = 55

Given :-

width of rectangulare channel (w) = 6m.

Depth of Channel d = 3m

Bed slop = 1 : 2000

C = 55

hydraulic mean depth = $m = \frac{A}{P}$

$$\frac{3 \times 6}{2 \times 3 + 6} = \frac{3 \times 6}{12}$$

$$= 1.5\ m.$$

$$Q = C\sqrt{mi}$$

$$= 55\sqrt{1.5 \times \frac{1}{2000}}$$

$$= 1.50\ m^3/s$$

$Q = AV$

~~$1.5 = 3 \times 6$~~

$1.5 = 3 \times 6 \times v$

$v = \frac{1.5}{18}$

$= 0.083$ m/s

An arthen channel with 3 m. wide base and sid slope 1:1 carries water with a depth of 1 m. the bed slope is 1 in 1600 Estimate the discharge using Mannings equation and take N = 0.04

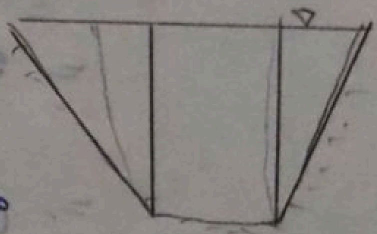
$w = 3m$

$d = 1m.$

depth of water = 1m

$N = 0.04$

Bed slop = i = 1:1600



$m = \cancel{\frac{A}{P}}$

$= \cancel{\frac{3 \times 1}{3+2\times 1}}$

$= \cancel{\frac{A}{5}}$

$= \cancel{0.6}$

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$$m = \frac{A}{P}$$

$$= \frac{\frac{1}{2} \times 5 \times 1}{2 \times \sqrt{2} + 3}$$

$$= 0.428$$

$$\simeq 0.43$$

$$C = \frac{1}{0.04} \times 0.43^{1/6}$$

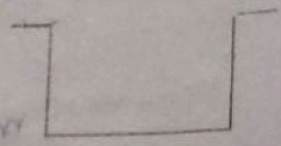
$$= 21.71$$

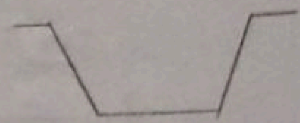
$$Q = C\sqrt{mi}$$

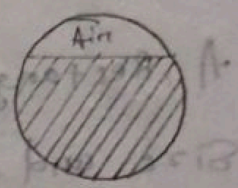
$$= 21.71 \sqrt{0.43 \times \frac{1}{1600}}$$

$$= 0.35 \ m^3/s$$

Types of channel Section :-

(a) Rectangular Channel Section 

(b) Trapezoidal Channel Section 

(c) Circulare Channel Section 

Most economical Section :-

→ Section of the channel for which the Cost of Construction will be minimum and we will have max^m discharge.

For rectangular Section :-

For the most economical section which is having minimum wetted perimeter so that the discharge will be maximum

in case of rectangular channel the two conditions are

$$\boxed{\begin{aligned} b &= 2d \\ m &= \frac{d}{2} \end{aligned}}$$

for max^m Q + max^m v

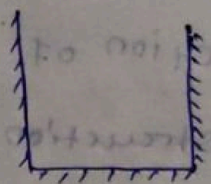
$$Q_{max} = C\sqrt{mi}$$

$$m\uparrow = \frac{A\uparrow}{P\downarrow}$$

$\uparrow Q$ $m\uparrow$

$\downarrow Q$ $m\downarrow$

A Rectangular has Crossection $8 m^2$ find its Size and discharge through the most economical Section if the bed slope is 1 in 1000 and $C = 55$



$A = 8 m^2$

$i = \frac{1}{1000}$

$C = 55$

$\cancel{M = \frac{A}{B}}$ $\qquad m = \frac{d}{2}$

$\cancel{b \times d = 8}$ $\qquad b \times d = 8$

$\cancel{b \times 2d \times d = 8}$ $\qquad b \times \frac{b}{2} = 8$

$b^2 = 16$

$b = \sqrt{16}$

$b = 4$ $\qquad d = b/2 = 2$

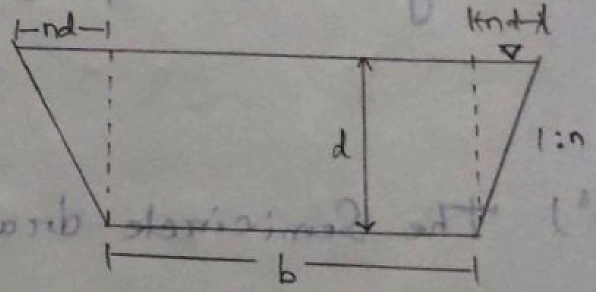
$m = \frac{2}{2}$

$m = 1$

$Q = 55\sqrt{1 \times \frac{1}{1000}}$

$= 1.73$

Most economical Section for trapizoidal Channel :-



$\sqrt{nd^2 + d^2}$

$= \sqrt{n^2 d^2 + d^2}$

$= \sqrt{d^2 (n^2+1)}$

$= d\sqrt{n^2+1}$

Side slope $= d\sqrt{n^2+1}$

wetted perimeter $= P = b + (2d\sqrt{n^2+1}$

Area $= A = \frac{1}{2}(b + b + 2nd) \times d$

$m = \frac{A}{P}$

The half of the top width of the trapizoidal section is = the length of the side slope

mathematicaly,

$$\boxed{\frac{b+2nd}{2} = d \times \sqrt{n^2+1}}$$

(2) $m = \frac{d}{2}$

hydraolic depth is = half of the depth

(3) The semicircle drawn from O with a radius = the depth of the flow will touch the three sides of the channel.

Q A trapizoidal channel has a side slope of one horizontal to two vertical and the bed slope of channel is 1:1500 the area of the section is 40 m^2 find the dimension of the section if it is economical determine the discharg of most economical section if C = 50

Ans:

Ans:- Side slope = $1H : 2V$ $= 1/2$
bed slope = $1 : 1500$

$A = 40 m^2$
$C = 50$

side slop $= d\sqrt{n^2+1}$

$2 = d\sqrt{(1/2)^2+1}$

$d = 1.8$

$= \frac{1}{2}(b + 2nd + b) \times d = 40$

$\Rightarrow \frac{1}{2}(2b + 2nd) \times d = 40$

$\Rightarrow (b + nd)\, d = 40$

$\Rightarrow bd + nd^2 = 40$

For most economical Section,

$$\frac{b + 2nd}{2} = n\sqrt{d^2+1}$$

$$m = \frac{d}{2}$$

$\Rightarrow \frac{A}{P} = \frac{d}{2}$

$\Rightarrow \frac{40}{b + 2d\sqrt{n^2+1}} = \frac{d}{2}$ —— ①

$\Rightarrow \frac{40}{b + 2d\sqrt{\left(\frac{1}{2}\right)^2+1}} = \frac{d}{2}$

$\Rightarrow 80 = bd + 2d^2 \sqrt{(1/2)^2+1}$

$\Rightarrow 80 = bd + 2d^2 \times \frac{\sqrt{5}}{2}$

$\Rightarrow 80 = bd + 2.22\, d^2$ —— (II)

$bd + 0.5\, d^2 = 40$ —— ⑤
$bd + 2.22\, d^2 = 80$ —— ①

$1.72\, d^2 = 40$

$d^2 = \frac{40}{1.72}$

$d^2 = 23.25$

$d = \sqrt{23.25}$

$= 4.82$

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$4.82 \times b + \frac{1}{2} \cancel{*} 4.82^2 \cancel{*} = 40$

$4.82 \times b = 40 - 11.61$

$b = \frac{28.39}{4.82}$

$= 5.89$

$= \frac{b + 2nd}{2}$

$= \frac{5.89 + 2 \times \frac{1}{2} \times 4.82}{2}$

$= 5.355$ m

$\frac{1}{2}\sqrt{4.82^2+1}$

$= 2.46$ m.

$$\frac{b+2\times\frac{1}{2}\times d}{2} = \frac{1}{2}\sqrt{d^2+1}$$

$$= \frac{b+d}{2} = \frac{1}{2}\sqrt{d^2+1}$$

$$= b+d = \sqrt{d^2+1}$$

$$= b+4.82 = \sqrt{4.82^2+1}$$

$$= b = 4.92-4.82$$

$$b = 0.1$$

$$Q = AC\sqrt{mi}$$

$$= 40\times 50\sqrt{\frac{4.82}{2}\times\frac{1}{1500}}$$

$$= 80.166 \ m^3/s$$

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Most economical Section for Circular channel :-

There are two condition for most economical section incase of circular open channel flow. as the Area of flow can not be maintained in case of circular crossection.

(i) For maximum velocity $\theta = 128^\circ 45'$

$d = 0.81D$

$m = 0.3D$

(ii) for maximum discharge $\theta = 154^\circ$

$d = 0.95D$

Flow through Circular Cross Section :-

Let the depth of water in the circular channel in = 'd'

Diameter of channel = ϕ D

$$Q = AC\sqrt{mi}$$

A = Area of flow = wetted area = Area of sector APBQA

Let 2θ in the angle made by the top surface of water at the centre circle 'O'.

$$360' = 2\pi = \pi R^2$$

$$1^c = \frac{\pi R^2}{2\pi}$$

$$2\theta = \frac{\pi R^2}{2\pi} \times 2\theta$$

$$= R^2 \theta$$

$$= OAQBO$$

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The rate of flow of water through a circular channel of diameter 0.6m. is 150 liter/second find the bed slope for maximum velocity. take $C = 60$

$C = 60$

$D = 0.6m.$

$Q = 150$ ltr/sec

$= 0.15 m^3/s$

For maximum velocity

$\theta = 128^\circ 45' = 128^\circ 45' \times \frac{\pi}{180} = 2.25$

$m = 0.3D = 0.3 \times 0.6 =$

$d = 0.81D$

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$$A = R^2\left(\theta - \frac{\sin 2\theta}{2}\right)$$

$$= \left(\frac{0.6}{2}\right)^2\left(2.25 - \frac{\sin 2\times 128^\circ 45'}{2}\right)$$

$$= 0.246\ m^2$$

$$0.15 = 0.246 \times 60 \times \sqrt{0.18\times i}$$

$$0.15 = 0.246 \times 60 \times \sqrt{i \times 0.18}$$

$$\cancel{0.15 = 14.76 \times 0.42 i}$$

$$\cancel{0.42 i = \frac{0.15}{14.76}} \quad 0.15 = 14.76 \times \sqrt{0.18 \times i}$$

$$\cancel{i = 0.01} \quad \sqrt{0.18\times i} = \frac{0.15}{14.76}$$

$$\cancel{i = 0.}$$

$$0.18 \times i = (0.01)^2$$

$$i = 0.0001$$

A Concrete Line Circular Channel of diameter 3m. has a bed slope of 1:500 Calculate the velocity and discharge for maximum velocity

maximum discharge

take $C = 50$

Pump

Pump :- Hydrolic machine which convert mechanical energy to hydrolic energy.

(I) Reciprocating pump

(II) Centrifugal pump

The hydrolic energy is in the form of pressure energy if the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydrolic machine is called centrifugal pump

Working Principle of Centrifugal Pump :-

⇒ The centrifugal pump works on the principle of forced vortex flow which means when a certain mass of liquid is rotated by a external torque, the rise in pressure head of the rotating liquid takes place.

⇒ The rise in pressure head at any point of the rotating liquid is propertion to the square of tangential velocity of the liquid at that point.

Mathematicaly :-

$$\boxed{\text{Rise in pressure head} = \frac{v^2}{2g} \text{ or } \frac{\omega^2 r^2}{2g}}$$

Thus at the outlet of the impeller, where the radius is more, the rise in pressure head will be more and the liquid will be discharged at the outlet with a high pressure.

Due to this high pressure head, the water can be lifted to a high level.

Main parts of a Centrifugal Pump :-

The main parts

(i) Impeller

(ii) Casing

(iii) Suction pipe with foot valve & strainer

(iv) Delivery pipe

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Impeller :-

The rotating Part of a Centrifugal pump is called impeller.

It Consist of a Series of backward Curved vanes
The impeller is mounted on a shaft which is connected to the shaft of an electric motor.

In case of Centrifugal pump the Power is transmitted from the shaft of electric motor to the shaft of the Pump and then to the impeller. Form the impeller The Power is given to water. thus the Power is decreasing from the shaft of the pump to the impeller then to water.

⇒ The following are the important efficiencies of a Centrifugal pump.

(i) Manometric Efficiency

(ii) Mechanical Efficiency

(iii) overall Efficiency

Manometric Efficiency (η_{man}) :-

The ratio of the manometric head to the head imparted by the impeller to the water is called as manometric efficiency.

Mathematically,

$$\eta_{max} = \frac{\text{Manometric head}}{\text{head imparted by the impeller to water}}$$

$$= \frac{H_m}{\frac{V_{w_2} U_2}{g}}$$

$$= \frac{g H_m}{V_{w_2} u_2}$$

The Ratio of the power given to the water at outlet of the pump to the power available at the impeller is known as manometric efficiency.

The given to the outlet of the pump of water

$$= \frac{w H_m}{1000} \text{ kW}$$

where,

U_2 = tangential velocity of impeller at outlet

$$= \frac{\pi D_2 N}{60}$$

where
D_2 = Diameter of the impeller at outlet.

W = weight of the water

$= \rho g Q$

Q = volume of water

V_{w_2} = The velocity of the water at the outlet of the impeller

The power at the impeller =

$$\frac{\text{workdone by the impeller / sec}}{1000} \text{ kW}$$

$$= \frac{W \times V_{w_2} U_2}{g \times 1000} \text{ kW}$$

$$\boxed{\eta_{man} = \frac{\frac{W H_m}{1000}}{\frac{W V_{w_2} U_2}{g \times 1000}} = \frac{g H_m}{V_{w_2} V_2}}$$

Mechanical ~~effer~~ efficiency :-

The ratio of the power available at the impeller to the power at the shaft of centrifugal pump is called as mechanical efficiency.

it is written

$$\eta_m = \frac{\text{Power at the impeller}}{\text{Power at the}}$$

Power at the impeller in kW = workdone by the

$$= \cancel{W \times V_{w_2} U_2} \quad \frac{\frac{W . V_{w_2} U_2}{g \times 1000}}{S.P}$$

- Power at shaft

Overall efficiency :- θ_0

It is define as the ratio of power output of the pump to the power input of the pump.

- The power output of the pump in kW

$$= \frac{\text{Weight of water lifted} \times H_m}{1000}$$

$$= \frac{W H_m}{1000}$$

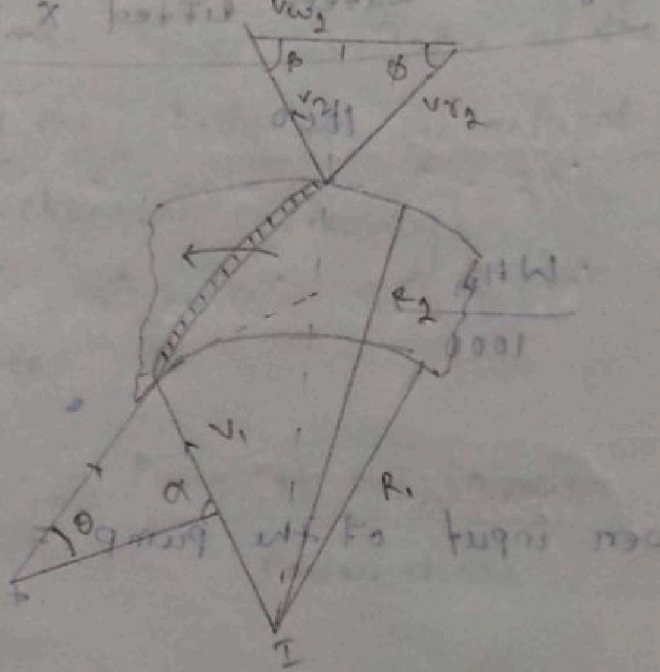
The power input of the pump = The power supplied by the electric motor

Mathematically,

$$\theta_0 = \frac{\frac{W H_m}{1000}}{\text{S.P. of the pump}}$$

$$\eta_0 = \eta_{man} \times \eta_m$$

The internal and the external diameter of the impeller of a Centrifugal pump are 200 mm and 400mm respectively. The pump is running at 1200 RPM. The vaneangle of the impeller at the inlate and outlet at 20° and 30° respectively. The water enters the impeller radially and velocity of flow is Constant. determine the velocity of flow per meter Sec.



N = speed of the impeller

D_1 = Diameter of the impeller at the inlate

U_1 = Tangential velocity of the impeller at inlate

$$= \frac{\pi D_1 N}{60}$$

D_2 = Diameter of the impeller at the outlet.

U_2 = Tangential velocity of impeller at the outlet.

$$= \frac{\pi D_2 N}{60}$$

V_1 = The absolute velocity of water at the inlate

V_{r_1} = is the relative velocity of water at inlate

α = angle made by absolute velocity v_1 at inlate with the direction of motion of vane.

θ = angle made by the relative velocity V_{r_1} at inlate with direction of motion of vane

V_2, V_{r_2}, β and ϕ at the corresponding value of outlet.

V_{f_2}, V_{f_1} the velocity of flow of inlate and outlet.

Given data :-

D_1 =

Internal diameter of impeller = 200mm

= 0.2m.

External diameter of impeller D_2 = 400mm

≃ 0.4m

N = 1200 rpm

vane angle at inlate = θ = 20'

vane angle at outlet = ϕ = 30'

Water enters the impeller radially means

$\alpha = 90'$

$V_{w_1} = 0$

velocity of flow =

$V_{f_1} = V_{f_2}$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.2 \times 1200}{60} = 12.56$$

$$\tan\phi = \frac{V_{f_2}}{U_1}$$

$$= \frac{V_{f_2}}{12.56}$$

$$\tan 20' = \frac{V_{f_2}}{12.56}$$

$$V_{f_2} = 12.56 \times \tan 20'$$

$$= 4.56 \text{ m/s.}$$

Heads :-

(i) Suction Head (h_s)

(ii) Delivery head (h_d)

(iii) Manometric head (h_m)

1. Suction head (h_s) :-

It is the vertical height of the centreline of the centrifugal pump above the water surface in the water tank or the sump from which water is to be lifted this height is called suction lift and is denoted by (h_s).

Delivery head :- (h_d)

The vertical distance between the centre line of the pump and the water surface in the tank to which water is deliver is called as delivery head.

Static head (h_s') :-

It is the sum of the suction head and delivery head.

$$\boxed{h_s' = h_s + h_d}$$

Manometric head :-

The manometric head is defined as the head against which a centrifugal pump has to work. it is denoted by (h_m).

(a) h_m = head imparted by the impeller to the water - the loss of head in the pump.

$$= \boxed{\frac{V_{w_2} u_2}{g} - \text{loss of head, in impeller \& casing.}}$$

(b) h_m = The total head at the outlet of the pump - The total head at the inlet of the pump

$$= \left(\frac{P_o}{\rho g} + \frac{V_o^2}{2g} + Z_o\right) - \left(\frac{P_i}{\rho g} + \frac{V_i^2}{2g} + Z_i\right)$$

(c) $$h_m = h_s + h_d + h_{fs} + h_{fd} + \frac{V_d^2}{2g}$$

where,

h_s = Suction head

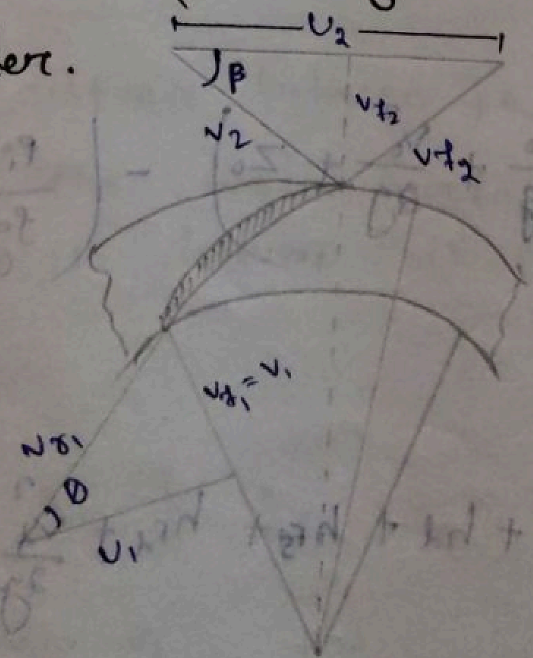
h_d = delivery head

h_{f_s} = Friction head loss in the Suction Pipe.

h_{f_d} = Friction head loss in the delivery pipe.

V_d = velocity of water in the delivery pipe

Q The internal and external diameters of the impeller of a Centrifugal pump are 200 mm and 400 mm respectively. The pump is running at 1200 rpm. The vane angles at inlate and outlet are 20° and 30° respectively. The water enters the impeller radially and the velocity of flow is constant. determine the workdone by the impeller per unit weight of water.



$\theta = 20^\circ \quad \phi\ 30^\circ$

$V_{f_1} = V_{f_2} = $ Constant

$D_1 = 200\,mm \simeq 0.2\,m$

$D_2 = 400\,mm \simeq 0.4\,m.$

$N = 1200$ rpm

$U_1 = 12.56\ m/s$

$U_2 = 25.13\ m/s$

$V_{f_1} = V_{f_2} = 4.57\ m.$

from the outlet velocity triangle

$$\tan\phi = \frac{V_{f_2}}{U_2 - V_{w_2}}$$

$$\Rightarrow \tan 30^\circ = \frac{4.57}{12.57 - V_{w_2}}$$

$$\Rightarrow \cancel{\tan}\ 0.57 = \frac{4.57}{12.57 - V_{w_2}}$$

$\Rightarrow$ ~~0.57 × 4.57 12.57 − Vw2~~

$\Rightarrow$ ~~0.57 × 4.57~~ $0.57 \times 12.57 - V_{w_2} = 4.57$

$$\Rightarrow V_{w_2} = \frac{4.57 - 0.57 \times 25.13}{-0.57} = 17.11\ m/s$$

work done by impeller per by . of water per second = $\frac{1}{g} \cdot V_{w_2} U_2$

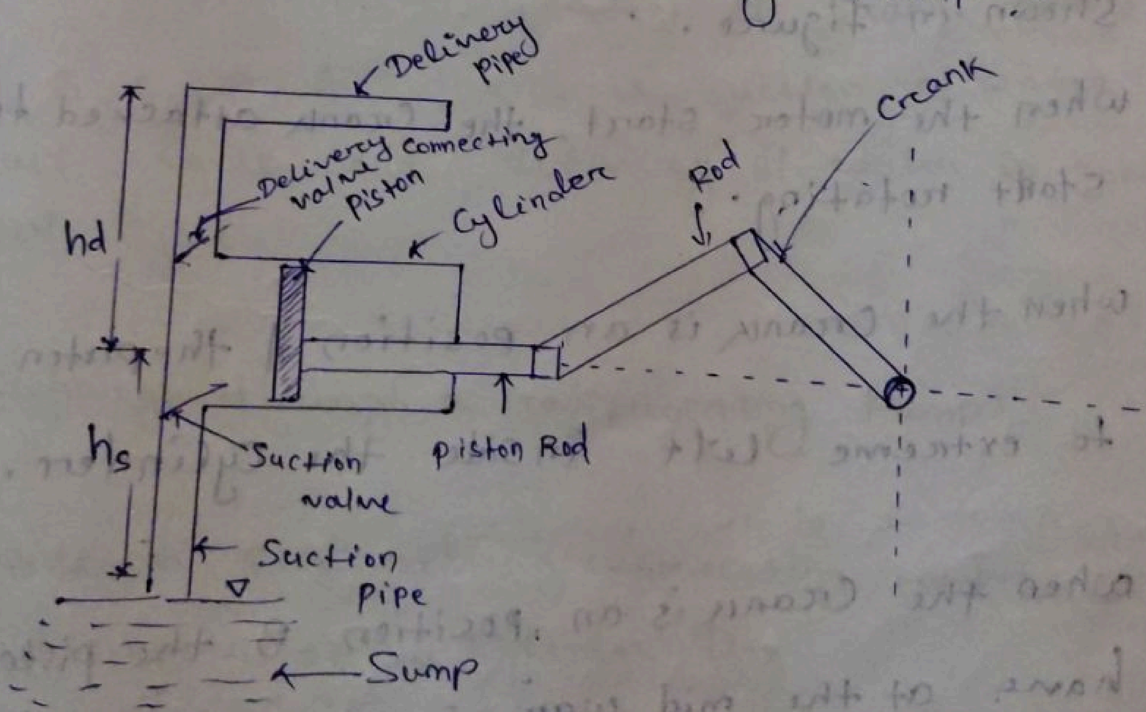
$= \frac{1}{9.81} \times 17.11 \times 25.13 = 43.83$ Nm

A centrifugal pump is to discharge 0.118 m^3/s at a speed of 1450 rpm against a head of 25m. the impeller diameter is 250 mm. and the width at the outlet is 50 mm and the manometric efficiency is 75%. determine the vane angle at the outlet periphery of the impeller

Reciprocating Pump :-

It the mechanical energy is used to convert into hydrolic energy or (Pressure energy) by shucking the liquid into a cylinder in which a piston is resiprocating. (Moving foreword & backword) which exerts the thrust on liquid and increases it hydrolics energies the pump is called a resiprocating Pump.

Main Parts of reciprocating Pump :-



single

vaccum pressure created inside th

(1) A cylinder with piston rod connecting rod & Cran

(2) Suction pipe

(3) Delivery pipe

(4) Suction valve

(5) Delivery valve

Working Principle of Reciprocating Pump!-

The crank it attach to the shaft of motor as shown in figure.

when the motor start, the crank attached to it start rotating.

when the crank is an position A the piston will move to extreme left inside the cylinder.

when the crank is an position B the piston will have at the mid way inside the cylinder when

when the crank is an position c the piston will move to extreme right inside the cylinder.

the total distance cover by the piston inside the cylinder $= l = 2r$

where,

r is the length of the crank as shown in fig.

when crank is an position C a vacaume is created inside the cylinder whose pressure is less than the atmospheric pressure acting on the surface of water is the sump. this couses suction of water from the sump into inside the cylinder by opening of the suction valve.

when the crank will move to position A it forces the water inside the cylinder to go out through the delivery pipe by opening the delivery valve.

So in one complete rotation of crank ie.

A, B, C, D, A, there is suction of water in half cycle and delivery of water in another half cycle.

Discharge through a resiprocating Pump:-

Consider a single acting resiprocating pump in which the diameter of the cylinder D.

Area of crossection of piston or cylinder $= \frac{\pi}{4} \times d^2$

radius of the crank $= r$

N = rpm of the crank

L = Length of the Stroke (2r)

h_s → height of the axis of the Cylinder from the water Surface in Sump

→ it is also called Suction head

h_d = → height of the delivery outlet above the axis of the Cylinder.

→ it is also called = delivery head

In one Complete revolution the volume of water discharged = Area × length of the stroke

= A × L

No of Revolution per second = $N/60$

Discharge of the pump per Second = Q

Q = volume × No of revolution per Second

$Q = A \times L \times \frac{N}{60}$

$$\boxed{Q = \frac{ALN}{60}}$$

Workdone persecond = the weight of water deliver per second = w

$$w = \rho g Q$$

$$wt = \frac{\rho g ALN}{60}$$

Workdone by the resiprocating pump :-

$$\boxed{\text{Workdone per Second} = \frac{\rho g ALN}{60} \times (hs + hd)}$$

Power required to drive the pump in KW.

$$P = \frac{\text{Workdone Per Second}}{1000}$$

$$P = \frac{\rho g ALN}{60 \times 1000} \times (hs + hd)$$

$$\boxed{P = \frac{\rho g ALN}{60000} \times (hs + hd)}$$

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Classification of reciprocating Pump :-

(a) according to the water being in contact with one Side or both Sides of the piston.

(i) Sigle acting Pump

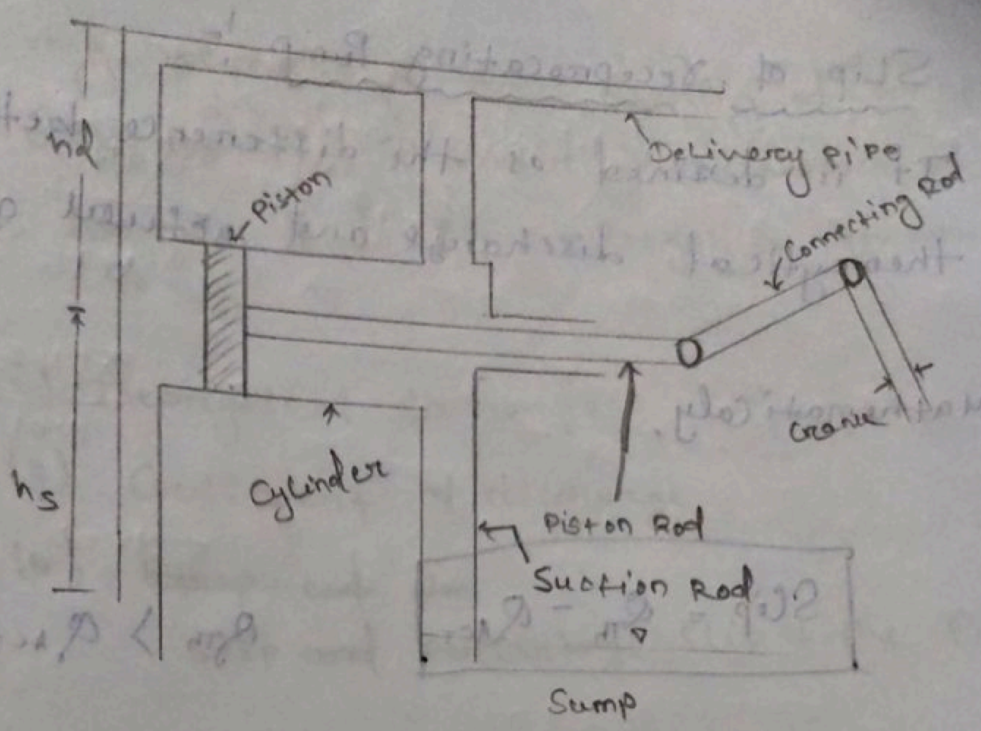
(ii) double acting Pump

(b) according to the NO of Cylinder provided,

(i) Single Cylinder pump

(ii) double Cylinder Pump

(iii) triple Cylinder Pump



Discharge of Double acting reciprocating pump

$$\boxed{Q = \frac{2ALN}{60}}$$

Workdone per Second $= \dfrac{2\rho g ALN\,(h_s + h_d)}{60}$

Power in kW $= \dfrac{2\rho g\, ALN\,(h_s + h_d)}{60000}$

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Slip of reciprocating Pump :-

It is defined as the difference between the theorytical discharge and actual discharge

Mathematicaly,

$$\boxed{Slip = Q_{Th} - Q_{ACT}} \qquad Q_{TH} > Q_{ACT}$$

Percentage Sleep

$$\boxed{= \frac{Q_{th} - Q_{Act}}{Q_{th}} \times 100} \qquad Q_{TH} < Q_{ACT}$$

$Q_{th} < Q_{Act}$

In this case ; slip will be Negative called Negative slip

Negative slip occures when the suction pipe is long and delivery pipe is short. and the pump is running at high speed.

A single acting reciprocating Pump Running at 50 rpm delivers 0.01 ~~m³~~ m^3/sec of water the diameter of the Piston is 200 mm and stroke length is 400 mm. determine

(i) Theorytical discharge

(ii) Coefficient of discharge

(iii) ~~Sleep and perc~~ Slip and percentage slip of the Pump.

$Q_{Act} = 0.01 \; m^3/sec$

$D = 200mm$
$= 0.2m$

speed of pump = $N = 50$ rpm

Stroke Length $(L) = 400$ mm $= 0.4$ m

Area of piston = $A = \frac{\pi}{4} \times 0.2^2$
$= 0.031$

$Q_{Th} = \frac{ALN}{60}$

$= \frac{0.31 \times 0.4 \times 50}{60} = 0.0103 \; m^3/s$

(ii) Coefficient of discharge =

$$C_d = \frac{Q_{Act}}{Q_{th}}$$

$$= \cancel{\frac{0.0103}{0.01}} \quad \frac{0.01}{0.0103}$$

$$\cancel{= 1.03} \quad = 0.97$$

(iii) $\text{slip} = Q_{th} - Q_{Act}$.

$$= 0.0103 - 0.01$$

$$= 0.0003 \; m^3/s$$

(iv) percentage slip

$$\boxed{\%\,\text{slip} = (1 - C_d) \times 100}$$

$$= \frac{Q_{th} - Q_{Act}}{Q_{th}}$$

$$= \frac{0.0003}{0.0103} \times 100$$

$$= 2.91\ \%.$$

A double acting reciprocating pump is running at 40 rpm is discharging $1 m^3$ of water per min. the pump has a stroke of 400 mm. the diameter of the piston is 200 mm. the delivery and suction head are 20m and 5 m. respectively. Find the slip of the pump and the power required to drive the pump.

$Q_{act} = 1 m^3/min$

$D = 200 mm$

$= 0.2 m.$

Stroke of pump = 400mm

$L = 0.4 m.$

$N = 40$ rpm

delivery head = 20m

suction head = 5m.

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Sol

Area of Piston $= \frac{\pi}{4} \times 0.2^2$

$= 0.031$

$Q_{Act} = \frac{1 m^3}{60}$

$= \frac{1}{60} m^3/sec$

$$Q_{th} = \frac{2ALN}{60}$$

$$= \frac{2 \times 0.031 \times 0.4 \times 40}{60}$$

$= \cancel{0.01650}\ 0.0165$

Slip $= Q_{th} - Q_{Act} = 0.0165 - 1/60$

$= -0.0001$

Power required to run the pump

$$= \frac{2 \rho g ALN (h_s + h_d)}{60000}$$

$$= \frac{2 \times 1000 \times 9.81 (0.031 \times 0.4 \times 40 (5+20)}{60000}$$

$= 4.05$

Indicator diagram :-

It is a graph between the pressure head in the cylinder and the distance traveled by the piston from the inner dead centre for one complete revolution of the crank.

In the graph, the pressure head is taken in ordinate (along y axis) and stroke length is taken as abscissa (along x axis).

The maximum distance travelled by the piston

= the stroke length

The ~~diff~~

Centrifugal pump	Reciprocating Pump
The discharg is continuous and smooth.	The discharge is fluctuating and pulsating.
It can handle large quantity of liquid	It can handle small quantity of liquid.
It can be used for highly viscuss liquid.	It can be used for less viscuss liquid as water.
It can be used for large discharges through small heads	It can be used for small discharges with high head.

the Cost is less	the cost is 4 times than that of Centrifugal Pump
It runs at high speed	It runs at low Speed.
The operation is Smooth without much noise.	The operation is complecated and produces more noise.
Its efficiency is high	It efficiency is Low.
Its installation and maintainans Cost is low	Its installation and maintainany is high