

Properties of fluid and fluid process

Fluid machines is that branch of science which deals with the behaviour of fluid (liquid and gases) and rest as well as in motion.

Static :- The study of fluid at rest is called fluid static.

Kinematics :- The study of fluid in motion where a pressure force are not consider is call fluid kinematics.

Dynamics :- The study of fluid in motion where a pressure force are consider is call fluid Dynamics.

Properties of fluid

Density :- Density is defined as the ratio of the mass of fluid to its volume.

Density is Denoted by ρ (Rho)

$$\rho = \frac{\text{mass}}{\text{volume}}$$

Specific weight and weight density

weight density of fluid is the ratio between weight of fluid to its volume.

$$\text{Specific weight} = \frac{\text{weight of fluid}}{\text{volume of fluid}}$$

$$\text{Specific weight} = \frac{\text{mass of fluid} \times g}{\text{volume of fluid}}$$

$$(\rho = \text{Rho}) \quad \text{S.W} = \rho g = \frac{N}{m^3}$$

It is denoted by w

Specific volume :-

Specific volume of fluid is defined as the ratio between volume of fluid to the mass of fluid.

$$\text{Specific volume} = \frac{\text{volume of fluid}}{\text{mass of fluid}}$$

$$= \frac{V}{\text{mass of fluid}} = \frac{V}{\rho \cdot V} = \frac{1}{\rho}$$

$$\text{Sp volume} = \frac{1}{\rho}$$

(S) Specific gravity :- Specific gravity is defined as the ratio of weight density (density) of fluid to the weight density (density) of standard fluid.
(unitless)

$$S = \frac{\text{density of fluid}}{\text{density of standard fluid}}$$

$$= \frac{\rho_f}{\rho_{wg}}$$

$$= \frac{\rho}{\rho_w} \quad (w = \text{water})$$

$$\text{Specific gravity of water} = \frac{1000}{1000}$$

$$S_w = 1$$

$$\text{Specific gravity of Hg} = \frac{13600}{1000}$$

(Hg = mercury)

$$S_{Hg} = 13.6$$

Q.1 Sp gravity of oil is .7 find

Solution :-

$$\text{Sp gravity of oil} = .7$$

$$S = \frac{\rho}{\rho_w}$$

$$.7 = \frac{\rho}{\rho_w}$$

$$\rho = \frac{.7}{1000}$$

$$\rho = 700 \text{ kg/m}^3$$

Q.2 density of petrol is $749 \frac{\text{kg}}{\text{m}^3}$ find
Sp gravity

Solution :- $S = \frac{\rho}{\rho_w}$

$$S = \frac{749}{1000}$$

$$S = 0.749$$

Liter = 1000 cm ³

Q. calculate the sp weight, (density and sp gravity of fluid which weight 7 N and liter of

Solution :-

$$\text{Specific weight} = \frac{\text{weight of fluid}}{\text{volume of fluid}}$$

$$\text{Sp weight} = \frac{7}{7000}$$

$$= 0.001 \text{ N/cm}^3$$

$$= 7 \times 1000$$

$$\boxed{\text{Sp weight} = 7000 \text{ N/m}^3}$$

$$\rho \text{ density} = \frac{\text{sp w}}{g}$$

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

$$\boxed{\rho = 713.55 \text{ kg/m}^3}$$

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

$$S = \frac{713.55}{1000}$$

$$S = 0.713$$

Q. Calculate density, specific weight and weight of 1 liter of petrol of specific gravity 0.7

Solution: -

$$\text{density} = ?$$

$$\text{weight} = ?$$

$$\text{Sp weight} = ?$$

$$\text{volume} = 1 \text{ litre petrol} \left[\frac{1}{1000} \text{ m}^3 \right]$$

$$\text{sp gravity (S)} = 0.7$$

$$\text{density} \times \text{weight} = \text{Sp gravity} \times \text{density of Standard fluid}$$

$$= 0.7 \times 1000$$

$$\rho = 700 \text{ kg/m}^3$$

$$\text{Sp weight} = \rho \times g$$

$$= 700 \times 9.81$$

$$= 6867 \frac{\text{N}}{\text{m}^3}$$

$$\text{weight} = \text{SP weight} \times \text{volume}$$

$$= 6867 \times \frac{1}{1000}$$

$$= 6.867 \text{ Kg}$$

dynamic viscosity ~~and~~

(H) μ / viscosity :- viscosity is define as the property of fluid which offers resistance to movement of one layer of fluid over another adjacent layer of fluid

Top layer causes on shear stress on adjacent lower layer while lower layer causes shear stress on the adjacent top layer

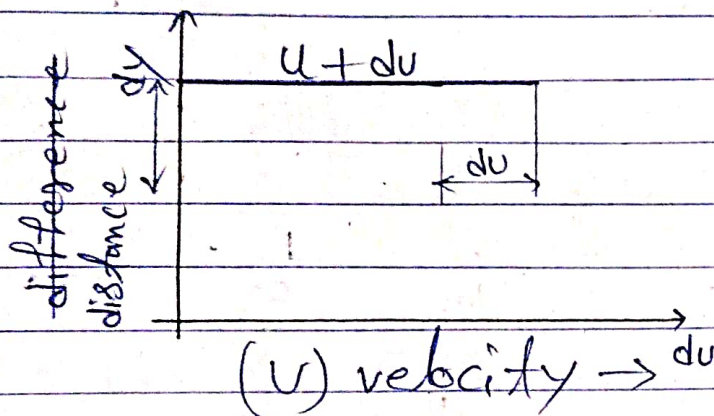
Newton's law of viscosity :- It states that shear stress is directly proportional to the rate of shear strain.

$$\text{rate of shear strain} = \frac{du}{dy}$$

$$\text{shear stress} = \tau$$

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

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



$$du/dy \text{ unit} = \text{second}$$

$$dy = \text{change in distance}$$

$$du = \text{change in velocity}$$

S.I unit of viscosity :-

$$\text{viscosity } (\mu) = \frac{\text{N-s}}{\text{m}^2} = (\text{Pa} \cdot \text{sec})$$

C.G.S unit of viscosity

$$\mu = \frac{\text{dyne-s}}{\text{cm}^2}$$

M.K.S unit of viscosity

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

$$1 \text{ poise} = \frac{1}{10} \frac{\text{N} \cdot \text{s}}{\text{m}^2}$$

$$1 \text{ centi poise} = \frac{1}{100} \text{ poise}$$

$$= \frac{1}{100} \times \frac{1}{10} \frac{\text{N} \cdot \text{s}}{\text{m}^2}$$

$$= \frac{1}{1000} \text{ Pa} \cdot \text{sec} \text{ and } \frac{\text{N} \cdot \text{s}}{\text{m}^2}$$

$$1 \text{ centi poise} = \frac{1}{1000} \frac{\text{N} \cdot \text{s}}{\text{m}^2}$$

(v) Kinematic viscosity (ν):- It is defined as the ratio between dynamic viscosity and density of fluid. It is denoted by ν (v).

$$\nu = \frac{\mu}{\rho} \quad \frac{\text{viscosity}}{\text{density}}$$

unit of kinematic viscosity is $\frac{\text{m}^2}{\text{sec}}$

$$\text{Newton} = F = ma$$

$$F = \text{mass} \times \text{acceleration}$$

$$= \text{kg} \times \frac{\text{m}}{\text{s}^2}$$

$$N = \text{kg} \frac{\text{m}}{\text{Sec}^2}$$

$$\frac{\mu}{s} = \frac{N \cdot s}{m^2} \cdot \frac{\text{kg}}{m^3}$$

$$= \frac{N \cdot s}{m^2} \times \frac{m^3}{\text{kg}}$$

$$= \frac{\cancel{\text{kg}} \cdot \frac{\text{m}}{\text{s}^2} \times s}{m^2} \times \frac{m^3}{\cancel{\text{kg}}}$$

$$\mu = \frac{m^2}{\text{Sec}}$$

$$10^{-6} \frac{m^2}{\text{Sec}} = 1 \text{ centi Stoke}$$

$$10^{-4} \frac{m^2}{\text{Sec}} = 1 \text{ Stoke}$$

Q. A plate 0.025 mm distance from a fixed plate moves at 60 cm per second and require a force of 2 Newton per unit Area to maintain the speed determine μ between the plate

Solution :- given that

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

$$\frac{du}{dy} = \frac{60 \text{ cm/sec}}{0.025 \text{ mm}} = \frac{0.6 \text{ m}}{0.025 \times 10^{-3} \text{ m}}$$

$$\mu = ?$$

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

$$2 = \mu \frac{0.6}{0.025 \times 10^{-3}}$$

$$\mu = \frac{2 \times 0.025 \times 10^{-3}}{0.6}$$

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

Answer in poise

$$1 \text{ poise} = \frac{1}{10} \frac{\text{N-s}}{\text{m}^2}$$

$$= \frac{\text{N-s}}{\text{m}^2} = 10 \text{ poise}$$

$$= 8.33 \times 10^{-5} \times 10$$

$$= \boxed{8.33 \times 10^{-4} \text{ poise}}$$

Q. Two horizontal plates are placed 1.25 cm apart the space between them being filled with oil of viscosity 14 poise. Calculate the shear stress in oil if upper plate is moved with a velocity of 2.5 m/sec.

Solution :- given that

$$\begin{aligned} \text{viscosity } (\mu) &= 14 \text{ poise} \\ &= 1.4 \text{ N-s/m}^2 \end{aligned}$$

$$\frac{du}{dy} = 2.5 \text{ m/sec}$$

$$\tau = ?$$

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

$$\tau = 2.4 \times \frac{2.5}{0.0125}$$

$$\tau = 280 \frac{N}{m^2}$$

- Q. Flat plate of area $2.5 \times 10^6 \text{ mm}^2$ is pulled with a speed of 0.4 m/sec relative to another plate located and at distance of 0.15 mm from it. Find the force and power require to maintain this speed if the fluid separating them is having viscosity as 1 poise .

Solution :-

Given that

force = ?

Power = ?

$$\frac{du}{dy} = 0.4 \text{ m/sec}$$

$$dy = 0.15 \text{ mm}$$

$$= 0.15 \times 10^{-3} \text{ m}$$

$$\text{Area} = 2.5 \times 10^6 \text{ mm}^2$$

$$= 2.5 \times 10^6 \times 10^{-6} = 2.5 \text{ m}^2$$

$$\text{viscosity}(\mu) = 1 \text{ poise}$$

$$= 0.1 \text{ N-s/m}^2$$

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

$$\tau = \frac{0.2 \times 0.4}{0.25 \times 10^{-3}}$$

$$\tau = 266.66 \frac{\text{N}}{\text{m}^2}$$

$$\tau = \frac{\text{Force}}{\text{Area}}$$

$$\text{Force} = \tau \times \text{Area}$$

$$\text{Force} = 266.66 \times 1.5$$

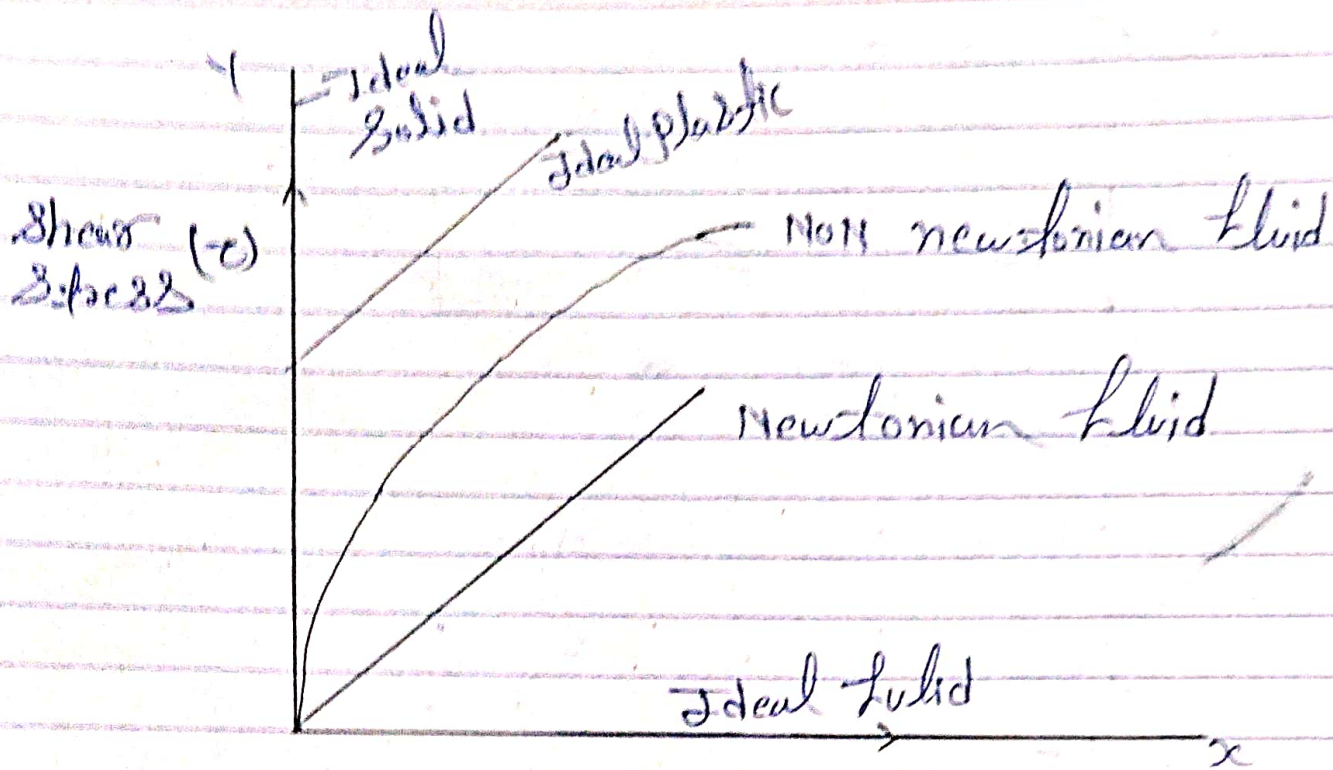
$$\text{Force} = 400 \text{ N}$$

$$\text{Power} = \text{Force} \times \text{Speed}$$

$$= 400 \times 0.4$$

$$\text{Power} = 160 \text{ watt}$$

- To change the cm into m divide by 100
- To change mm into m divide by 1000
- To change the m into cm multiply by 100
- To change the N-s/m^2 into poise multiply by 10
- To change the poise into N-s/m^2 divide by 10
- To change m into mm multiply by 1000



Rate of Shear Strain ($\frac{du}{dy}$)
(velocity gradient)

$$y = mx \quad \text{line}$$

1 Ideal fluid :- A fluid which is incompressible and having no viscosity is known as Ideal fluid.

Ideal fluid is only an Imaginary fluid as all the fluid which exist have some viscosity.

2 Real Fluid :- A fluid which possesses viscosity is known as real fluid.

3 Newtonian Fluid :- A Real fluid in which shear stress is directly proportional to the rate of shear strain is known as Newtonian fluid.

* which is follow a Newton's law of viscosity is called Newtonian fluid.

4 Non Newtonian fluid :- A fluid which is shear stress not proportional to the rate of shear strain.

which is not follow a Newton's law of viscosity is called Non Newtonian fluid.

5 Ideal Plastic fluid :- A fluid in which shear stress is more than the yield value and the shear stress is proportional to the rate of shear strain is known as Ideal plastic fluid.

6. Ideal Solid:- A fluid in which no shear strain is present is known as Ideal Solid.

Q. Determine the specific gravity having fluid viscosity 0.05 poise and kinematic viscosity 0.035 Stokes.

Solution:- given that

$$\begin{aligned}\mu &= 0.05 \text{ poise} = 5 \times 10^{-3} \frac{\text{N-s}}{\text{m}^2} \\ \nu &= 0.035 \text{ Stoke} = \frac{35 \times 10^{-6} \text{ m}^2}{\text{sec}} \\ &= 0.035 \times 10^{-4} \frac{\text{m}^2}{\text{sec}}\end{aligned}$$

$$S = \frac{\text{density of fluid}}{\text{density of standard fluid}}$$

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

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

$$\rho = 1.4285 \text{ kg/m}^3$$

$$S = \frac{2.4285}{1000}$$

$$S = 2.4285 \times 10^{-3}$$

Q.2 Find the kinematic viscosity of an oil having density 981 kg/m^3 the shear stress at a point in oil is 0.2452 N/m^2 and velocity gradient at that point is 0.2 per second.

Solution :- given that

$$\mu = ?$$

$$\rho = ?$$

$$\rho = 981 \text{ kg/m}^3$$

$$\tau = 0.2452 \text{ N/m}^2$$

$$\frac{du}{dy} \text{ velocity gradient} = 0.2$$

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

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

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

$$\mu = 0.2452 \times 0.2$$

$$\mu = 2.226 \frac{\text{N-s}}{\text{m}^2}$$

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

$$\nu = \frac{2.226}{981}$$

$$\nu = 2.2497 \times 10^{-3} \frac{\text{m}^2}{\text{Sec}}$$

$$\nu = 2.249 \times 10^{-3} \text{ poise}$$

$$\nu = 22.49 \text{ Stoke}$$

Q. Determine the viscosity of liquid having kinematic viscosity 6 Stoke and sp gravity 1.2

Solution :- given that

$$\begin{aligned} \text{Specific gravity} &= 1.2 \\ \nu &= 6 \text{ Stoke} \end{aligned}$$

$$\mu = ?$$

$$\rho = \text{sp gravity} \times \text{density of standard fluid}$$

$$\rho = 1.9 \times 1000$$

$$\rho = 1900 \text{ kg/m}^3$$

$$\eta = \frac{\mu}{\rho} \quad \mu = \rho \times \eta$$

$$\mu = 1900 \times 6 \times 10^{-4}$$

$$\mu = 1.14 \frac{\text{N-s}}{\text{m}^2}$$

$$\mu = 0.114 \text{ Poise}$$

Bulk modulus :- It is the ratio b/w
Change in pressure and
volumetric strain

It is represented by
K.

$$K = \frac{\text{Change in pressure}}{\text{change volumetric strain}}$$

$$K = - \frac{\Delta P}{\Delta V} \cdot V \quad \text{Pascal}$$

Compressibility :- It is Define as the
Difference between volumetric
strain by change in pressure.

compressibility is reciprocal $\rightarrow$ of bulk
modulus of elasticity.

$$\text{Compressibility} = \frac{1}{K}$$

$$= - \frac{\frac{1}{V} \Delta P}{\Delta V}$$

$$= - \frac{\Delta V}{V \Delta p}$$

$$= \frac{\text{volumetric strain}}{\text{change in pressure}}$$

Q. Determine the bulk modulus of elasticity of liquid if the pressure of liquid is increased from 70 N/cm^2 to 130 N/cm^2 the volume of liquid decreases 0.25% .

Solution: — given that

$$\text{Initial pressure} = 70 \text{ N/cm}^2$$

$$\text{Final pressure} = 130 \text{ N/cm}^2$$

$$\text{volume decreases} = 0.25\%$$

$$\text{Change in pressure} = 130 - 70 = 60 \text{ N/cm}^2$$

$$K = \frac{\Delta p}{-\frac{\Delta V}{V}}$$

$$\frac{-\Delta V}{V} = 0.25\% = \frac{0.25}{100}$$

$$K = \frac{60}{\frac{0.25}{100}} = \frac{60 \times 100}{0.25} = \frac{60 \times 10^4}{15}$$

$$= \frac{60 \times 10^4}{15}$$

$$= 40000 \text{ N/cm}^2$$

$$= 4 \times 10^4 \text{ N/cm}^2$$

Q.2 what is bulk modulus of elasticity of liquid which is compressed in a cylinder from a volume of 0.0225 m^3 at 80 N/cm^2 pressure to a volume of 0.0224 at 150 N/cm^2 pressure

Solution :- given that

$$P_1 = 80 \text{ N/cm}^2$$

$$P_2 = 150 \text{ N/cm}^2$$

$$V_1 = 0.0225 \text{ m}^3$$

$$V_2 = 0.0224 \text{ m}^3$$

$$\Delta P = 70 \text{ N/cm}^2$$

$$\Delta V = -0.0001 \text{ m}^3$$

$$K = \frac{-\Delta P \cdot V}{\Delta V}$$

$$K = \frac{\Delta P}{\frac{\Delta V}{V}}$$

$$K = \frac{70}{-(-0.002)} \\ 0.0225$$

$$K = \frac{70 \times 0.0225}{0.002}$$

$$K = 8750 \text{ N/cm}^2$$

$$K = 8.75 \times 10^3 \text{ N/cm}^2$$

Surface tension :- Surface tension is force acting on surface of liquid in contact with gas such that the contact surface behaves like a membrane under tension.

The magnitude of this force per unit length of the free surface is called surface tension. It is denoted by σ (sigma) and SI unit is N/m .

Surface tension on liquid drop last

P = Pressure inside the drop last

σ = Surface tension

d = dia of drop last

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

Surface tension on hollow bubble

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

Q.1 The surface tension of water in contact with air at a 20°C $\sigma = 0.0725 \text{ N/m}$ the pressure inside the drop last of water is 850 be 0.02 N/cm² the outside pressure calculate the diameter of droplet of water.

Solution :- given that

$$T = 20^\circ\text{C}$$

$$\sigma = 0.0725 \text{ N/m}$$

$$P = 0.02 \text{ N/cm}^2$$

$$P = 0.02 \left(\frac{1}{100}\right)^2$$

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

$$d = \frac{4 \times 0.0725}{0.02}$$

$$\left(\frac{1}{100}\right)^2$$

$$d = 2.45 \times 10^{-3} \text{ m}$$

$$d = 2.45 \text{ mm}$$

Q.2 Find the surface tension in soap bubble of 4mm diameter when the inside pressure is 2.5 N/m² above the atmospheric pressure :-

Solution :- given that

$$\sigma = ?$$

$$d = 4 \text{ mm} = 0.04 \text{ m}$$

$$P = 2.5 \text{ N/m}^2$$

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

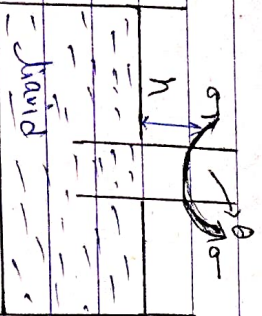
$$\sigma = \frac{P \times d}{8}$$

$$\sigma = \frac{2.5 \times 0.04}{8}$$

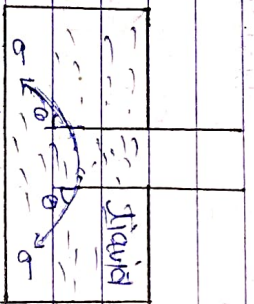
$$\sigma = 0.0125 \text{ N/m}$$

Capillarity :- Capillarity is defined as a phenomenon of rise or fall of liquid surface in small tube relative to adjacent general level of liquid when the tube is held vertically in the liquid. The rise of liquid surface is known as capillary rise while the fall of liquid surface is known as capillary depression.

It is expressed in terms of cm or mm of liquid.



Capillary rise



Capillary fall

Weight of water = $m \times g$

$$= \rho \times V \times g$$

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

$$m = \rho \times V$$

$$W = \rho \times \left[\frac{\pi}{4} \times d^2 \times h \right] \times g$$

h = Capillary rise

$$\text{Upward force} = \sigma \times \cos \theta \times \pi \times d$$

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

$$h = \frac{4 \times \sigma \times \cos \theta}{\rho \times g} \quad \text{m of liq}$$

Q.3 Calculate capillary rise in a glass tube of 2.5 mm diameter when immersed vertically in water. (2) mercury take surface tension $\sigma = 0.0725 \text{ N/m}$ (water per meter) for water and $\sigma = 0.52 \text{ N/m}$ for mercury in contact with air. The specific gravity for mercury is 13.6 and angle of contact = 130° .

Solution: — given that

$$d = 2.5 \text{ mm}$$

$$\sigma_w = 0.0725 \text{ N/m}$$

$$\sigma_m = 0.52 \text{ N/m}$$

$$\text{SP. gravity}_m = 13.6$$

$$T_m = 130^\circ \text{C}$$

$$\theta_w = 0^\circ$$

$$\text{SP. gravity} = \frac{\text{density of fluid}}{\text{density of standard fluid}}$$

$$S = \frac{\rho_{Hg}}{\rho_w}$$

$$S_{Hg} = \text{SP. g} \times \rho_w$$

$$S_{Hg} = \text{SP. gravity} \times \text{density of standard fluid}$$

$$S_{Hg} = 13.6 \times 1000$$

$$\rho_{Hg} = 13600 \text{ kg/m}^3$$

$$\rho_m = \frac{\rho_w}{S_{Hg}}$$

$$\rho_m = \frac{1000}{13.6} = 73.53 \text{ kg/m}^3$$

$$\rho_m = -4 \times 10^{-3} \text{ m}$$

$$h_w = \frac{4\sigma \cos \theta}{\rho_w g}$$

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

$$h_w = 0.011924 \text{ m}$$

Q.4 The capillary rise in the glass tube is not to exceed 0.2 mm of water. Determine its minimum size given that surface tension of water in contact with air is 0.0725 N/m

Solution:— Given that

$$h = 0.2 \text{ mm} \Rightarrow 2 \times 10^{-4} \text{ m}$$

$$\sigma = 0.0725 \text{ N/m}$$

$$\theta = 0^\circ$$

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

$$h = \frac{4 \times 0.0725 \times \cos(0^\circ)}{1000 \times 9.81 \times d}$$

$$d = \frac{4 \times 0.0725 \times \cos(0^\circ)}{1000 \times 9.81 \times 2 \times 10^{-4}}$$

$$d = 0.447 \text{ m}$$

Q.5 Find out the minimum size of glass tube that can be used to measure water level if the capillary rise in the tube is restricted to 2 mm consider surface tension of water in contact with air is 0.073575 N/m

Solution:— Given that

$$h = 2 \text{ mm} \Rightarrow 2 \times 10^{-3} \text{ m}$$

$$\sigma = 0.073575 \text{ N/m}$$

$$\theta = 0^\circ$$

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

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

$$d = \frac{4 \times 0.073575 \times \cos(0^\circ)}{1000 \times 9.81 \times 2 \times 10^{-3}}$$

$$d = 0.045 \text{ m}$$

vapour Pressure :- The pressure at which liquid is converted into vapour is known as vapour pressure.

cavitation :- The phenomenon of formation of vapour bubble of a following liquid in a region where the pressure of liquid falls below the vapour pressure and sudden collapsing of this vapour bubble in a region of high pressure.

Pressure and its measurement

Pressure :- Pressure is defined as the force per unit area is called pressure.

Force Applied perpendicular to the surface always.

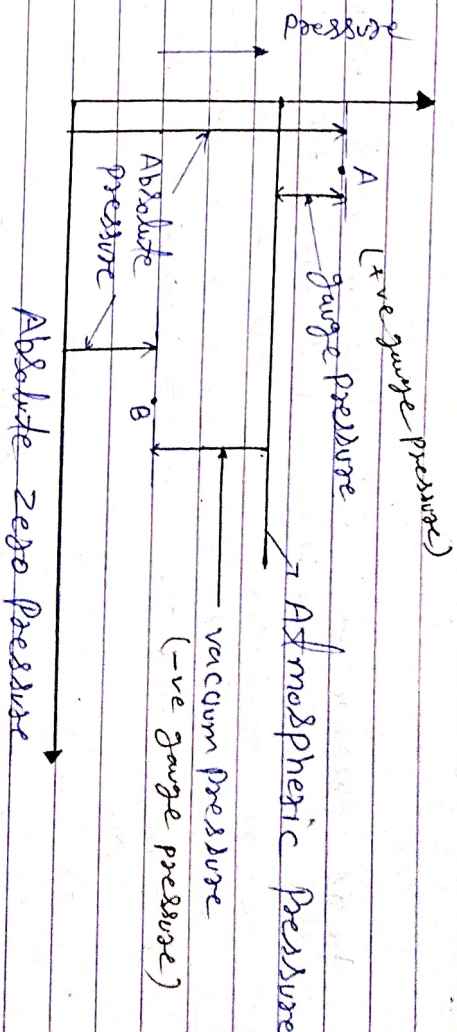
SI unit = Pascal

1 Pascal = 1 N/m^2

1 bar = 10^5 Pascal

1 bar = $100 \times 10^3 \text{ Pa} = 10^5 \text{ Pa}$

Absolute, gauge, Atmospheric and vacuum pressure



Absolute pressure at A = Atmospheric pressure + gauge pressure

Absolute pressure at B = Atmospheric pressure - gauge pressure
(and)
= Atmospheric pressure + vacuum pressure

Atmospheric pressure = Absolute pressure - Gauge pressure

Gauge pressure = Absolute pressure - Atmospheric pressure

Absolute pressure :- Absolute pressure is the pressure which is measured relative to vacuum or Absolute zero pressure.

Gauge pressure :- It is defined as the pressure which is measured with the help of pressure measuring instrument in which atmospheric pressure is taken as datum. The Atmospheric pressure on the scale is marked as zero.

Vacuum pressure :- It is defined as the pressure below the atmospheric pressure is known as vacuum pressure.

Absolute pressure = 101.35 kPa

What are the gauge pressure and Absolute pressure at a point 3m below the free surface of liquid having a density of 1.53 kg/m^3 into 10^3 kg/m^3 If the atmospheric pressure is equal to the 750mm of mercury.

Solution :- given that

$h_1 = 3\text{m}$

Gauge pressure = ?

Absolute pressure = ?

density of liquid = $1.53 \times 10^3 \text{ kg/m}^3$

height of liquid = 3m and height of mercury = 750mm $\Rightarrow 0.75\text{m}$

$P_{\text{atm}} = \rho_{\text{gh}} \Rightarrow 13600 \times 9.81 \times 0.75 \Rightarrow 100062 \text{ N/m}^2$

$P_{\text{gauge}} = \rho_{\text{gh}} \Rightarrow 1.53 \times 10^3 \times 9.81 \times 3$
 $P_{\text{gauge}} = 45027.9 \text{ N/m}^2$

Absolute pressure = Atmospheric pressure + gauge pressure

Absolute pressure = $100062 + 45027.9$

Absolute pressure = 145090 N/m^2

calculate the pressure due to a column of 0.3m of (A) water (B) oil of specific gravity 0.8 (C) mercury of sp gravity 13.6

Solution:-

given data

$$h = 0.3 \text{ m}$$

$$\text{sp gravity of oil} = 0.8$$

$$\text{sp gravity of mercury} = 13.6$$

$$\text{Pressure} = 894 \text{ N/m}^2$$

$$\text{for water} = 1000 \times 9.81 \times 0.3$$

$$\text{Pressure of water} = 2943 \text{ N/m}^2$$

$$\text{for oil} = 800 \times 9.81 \times 0.3$$

$$\text{Pressure of oil} = 2354.4 \text{ N/m}^2$$

$$\text{for mercury} = 13600 \times 9.81 \times 0.3$$

$$\text{Pressure of mercury} = 40024.8 \text{ kg/sec}^2 \text{ N/m}^2$$

Find the pressure which is equal to 760 mm of mercury

Solution:-

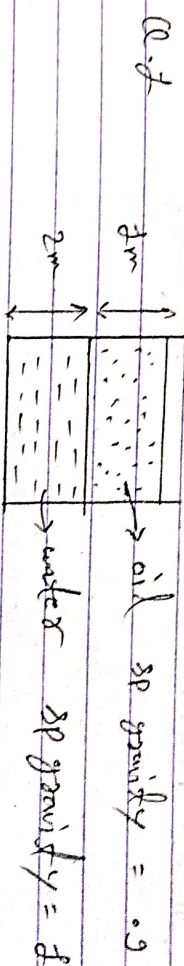
given data

$$h = 760 \text{ mm} \Rightarrow 0.76 \text{ m}$$

$$\text{Pressure} = 894 \text{ N/m}^2$$

$$P = 13600 \times 9.81 \times 0.76$$

$$P = 101396.16 \text{ kg/sec}^2 \text{ N/m}^2$$



Solution:-

$$h_1 = h_2 = 2 \text{ m}$$

$$\text{sp gravity of oil} = 0.8 \Rightarrow 800$$

$$\text{sp gravity of water} = 1$$

$$P = 894 \text{ N/m}^2$$

$$P = 900 \times 9.81 \times 1$$

$$P_A = 8827 \text{ N/m}^2 \text{ of oil}$$

$$P_{\text{water}} = 900 \times 9.81 \times 2$$

$$= 1766 \text{ N/m}^2$$

$$P_B = 1766 + 8827$$

$$P_{\text{of B}} = 28447 \text{ N/m}^2$$

measurement of pressure

pressure of liquid is measured by following devices :-

- 1) Manometers
- 2) Mechanical gauges

2 Mechanical gauges :-

Mechanical gauge are defined as the devices used for measuring the pressure by balancing the fluid column by spring or dead weight example :- Bourdon tube

Pressure gauge

2) diaphragm

3) dead weight pressure gauge

4) Bellows pressure gauge

Manometer :- Manometer are defined as the devices used for measuring the pressure at a point in a fluid by balancing the column of fluid by the same or another column of fluid they are

classified as :-

- 1) Simple manometer
- 2) differential manometer

1) Simple manometer :- Simple manometer

having 2 of its end connected to a point where pressure is to be measured and another end remains open to the atmosphere.

- Simple manometers are :-
- 1) Piezometer
 - 2) U tube manometer
 - 3) Single column manometer

a) 1) A U tube manometer is used to measure the pressure of oil of sp gravity 0.85 following in a pipe line its left end is connected to the pipe and right limb and is connected to the atmosphere the centre of the pipe is shown below the level of mercury (13.6) in the right limb if the difference of mercury level in the two

limb is 160 mm. Determine the pressure of oil in the tube.

Solution :- given that

$$\begin{aligned} S_1 &= 0.85 \\ S_2 &= 13.6 \\ h_1 &= 60 \text{ mm} \\ h_2 &= 160 \text{ mm} \end{aligned}$$

Pressure in left limb

$$h + S_1 h_1$$

Pressure in right limb

$$S_2 h_2$$

$$h = S_2 h_2 - S_1 h_1$$

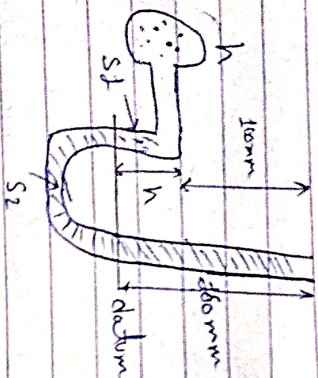
$$h = 13.6 \times 160 - 0.85 \times 60$$

$$h = 2125 \text{ mm} \Rightarrow 2.125 \text{ m}$$

$$P = wh$$

$$P = 9.81 \times 2.125$$

$$P = 20.846 \text{ kN/m}^2$$



Q.2 The of water in a pipe line was measured by means of the reading of the pressure inside the pipe line. Calculate

Solution :- given that

$$\begin{aligned} h_1 &= 100 \\ h_2 &= 800 \\ S_1 &= 1 \\ S_2 &= 13.6 \end{aligned}$$

$$h + S_1 h_1 = S_2 h_2$$

$$h = S_2 h_2 - S_1 h_1$$

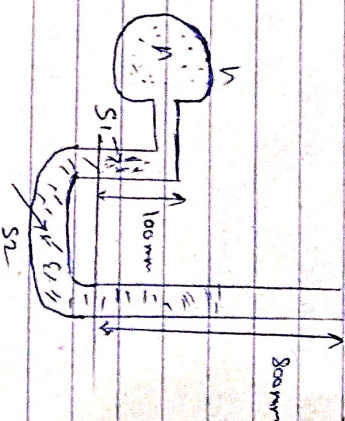
$$h = 13.6 \times 800 - 1 \times 100$$

$$h = 10780 \text{ mm} \Rightarrow 10.780 \text{ m}$$

$$P = wh \quad (\text{where } w = \text{gravity})$$

$$P = 9.81 \times 10.780$$

$$P = 105.75 \text{ kN/m}^2$$



a) A U tube manometer containing mercury was used to find the negative pressure in a pipe containing water. The right limb was open to atmosphere. Find the vacuum pressure in a pipe if difference of mercury level in the limbs was 40 mm in a height of water in the left limb 40 mm.

Solution :-

$$P = h + h_1 s_1 + h_2 s_2$$

$$= h + 40 \times 1 + 400 \times 13.6$$

$$= h + 5.4$$

$$h = -5.4 \text{ m}$$

($w = \text{gravity}$)

$$P = wh$$

$$P = 9.81 \times -5.4$$

$$\text{Pressure} = -53.734 \text{ kN/m}^2$$

a) A simple U tube manometer containing mercury is connected to a pipe in which an oil of specific gravity 0.8 is flowing. The pressure in the pipe is vacuum the other end of manometer is open in atmosphere. Find the vacuum pressure in pipe if the difference in mercury level in the two limbs is 200 mm and height of oil in the left limb from free surface of the pipe is 750 mm below.

Solution :- Given that

$$h_1 = 750 \text{ mm}$$

$$h_2 = 200 \text{ mm}$$

$$s_1 = 0.8$$

$$s_2 = 13.6$$

$$= h + h_1 s_1 + h_2 s_2$$

$$= h + 750 \times 0.8 + 200 \times 13.6$$

$$= h + 2840$$

$$h = -2840 \text{ mm} \Rightarrow -2.84 \text{ m}$$

$$P = wh$$

$$P = 9.81 \times -2.84$$

$$P = -27.86 \text{ kN/m}^2$$

2. Differential manometer is Differential manometers are the devices used for

measuring the difference of pressure between two points in a pipe or in two different pipe. A differential manometer consists of a U tube containing a heavy liquid whose two ends are connected to the points. whose difference of pressure is to be measured. most commonly types of differential manometer are

$h_A + h_1 S_1$	1) U tube differential manometer
Pressure in right limb	
$h_A + (h_1 - h) h_s$	2) inverted U tube differential manometer
Pressure in left limb	
$h_B + S_2 h_2 + S h$	

a) A Differential manometer connected at two point A and B in a pipe containing oil of sp gravity 0.9 shows a difference in mercury level as 150 mm find the difference in pressure at the two points.

Solution:- Given that

$$h = 150 \text{ mm}$$

$$S = 13.6$$

$$S_1 = 0.9$$

$$h_A - h_B = h (S - S_1)$$

$$= 150 (13.6 - 0.9)$$

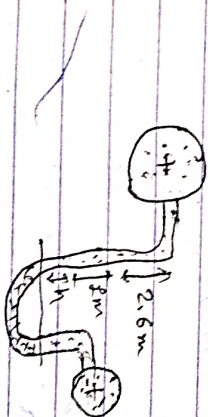
$$h_A - h_B = 1905 \text{ mm} \Rightarrow 1.905 \text{ m}$$

$$\text{Pressure} = \rho h (A - h_B)$$

$$\text{Pressure} = 9.81 \times 1.905$$

$$\text{Pressure} = 18.68 \text{ kN/m}^2$$

Q.2 figure shows a U tube Differential manometer connecting the pressure pipes at point B under a pressure of 100 kN/m² the pipe contains oil of sp gravity 0.8 under a pressure of 200 kN/m² find the difference of pressure measured by mercury as fluid filling U tube



Solution :- Given fluid

$$P_A = 110 \text{ kN/m}^2$$

$$h_A = ?$$

$$P_B = 200 \text{ kN/m}^2$$

$$h_B = ?$$

$$\Delta_1 = 1.6$$

$$\Delta_2 = 0.8$$

$$h_A = \frac{P_A}{\rho} = \frac{110}{9.81} = P_A = 11.21 \text{ m}$$

$$h_B = \frac{P_B}{\rho} = \frac{200}{9.81} = P_B = 20.38$$

equating pressure head X-X

$$h \times 13.6 + (1 + 2.6) S_1 + h_A = (h + 1) S_2 + h_B$$

$$h \times 13.6 + 3.6 \times 1.6 + 11.21 = (h + 1) 0.8 + 20.38$$

$$13.6h + 5.76 + 11.21 = 0.8h + 0.8 + 20.38$$

$$13.6h - 0.8h = 20.38 - 16.97$$

$$12.8h = 4.21$$

$$h = 4.21 / 12.8$$

$$h = 0.328 \text{ m}$$

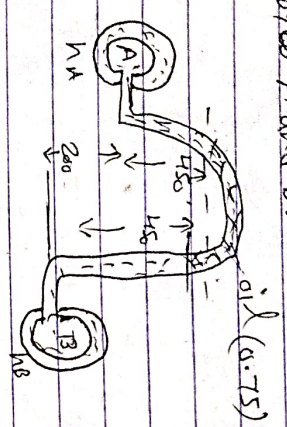
0.014
0.014

Q.3 The figure shows an inverted differential manometer 0.8 connected to differential pipe

Q.4 A inverted differential manometer is connected to two pipes A and B carrying water under pressure as shown in figure the fluid in manometer is oil of SP gravity 0.75 Determine the pressure Difference b/w A and B.

Solution :-
Given that :-

SP gravity = 0.75
 $h_A = ?$
 $h_B = ?$



Difference of oil in the left limb $(45 + 200) - 15 = 200 \text{ mm}$

$h = 0.2 \text{ m}$

Pressure head in the left limb below X-X

$= h_A - 0.45 \times 1 = h_A - 0.45$

Pressure head in the right limb below X-X

$h_B - 0.15 \times 1 - 0.2 \times 0.75$

$= h_B - 0.6$

Equating Pressure head of both limb

$h_A - 0.45 = h_B - 0.6$

$h_A - h_B = 0.15 \text{ m}$

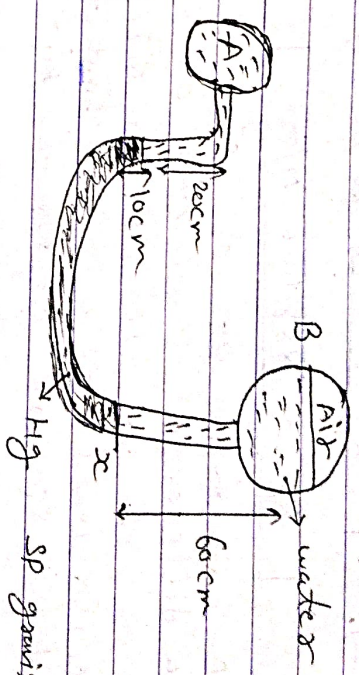
$\frac{P_A}{\rho g} - \frac{P_B}{\rho g} = 0.15 \Rightarrow P_A - P_B = 0.15 \times \rho g$

$P_A - P_B = 0.15 \times 9.81$

$P_A - P_B = 1.47 \text{ kN/m}^2$

Q.5 A Differential manometer is connected at the two point a and b shown in figure at B Air Pressure is 9.81 N/cm^2 (Absolute) find the Absolute pressure at A.

oil of
SP gravity
 $= 0.9$



Solution :-
Given that

$P_B = 9.81 \text{ N/cm}^2$

SP of oil = 0.9

SP of Hg = 13.6

$P_A + \rho g h_1 + \rho g h_2 - \rho g h_3 - P_B = 0$

Putting value in eqn (i)

$P_A = x$

then,

$x + 0.9 \times 10 \times 9.81 + 0.9 \times 10 \times 9.81 - 9.81 = 0$

$$\Rightarrow X + 900 \times 9.81 \times 0.2 + 13600 \times 9.81 \times 0.1 - 1000 \times 9.81 \times 0.6 - 9.81 \times 10^4$$

$$\Rightarrow X + (-88878.6) = 88878.6 \text{ N/m}^2$$

$$P_A = 88878.6 \text{ N/m}^2$$

A Pipe contain an oil of sp gravity 0.8 a differential manometer at the two point A and B of the pipe show a difference in mercury level. at a 20cm find the difference of the pressure at the two point

Solution :- Given that

$$\text{sp gravity of oil} = 0.8$$

$$\text{Difference in mercury level} = 20 \text{ cm} \Rightarrow 0.20 \text{ m}$$

$$\rho_{\text{oil}} = 13600 \text{ kg/m}^3$$

$$\rho_{\text{oil}} = 800 \text{ kg/m}^3$$

To find pressure difference

$$P_A + [800 \times 9.81 \times (h + 0.20)] = P_B + (800 \times 9.81 \times h) + (13600 \times 9.81 \times 0.20)$$

$$P_A - P_B = (13600 \times 9.81 \times 0.20) - (800 \times 9.81 \times 0.20)$$

$$P_A - P_B = (13600 \times 9.81 \times 0.20) - (800 \times 9.81 \times 0.20)$$

$$P_A - P_B = 25113.6 \text{ N/m}^2$$

$$\text{Pressure Difference} = 25.11 \text{ kN/m}^2$$

Q.7 A differential manometer connected at two points at A and B of a horizontal pipe containing an oil of sp gravity of 0.85 show a difference in mercury level as shown. Determine the difference in pressure at the two points.

Solution :- Given that,

$$\text{Height Difference} = \text{same} \Rightarrow 0.1 \text{ m}$$

$$\text{sp gravity of oil} = 0.85$$

$$\text{density of oil} = 850 \text{ kg/m}^3$$

$$\text{sp gravity of mercury} = 13.6$$

$$\text{density of mercury} = 13600 \text{ kg/m}^3$$

$$\Delta P = \rho g h$$

$$\Delta P = (\rho_{\text{oil}} - \rho_{\text{oil}}) \times g \times h$$

$$\Delta P = (13600 - 850) \times 9.81 \times 0.1$$

$$\Delta P = 12750 \times 9.81 \times 0.1$$

Pressure Difference = 12507.75 N/m^2

$$\Delta P = 12.50 \text{ kN/m}^2$$

Hydrostatic Pressure on Surface

Total Pressure :- Total pressure is defined as the force exerted by a static fluid on a surface, either plane or curved when the fluid comes in contact with the surface. This total force always acts normal to the surface.

Centre of Pressure :- It is defined as the point of application of the total pressure on the surface. There are four cases of submerged surface on which the total pressure force and centre of pressure is to be determined the submerged surface may be :-

1. Horizontal plane surface
2. Vertical plane surface
3. Inclined plane surface
4. Curved surface

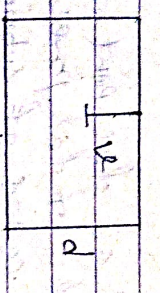
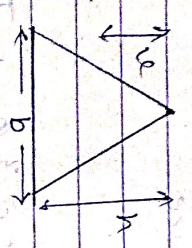
Formula

Centre of Pressure :- $\frac{I_G \sin^2 \theta}{A h} + \bar{h}$

Total pressure force :- $\rho g A h$

I_G = Moment of inertia of the object

A = Surface Area
 ρ = density
 h = distance of centre of gravity from the free surface

Plane surface	C.G.	Area	Moment of inertia about an axis
	$h = \frac{d}{2}$	$A = bd$	$I_G = \frac{bd^3}{12}$
	$h = \frac{d}{2}$	$A = \pi \times \frac{d^2}{4}$	$I_G = \frac{\pi d^4}{64}$ mm ⁴ cm ⁴
	$h = \frac{2h}{3}$	$A = \frac{1}{2}bh$	$I_G = \frac{bh^3}{36}$

vertical plane surface numerical

Q-1 A rectangular plane surface is 2m wide and 3m deep arise in vertical plane in water determine the total pressure and position of

centre of pressure on the plane surface when its upper edge is horizontal and

- 1) Consider with water surface
- 2) 2.5 below the free water surface

Solution :- Given shaft

$b = 2m$
 $d = 3m$

Total pressure = $\rho g A h$

$A = bd$
 $A = 2 \times 3$
 $A = 6m$

$TP = \rho g A h$
 $= 1000 \times 9.81 \times 6 \times 1.5$

$TP = 88290 N$
 $TP = 88290 KN$

Centre pressure = $I_G \sin^2 \theta + h$
 ATN

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

$$JG = \frac{2 \times 3^3}{12}$$

$$JG = 4.5$$

$$CP = 4.5 \times 1 + 1.5$$

$$CP = 6 \times 1.5$$

$$\boxed{\text{Centre of pressure} = 2 \text{ m}}$$

(ii) 2.5 m below the free water surface

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

$$= 1000 \times 9.81 \times 6 \times 1$$

$$TP = 235440 \text{ N}$$

$$\boxed{TP = 235.44 \text{ kN}}$$

$$\text{Centre of pressure} = \frac{JG \sin^2 \theta}{Ah} + h$$

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

$$JG = \frac{2 \times 3^3}{12}$$

$$JG = 4.5$$

$$= \frac{4.5 \times 1}{6 \times 4} + 4$$

$$\boxed{\text{Centre of pressure} = 4.1875 \text{ m}}$$

Q.2 determine the total pressure of on a circular plate of diameter 1.5 m which is placed vertically in water in such a way that centre of the plate is 3 m below the free surface of water find the position of centre of pressure also.

Solution:- Given that

$$d = 1.5$$

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

$$A = \frac{\pi}{4} \times 1.5^2$$

$$A = 1.767 \text{ m}$$

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

$$TP = 5000 \times 9.81 \times 1.767 \times 3$$

$$TP = 52002.81 \text{ N}$$

$$TP = 52.00 \text{ kN}$$

$$\text{Centre of Pressure} = \frac{IG \sin^2 \theta}{Ah}$$

$$IG = \frac{\pi}{64} d^4$$

$$IG = \frac{\pi}{64} \times 1.5^4$$

$$IG = 0.2485$$

$$= \frac{0.2485 \times 1}{3} + 3$$

$$1.767 \times 3$$

$$\text{Centre of Pressure} = 3.04 \text{ m}$$

Q.1 Determine the total pressure and centre of pressure on an isosceles triangular plate of base 4m and altitude 4m when it is immersed vertically in an oil of sp gravity 0.9 the top of the plate coincides with the free surface of oil.

Solution :- Given that

$$b = 4 \text{ m}$$

$$h = 4 \text{ m}$$

$$\text{sp gravity} = 0.9$$

$$\rho \text{ of oil} = 900 \text{ kg/m}^3$$

$$\therefore \text{Centroid} :- \bar{h} = \frac{h}{3} = \frac{4}{3}$$

$$\bar{h} = 1.33 \text{ m}$$

$$IG = \frac{bh^3}{36} = \frac{4 \times 4^3}{36} \Rightarrow 7.11 \text{ m}^4$$

$$A = \frac{1}{2} b \times h$$

$$A = \frac{1}{2} \times 4 \times 4$$

$$A = 8 \text{ m}^2$$

To find Total pressure :-

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

$$\rho_{\text{total}} = 900 \times 9.81 \times 8 \times 1.33$$

$$\rho_{\text{total}} = 93840.56 \text{ N/m}^2$$

$$\boxed{\text{Total pressure} = 93.84 \text{ kN/m}^2}$$

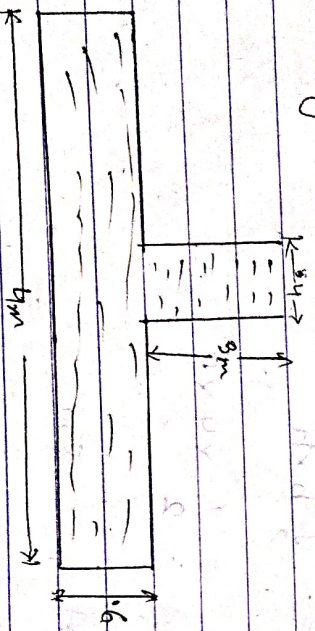
$$\text{Position of centre of pressure} = \frac{I_G \sin^2 \theta}{A \bar{h}} + \bar{h}$$

$$\Rightarrow \frac{7.111 \times 1}{8 \times 1.33} + 1.33$$

$$\boxed{\text{Centre of pressure} = 1.93 \text{ m}}$$

Q.2 (1) Total pressure on the bottom of the tank

(2) weight of water in the tank



Solution :- given that

$$b = 2 \text{ m}$$

$$A = L \times b$$

$$L = 4 \text{ m}$$

$$A = 4 \times 2$$

$$A = 8 \text{ m}$$

$$\bar{h} = 3.6 \text{ m}$$

$$\rho_{\text{total}} = \rho g A \bar{h}$$

$$= 900 \times 9.81 \times 8 \times 3.6$$

$$\boxed{\text{Total pressure} = 282.52 \text{ kN}}$$

(2) weight of the water in tank

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

$$m = \rho V$$

$$\rho \times m = \rho V \times g$$

$$V_1 = 0.4 \times 3 \times 2$$

$$V_1 = 2.4 \text{ m}^3$$

$$V_2 = 0.6 \times 4 \times 2$$

$$V_2 = 4.8$$

$$V = V_1 + V_2$$

$$V = 2.4 + 4.8$$

$$V = 7.2 \text{ m}^3$$

$$W = 1000 \times 9.81 \times 7.2$$

$$W = 70632 \text{ N}$$

$$\text{Weight in tank} = 70632 \text{ N}$$

Q.3 A rectangular plane surface 3m width and 3m depth lies in water in such way that its plane makes an angle of 30° with the free surface at the centre of pressure and position of the centre of pressure when the upper edge is 1.5m below the free surface of water.

Solution:- Given that

$$b = 3 \text{ m}$$

$$d = 3 \text{ m}$$

$$\rho_w = 1000 \text{ kg/m}^3$$

$$\theta = 30^\circ$$

To find $\bar{h}$:-

$$\sin \theta = \frac{h}{r} = \frac{x}{1.5}$$

$$\sin(30^\circ) \times 1.5 = x$$

$$x = 0.75$$

$$\bar{h} = x + 1.5$$

$$\bar{h} = 0.75 + 1.5$$

$$\bar{h} = 2.25 \text{ m}$$

$$A = b \times d$$

$$A = 3 \times 3$$

$$A = 9 \text{ m}^2$$

To find total pressure

$$P_{\text{total}} = \rho \cdot A \cdot \bar{h}$$

$$P_{\text{total}} = 1000 \times 9.81 \times 9 \times 2.25$$

$$P_{\text{total}} = 198272.25 \text{ N}$$

Position of centre of pressure :-

$$\Rightarrow \bar{I}_G \sin^2 \theta + \frac{A h^3}{12}$$

$$\bar{I}_G = \frac{b d^3}{12}$$

$$= \frac{2 \times (3)^3}{12}$$

$$\bar{I}_G = 4.5$$

$$P_{\text{centre}} = \frac{\bar{I}_G \sin^2 \theta}{A h} + \bar{h}$$

$$P_{\text{centre}} = \frac{4.5 \times \sin(30)^\circ}{6 \times 2.25} + 2.25$$

$$P_{\text{centre}} = 2.33 \text{ m}$$

$$\text{Position of centre of pressure} = 2.33 \text{ m}$$

Q.3 A rectangular plane surface 3m width and 4m deep lies in water in such away that its plane makes an angle of 30° with free surface of water. Determine the total force and position of centre of pressure when the upper edge is 2m below the free surface.

Solution :-

Given that

$$b = 3 \text{ m}, \quad A = b d$$

$$d = 4 \text{ m}, \quad A = 3 \times 4$$

$$\theta = 30^\circ, \quad A = 12 \text{ m}^2$$

$$J_w = \text{locking } \text{m}^3$$

Upper edge is 2m below

$$\sin \theta = \frac{h}{k}$$

$$\sin \theta = \frac{x}{2}$$

$$\sin \theta = \frac{x}{2}$$

$$\theta = 30^\circ$$

$$\sin(30) \times 2 = x$$

$$x = 9m$$

$$\bar{h} = 2m + x$$

$$\bar{h} = 2 + 1$$

$$\bar{h} = 3m$$

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

$$P_{\text{total}} = 1000 \times 9.81 \times 12 \times 3$$

$$P_{\text{total}} = 353160 \text{ N}$$

$$\text{Total pressure} = 353.16 \text{ kN}$$

$$\text{Position of centre of pressure} = \frac{I_G \sin^2 \theta}{A \bar{h}} + \bar{h}$$

$$I_G = \frac{bd^3}{12} \Rightarrow \frac{3 \times 4^3}{12}$$

$$I_G = 16$$

$$P_{\text{centre}} = \frac{I_G \sin^2 \theta}{A \bar{h}} + \bar{h}$$

$$P_{\text{centre}} = \frac{16 \times \sin^2(30^\circ)}{12 \times 3} + 3$$

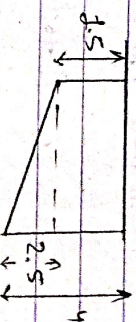
$$P_{\text{centre}} = 3.11 \text{ m}$$

A circular plate 3m diameter is immersed in a water in such a way that its greatest and least depth below the free surface are 4m and 1.5m respectively. Determine the total pressure on one face of the plate and position of centre of pressure?

Solution :- Given that

$$d = 3m$$

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



$$A = \frac{\pi}{4} \times 3^2$$

$$A = 7.06 \text{ m}^2$$

$$\rho_w = 1000 \text{ kg/m}^3$$

$$\theta = 30^\circ$$

$$\sin \theta = \frac{1}{2} = \frac{2.5}{5}$$

$$\sin \theta = 0.833$$

$$\theta = 56.46^\circ$$

$$\sin^{-1}(0.833)$$

$$\sin \theta = \frac{x}{1.5}$$

$$x = 0.83 \times 1.5$$

$$x = 1.24$$

$$\bar{h} = 1.24 + 1.5$$

$$\bar{h} = 2.74 \text{ m}$$

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

$$P_{\text{total}} = 1000 \times 9.81 \times 1.06 \times 2.74$$

$$P_{\text{pressure total}} = 289768.564 \text{ N/m}^2$$

Centre of position of pressure :-

$$P_{\text{centre}} = \frac{I_G \sin^2 \theta}{A \bar{h}} + \bar{h}$$

$$I_G = \frac{\pi}{64} d^4$$

$$I_G = \frac{\pi}{64} 3^4$$

$$I_G = 3.976$$

$$P_{\text{centre}} = \frac{I_G \sin^2 \theta}{A \bar{h}} + \bar{h}$$

$$= \frac{3.976 \times \sin^2(56.40)}{1.06 \times 2.74} + 2.74$$

$$P_{\text{centre}} = 2.88 \text{ m}$$

Q.2 If in the above problem given the circular plate is having a concentric circular hole at diameter 1.5 m calculate the total pressure and centre of pressure?

Solution :- given that

$$d_1 = 3 \text{ m} \quad h_1 = 4$$

$$d_2 = 1.5 \text{ m} \quad h_2 = 1.5$$

$$A = \frac{\pi}{4} (d_1^2 - d_2^2)$$

$$A = \frac{\pi}{4} \times (3^2 - 1.5^2)$$

$$A = 5.30 \text{ m}$$

$$\bar{h} = 2.74$$

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

$$= 1000 \times 9.81 \times 5.30 \times 2.74$$

$$= 142460.82 \text{ N/m}^2$$

$$\boxed{\text{Total pressure} = 142.46 \text{ kN/m}^2}$$

$$\text{Centre of pressure} = \frac{I_G \sin^2 \theta}{\bar{h}} + \bar{h}$$

$$I_G = \frac{\pi}{64} (d_o^4 - d_i^4)$$

$$= \frac{\pi}{64} \times (3^4 - 1.5^4)$$

$$I_G = 3.72$$

$$\text{Centre of pressure} = \frac{I_G \sin^2 \theta}{\bar{h}} + \bar{h}$$

$$= \frac{3.72 \times \sin(56.40)^2}{5.30 \times 2.74} + 2.74$$

$$\boxed{\text{Centre of pressure} = 2.92 \text{ m}}$$

Q. A rectangular tank 5m long and 2m wide contains water upto depth of 2.5m calculate the total pressure in the base of the tank?

Solution :- Given that

$$(1) \text{ length} = 5 \text{ m}$$

$$(2) \text{ width} = 2 \text{ m}$$

$$(3) \text{ depth} = 2.5 \text{ m}$$

$$A = b d$$

$$A = 5 \times 2$$

$$A = 10 \text{ m}$$

$$\bar{h} = \frac{\text{length}}{2}$$

$$\bar{h} = \frac{5}{2}$$

$$\bar{h} = 2.5 \text{ m}$$

$$\rho = 1000 \text{ kg/m}^3$$

$$g = 9.81$$

Total pressure = $\rho g A h$

$$= 1000 \times 9.81 \times 10 \times 2.5$$

$$\boxed{\text{Total pressure} = 245.25 \text{ kN/m}^2}$$

$$\text{Centre of pressure} = \frac{J_G \sin^2 \theta}{A h} + h$$

$$J_G = \frac{\rho b d^3}{12} = \frac{5 \times 2^3}{12}$$

$$J_G = 3.33$$

$$\text{Centre of pressure} = \frac{J_G \sin^2 \theta}{A h} + h$$

$$(\text{Assume } \theta = 56.40^\circ)$$

$$\text{Centre of pressure} = \frac{3.33 \times \sin(56.40)^\circ}{10 \times 2.5} + 2.5$$

$$\boxed{\text{Centre of pressure} = 2.59 \text{ m}}$$

Discharge or rate of flow

It is defined as the quantity of fluid flowing per second through a section of pipe. It is denoted by Q .

$$Q = AV$$

where,

$$A = \text{Area}$$

$$V = \text{velocity}$$

$$J_G \text{ unit } m^3/\text{sec in liquid (or) liter/sec}$$

$$\text{for gas} = \text{kg/sec (or) N/sec}$$

continuity equation (continuity)

Continuity equation based on the principle of conservation of mass. A fluid flowing through a pipe at all the cross section the quantity of fluid per second is constant.

Continuity equation $\Rightarrow$

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

where,

$$A = \text{Cross section Area at section 1}$$

$$V = \text{velocity at section 1 and 2}$$

$$\rho = \text{density of fluid}$$

Q.1 The diameter of pipe at section 1 and 2 are 40 cm and 15 cm respectively. Find the discharge through the pipe if the velocity of water flowing through a pipe at section 1 is 5 m per second. Also determine velocity at section 2.

Solution:— Given that

$$A_1 = 40 \text{ cm} \Rightarrow 0.4 \text{ m}$$

$$A_2 = 15 \text{ cm} \Rightarrow 0.15 \text{ m}$$

$$V_1 = 5 \text{ m/sec}$$

$$V_2 = ?$$

$$Q = ?$$

Using continuity equation

$$Q_1 = Q_2$$

$$A_1 V_1 = A_2 V_2$$

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

$$Q = 0.039 \frac{\text{m}^3}{\text{sec}}$$

$$Q = A_1 V_1$$

$$A_1 V_1 = A_2 V_2$$

$$0.039 = \frac{\pi \times 0.15^2 \times V_2}{4}$$

$$V_2 = \frac{0.039 \times 4}{\pi \times 0.15^2}$$

$$V_2 = 2.20 \text{ m/sec}$$

Q.2 30 cm diameter pipe conveying water branched into two pipe of diameter 20 cm and 15 cm respectively. If the average velocity in the 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 diameter pipe is 2 m/sec.

Solution:— Given that

$$A_1 = 30 \text{ cm} \Rightarrow 0.3 \text{ m}$$

$$A_2 = 20 \text{ cm} \Rightarrow 0.2 \text{ m}$$

$$A_3 = 15 \text{ cm} \Rightarrow 0.15 \text{ m}$$

$$V_1 = 2.5 \text{ m/sec}$$

$$V_2 = 2 \text{ m/sec}$$

$$V_3 = ?$$

$$Q_1 = A_1 V_1$$

$$Q_1 = \frac{\pi}{4} \times 0.3^2 \times 2.5$$

$$Q_1 = 0.176 \frac{m^3}{sec}$$

$$Q_1 = Q_2 + Q_3, \quad Q_2 = 0.062 \frac{m^3}{sec}$$

$$\frac{Q_1 - Q_2}{A_3} = V_3$$

$$\frac{0.176 - 0.062}{\frac{\pi}{4} \times 0.15^2} = V_3$$

$$V_3 = 6.45 \text{ m/sec}$$

Q3 The diameter of pipe at section one and two are 200mm and 300mm respectively. If the velocity of water flowing through the at section one is 4m per second find :-

① Discharge through the pipe

② velocity of water at section 2

Solution :-

Given that

$$d_1 = 200 \text{ mm} \Rightarrow 0.2 \text{ m}$$

$$d_2 = 300 \text{ mm} \Rightarrow 0.3 \text{ m}$$

$$V_1 = 4 \text{ m/sec}$$

$$V_2 = ?$$

$$Q = ?$$

$$Q = A_1 V_1$$

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

$$Q = 0.125 \frac{m^3}{sec}$$

$$Q_1 = A_1 V_1$$

$$Q_1 = Q_2$$

$$A_1 V_1 = A_2 V_2$$

$$0.125 = \frac{\pi}{4} \times 0.3^2 \times V_2$$

$$V_2 = \frac{0.125}{\frac{\pi}{4} \times 0.3^2}$$

$$V_2 = 1.76 \text{ m/sec}$$

Q.4 A pipe has cross section Area 700 cm^2 at one end and velocity at this end is 8 m/sec . Determine the discharge through pipe and Area of cross section and diameter of other section. If the velocity at that end is 3 m/sec .

Solution :- given that

$$A_1 = 700 \text{ cm}^2 \Rightarrow 0.07 \text{ m}^2$$

$$V_1 = 8 \text{ m/sec}$$

$$A_2 = ?$$

$$V_2 = ? \text{ m/sec}$$

$$Q = ?$$

$$d = ?$$

$$Q = A_1 V_1$$

$$Q = 0.07 \times 8$$

$$Q = 0.08$$

$$Q = A_1 V_1 = A_2 V_2$$

$$A_1 V_1 = 0.08$$

$$0.08 = A_2 \times 3$$

$$A_2 = \frac{0.08}{3}$$

Q. A 25 cm diameter pipe carries oil of sp gravity 0.9 and velocity of 3 m/sec at another section the diameter is 20 cm. Find the velocity at this section and also mass flow rate of oil?

Solution :- given that

$$D_1 = 25 \text{ cm} \Rightarrow 0.25 \text{ m} \quad A_1 = 0.049 \text{ m}^2$$

$$D_2 = 20 \text{ cm} \Rightarrow 0.2 \text{ m} \quad A_2 = 0.0314 \text{ m}^2$$

$$V_1 = 3 \text{ m/sec}$$

$$V_2 = ?$$

$$Q = ?$$

$$Q = A_1 V_1$$

$$Q = 0.049 \times 3$$

$$Q = 0.147 \text{ m}^3/\text{sec}$$

rate of flow (volume)

$$\text{mass of flow rate} = \rho \times A \times V$$

$$= 132.3 \text{ kg/sec}$$

$$\text{rate of mass} = 132.3 \text{ kg/sec}$$

$$Q_1 = Q_2$$

$$A_1 V_1 = A_2 V_2$$

$$V_2 = \frac{Q}{A_2}$$

$$V_2 = \frac{0.147}{\frac{\pi}{4} \times 0.2^2}$$

$$V_2 = 4.679 \text{ m/sec}$$

Q2 A fluid having mass density of 746 kg/m^3 flowing through pipe with the rate of 150 liters/sec if the inlet and outlet diameter is 30 cm and 20 cm respectively find :-

- (i) Inlet velocity
- (ii) outlet velocity
- (iii) mass flow rate

Solution :- Given data

$$Q = 150 \text{ liter/sec} \Rightarrow 0.15 \text{ m}^3/\text{sec}$$

$$\rho = 746 \text{ kg/m}^3$$

$$d_1 = 30 \text{ cm}$$

$$d_2 = 20 \text{ cm}$$

$$A_1 = \frac{\pi}{4} \times 0.3^2 \text{ m}^2$$

$$A_2 = \frac{\pi}{4} \times 0.2^2 \text{ m}^2$$

$$Q = A_1 V_1$$

$$V_1 = \frac{Q}{A_1}$$

$$v_1 = 19.09 \text{ m/sec}$$

$$v_2 = \frac{Q}{A_2}$$

$$v_2 = \frac{0.45}{\frac{\pi \times 0.2^2}{4}}$$

$$v_2 = 4.77 \text{ m/sec}$$

$$\text{mass flow rate} = \rho A v$$

$$= 746 \times \frac{\pi \times 0.12^2}{4} \times 19.09$$

$$\text{mass flow rate} = 111.89 \text{ kg/sec}$$

Buoyancy :- when a body is immersed in a fluid an upward force is exerted by the fluid on the body this upward force is equal to the weight of the fluid displaced by the body and is called the force of buoyancy.

centre of Buoyancy :- It is defined as the point through which the force of buoyancy is supposed to act the centre of buoyancy will be the centre of gravity of the fluid displaced.

Q. Find the volume of water displaced and position of centre of buoyancy for a wooden block of width 2.5m and depth 1.5m when it floats horizontally in water the density of wooden block is 650 kg/m^3 and length 6m?

Solution :- given that

$$b = 2.5 \text{ m} \quad \text{width displaced} = ?$$

$$d = 1.5 \text{ m}$$

$$l = 6 \text{ m}$$

$$h = ?$$

$$\text{Position of centre of buoyancy} = ?$$

$$\rho_{\text{wooden}} = 650 \text{ kg/m}^3$$

Weight of body = Weight of water displaced

$$W_b = W_v$$

$$650 \times 9.81 \times 6 \times 1.5 \times 2.5 = 1000 \times 9.81 \times 6 \times 2.5 \times h$$

$$h = \frac{650 \times 9.81 \times 6 \times 1.5 \times 2.5}{1000 \times 9.81 \times 6 \times 2.5}$$

$$\text{height} = 0.975 \text{ m}$$

Position of centre of Buoyancy = $\frac{h}{2}$

$$= \frac{0.975}{2}$$

$$\text{Centre of Buoyancy} = 0.487 \text{ m}$$

$$\text{Water displacement} = 16h$$

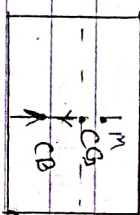
$$= 6 \times 2.5 \times 0.975$$

$$\text{Water displacement} = 14.625 \text{ m}^3$$

3. Floating (Stability of floating) :-

- (a) Neutral
- (b) Stable
- (c) Unstable

(a) Neutral equilibrium :-

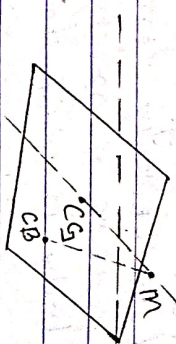


CG = centre of gravity
CB = centre of Buoyancy
M = Metacentric Point

Neutral equilibrium

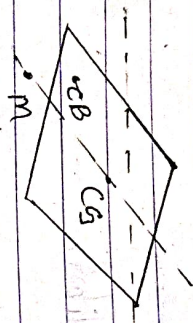
Neutral equilibrium:- If the point M is at the centre of gravity of the body the floating body will in neutral equilibrium

(b) Stable equilibrium :- If the point M is above the CG the floating body will be in stable equilibrium



M = Metacentric Point

(c) unstable equilibrium:- If the point M is below the CG the floating body will be in unstable equilibrium.



Stability of submerged body:-

i) unstable equilibrium:- If weight of body is equal to buoyancy force but the centre of buoyancy is below the centre of gravity the body is in unstable equilibrium.

(ii) Stable equilibrium:- If weight of body is equal to buoyancy force but the centre of buoyancy is above the centre of gravity the body is in stable equilibrium.

(iii) Neutral equilibrium:- If weight of body is equal to buoyancy force and centre of buoyancy and centre of gravity are at the same point the body is said to be in neutral equilibrium.

1) Metacentric point (metacentre):- Metacentre is defined as the point at which the line of action of force of buoyancy will meet the original axis of body when body is given small angular displacement.

2) metacentric height:- It is distance b/w metacentre of floating body and centre of gravity of the body it is called metacentric height.

metacentric height = G_m
metacentre = m

$$G_m = \frac{I}{V} - B G$$

If result in, the body is in stable equilibrium
-ve body is in unstable equilibrium

Q. 7 A solid cylinder of diameter 4m and height 4m find the metacentric height of the cylinder if the sp gravity of material of cylinder is 0.6 and it is floating in water with its axis vertical. State whether equilibrium

is stable or unstable?

Solution:- Given float

$$b = ?$$

$$d = y_m$$

$$h = y_m$$

$$f_{gravity} = 0.6$$

$$G_m = ?$$

$$G_m = \frac{I}{V} - BG$$

$$I = \frac{\pi d^4}{64}$$

$$I = \frac{\pi y^4}{64}$$

$$I = 12.56 \text{ m}^4$$

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

$$h = 2.4 \text{ m}$$

$$V = \frac{\pi \times y^2 \times 2.4}{4}$$

$$V = 30.95 \text{ m}^3 \text{ sec } (30.15)$$

Centre of gravity = 2m

weight of body = weight of water

$$f_{gv} = f_{gw}$$

$$600 \times 9.81 \times \frac{\pi}{4} \times d^3 \times y = 1000 \times 9.81 \times \frac{\pi}{4} \times d^3 \times h$$

$$600 \times y = 1000 \times h$$

$$h = \frac{600 \times y}{1000}$$

$$h = 2.4 \text{ m}$$

$$(CB) \text{ centre of buoyancy} = \frac{h}{2}$$

$$= \frac{2.4}{2}$$

$$CB = 1.2 \text{ m}$$

$$BG = \text{centre of gravity} - CB$$

$$= 2 - 1.2$$

$$BG = 0.8 \text{ m}$$

$$GM = \frac{I}{V} = BG$$

$$= \frac{12.56}{30.15} = 0.8$$

$$GM = -0.383$$

Q2 A block of wood of sp gravity 0.7 floats in water. Determine the metacentric height of the block if its size is $2 \times 1 \times 0.8$ m

Unit - 02

F_g = gravity force

F_v = viscous force

F_p = pressure force

F_A = Area of force

F_c = compressible force

F_t = disturbance force

$$F_{ac} = F_g + F_v + F_p + F_A + F_c \quad \text{if } F_c \text{ is negligible}$$

$$F_{ac} = F_g + F_v + F_p + F_t \rightarrow \text{Raynolds eqn of motion}$$

$$\text{if } F_t = 0 \quad F_t \text{ is negligible}$$

$$F_x = F_g + F_v + F_p \quad \text{Navier Stokes equation}$$

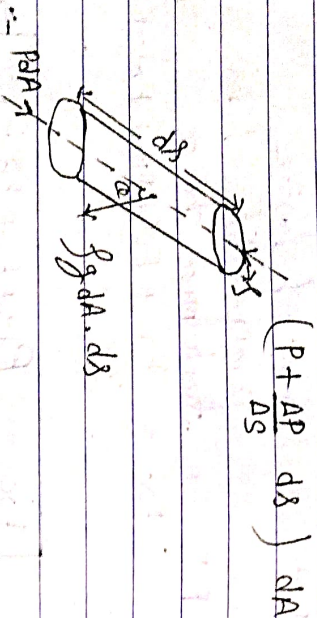
$$\text{if } F_v = 0 \quad \text{negligible}$$

$$F_{ac} = F_g + F_p \rightarrow \text{Euler's eqn of motion}$$

Euler's equation of motion :- This eqn of motion in which the forces

due to gravity and pressure are taken into the consideration.

This is derived by considering the motion of fluid element along the streamline.



Force acting on the cylindrical element :-

1) Pressure force $P da$ in the direction of flow

2) Pressure force $(P + \frac{dP}{ds} \cdot ds) da$ in the opposite

direction of flow.

3) Weight of element $\gamma da \cdot ds$

where θ = angle b/w direction of flow of fluid and line of action of

weight of the element

The resultant force on the fluid element in the direction of streamline must be equal to mass of fluid element into acceleration in the direction of streamline.

$$F_s = M \times a$$

Considering L.H.S :-

$$P da - \gamma da \cdot ds \cos \theta - (P + \frac{dP}{ds} \cdot ds) da$$

$$\gamma da - \gamma da \cdot ds \cos \theta - P da - \frac{dP}{ds} \cdot ds da$$

$$L.H.S \Rightarrow \gamma da \cdot ds \cos \theta - \frac{dP}{ds} \cdot ds da$$

R.H.S :-

$$= m \cdot a$$

$$a = \frac{dv}{ds}$$

velocity is function of s & t

partial diff

$$= \frac{dv}{ds} \cdot \frac{ds}{dt} + \frac{dv}{dt}$$

$$a_s = \frac{v dv}{ds} + \frac{dv}{dt} \left(\int \frac{ds}{dt} = \frac{m}{s} \Rightarrow \text{velocity} \right)$$

Flow of fluid is steady flow $\Rightarrow \frac{dv}{dt} = 0$

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

$$- \int g \cdot dA \cdot ds \cos \theta - \frac{dP}{ds} \cdot ds dA = \rho \times v dv$$

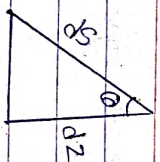
$$\because \rho = \frac{m}{V} \Rightarrow m = \rho V$$

$$V = ds \cdot dA \Rightarrow \rho \times ds \cdot dA$$

$$\Rightarrow - \int g \cdot dA \cdot ds \cos \theta - \frac{dP}{ds} \cdot ds dA = \rho ds dA \times v dv$$

$$\Rightarrow - \int g \cos \theta - \frac{dP}{ds} = \rho \frac{v dv}{ds}$$

$$\frac{dP}{ds} + \rho \frac{v dv}{ds} + \rho g \cos \theta = 0$$



$$\cos \theta = \frac{A}{R} \left(\frac{\text{Area}}{\text{radius}} \right) = \frac{dz}{ds}$$

$$\frac{dP}{ds} + \rho \frac{v dv}{ds} + \rho g \frac{dz}{ds} = 0$$

ds common $\Rightarrow$ multiply by ds

$$dP + \rho v dv + \rho g dz = 0$$

ρ (rho) on divide $\Rightarrow$ divide by rho

$$\frac{dP}{\rho} + v dv + g dz = 0 \quad \text{Euler's equation}$$

Integrating Euler's eqn

$$\int \frac{dP}{\rho} + \int v dv + \int g dz = 0$$

$$\frac{P}{\rho} + \frac{v^2}{2} + dz = \text{constant}$$

$\frac{P}{\rho}$ or $\frac{P}{\rho \gamma}$ and $\frac{v^2}{2}$ or $\frac{v^2}{2g}$

$$\frac{P}{\rho \gamma} + \frac{v^2}{2g} + z = C \quad \text{Bernoulli's eqn}$$

$\frac{p}{\rho g}$ = pressure head (m) / pressure energy per unit weight

$\frac{v^2}{2g}$ = velocity head (m) / kinetic energy per unit weight

z = Potential head (m) / Potential energy per unit weight

Assumptions: - made in the derivation of Bernoulli's eqn

- 1) fluid is ideal (ie) viscosity is zero
- 2) fluid is flowing in steady
- 3) the flow is incompressible
- 4) the flow is irrotational.

Q. water is flowing through a pipe of 5cm of diameter under a pressure of 29.43 N/cm² and mean velocity 2m/s find the total head of total energy per unit weight of water at a cross section which is 5m above the datum line.

Solution: - given find

$$d = 5 \text{ cm} = 0.05 \text{ m}$$

$$p = 29.43 \text{ N/cm}^2 = 2994300 \text{ N/m}^2$$

$$v = 2 \text{ m/s}$$

$$h_2 = 5 \text{ m}$$

$\rho_w = 1000 \text{ kg/m}^3$

Total head / total energy = $\frac{p}{\rho g} + \frac{v^2}{2g} + z$

$$\text{Total head} = \frac{2994300}{1000 \times 9.81} + \frac{(2)^2}{2 \times 9.81} + 5$$

$$\text{Total head} = 35.20 \text{ m}$$

Q.2 A pipe through which water is flowing is having dia 20cm and 10cm at the cross section 1 and 2 respectively the velocity of the water at section 1 given 4m/s find the velocity head at the section 1 and 2 also rate of flow (liters/sec)

Solution: -

$$d_1 = 20 \text{ cm}$$

$$d_2 = 10 \text{ cm}$$

$$v_1 = 4 \text{ m/s}$$

$$\text{velocity head} = ?$$

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

$$\frac{v_2^2}{2g} = \frac{(4)^2}{2 \times 9.81}$$

$$\text{velocity head} = 0.815 \text{ m}$$

$$Q_1 = Q_2$$

$$A_1 V_1 = A_2 V_2$$

$$\frac{\pi (d)^2}{4} \times V_1 = \frac{\pi (d)^2}{4} \times V_2$$

$$V_2 = \frac{\pi \times (0.2)^2 \times V_1}{\frac{\pi}{4} \times (0.1)^2}$$

$$V_2 = \frac{\pi \times (0.2)^2 \times V_1}{\frac{\pi}{4} \times (0.1)^2}$$

$$V_2 = 16 \text{ m/s}$$

$$\frac{(V_2)^2}{2g} = \frac{(16)^2}{2 \times 9.81}$$

$$\text{Velocity head} = 13.04 \text{ m}$$

$$\text{Flow rate } Q_1 = A_1 V_1$$

$$= \frac{\pi \times (0.2)^2 \times 16}{4}$$

$$Q_1 = 0.525 \text{ m}^3/\text{sec} \Rightarrow 11000 \text{ lit/sec}$$

$$Q_1 = 125 \text{ lit/sec}$$

$$Q_2 = A_2 V_2$$

$$= \frac{\pi \times (d)^2 \times V_2}{4}$$

$$= \frac{\pi \times (0.1)^2 \times 16}{4}$$

$$Q_2 = 0.5256 \text{ m}^3/\text{sec} \Rightarrow 11000 \text{ lit/sec}$$

Q.3 The water is flowing through a pipe having dia 20 cm and from and at found the flow rate section 1 is 35 m above datum if the pressure is 3924 N/cm² find the intensity of pressure at section 2?

Solution :-

given that

$$P_2 = 2$$

$$d_1 = 20 \text{ cm}, d_2 = 10 \text{ cm}$$

$$d_1 = 0.2 \text{ m}, d_2 = 0.1 \text{ m}$$

$$Q = 35 \text{ l/sec} = 0.035 \text{ m}^3/\text{sec}$$

$$Z_1 = 6 \text{ m}, P_1 = 39.24 \text{ N/cm}^2$$

$$Z_2 = 4 \text{ m}, P_2 = 39.24 \text{ N/cm}^2$$

$$\therefore Q = A_1 V_1$$

$$0.035 = \frac{\pi \times (0.2)^2 \times V_1}{4}$$

$$V_1 = 0.035$$

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

$$V_1 = 1.11 \text{ m/sec}$$

$$V_2 = \frac{0.035}{\frac{\pi \times (0.1)^2}{4}}$$

$$V_2 = 4.45 \text{ m/s}$$

Using Bernoulli's eqn to find intensity of pressure

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

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

$$\frac{P_2}{\rho g} = \frac{392400}{1000 \times 9.81} + \frac{(1.1)^2}{2 \times 9.81} + 6 - \frac{(4.45)^2}{2 \times 9.81} - 4$$

$$\frac{P_2}{\rho g} = 41.0508 \text{ m}^2$$

$$P_2 = 41.0508 \times 1000 \times 9.81$$

$$P_2 = 402708.348 \text{ N/m}^2$$

Q.4 water is flowing through pipe having dia 300mm and 200mm at the bottom and upper end respectively. The intensity of pressure at the bottom is 24.525 N/cm². The pressure at the upper end is 9.81 N/cm².

Determine the diff in datum head. Note of flow through pipe is well sec².

Solution $\rightarrow$ Given that $d_1 = 300 \text{ mm} \rightarrow 0.3 \text{ m}$

$$d_2 = 200 \text{ mm} \rightarrow 0.2 \text{ m}$$

$$P_1 = 24.525 \text{ N/cm}^2 = 245250 \text{ N/m}^2$$

$$P_2 = 9.81 \text{ N/cm}^2 \rightarrow 98100, \rho = 1000 \text{ kg/m}^3 \rightarrow 1000 \text{ kg/m}^3$$

$$Q = A_1 V_1 \Rightarrow V_1 = \frac{Q}{A_1} \Rightarrow \frac{0.04}{\frac{\pi \times (0.3)^2}{4}}$$

$$V_1 = 0.565 \text{ m/s}, V_2 = \frac{Q}{A_2} \Rightarrow \frac{0.04}{\frac{\pi \times (0.2)^2}{4}}$$

Using Bernoulli's eqn

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

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

$$Z_2 - Z_1 = \frac{245250}{1000 \times 9.81} + \frac{(0.565)^2}{2 \times 9.81} - \frac{98100}{1000 \times 9.81} - \frac{(2.2)^2}{2 \times 9.81}$$

$$Z_2 - Z_1 = 25.016 - 10.082$$

$$Z_2 - Z_1 = 14.934 \text{ m}$$

The diff in datum head = 14.934

Q.1 The water is flowing through a sloped pipe of length 100m having diameter 300mm at the upper end and 300mm at lower end at the rate of 50 l/sec. The pipe has a slope of 1 in 30. Find the pressure at the lower end if the pressure at higher level is 18.19.62 N/cm²

Solution:-
Given that

$L = 100m$

Upper $d_1 = 300mm \Rightarrow 0.3m$

Lower $d_2 = 300mm \Rightarrow 0.3m$

$Q = 50 \text{ l/sec} \Rightarrow 0.05 \text{ m}^3/\text{sec}$

Slope = 1 in 30

Higher depth = 18.19.62 N/cm² = 181962 N/m²

$P_2 = ?$

$Z_2 = 0$

$Z_1 = 3.33$

$Q = A_1 V_1$

$0.05 = \frac{\pi \times (d)^2}{4} \times V_1$

$V_1 = \frac{0.05}{\frac{\pi \times (0.3)^2}{4}}$

$V_1 = 0.176 \text{ m/sec}$

$Q = A_2 V_2$

$V_2 = \frac{Q}{A_2}$

$V_2 = \frac{0.05}{\frac{\pi \times (0.3)^2}{4}}$

$V_2 = 0.176 \text{ m/sec}$

$V_2 = 0.176 \text{ m/sec}$

using Bernoulli's eqn

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

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

$0 = \frac{181962}{1000 \times 9.81} + \frac{(0.176)^2}{2 \times 9.81} + 3.33 - \frac{P_2}{1000 \times 9.81} - \frac{(0.176)^2}{2 \times 9.81}$

$P_2 = 23.327$

$P_2 = 23.327 \times 1000 \times 9.81$

$P_2 = 228838.412 \text{ N/m}^2$

Bernoulli's eqn for real fluid

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

A pipe of diameter 400mm carries water at a velocity of 25m/sec. The pressure at the point A and B are given as 28.43 N/cm² and 22.563 N/cm² while the datum head at A and B are 28m and 30m. Find the loss of head b/w A and B.

Solution :- Given shaft

$$d = 400 \text{ mm} = 0.4 \text{ m}$$

$$v_1 = 25 \text{ m/sec}$$

$$P_1 = 28.43 \text{ N/cm}^2 \Rightarrow 284300 \text{ N/m}^2$$

$$P_2 = 22.563 \text{ N/cm}^2 \Rightarrow 225630 \text{ N/m}^2$$

$$z_1 = 28 \text{ m}$$

$$z_2 = 30 \text{ m}$$

$$v_2 = 25 \text{ m/sec}$$

$$Q = A_1 v_1 = A_2 v_2$$

$$Q = \frac{\pi}{4} d^2 \times v_1$$

$$Q = \frac{\pi}{4} \times (0.4)^2 \times 25$$

$$Q = 3.141 \text{ m}^3/\text{sec}$$

Bernoulli's eqn

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

$$\frac{284300}{1000 \times 9.81} + \frac{25^2}{2 \times 9.81} + 28 = \frac{225630}{1000 \times 9.81} + \frac{25^2}{2 \times 9.81} + 30 + H_L$$

$$89.855 = 84.855 + H_L$$

$$H_L = 89.855 - 84.855$$

$$H_L = 5 \text{ m}$$

Q.2 Point A located in a constant diameter pipe axis on which velocity is 2m/sec and pressure is 10kN/m². Find (i) velocity head (ii) pressure head

Solution :- Given shaft

$$P = 10 \text{ kN/m}^2$$

$$v = 2 \text{ m/sec}$$

$$\text{Pressure head} = \frac{p}{\rho g}$$

$$= \frac{10 \times 10^3}{1000 \times 9.81}$$

$$P_H = 1.018 \text{ m}$$

$$\text{velocity head} = \frac{V^2}{2g}$$

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

$$V_H = 0.203 \text{ m}$$

Q.2 Pipe whose dia at Section 1 is 200mm placed 6m above the datum line and at Section 2 with dia 50mm is placed at 4m above the datum line. The pressure of water at Section 1 is 500kN/m². If velocity at flow at the Section 1 is 1m/s. Determine the intensity of pressure at Section 2.

Solution:- Given that

$$d_1 = 200 \text{ mm} \Rightarrow 0.2 \text{ m}$$

$$d_2 = 50 \text{ mm} \Rightarrow 0.05 \text{ m}$$

$$Z_1 = 6 \text{ m}$$

$$Z_2 = 4 \text{ m}$$

$$P_1 = 500 \text{ kN/m}^2 \Rightarrow$$

$$P_2 = ?$$

$$V_1 = 1 \text{ m/s}$$

$$V_2 = ?$$

$$Q = A_1 V_1 = \frac{\pi}{4} \times (0.2)^2 \times 1$$

$$Q = 0.0314 \text{ m}^3/\text{s}$$

$$Q = A_2 V_2$$

$$V_2 = \frac{Q}{A_2}$$

$$= \frac{0.0314}{\frac{\pi}{4} \times (0.05)^2}$$

$$V_2 = 15.78 \text{ m/s}$$

Using Bernoulli's eqn

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

$$\frac{P_2}{\rho g} = \frac{500 \times 10^3}{1000 \times 9.81} + \frac{1^2}{2 \times 9.81} + 6 - \frac{15.78}{2 \times 9.81} - 4$$

$$\frac{P_2}{\rho g} = 40.32$$

$$P_2 = 40.32 \times 1000 \times 9.81$$

$$P_2 = 395615.8 \text{ N/m}^2$$

$$P_2 = 395.61 \text{ kN/m}^2$$

Q.2 The water is flowing through a tapering pipe having diameter 300mm and 150mm at section 1 and 2 respectively the discharge through the pipe is 40 lit/sec the section 1 is 1m above datum and section 2 is 6m above datum. Find the intensity of pressure at section 2 if that at section 1 is 400 kN/m².

Solution:- Given that

$$d_1 = 300 \text{ mm} \Rightarrow 0.3 \text{ m}$$

$$d_2 = 150 \text{ mm} \Rightarrow 0.15 \text{ m}$$

$$Q = 40 \text{ lit/sec} \Rightarrow 0.04 \text{ m}^3/\text{sec}$$

$$Z_1 = 1 \text{ m}$$

$$Z_2 = 6 \text{ m}$$

$$P_1 = 400 \text{ kN/m}^2 \Rightarrow 400 \times 10^3$$

$$V_1, V_2 = ? \quad P = ?$$

$$Q = A_1 V_1$$

$$V_1 = \frac{Q}{A_1}$$

$$= \frac{0.04}{\frac{\pi}{4} \times (0.3)^2}$$

$$V_1 = 0.565 \text{ m/sec}$$

$$Q = A_2 V_2$$

$$V_2 = \frac{Q}{A_2}$$

$$= \frac{0.04}{\frac{\pi}{4} \times (0.15)^2}$$

$$V_2 = 2.263 \text{ m/sec}$$

Using Bernoulli's eqn

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

$$P_2 = \frac{400 \times 10^3}{2 \times 9.81} + 30 - \frac{2.263^2}{2 \times 9.81} = 6$$

$$\frac{P_2}{\rho g} = 44.52$$

$$P_2 = 44.52 \times 1000 \times 9.81$$

$$P_2 = 436845.81 \text{ N/m}^2$$

$$P_2 = 436.84 \text{ kN/m}^2$$

Q.3 A pipe line carrying oil of sp gravity 0.87 changed in diameter from 200mm diameter at position A to 500mm diameter at position B which (flow) 4m at higher level if the pressure A and B are 9.81 N/cm² and 5.886 N/cm² respectively and the discharge is 200 lit/sec determine the loss of head and direction of flow?

Solution:-
Given that

$$d_1 = 200 \text{ mm} \Rightarrow 0.2 \text{ m}$$

$$d_2 = 500 \text{ mm} \Rightarrow 0.5 \text{ m}$$

$$Q = 200 \text{ lit/sec} \Rightarrow 0.2 \text{ m}^3/\text{sec}$$

$$z_1 = 0 \text{ m}$$

$$z_2 = 4 \text{ m}$$

$$v_1 = ?$$

$$v_2 = ?$$

$$P_1 = 9.81 \text{ N/cm}^2 \Rightarrow 98100 \text{ N/m}^2$$

$$P_2 = 5.886 \text{ N/cm}^2 \Rightarrow 58860 \text{ N/m}^2$$

$$\text{sp gravity} = 0.87$$

$$\text{density } (\rho) = 870 \text{ kg/m}^3$$

$$Q = A_1 v_1$$

$$v_1 = \frac{Q}{A_1}$$

$$v_1 = \frac{0.2}{\frac{\pi}{4} \times 0.2^2}$$

$$v_1 = 6.366 \text{ m/sec}$$

$$v_1 = 6.366 \text{ m/sec}$$

$$v_2 = \frac{0.2}{\frac{\pi}{4} \times 0.5^2}$$

$$v_2 = 0.509 \text{ m/sec}$$

$$v_2 = 1.01 \text{ m/sec}$$

Bernoulli's eqn for real fluid

$$\frac{P_1}{\rho g} + \frac{(v_1)^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{(v_2)^2}{2g} + z_2 + h_L$$

$$E_A = E_B + h_L$$

$$\frac{98100}{870 \times 9.81} + \frac{6.366^2}{2 \times 9.81} + 0 = \frac{58860}{870 \times 9.81} + \frac{1.01^2}{2 \times 9.81} + 4 + h_L$$

$$E_A = 13.540 = E_B = 10.948 + h_L$$

$$h_L = 13.540 - 10.948$$

$$h_L = 2.592 \text{ m}$$

$$E_A > E_B,$$

Fluid will flow from point A to point B.
direction. ~~become~~ $E_A > E_B$

Unit - 3

Flow through Pipe

Types of fluid flow :-

1. Steady and unsteady fluid :-

Steady flow :- If define as the that of flow in which fluid characterstic (property) like velocity, pressure density etc. at a point do not change with the time.

unsteady flow :- unsteady flow is define as the that type of flow in which fluid property like velocity, pressure, density etc. at a point change with the time.

2. uniform and non-uniform flow :-

uniform flow is define as that type of flow in which the velocity at given time does not change with respect to space (that is length of direction of flow).

$$\text{uniform flow} = \frac{dv}{ds} = 0$$

Non-uniform :- non-uniform is define as that type of flow in which the velocity at given time does change with respect to space

$$\text{non-uniform} = \frac{dv}{ds} \neq 0$$

dv = change in velocity
 ds = change in space

3) compressible and incompressible flow :-

compressible flow is that type of flow in which the density of fluid changes from point to point

$$\rho \neq c$$

Incompressible flow is that type of flow in which density is constant for fluid flow

$$\rho = c$$

$$\rho = \text{density}$$

$$c = \text{constant}$$

4) laminar and turbulent flow :-

Laminar flow :- laminar flow is define as that type of flow in which fluid particles moves along well define path or stream line and all stream line are straight or parallel.

turbulent flow :- turbulent flow is that

type of flow in which fluid particles moves in zig-zag way. due to movements of fluid particles in zig-zag way the eddies formation takes place which are responsible for high energy loss.

(Re) Reynold number = $\frac{\text{Inertial force}}{\text{viscous force}}$

$$Re = \frac{\rho v D}{\mu}$$

where,

$$\rho = \text{density} \quad v = \text{velocity}$$

$$D = \text{Diameter of pipe}$$

$$\mu (\text{dynamic}) = \text{Dynamic viscosity}$$

$$\nu (\text{kin}) = \text{kinematic viscosity}$$

$Re < 2000$ { Laminar flow }

$Re > 4000$ { Turbulent flow }

$2000 < Re < 4000$ { Transition flow }

5) Rotational and Irrotational flow :-

Rotational flow :- Rotational is that type of flow in which fluid particles flowing along stream lines and also rotate about their axis

Irrotational flow :- Irrotational flow is that type of flow in which fluid particles flowing along stream lines and do not rotate about their axis.

c) one, two and three dimensional flow :-

one dimensional flow :- one dimensional flow is that type of flow in which the flow parameter such as velocity is function of time or one space coordinate only say x
 $u = f_1(x)$ $w = 0$

two dimensional flow :- two dimensional flow is that type of flow in which the velocity is function of time and two rectangular space coordinate x and y

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

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

three dimensional flow :- Three dimensional flow is that type of flow in which the velocity is function of time and three mutually perpendicular direction

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

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

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

Hydraulic coefficient

- 1 coefficient of discharge (C_d)
 - 2 coefficient of velocity (C_v)
 - 3 coefficient of contraction (C_c)
- 1 $\Rightarrow$ Actual discharge
theoretical discharge

$$C_d = 0.61 \text{ to } 0.65$$

2) $\Rightarrow$ Actual velocity
Theoretical velocity

$$C_v = 0.95 \text{ to } 0.99$$

3) $\Rightarrow$ Area of vena contracta
area of orifice

$$C_c = 0.61 \text{ to } 0.69$$

$$C_c \times C_v = C_d$$

Practical Application of Bernoulli's eqn

- 1 venturimeter
- 2 orifice meter
- 3 Pitot tube

1 venturimeter :- venturimeter is a device used for measuring the rate of flow of a fluid flowing through a pipe. It consists of three parts (1) converging part (2) throat (3) diverging part. It is based on

The principle of Bernoulli's eqn.

Bernoulli's eqn

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

$$\left[\frac{P_1}{\rho g} - \frac{P_2}{\rho g} \right] = \frac{(V_1)^2}{2g} - \frac{(V_2)^2}{2g}$$

h = difference of pressure head

$$h = \frac{(V_1)^2}{2g} - \frac{(V_2)^2}{2g}$$

$$\text{continuity eqn} = A_1 V_1 = A_2 V_2$$

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

$$h = \frac{V_2^2}{2g} - \frac{(A_2 V_2)^2}{2g A_1^2}$$

$$= \frac{1}{2g} \left[V_2^2 - \frac{A_2^2 V_2^2}{A_1^2} \right]$$

$$h = \frac{V_2^2}{2g} \left[1 - \frac{A_2^2}{A_1^2} \right] = \frac{V_2^2}{2g} \left[\frac{A_1^2 - A_2^2}{A_1^2} \right]$$

$$\frac{A_1^2 \times 2gh}{A_1^2 - A_2^2} = V_2^2 \Rightarrow V_2 = A_1 \sqrt{\frac{2gh}{A_1^2 - A_2^2}}$$

$$Q = A_1 V_1 = A_2 V_2$$

$$\text{theoretical } (Q) = \frac{A_2 \times A_1 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$C_d = \frac{Q_{\text{Actual}}}{Q_{\text{theoretical}}}$$

$$Q_{\text{actual}} = C_d \times Q_{\text{theoretical}}$$

$$Q_{\text{Actual}} = C_d \times \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$h = \text{pressure head difference}$$

$$h = x \left[\frac{S_h}{S_o} - 1 \right] \quad S_h > S_o$$

$$h = x \left[1 - \frac{S_l}{S_o} \right]$$

$$\begin{aligned} S_h &= \text{Sp. gravity of heavier fluid} \\ S_o &= \text{Sp. gravity of flowing fluid} \\ S_l &= \text{Sp. gravity of lighter fluid} \end{aligned}$$

$$h = x \left[1 - \frac{S_l}{S_h} \right]$$

Q. A Horizontal venturimeter with inlet and throat diameter 30cm and 15cm used to measure the flow of water. The reading of differential manometer connected to the inlet and the throat is 20cm of mercury. determine the rate of flow take $C_d = 0.98$?

Solution :-
given data

$$d_1 = 30 \text{ cm} \Rightarrow 0.3 \text{ m}$$

$$d_2 = 15 \text{ cm} \Rightarrow 0.15 \text{ m}$$

$$x = 20 \text{ cm} \Rightarrow 0.2 \text{ m}$$

$$\rho_{\text{mg}} = 13600 \text{ kg/m}^3$$

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

$$C_d = 0.98$$

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

$$A_1 = \frac{\pi}{4} (0.3)^2$$

$$A_1 = 0.070$$

$$A_2 = \frac{\pi}{4} (0.15)^2$$

$$A_2 = 0.017$$

$$h = x \left[\frac{S_h}{S_w} - 1 \right]$$

$$h = 0.2 \left[\frac{13600 - 1}{1000} \right]$$

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

$$Q_{\text{actual}} = \frac{C_d A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$Q_{\text{act}} = \frac{0.98 \times 0.070 \times 0.017 \sqrt{2 \times 9.81 \times 2.52}}{\sqrt{(0.070^2 - 0.017^2)}}$$

$$Q_{\text{act}} = 0.120 \text{ m}^3/\text{sec}$$

$$= 120 \text{ lit/sec}$$

Q.2 An oil of sp. gravity 0.8 is flowing through a venturimeter having inlet dia of 20 cm and throat dia 10 cm the oil mercury differential manometer shows a reading of 25 cm calculate the discharge of oil through the horizontal venturimeter take $C_d = 0.98$

Solution :-
 Given data

$$d_1 = 20 \text{ cm} \Rightarrow 0.2 \text{ m}$$

$$d_2 = 10 \text{ cm} \Rightarrow 0.1 \text{ m}$$

$$x = 25 \text{ cm} \Rightarrow 0.25 \text{ m}$$

$$C_d = 0.98$$

$$\rho_{\text{oil}} = 800$$

$$\rho_{\text{Hg}} = 13600$$

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

$$A_1 = \frac{\pi}{4} (0.2)^2$$

$$A_1 = 0.031$$

$$A_2 = \frac{\pi}{4} d_2^2$$

$$A_2 = \frac{\pi}{4} (0.1)^2$$

$$A_2 = 0.007$$

$$h = \frac{2c}{S_0} \left[\frac{S_0}{2} - 1 \right]$$

$$= 0.25 \left[\frac{1360}{800} - 1 \right]$$

$$h = 4m$$

$$Q_{Act} = c d \times \frac{A_1 A_2 \sqrt{2 g h}}{\sqrt{A_1^2 + A_2^2}}$$

$$= 0.98 \times \frac{0.031 \times 0.007 \sqrt{2 \times 9.81 \times 4}}{\sqrt{0.031^2 + 0.007^2}}$$

$$Q_{Act} = 0.98 \times \frac{\frac{\pi}{100} \times \frac{\pi}{400} \sqrt{2 \times 9.81 \times 4}}{\sqrt{\left(\frac{\pi}{100}\right)^2 + \left(\frac{\pi}{400}\right)^2}}$$

$$= 0.070 \text{ m}^3/\text{sec}$$

$$Q_{Act} = 70 \text{ lit/sec}$$

Assignment - 1 CT-01

(i) Newton's law of viscosity :- It states that shear stress is directly proportional to the rate of shear strain

$$\text{rate of shear strain} = \frac{du}{dy}$$

$$\text{shear stress} = \tau$$

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

$\frac{du}{dy}$ = change in distance
change in velocity

μ = viscosity

τ = shear stress

(ii) Bulk modulus :- It is the ratio b/w change in pressure and volumetric strain. It is represented by "K"

$$K = \frac{\text{change in pressure}}{\text{volumetric strain}}$$

$$K = \frac{-\Delta P}{\frac{\Delta V}{V}} \Rightarrow - \frac{\Delta P}{\Delta V} \times V$$

(iii) Kinematic viscosity :- It is defined as the ratio of density of fluid to its dynamic viscosity and denoted by the greek symbol ν called (mv).

$$\nu = \frac{\text{viscosity}}{\text{density}}$$

$$\nu = \frac{m^2}{s} \text{ stoke}$$

(iv) Metacentre :- Metacentre is defined as the point of which the line of action of force of buoyancy will meet the normal axis of body when body is given small, angular displacement.

(v) Centre of pressure :- centre of pressure is defined as the point of

Application of the total pressure on the surface there are four cases of submerged surface on which the total pressure force and centre of pressure is to be determined the submerged surface may be horizontal plane, vertical plane, inclined plane, curved plane.

centre of pressure

$$CP = \frac{I_G \sin 2\alpha}{A \bar{h}} + \bar{h}$$

Q.2 A Pipe contain and oil of sp gr 0.8 A difference level of the pipe should difference in mercury level as 20cm find the difference of the pressure at the two point

Solution:- given that

$$sp. \text{ gravity} = 0.8$$

$$h_{Hg} = 20 \text{ cm} = 0.2 \text{ m}$$

$$\rho_{oil} = 800 \text{ kg/m}^3$$

$$\rho_{Hg} = 13600 \text{ kg/m}^3$$

We know that

$$P_A + \rho_{oil} g x = P_B + \rho_{oil} g x + \rho_{Hg} g h$$

$$P_A + \rho_{oil} g x = P_B + \rho_{oil} g (x - 0.2) + \rho_{Hg} g (0.2)$$

$$P_A + \rho_{oil} g x = P_B + \rho_{oil} g x - \rho_{oil} g (0.2) + \rho_{Hg} g (0.2)$$

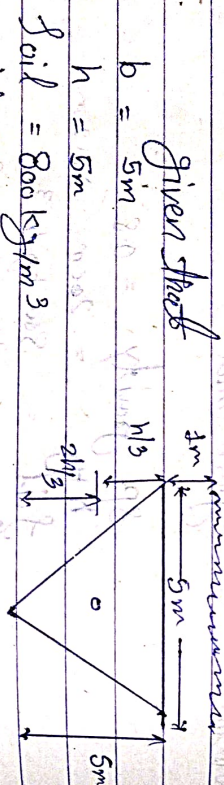
$$P_A - P_B = \rho_{\text{oil}} \times g \times 0.2 - \rho_{\text{air}} \times g \times (0.2)$$

$$P_A - P_B = 9.81 \times 0.2 (13600 - 800)$$

$$P_A - P_B = 25113.6 \text{ N/m}^2$$

Q.3 Determine the total pressure and centre of pressure of an isosceles triangular plate of base 5m and altitude 5m when the plate is immersed vertically in oil of sp. gravity 0.8 the base of the plate is 1m below the free surface of water.

Solution:-



Given that

$$b = 5 \text{ m}$$

$$h = 5 \text{ m}$$

$$\rho_{\text{oil}} = 800 \text{ kg/m}^3$$

$$\rho_{\text{gravity}} = 0.8$$

Plate is 1m below

$$\therefore \text{Total pressure} = \rho_{\text{oil}} \times g \times \bar{h}$$

$$\bar{h} = \frac{h}{3} + 1$$

$$\bar{h} = \frac{h}{3} + 1 \Rightarrow \frac{5}{3} + 1$$

$$\bar{h} = 2.666 \text{ m}$$

$$A = \frac{1}{2} \times b \times h$$

$$= \frac{1}{2} \times 5 \times 5$$

$$A = 12.5 \text{ m}^2$$

$$I_G = \frac{bh^3}{36} \Rightarrow \frac{5 \times 5^3}{36}$$

$$I_G = 17.361 \text{ m}^4$$

$$\text{Total pressure} = \rho_{\text{oil}} \times g \times \bar{h} \times A$$

$$\text{Total pressure} = 800 \times 9.81 \times 2.666 \times 12.5$$

$$\text{Total pressure} = 260346 \text{ N}$$

$$\text{Total pressure} = 260.346 \text{ kN}$$

$$\text{Centre of pressure} = \frac{I_G \sin^2 \theta}{A \bar{h}} + \bar{h}$$

$$= \frac{17.361 \times 1}{12.5 \times 2.666} + 2.666$$

$$\text{Centre of pressure} = 3.182 \text{ m}$$

Q.4 write the assumptions of Bernoulli's equation with Euler's equation.

Also write forces involved in Euler's equation.

Solution:- Bernoulli's equation
$$\frac{p}{\rho g} + \frac{V^2}{2g} + Z = \text{constant}$$

where $\frac{p}{\rho g}$ = pressure head
 $\frac{V^2}{2g}$ = velocity head
 Z = potential head

Assumptions:- (i) fluid is ideal

(ii) velocity is zero

(iii) the flow is incompressible

(iv) the flow is irrotational

$$f = 0$$

Forces acting on the Euler eqn in following

(i) Pressure force $p \, da$ in the direction of flow

(ii) Pressure force $(p + \rho \, dh \, ds) \, da$ in the opposite direction of flow

(iii) weight of element $\rho g \, da \, ds$

Q.5 A pipe through which water is flowing having diameter 40 cm and 90 cm at cross section 1 and 2 respectively. The velocity of water at section 1 is 5 m/s. Find the velocity head at section 1 and 2 and also rate of discharge.

Solution:-

$$d_1 = 40 \text{ cm} \Rightarrow 0.4 \text{ m}$$

$$d_2 = 90 \text{ cm} \Rightarrow 0.9 \text{ m}$$

$$V_1 = 5 \text{ m/s}$$

$$V_2 = ?$$

$$\text{velocity head 1 and 2} = ?$$

$$\text{rate of discharge} = ?$$

$$\text{velocity head 1} = \frac{V_1^2}{2g}$$

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

$$= 1.274 \text{ m}$$

$$V_1 = A_1 V_1 = A_2 V_2$$

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

$$V_2 = \frac{\pi \times (0.4)^2 \times 5}{\pi \times (0.9)^2}$$

$$V_2 = \frac{\pi \times (0.4)^2 \times 5}{\pi \times (0.9)^2}$$

$$V_2 = 20 \text{ m/s}$$

$$\text{velocity head at } 2 \text{ (} V_2 \text{)} = \frac{(V_2)^2}{2g}$$

$$= \frac{(20)^2}{2 \times 9.81}$$

$$V_2 = 20.387 \text{ m/s}$$

$$\text{rate of discharge} = Q = A_1 V_1$$

$$Q = \frac{\pi}{4} \times (0.4)^2 \times 5$$

$$Q = 0.628 \text{ m}^3/\text{sec}$$

$$Q = 628 \text{ lit/sec}$$

And

$$Q_2 = A_2 V_2$$

$$Q_2 = \frac{\pi}{4} \times (0.2)^2 \times 20$$

$$Q = 0.628 \text{ m}^3/\text{sec}$$

$$Q = 628 \text{ lit/sec}$$

As water is flowing through a taper pipe of length 50m having diameter 40cm at the upper end and 20cm at the lower end at the rate of 60 lit/sec the pipe has a slope in 1 in 40. find the pressure at the lower end if the pressure at the higher level is 24.525 N/cm²

Solution :-
Given that

$$L = 50 \text{ m}$$

$$d_1 = 40 \text{ cm} = 0.4 \text{ m}$$

$$d_2 = 20 \text{ cm} = 0.2 \text{ m}$$

$$Q = 60 \text{ lit/sec} = 0.06 \text{ m}^3/\text{sec}$$

$$\text{slope} = 1 \text{ in } 40$$

$$P_2 = 24.525 \text{ N/cm}^2$$

$$P_2 = 245250 \text{ N/m}^2$$

$$P_1 = ?$$

$$Z_1 = 50 \times \frac{1}{40} = 1.25 \text{ m}$$

$$Z_2 = 0 \text{ m}$$

$$Q = A_1 V_1$$

$$V_1 = 0.06$$

$$Q = \frac{\pi}{4} \times (0.4)^2 \times V_1$$

$$V_1 = 0.477 \text{ m/s}$$

$$Q = A_2 V_2$$

$$V_2 = \frac{0.06}{\frac{\pi}{4} \times (0.2)^2}$$

$$V_2 = 1.909 \text{ m/s}$$

using Bernoulli's eqn

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

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

$$\frac{P_2}{\rho g} = \frac{245250}{1000 \times 9.81} + \frac{(0.477)^2}{2 \times 9.81} + 1.25 - \frac{(1.909)^2}{2 \times 9.81} - 0$$

$$\frac{P_2}{\rho g} = 26.076$$

$$P_2 = 26.076 \times 1000 \times 9.81$$

$$P_2 = 255805.56 \text{ N/m}^2$$

$$P_2 = 255.80 \text{ kN/m}^2$$

Unit 2 Revision

~~Definition~~ - ~~It state that the fluid~~
~~is ideal and incompressible~~
~~fluid~~

Definition:- It state that in a
steady, ideal or an incompressible
fluid the energy at any point of the
fluid is
Pressure energy, kinetic energy and
Potential energy.

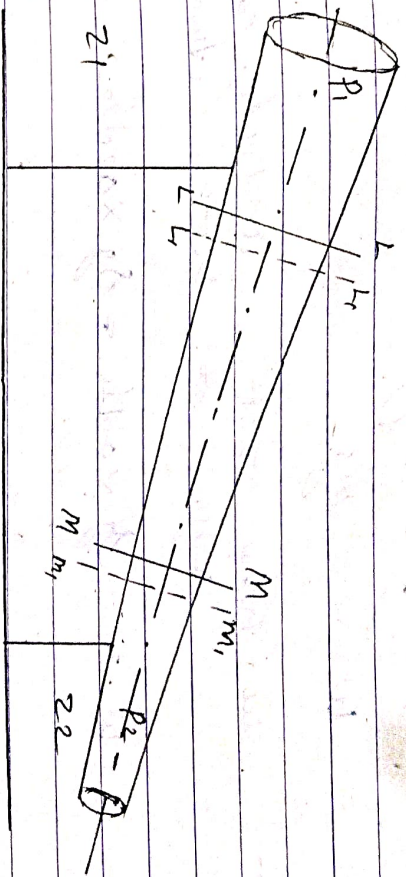
$$\frac{P}{\rho} + \frac{V^2}{2g} + Z = \text{constant}$$

Assumptions:- The fluid is non viscous

The fluid is ideal and incompressible
fluid

The only force acting on the fluid is
pressure force and gravitational force

The flow is continuous and steady



Let,

P_1 = Pressure at 1-1.
 V_1 = velocity at 1-1.

A_1 = Area at pipe 1-1
 Z_1 = datum height at 1-1

P_2, V_2, Z_2 = corresponding values at 2-2

Formula:- Loss of potential energy +

work done by pressure = gain kinetic energy

Consider weight of fluid b/w L-L and L-L₂

$$W = \rho \times V \times \text{volume}$$

$$\rho W = \rho \times a \times \Delta L$$

$$W = mg$$

We know that continuity equation
weight at section 1 = weight at section 2

$$W = \rho \times a_1 \times \Delta L_1 = \rho \times a_2 \times \Delta L_2$$

$$a_1 \Delta L_1 = a_2 \Delta L_2 = \frac{W}{\rho}$$

$$W = mg$$

$$a_1 \Delta L_1 = a_2 \Delta L_2 = \frac{mg}{\rho}$$

$$a_1 \Delta L_1 = a_2 \Delta L_2 = \frac{m}{\rho}$$

work done by pressure at L-L₁

$$\text{workdone} = \text{force} \times \text{distance}$$

$$\text{force} = \text{pressure} \times \text{Area}$$

$$\text{workdone} = P \times A \times \text{distance}$$

$$= P_1 \times a_1 \times \Delta L_1$$

$$\text{workdone at M-M}_1$$

$$= P_2 \times a_2 \times \Delta L_2$$

total work done by pressure

$$= P_1 \times a_1 \times \Delta L_1 - P_2 \times a_2 \times \Delta L_2$$

$$= \Delta L_1 (a_1 P_1 - a_2 P_2) = \frac{m}{\rho} \left\{ \right.$$

$$\text{total workdone} = (P_1 - P_2) \times \frac{m}{\rho}$$

$$\text{kinetic energy at section L-L}_1 = \frac{1}{2} m v_1^2$$

$$\text{at section M-M}_1 = \frac{1}{2} m v_2^2$$

gain kinetic energy

$$= \frac{1}{2} m v_1^2 - \frac{1}{2} m v_2^2$$

$$= m \left(\frac{v_1^2}{2} - \frac{v_2^2}{2} \right)$$

Potential energy at section $m m_1 = m g z_1$

Potential energy at section 1-1 = $m g z_1$

loss of potential energy = $m g z_1 - m g z_2$

$$= m g (z_1 - z_2)$$

Applying a formula of Bernoulli's

loss of potential energy + static work done by pressure = gain in kinetic energy

$$m g (z_1 - z_2) + \frac{m}{\rho} (p_1 - p_2) = m \left(\frac{v_1^2}{2} - \frac{v_2^2}{2} \right)$$

$$g z_1 - g z_2 + \frac{p_1 - p_2}{\rho} = \frac{v_1^2}{2} - \frac{v_2^2}{2}$$

an fluid का

$$- g z_1 - g z_2 + \frac{p_1 - p_2}{\rho} = \frac{v_1^2}{2} - \frac{v_2^2}{2}$$

$$\frac{p_1}{\rho} + \frac{v_1^2}{2} + z_1 = \frac{p_2}{\rho} + \frac{v_2^2}{2} + z_2$$

Application :- Airplane wings

Flow measuring device

water supply system

Ship design

Pump and turbine

Limitations :- It is only for incompressible fluid

Flow must be steady

Flow must be along a stream line

Francis Turbine

Principle :- Francis turbine is reaction type water turbine.

at intake use tower water in medium head fixed flow type turbine. It has radial direction at entry and axial direction at exit.

Principle :- Newton's law of motion. Force change in velocity.

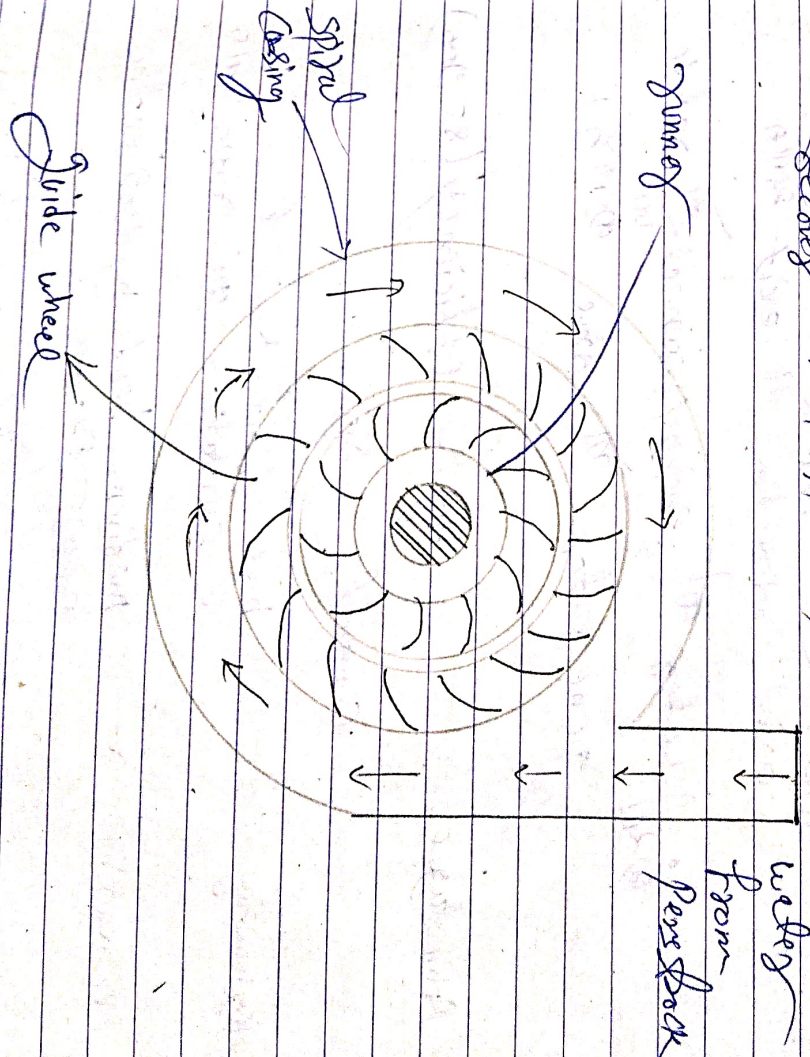
Force on water due to reaction turbine is change in velocity. It is pressure change.

Construction :- Casing is spiral casing in which guide vanes are uniform distribution.

Guide vane :- It is on flow control.

Runner :- It is curved vanes rotating wheel which convert water energy into mechanical energy.

Draft tube :- It is a smooth discharge at tail race. It converts kinetic energy into static pressure.



nothing

Spinal Casing

- Guide Veneys 4/10/91 New 3112
 direct share constant 9224 New 311

center $\rightarrow$ jomney blades on radial
 direction $\rightarrow$ hid $\rightarrow$ april 9 3/2
 axial direction $\rightarrow$ exit april 9

20-11/ water of energy joined at date
 20-11/ gene gates at date
 20-11/

Advantage :- High efficiency (85-90%)

Compact design

disadvantage :- high initial cost
caustation on fire safety

Application in medium head hydroelectric power plants

linely used in large capacity hydro projects

Pelton wheel turbine

① Innovation:- Pelton wheel turbine has
small & it impulse type & water turbine
on mt use small high head & it low discharge
flow type small & economical

Principle :- 1st Newton's Second Law of motion

turned $\rightarrow$ bullets $\rightarrow$ strike $\rightarrow$ mechanical
 energy $\rightarrow$ kinetic energy $\rightarrow$ impulse
 force $\rightarrow$ velocity change
 pressure constant

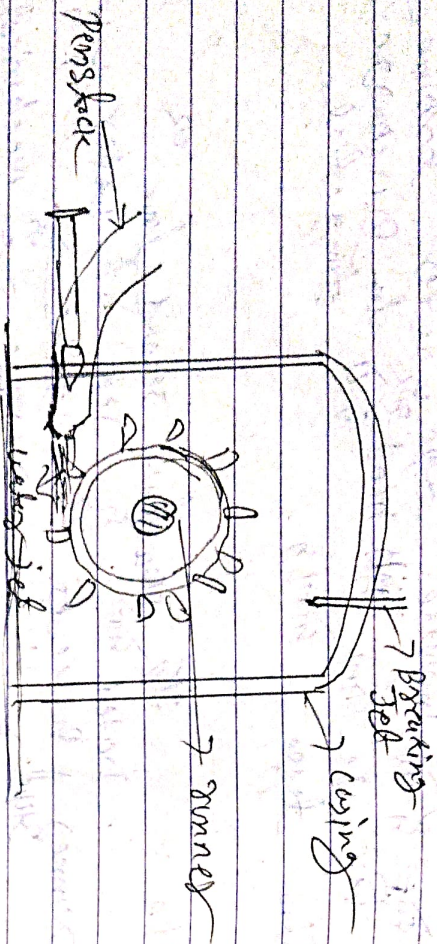
Constriction :- No role with speed :-

high head water by high velocity
 21 Jet convert at 711 3/4 311 Spread
 21 Jet m1 floor corral 311 3/4

Runney :- Periphrast & double hemispherical
Buckets at 5113

Caving - Wilkes splashes on. Confine 9/24/15
31K Spoke discharge 9/24/15

Nozzle Brake :- turbine on shaft of low opposite direction of Jet flow



Working :- 1. High Pressure water Penstock to Nozzle at high velocity

2. Nozzle will on high velocity Jet at

3. Jet Turbine on buckets on splitter
4. Strike at 180 degree
5. Kinetic energy

6. Turbine shaft on to shaft of generator

Advantage :- 1. High efficiency at high heads

2. Simple design and easy maintenance

3. No cavitation problems

Disadvantage :- 1. Sift high head and discharge
2. Suitable large quantity discharge

Application :- High head hydroelectric power plants

maintained regions to hydro projects.

UNIT - 4

Hydraulic Turbine

Impact of Jet :-

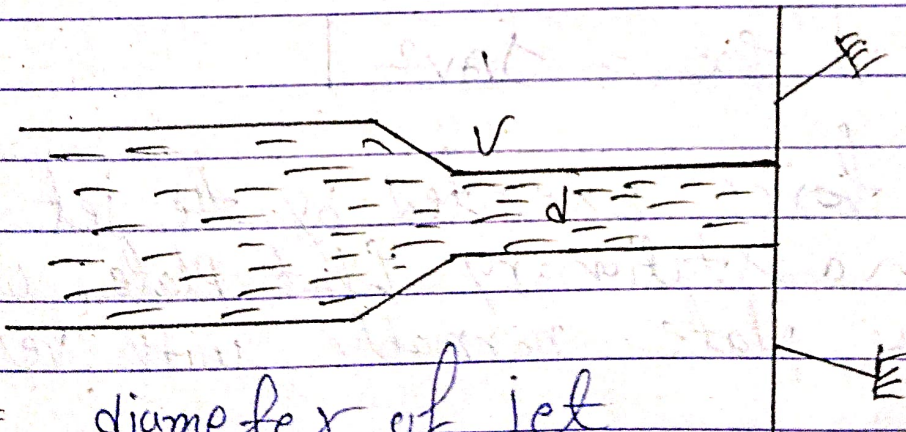
Impact of Jet means force exerted by the jet on a plate which may be stationary or moving.

The force exerted by the jet on a plate will be considered:

(1) (On a stationary plate)

- (i) Plate is vertical to the jet
- (ii) Plate is inclined
- (iii) Plate is curved

(i) Force exerted by the jet on a stationary vertical plate



d = diameter of jet

V = velocity of jet

A = cross section Area of jet $\Rightarrow \frac{\pi}{4} d^2$

Force Exerted by the jet on a vertical plate

F_x = Rate of change of momentum in the direction of force

$$F_x = \frac{dm}{dt}$$

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

= $\frac{mass}{time}$ (velocity of jet before striking - velocity of jet after striking)

$$\frac{m}{t} [V - 0]$$

$$F_x \Rightarrow \rho A V V \Rightarrow \rho A V^2$$

$$F_x = \rho A V^2$$

Q.1 Find the force Exerted by the jet of dia 75mm on a stationary flat plate when a jet strikes the plate normally with velocity 20m/s

Solution :- given that

$$d = 75 \text{ mm}$$

$$V = 20 \text{ m/sec}$$

$$F_{xc} = ?$$

$$F_x = \rho A V^2$$

$$F_x = \frac{1000 \times \pi \times (0.075)^2 \times 20^2}{4}$$

$$F_x = 1767.145 \text{ Newton}$$

Q.2 water is flowing through a pipe at the end of which the diameter of nozzle is 100mm and the head of water at the center nozzle is 10m. Find the force exerted by the jet on water on a fixed vertically plate. the coefficient is velocity is 0.95

Solution $\Rightarrow$ given that

$$\begin{aligned} \text{dia of Nozzle} &= 100 \text{ mm} \\ \text{head of water} &= 10 \text{ m} \\ C_v &= 0.95 \end{aligned}$$

$$CV = \frac{\text{Actual velocity}}{\text{Theoretical velocity}}$$

$$\text{Theoretical velocity} = \sqrt{2gh}$$

$$= 44.29$$

$$\text{Actual velocity} = \text{Theoretical} \times CV$$

$$= 44.29 \times 0.95$$

$$= 42.07$$

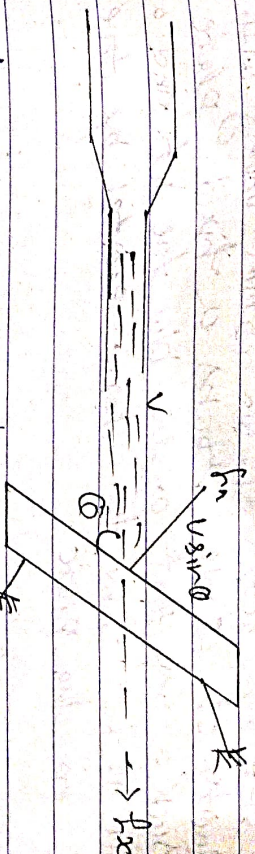
$$F_x = \rho A V^2$$

$$F_x = 1000 \times \frac{\pi}{4} \times 0.07^2 \times 42.07^2$$

$$F_x = 13394.27 \text{ Newton}$$

Force exerted by the jet on a stationary inclined plate.

Force normal to the fixed inclined plate



Force normal to the fixed inclined plate (F_n)

$$F_n = \frac{m}{t} \cdot (initial\ velocity - final\ velocity)$$

$$= \rho A V [V \sin \theta - 0]$$

$$F_n = \rho A V^2 \sin \theta$$

Force in the direction of jet (x)

$$F_x = F_n \sin \theta$$

$$= \rho A V^2 \sin \theta \cdot \sin \theta$$

$$= \rho A V^2 \sin^2 \theta$$

Force in the direction of (y)

$$F_y = F_n \cos \theta$$

$$F_y = \rho A V^2 \sin \theta \cdot \cos \theta$$

Q.3 A jet of water of dia 75mm moving with a velocity of 25 m/s strikes a fixed plate in such a way that angle b/w the jet and a plate is 60° . Find the force exerted by the jet on the plate.

- (i) in the direction normal to the plate
(ii) in the direction of jet

Solution:— given that

$$V = 25 \text{ m/s}$$

$$d = 75 \text{ mm}$$

$$\theta = 60^\circ$$

normal force in the direction of jet

$$F_n = \rho A V^2 \sin \theta$$

$$F_n = 1000 \times \frac{\pi}{4} \times (0.075)^2 \times (25)^2 \times \sin(60)$$

$$F_n = 2391.23 \text{ N}$$

force in a direction of jet

$$F_x = \rho A V^2 \sin^2 \theta$$

Q.4 A jet of water of diameter 50mm strikes a fixed plate in such a way that the angle b/w the plate and jet is 30° . The force exerted in the direction of jet is 1471.5 N. Determine the rate of flow of water.

Solution:— given that

$$d = 50 \text{ mm}$$

$$\theta = 30^\circ$$

$$F_x = 1471.5 \text{ N}$$

$$V = ?$$

$$F_x = \rho A V^2 \sin^2 \theta$$

$$1471.5 = 1000 \times \frac{\pi}{4} \times (0.05)^2 \times V^2 \times \sin^2(30)$$

$$V = \sqrt{\frac{1471.5}{1000 \times \frac{\pi}{4} \times (0.05)^2 \times \sin^2(30)}}$$

$$V = 54.751 \text{ m/sec}$$

$$Q = AV$$

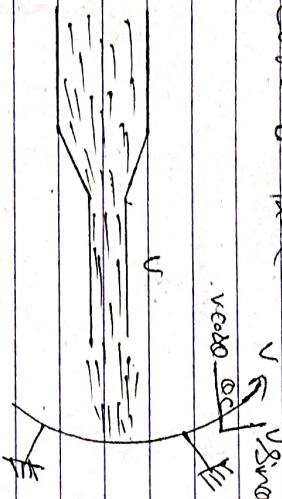
$$Q = \frac{\pi}{4} \times 0.05^2 \times 54.751$$

$$Q = 0.1075 \text{ m}^3/\text{sec}$$

$$Q = 107.5 \text{ lit/sec}$$

$$\text{discharge} = 0.1075 \text{ m}^3/\text{sec}$$

force exerted by jet on stationary curved plate



force in the direction of jet (F_x)

$$F_x = \frac{m}{t} (\text{initial velocity} - \text{final velocity})$$

$$= \rho AV [v - v \cos \alpha]$$

$$F_x = \rho AV^2 [1 + \cos \alpha]$$

force in the direction of y

$$F_y = \frac{m}{t} (\text{initial velocity} - \text{final velocity})$$

$$= \rho AV [0 - v \sin \alpha]$$

$$F_y = -\rho AV^2 \sin \alpha$$

Q.5 A jet of water of dia 50mm moving with a velocity of 40m/sec strikes a curved fixed symmetrical plate at the centre find the force exerted by the jet of water in direction of jet if the jet is deflected through an angle of 120° at the outlet of curved plate?

Solution $\Rightarrow$

Given that

$$d = 50 \text{ mm (0.05 m)}$$

$$V = 40 \text{ m/sec}$$

$$\alpha = 120^\circ - 180^\circ = 60^\circ$$

$$F_x = \rho AV^2 [1 + \cos \alpha]$$

$$F_x = \rho \times \frac{\pi}{4} \times 0.05^2 \times 40^2 \times (1 + \cos 60^\circ)$$

$$F_x = 4732.388 \text{ N}$$

$$F_y = -\rho A V^2 \sin \alpha$$

$$F_y = -\rho \times \frac{\pi}{4} \times 0.05^2 \times 40^2 \times \sin(60^\circ)$$

$$F_y = -2720.699 \text{ N}$$

Q.6 A jet of water of diameter 50mm moving with a velocity of 20m/sec strikes a fixed plate in such a way that the angle between the jet and plate is 60° . Find the force exerted by the jet on the plate (i) in the direction normal to the plate (ii) in the direction of jet

Solution $\Rightarrow$ given that

$$d = 50 \text{ mm} \Rightarrow 0.05 \text{ m}$$

$$V = 20 \text{ m/sec}$$

$$\rho = 1000 \text{ kg/m}^3$$

$$\alpha = 60^\circ$$

$$F_n = \rho A V^2 \sin \alpha$$

$$F_n = \rho \times \frac{\pi}{4} \times 0.05^2 \times 20^2 \times \sin(60^\circ)$$

$$F_n = 680.174 \text{ N}$$

$$F_x = F_n \sin \alpha$$

$$= \rho A V^2 \sin^2 \alpha$$

$$F_x = \rho \times \frac{\pi}{4} \times 0.05^2 \times 20^2 \times 8 \sin(60^\circ)^2$$

$$F_x = 589.04 \text{ N}$$

$$F_y = \text{Inertia force} \\ \text{viscous force}$$

$$F_{\text{grade}} = \text{Inertia force} \\ \text{gravity force}$$

$$F_{\text{Euler}} = \text{Inertia force} \\ \text{pressure force}$$

$$F_{\text{Mach}} = \text{Inertia force} \\ \text{Elastic force}$$

Page

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weber's no = $\frac{\text{Inertia force}}{\text{Surface tension force}}$