UNIT - III

FLUIDS

A substance which can flow under the action of shear force. | Study of ~~phy~~ physical behaviour of fluid is in under fluid mechanics.

* **Hydrostatics** :- study of fluid at rest.
* **Kinematics** :- study of fluid in motion, without considering the pressure force and energy causing motion is called fluid kinematics
* **Dynamics** :- Study of fluid in motion, if the pressure force and energy force causing motion are considered.

* Properties of Fluid :→

① Density or Mass Density :→ $\rho = \frac{\text{Mass of Fluid}}{\text{Vol. of Fluid}}$

$$\rho = \frac{m}{V} \qquad \rho_{water} = 1000\ kg/m^3 \quad \text{or} \quad 1\ gm/cm^3$$

② Specific weight or Weight Density :→

Weight per unit volume called weight density.

$$w = \frac{\text{weight of Fluid}}{\text{Vol. of fluid}} = \frac{m \cdot g}{V} = \rho g \quad N/m^3$$

③ Specific Volume :→

Volume of a fluid occupied by a unit mass.

$$= \frac{V}{m} = \frac{1}{\rho} \qquad m^3/kg$$

④ Specific Gravity :→

It is the ratio of weight density of fluid to the weight density of standard fluid.

$$s\ (\text{for Fluid}) = \frac{\text{weight density of liquid}}{\text{weight density of water}}$$

$$s\ (\text{for gas}) = \frac{\text{weight density of gas}}{\text{weight density of air}}$$

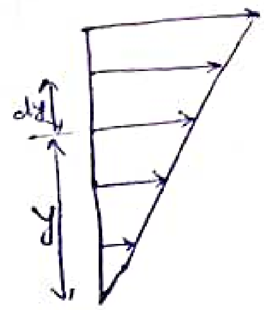
Specific gravity of mercury = 13.6

density of mercury = $13.6 \times 1000 = 13600\ kg/m^3$

Viscosity :→ viscosity is define as the property of fluid which offer resistance to the movement of one layer over another adjacent layer of fluid. * Newtons Law of viscosity :-

Shear stress is proportional to the rate of change of velocity with respect to y in the normal direction or velocity gradiant

$$\tau \propto \frac{du}{dy} \quad , \tau = \mu \frac{du}{dy}$$



The above relationship is called Newton's Low of viscosity where, μ is the constant of proportionality and is called the coefficient of dynamic viscosity or only viscosity.

$$\frac{N \cdot Sec}{m^2} = Pa \cdot Sec$$

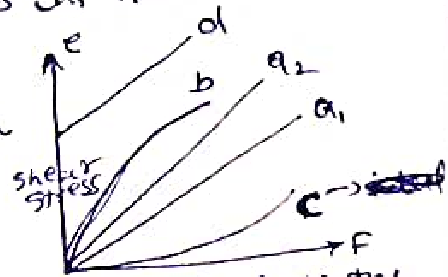
$$\frac{1\,NS}{m^2} = 10 \text{ poise}$$

Kinematic viscosity :- It is the ratio of dynamic viscosity to the density of fluid

$$\nu = \frac{\mu}{\rho} \quad m^2/sec.$$

Types of fluid :-

Ideal fluid :- ① fluid which is non viscous in nature.
② Imaginary fluid, $\tau = 0$



Newtonian fluid :→ a_1 & a_2 follow Newtonian
a_2 is more visous as compare to a_1

$$\tau = \mu\, du/dy$$

Non Newtonian fluid :- Shear stress is not proportional to the velocity gradian eg thick lubricating oil $\tau = \mu \left(\frac{du}{dy}\right)^n$

* for Non Newtonian n is less then unity then it is called Pseudo- plastics eg - milk, blood;
* when n is greater then unity is called dilatant
eg - concentrated solutⁿ of sugar.

* Real fluid :- A fluid which have some viscosity called Real fluid. use in actual practice.

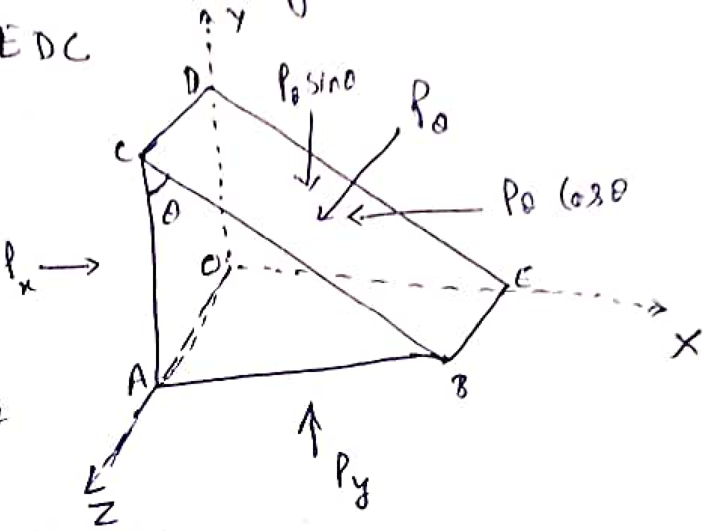
Ideal plastic :- A fluid whose shear stress is more than a yield stress and shear stress is proportional to velocity gradiant is known as ideal plastic. shown by curve d

e - ideal solid, b - pseudo plastic, d = ideal plastic
f - Ideal fluid, c - dilatant, f - Ideal fluid

P.T.O. numericals

Pascal Law :→ The intensity of Pressure at any Point in a static fluid in all direction is equal.

Consider a wedge shape element of size dx, dy, ds and P_x, P_y, P_θ be the Pressure acting normal to the Surface OACD, OABE, BEDC



force acting on OACD = $P_x(dy \times 1)$

OABE = $P_y(dx \times 1)$

BEDC = $P_\theta(ds \times 1)$

weight of element = volume × density × gravity

$= dv \cdot \rho \cdot g$

$= \frac{1}{2} \times (AB \times AC) \cdot 1 \times \rho g = \frac{1}{2} dx \cdot dy \, \rho g$

Now Resolving forces in X - direction

$P_x \, dy \times 1 - P_\theta \, ds \cdot 1 \cdot \cos\theta = 0$.

$\therefore \cos\theta = \frac{dy}{ds}$ $\boxed{dy = ds \cos\theta}$

$P_x \, dy - P_\theta \, dy = 0$

$\boxed{P_x = P_\theta}$ —(I)

Now Resolving force in Y - direction

$P_y \, dx - P_\theta \, ds \sin\theta - \frac{1}{2}(dx \, dy) \rho \cdot g = 0$

$P_y \, dx - P_\theta \, ds \sin\theta = 0$ $\therefore$ dx & dy very small can neglected

$P_y \, dx - P_\theta \, dx = 0$ ~~Sinθ = ds~~ $\cdot$ $\sin\theta = \frac{dx}{ds}$ $dx = ds \sin\theta$

$\boxed{P_y = P_\theta}$ —(II)

from (I) & (II).

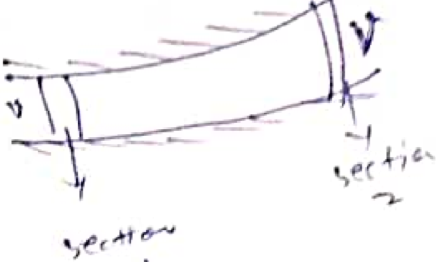
$\boxed{P_x = P_y = P_\theta}$

The above relation show that the Pressure at any Point x, y, z in a static fluid is independent on θ. It follow that the pressure in all direction in a static fluid is same.

Energy Possessed By fluid :→

(1) pressure (2) kinetic (3) Potential energy

Consider one dimensional incompressible fluid flow system in a control vol. At the entry assume pressure intensity p, velocity v density ρ to be uniform at cross sectional area A.



During the small time dt this section move by a small distance ds such that the variation in the fluid property is neglected

workdone during the displacement

$$= p \cdot A \cdot ds$$

$$= p A v \cdot dt$$

$v = \frac{ds}{dt}$

mass of fluid $= A \cdot ds \cdot \rho$

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

Flow work per unit mass. $= \frac{pAv\,dt}{A\,ds\,\rho}$

$$= \frac{pAv\,dt}{Av\,dt\,\rho} = p/\rho$$

Kinetic energy :→ Kinetic energy of the fluid is possesed by virtue of its motion. From 2nd Law

$dF = ma = m\frac{dv}{dt}$, $dw = dF \cdot ds = m\frac{dv}{dt}ds = m\frac{ds}{dt}dv$

$dw = m v\,dv$

$dw = m v \cdot dv$

integrate $w = m\frac{v^2}{2}$ → $W = m\frac{v^2}{2}$

The above relation show the work require to accelerate the Fluid of mass m and velocity v, then kinetic energy

$K = m\frac{v^2}{2}$ for unit mass $K = \frac{v^2}{2}$

Potential energy :- The Potential energy is the energy possessed by the fluid by virtue of its position with reference to some datum. It represent the work require to move the fluid against the gravitational force from the reference position. $P.E = \cancel{ggh}$ mgh

$P.E = mgh$

Numerical on viscosity or Newtons Low

Q. Two plate are placed at a distance of 0.15 mm apart. The lower plate is fixed while the upper plate having a surface area of $1.0\,m^2$ is pulled with a speed of 0.3 m/s. Find the force & Power require if the fluid placed b/w the two plates is having dynamic viscosity of 1.5 poise.

Sol
$\mu = 1.5$ poise $= 0.15\ N/m^2$ $A = 1.0\,m^2$

$dy = 0.15\,mm = 0.15 \times 10^{-3}\ m$ $du = 0.3\ m/sec$

$\tau = \mu \dfrac{du}{dy}$, $\tau = 0.15 \times \dfrac{0.3}{0.15 \times 10^{-3}} = 300\ N/m^2$

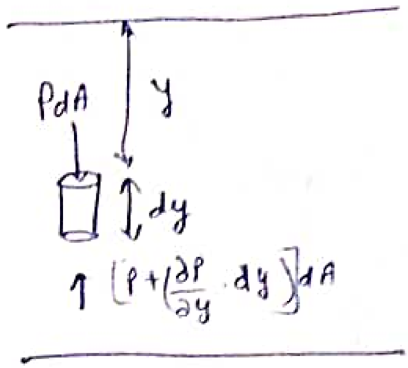
$F = \tau \times A = 300 \times 1 = 300\ N$

Power = Force × dist moved in one second

$= 300 \times 0.3 = 90$ J/sec or 90 watt.

Presure variation in static fluid

pressure force acting on cylindrical elements



① vertically downward $= P \times dA$

② vertically upward

$$\left[P + \left(\frac{\partial P}{\partial y}\, dy\right)\right] dA$$

③ Weight $= mg = dA\, dy \times \rho \times g$

④ Summition of pressure force on curved surface of cylindrical fluid element is equal to zero.

$$P\, dA - \left[P + \left(\frac{\partial P}{\partial y}\, dy\right)\right] dA + dA\, dy\, \rho g = 0$$

$$P dA - P dA - \frac{\partial P}{\partial y}\, dy\, dA + dA\, dy\, \rho g = 0$$

$$-\frac{\partial P}{\partial y} + \rho g = 0$$

$$\frac{\partial P}{\partial y} = \rho g$$

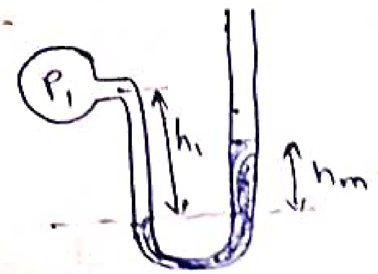
Since the pressure is varying in only one direction so partialy derivation convert into exact differential

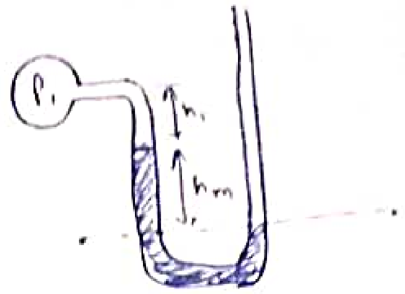
$$\frac{dP}{dy} = \rho g$$

$$\int dP = \int \rho g\, dy$$

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

U-Tube Manometer





$P_1 + \rho_1 g h_1 = \;\; + \rho_m g h_m$

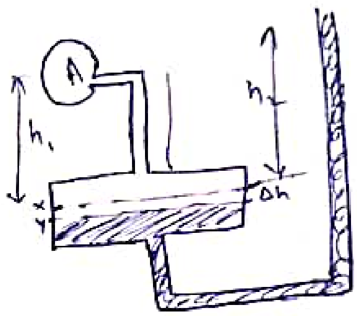
Left Right

$P_1 = \rho_2 g h_2 - \rho_1 g h_1$

$P_1 + \rho g h_1 \;\; + \rho g h_m$

$P_1 + \rho g h_1 + \rho g h_2 = 0.$

Single Column Manometer



left limb $= \rho_1 g(\Delta h + h_1) + P_A$

Right limb $= \rho_2 g(\Delta h + h_2)$

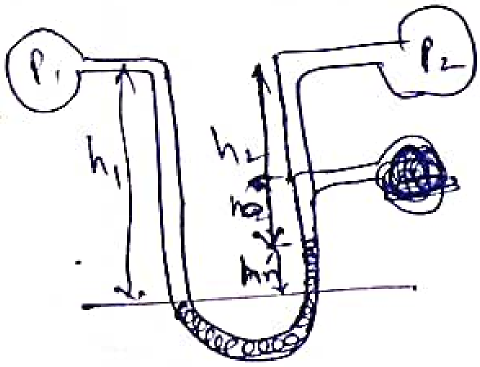
equate

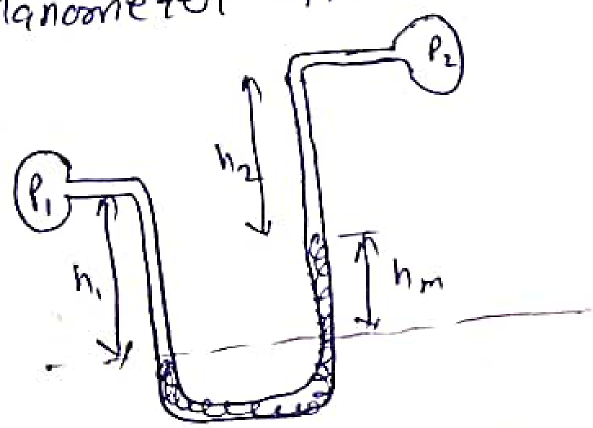
$P_A + \rho_1 g(\Delta h + h_1) = \rho_2 g(\Delta h + h_2)$

$P_A = \rho_2 g \Delta h + \rho_2 g h_2 - \rho_1 g \Delta h - \rho_1 g h_1$

$P_A = \cancel{\rho_1 g (\Delta h} \, \Delta h(\rho_2 g - \rho_1 g) + \rho_2 g h_2 - \rho_1 g h_1$

Differential U-Tube Manometer





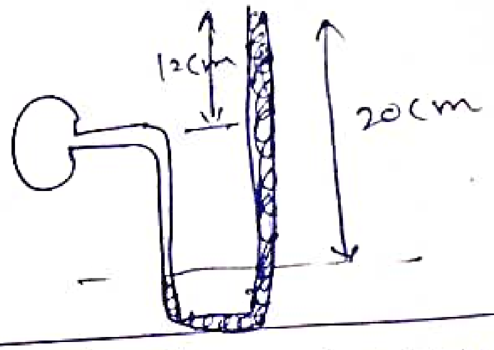
$\rho_1 g h_1 + P_1 = \rho_2 g h_2 + P_2 + \rho_m g h_m$

$P_1 - P_2 = \rho_2 g h_2 + \rho_m g h_m - \rho_1 g h_1$

$\rho_1 g h_1 + P_1 = \rho_2 g h_2 + P_2 + \rho_m g h_m$

$P_1 - P_2 = \rho_2 g h_2 + \rho_m g h_m - \rho_1 g h_1$

Q) The right limb of a simple U-tube manometer containing mercury is open to the atm. while the left limb is connected to a pipe in which a fluid of sp. gr. 0.9 is flowing. The centre of the pipe is 12 cm below the level of mercury in the right limb. Find the pressure of fluid in the pipe if the diff of mercury level in the two limb is 20 cm.

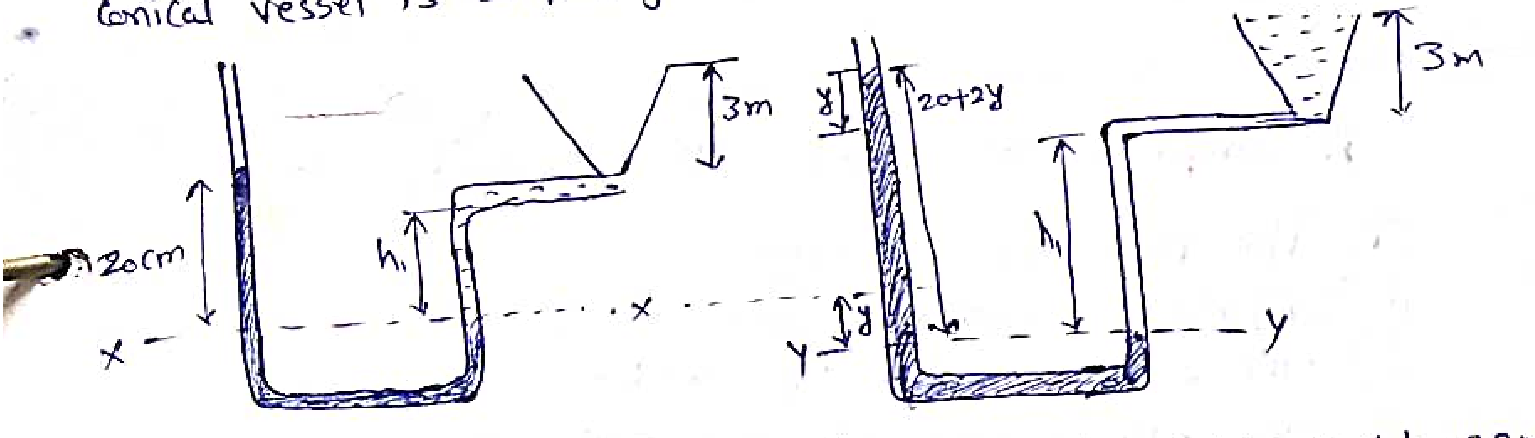


$$P + \rho g h_1 = \rho_2 g h_2$$

$$P + 900 \times 9.81 \times 0.08 = 13600 \times 9.8 \times 0.2$$

$$P = 25977\ N/m^2$$

Q) A conical vessel having its outlet A to which U-tube manometer is connected. The reading of the manometer is indicated in the figure, when the conical vessel is empty, i.e. the water surface is at level A. Find the reading of the manometer when the conical vessel is completely filled with water.



$\rho_1 = 1000\ kg/m^3$ $\rho_2 = 13600\ kg/m^3$, Diff b/w mercury level $h_2 = 0.2m$

Section x-x $\rho_1 g h_1 = \rho_2 g h_2$

$$\boxed{h_1 = 2.72m}$$

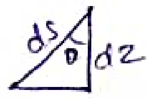
section y-y

$$\rho_2 g (2y + 0.2) = \rho_1 g (h_1 + 3 + y)$$

$$y = 0.1145m = 11.45cm$$

manometer reading $= 2y + 20 = 2 \times 11.45 + 20$
$= 42.9cm$

*. Bernoulli's Equation :→

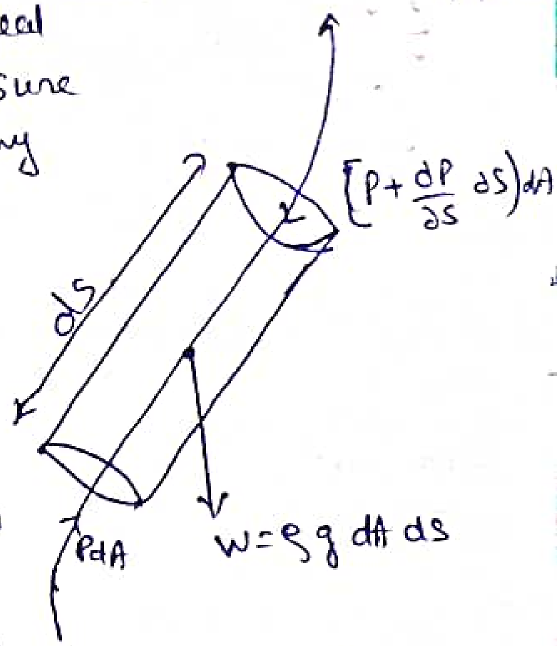


In a streamline, steady flow of an ideal and incompressible fluid the sum of pressure energy, kinetic energy & potential energy at any point in the fluid flow is constant.

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

$\frac{P}{\rho g}$ Pressure head, $\frac{V^2}{2g}$ velocity head.

z Potential head



Consider a cylindrical element with area dA length ds, lets θ be the angle b/w the direction of the flow of fluid and the line of action of gravitional force on the element. Then

1. Pressure force along the direction of flow = PdA
2. Pressure force opposite to the direction of flow = $\left[P + \frac{\partial P}{\partial s} ds\right] dA$
3. Gravitional force on the cylindrical element = $\rho g\, dA\, ds$
4. Component of the gravitional force opposite to the direction of flow = $\rho g\, dA\, ds \cos\theta$

Net force = mass of fluid element ×

Net force = m.a

Hence

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

$$a = \frac{dv}{dt} = \left(\frac{\partial v}{\partial s}\right)\left(\frac{ds}{dt}\right) + \left(\frac{\partial v}{\partial t}\right)\left(\frac{dt}{dt}\right)$$

$$\frac{dV}{dt} = \left(\frac{\partial v}{\partial s}\right)\left(\frac{ds}{dt}\right) + \left(\frac{\partial v}{\partial t}\right)$$

for steady flow $\frac{\partial v}{\partial t} = 0$.

$$\frac{dv}{dt} = \left(\frac{\partial v}{\partial s}\right) V + 0$$

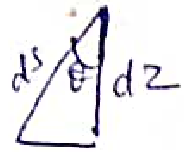
$$\left(-\frac{\partial P}{\partial s} ds\right) dA - \rho\, dA\, ds\, g \cos\theta = \rho\, dA\, ds\, v \frac{dv}{ds}$$

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

$$-\frac{\partial P}{\partial s} - \rho g \cos\theta = \rho v \frac{dv}{ds}$$

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

$$-\frac{\partial P}{\partial s} - \rho g \frac{dz}{ds} = \rho v \frac{dv}{ds}$$



$$-\partial P - \rho g\, dz - \rho v\, dv = 0$$

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

$$P + \rho g z + \rho \frac{v^2}{2} = 0.$$

$$\frac{P}{\rho g} + Z + \frac{v^2}{2g} = 0.$$

ρg deviding

(1). If there are losses due to change in shape, a term h_L is to be added to the right side of the eqn. where h is the energy loss per unit weight

$$\frac{P}{\rho g} + Z_1 + \frac{v^2}{2g} = \frac{P_2}{\rho g} + \frac{v^2}{2g} + Z_2 + h_L$$

(2) If mechanical energy added or taken out per unit weight

$$\frac{P}{\rho g} + Z. + \frac{v^2}{2g} = \frac{P_2}{\rho g} + Z + \frac{v^2}{2g} \pm E$$

+E for Turbine, −E for Pump.

$$\boxed{\text{Power } P = \frac{\rho g Q E}{1000} \text{ KW.}}$$

Application → venturimeter.

Assumption of Bernoulli's Equation :→

1. The flow is steady
2. Fluid is incompressible
3. The flow is ideal (non viscous).
4. The fluid flow is irrotational
5. The velocity of the fluid particle across any crosssection of the tube is constant.

) One end of a U-tube manometer containing mercury is open to atmosphere, while the other end of the tube is connected to a pipe in which a fluid of specific gravity 0.85, and having vaccum is flowing. Find the vacuum pressure of the fluid flowing in the pipe if the difference in the mercury level of the two limb is 20cm and the height of the mercury column in the left limb is 10cm below the centre of pipe.

Sol

$\rho_1 = 850\ kg/m^3$, $\rho_2 = 13600\ kg/m^3$

Diff b/w mer level $= 0.2\ m = h_2$

$h_1 = 0.1 m$

$P_1 + \rho g h_1 + \rho_2 g h_2 = 0.$

$P_1 = -27489\ N/m^2$

Numerical on Bernoulli's.

Q) 50 lit/sec water is flowing down through an inclined conical pipe of dia 500mm and 250mm at the inlet and outlet respectively and the inlet is raised by 1 unit vertical for every 25 unit of the pipe length. If the ~~the~~ length of pipe is 100 m and the pressure at the inlet is 2.5 bar, determine the pressure at the outlet of the pipe

Sol

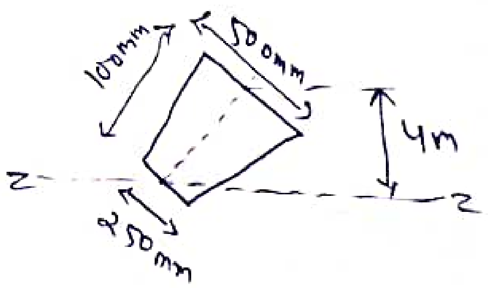
$L = 100\ m$

$Q = 50\ lit/sec = 0.05\ m^3/sec$

$P_1 = 2.5\ bar = 2.5 \times 10^5\ N/m^2$

$d_1 = 0.5 m$, $a_1 = \frac{\pi}{4} d_1^2$

$d_2 = 0.25 m$ $a_2 = \frac{\pi}{4} d_2^2$



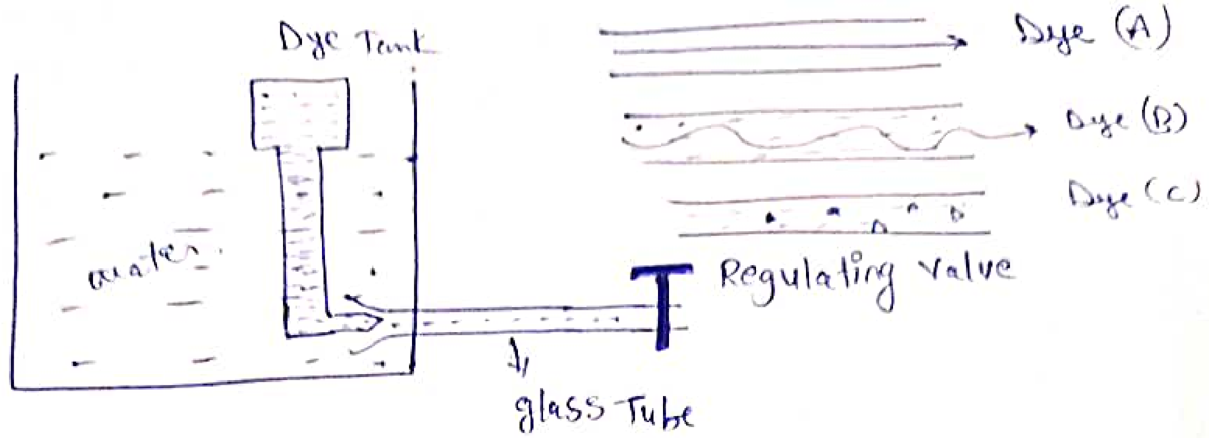
$Q = a_1 v_1 \rightarrow v_1 = 0.255\ m/sec$

$Q = a_2 v_2 \rightarrow v_2 = 1.02\ m/sec$

$$\frac{P}{\rho_1 g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

$$\boxed{P_2 = 2.887 \times 10^5\ Pa}$$

Laminar and Turbulent Flow :-



① Tank Contain Constant Head

Laminar Flow :→ Stream line flow.

Turbulent Flow :→ fluid Particles move in zig-zag.

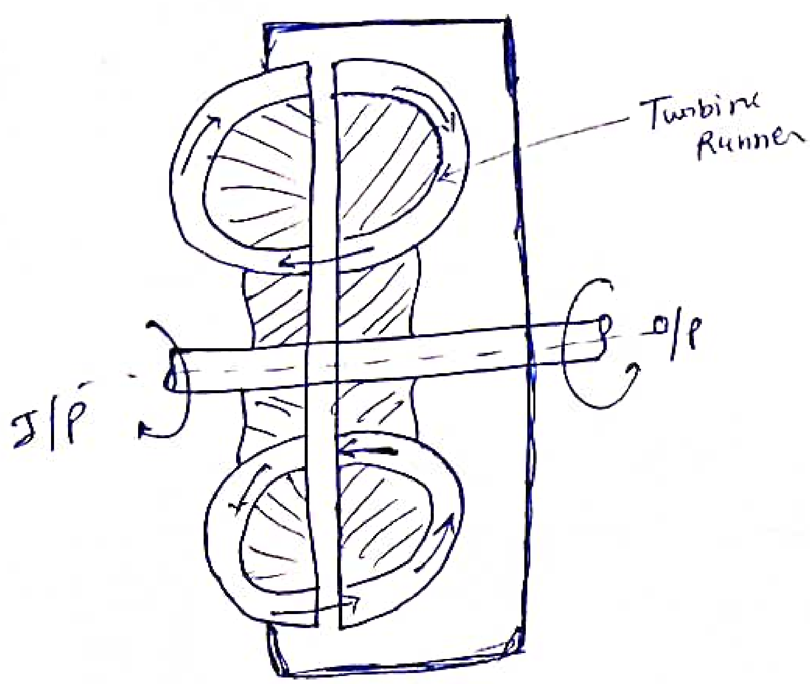
$$\text{Reynold's Number} = \frac{\text{Inertia force}}{\text{Viscous force}} = \frac{\rho v d}{\mu}$$

Laminar Flow < 2000

Turbulent flow > 3000

Transition flow b/w 2000 to 3000

Fluid Coupling :→

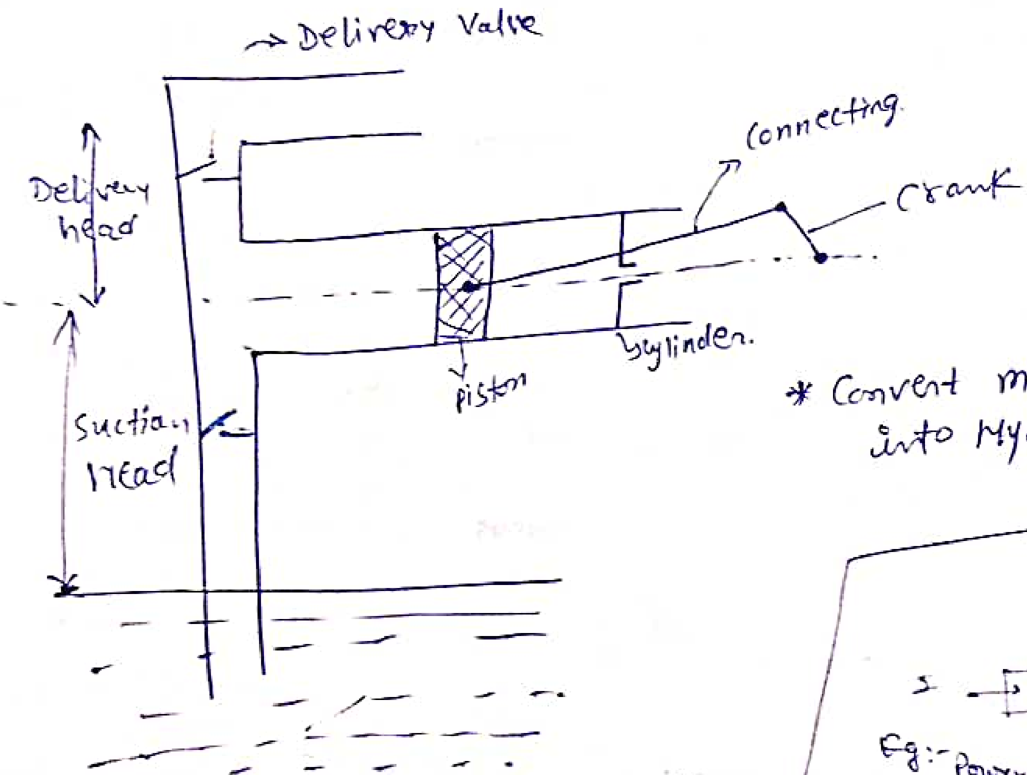


① use for mechanical transmission
eg - gear, clutch assembly

② Oil is used as working medium
non corrosive

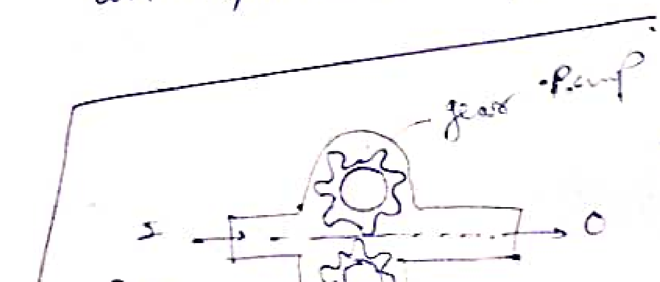
Pump :→ Pump is a device which Convert the mechanical energy into the energy of the fluid or increase pressure head, Kinetic head use for water supply, agreeculture work

Pump
- Positive displacement
  - Reciprocating
  - Rotary
    - gear
    - Lobe
    - vane
- Centrifugal.



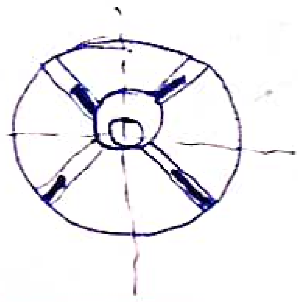
* Convert mechanic energy into Hydraulic energy

Reciprocating Single acting Pump



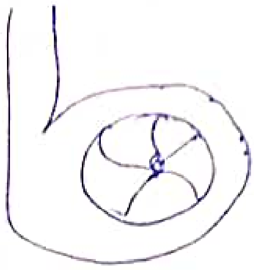
Eg:- Power oth m/c use pumping.
* plastic gear used

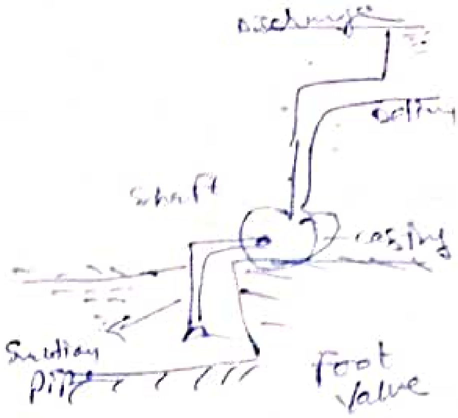
gear, lobe vane



Lobe Pump

Centrifugal Pump.





Centrifugal	Reciprocating
① continuous and smooth	① fluctuating delivery
② Initial & running cost low	② High cost
③ High viscous	③ Low viscous.
④ High efficiency	④ Low efficiency.

* Turbine :- KE to mechanical energy.

A water turbine convert the available Potential and kinetic energy of the water into usefull mechanical energy.

classification of Turbine

① Impulse - eg - Peton

② Reaction - eg - Francis, Kaplan

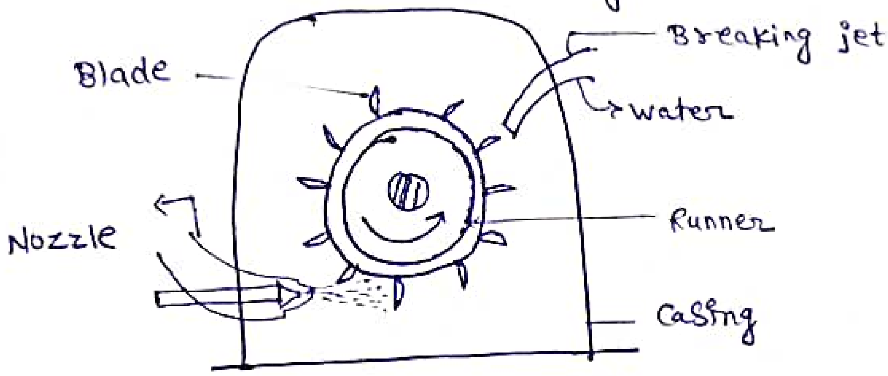
According to available Head.

Low	<30m	Kaplan
Medi	100 m	Kaplan, Francis
High	>100m	Peton.

Tangential	Peltan
Radial	Francis
Axial	Kaplan

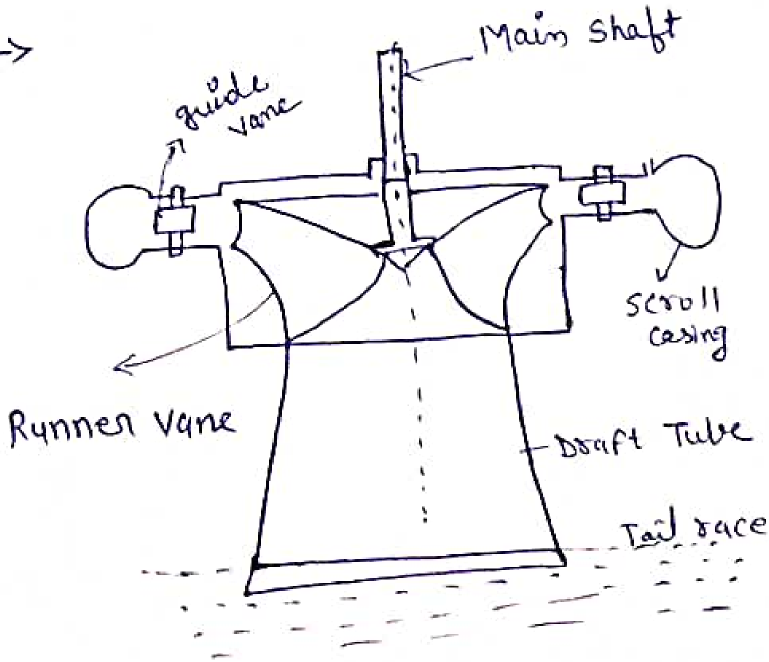
Impulse Turbine :→ The available Potential energy of water is first Converted into Kinetic energy by means of nozzle. The high velocity of jet Coming out of the nozzle strikes series of blades fixed around the Periphery of the rim of a Circular disc. The resulting Change in the momentum of water force the blade to move, which in turn, rotate the disc. (Newton 2nd Law)

Eg:- Pelton Turbine :→ Tangential flow

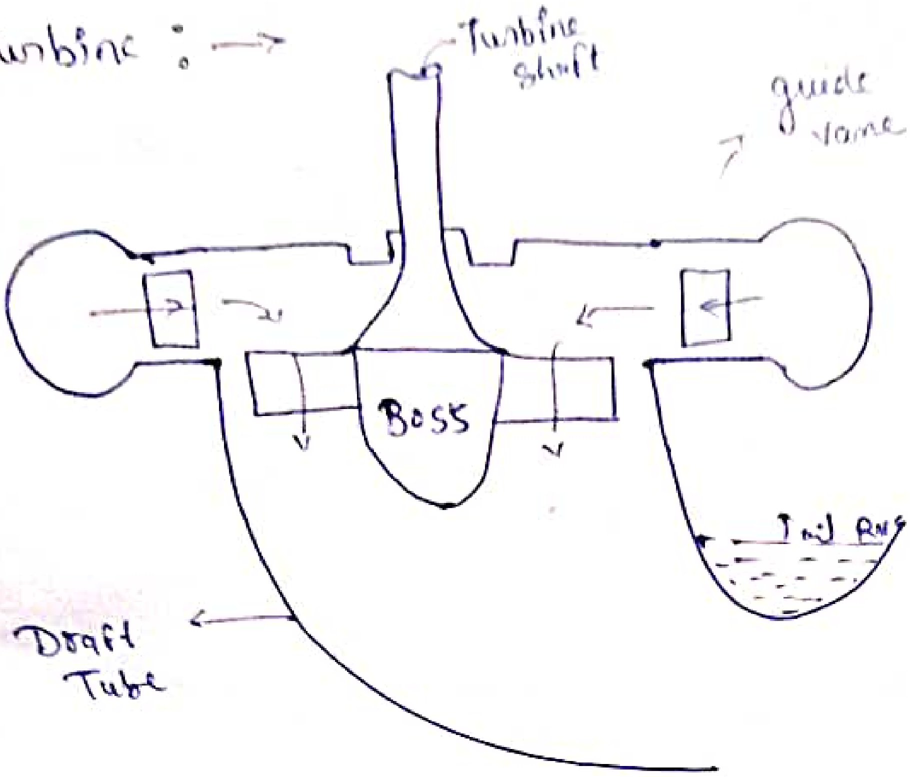


*. Reaction Turbine :→

eg:- Francis Turbine



* Kaplan Turbine :→



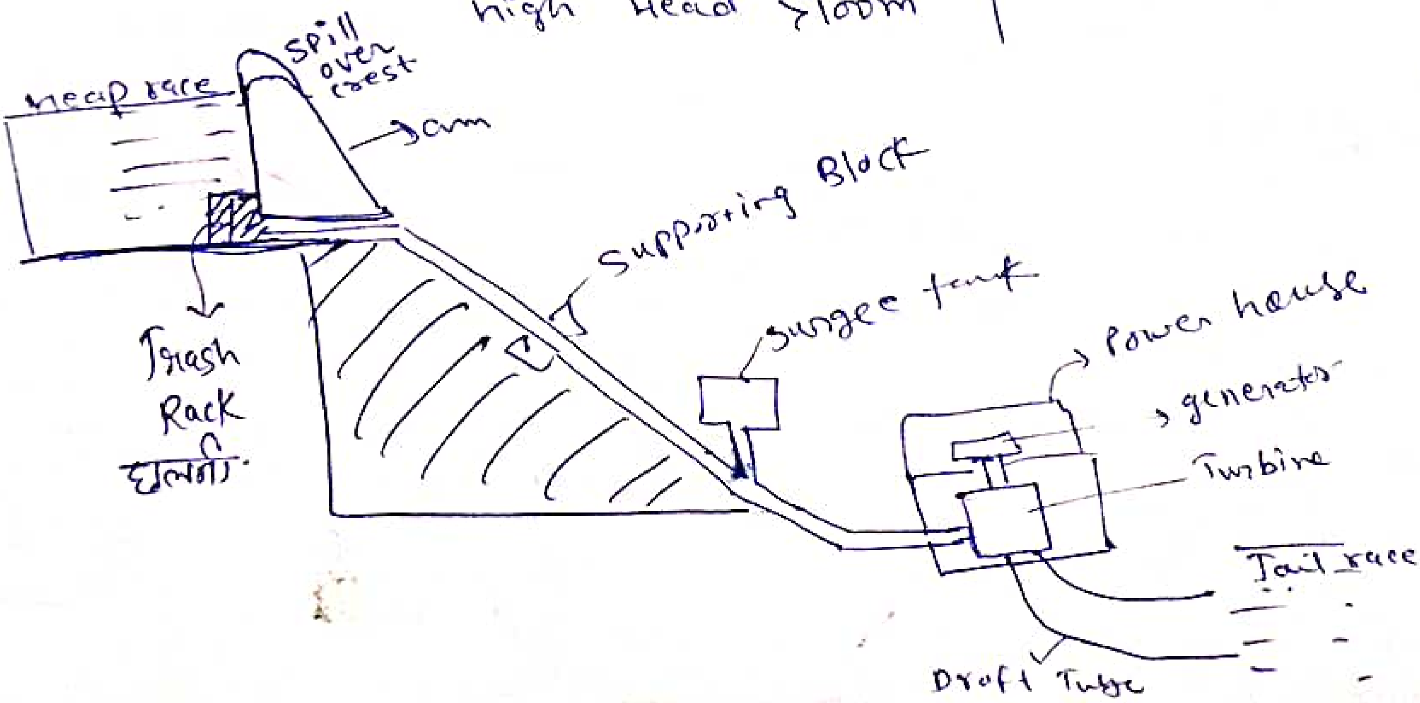
* Hydro-electric Power Plant :→

~~Hydraulic~~ ~~I~~ Hydro-Power Plant are installed where the availability of water in huge quantity and at a sufficient head.

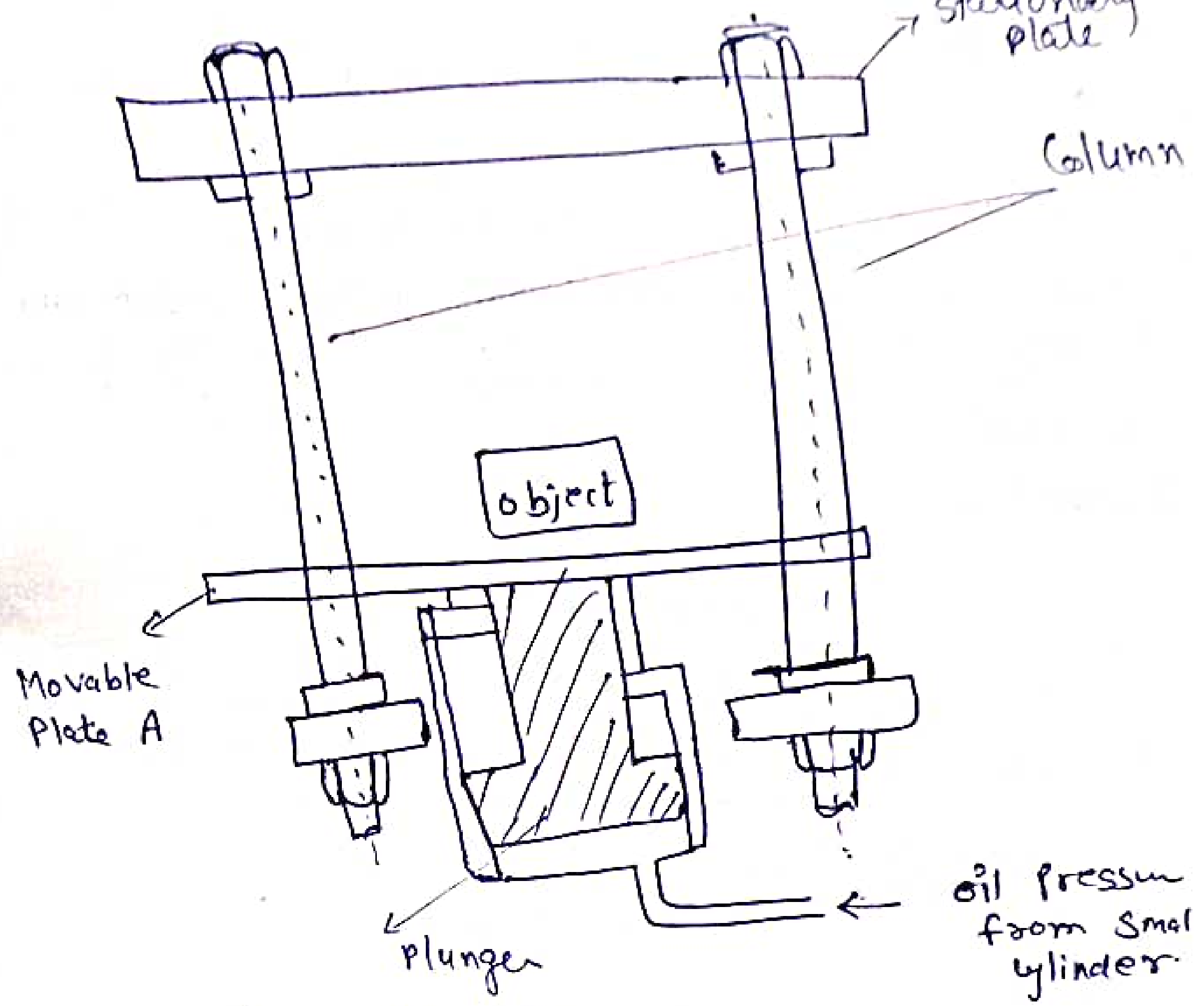
Near 20% of the Power of the world is met by hydro-electric Power Plants

- No fuel used
- Low running cost compare to thermal Plant
- Low starting & stoping time
- Long life

Classification	Low head	30m	Base load Plant
	medium head	100m	Peak Load Plant
	high Head	>100m	



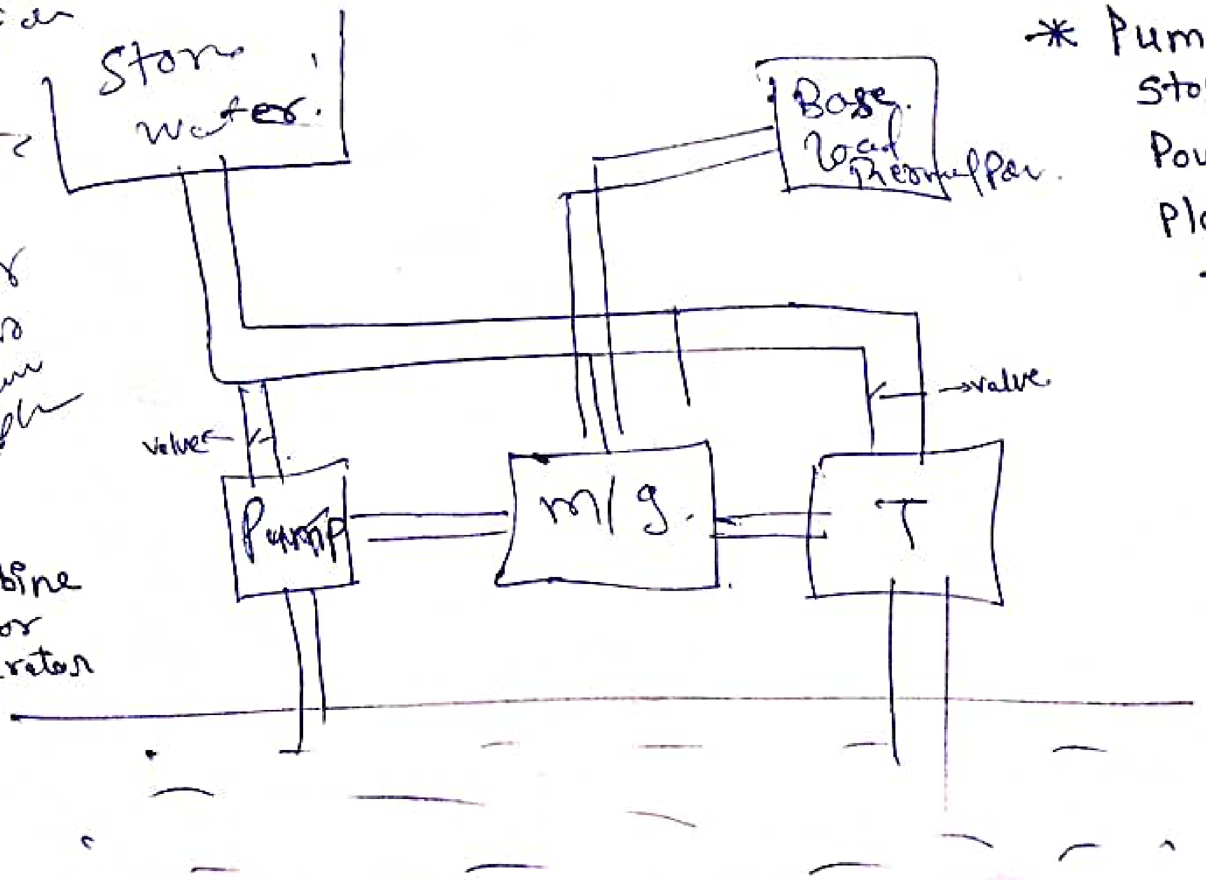
* Hydraulic M/c :- Hydraulic press, Hydraulic crane



Hydraulic press

* Pumped storage Power plant *

Combination of Hydraulic & Thermal or Nuclear Power plant



T- Turbine
M- Motor
G- Generator