# Fundamentals
# of
# Mechanical Engineering and Mechatronics

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# Unit-3
# Introduction to Fluid Mechanics and Applications


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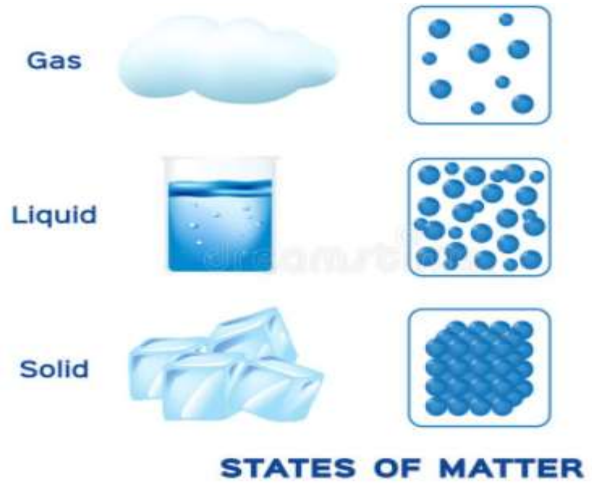
# Unit - III Introduction to Fluid Mechanics and Applications

## SYLLABUS

**Introduction:** Fluids properties, pressure, density, dynamic and kinematic viscosity, specific gravity, Newtonian and Non-Newtonian fluid, Pascal's Law, Continuity Equation, Bernoulli's Equation and its applications, Basic Numerical problems.

Working principles of hydraulic turbines & pumps and their classifications, hydraulic accumulators, hydraulic lift and their applications.

# Introduction




❖A matter exists in either the solid state or the fluid state.

❖The fluid state is further divided into

➢Liquid state

➢Gaseous state

❖In fact the same matter may exist in any one of the three states i.e. solid, liquid and gaseous.

❖For example water occurs in a liquid state, may also occur in solid state as ice and in a gaseous state as vapour.

❖In solids the molecules are very closely spaced.

❖In liquids the spacing between the molecules is relatively large.

❖In gases the space between the molecules is still larger.

# Fluid mechanics

- “Fluid mechanics is that branch of science which deals with the behavior of the fluids at rest as well as in motion.”

- In general the scope of fluid mechanics is very wide which includes the study of all liquids and gases.

- It has applications in mechanical, civil, chemical and biomedical engineering, biology etc.

# Q .1 Define fluid and what is difference between gas and liquid?

- ➢Fluid may be defined as a substance which is capable of flowing. It has no definite shape of its own, but conforms to the shape of the containing vessel.

or

- ❖“**A fluid is a substance which deforms continuously under the action of tangential or shear force.**”

- ❖**A liquid** is a fluid, which possesses a definite volume, which may vary slightly with temperature and pressure.

- ❖**A gas** is a fluid, which is compressible and possesses no definite volume but it always expands until its volume is equal to that of the container.

- ❖Examples of fluids are : Water, Milk, Kerosene, Petrol, Gases etc.

# Q. 2 Define the following fluid properties of a Fluid.

1. Pressure
2. Density
3. Specific Weight(**weight density)**
4. Specific Gravity
5. **Specific volume**

# 1.Pressure (P)

❖"It is defined as normal force per unit area."

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

❖It is a scalar quantity.

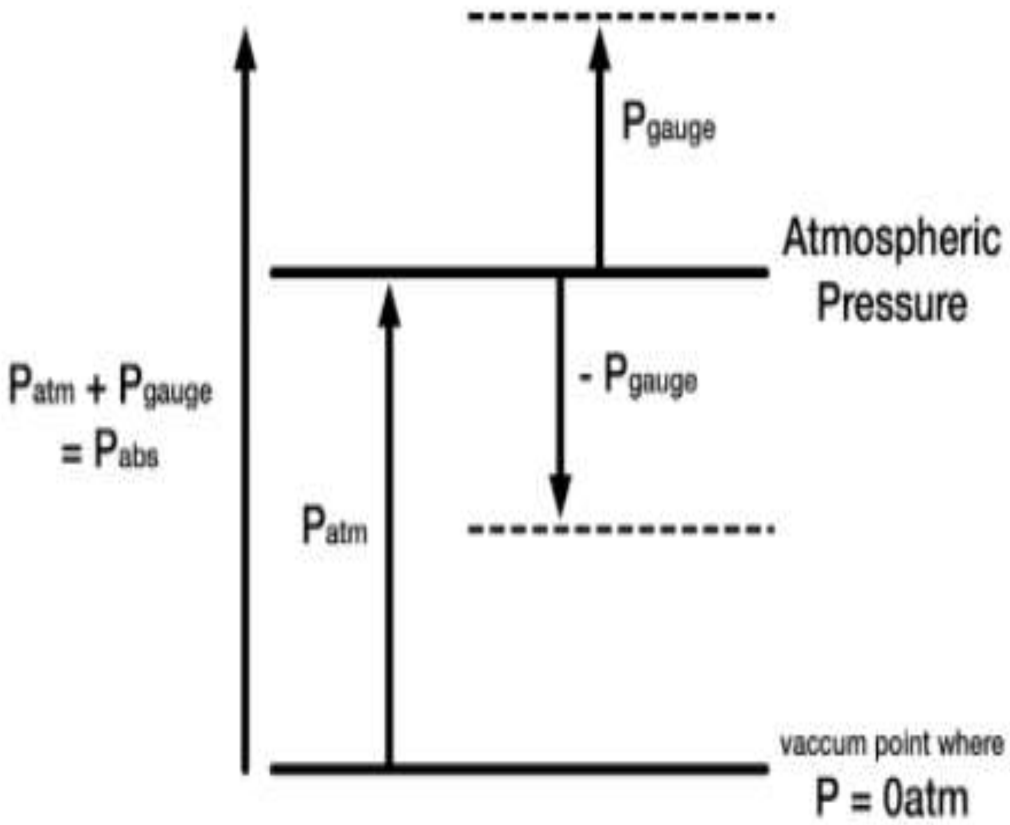
❖Units of Pressure :

➢ $N/m^2$

➢ Pascal (Pa) (1 Pa = 1 $N/m^2$)

➢ atm (1 atm = 101325 Pa = 101.325 kPa)

➢Bar (1 bar =$10^5$ Pa = $10^5$ $N/m^2$



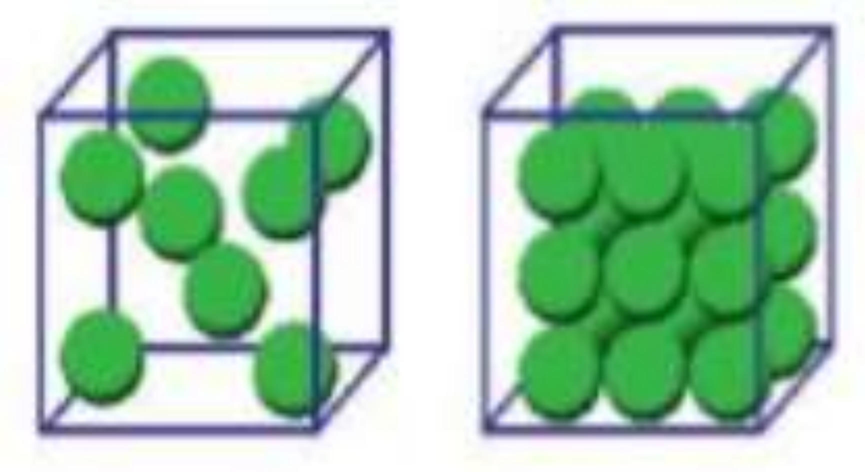
# 2. Density($\rho$) or mass density

❖"It is defined as mass per unit volume of the substance."

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

❖Units of density

- $Kg/m^3$
- $g/cm^3$ or $g/cc$ $\quad$ ($1\ g/cc = 10^3\ kg/m^3$)



❖For example

- $\rho_{water} = 1000\ kg/m^3$
- $\rho_{air} = 1.2\ kg/m^3$
- $\rho_{steel} = 7850\ kg/m^3$

# 3.Specific Weight (ω) or weight density

- "It is defined as weight per unit volume ."

$$\omega = \frac{weight}{Volume} = \frac{mg}{V} = \rho g \qquad [\rho = \frac{m}{V}]$$

- Unit of specific weight is $N/m^3$

# 4.Specific Gravity

❖ " It is defined as the density of the fluid w.r.t. the density of standard fluid."

$$\textbf{Specific Gravity(s)} = \frac{\boldsymbol{density\ of\ a\ fluid}}{\boldsymbol{density\ of\ standartd\ fluid}}$$

➢ For liquid, standard fluid is water ( at **4 °C(39.2 °F), 1 atm, 1000 kg/m$^3$**).

➢ For gases, standard fluid is Air/$H_2$.

# 5. Specific volume(v)

- “It is defined as volume per mass unit of the substance.”

$$\mathrm{v} = \frac{V}{m}$$

- Units of Specific volume

- $m^3/Kg$

**Problem 1.1** *Calculate the specific weight, density and specific gravity of one litre of a liquid which weighs 7 N.*

**Solution.** Given :

$$\text{Volume} = 1 \text{ litre} = \frac{1}{1000}\,\text{m}^3 \quad \left(\because\ 1 \text{ litre} = \frac{1}{1000}\,\text{m}^3 \text{ or } 1 \text{ litre} = 1000 \text{ cm}^3\right)$$

$$\text{Weight} = 7 \text{ N}$$

(*i*) Specific weight ($w$)

$$= \frac{\text{Weight}}{\text{Volume}} = \frac{7\,\text{N}}{\left(\frac{1}{1000}\right)\text{m}^3} = \mathbf{7000\ N/m^3}.\ \textbf{Ans.}$$

(*ii*) Density ($\rho$)

$$= \frac{w}{g} = \frac{7000}{9.81}\ \text{kg/m}^3 = \mathbf{713.5\ kg/m^3}.\ \textbf{Ans.}$$

(*iii*) Specific gravity

$$= \frac{\text{Density of liquid}}{\text{Density of water}} = \frac{713.5}{1000} \quad \{\because\ \text{Density of water} = 1000\ \text{kg/m}^3\}$$

$$= \mathbf{0.7135}.\ \textbf{Ans.}$$

**Problem 1.2** *Calculate the density, specific weight and weight of one litre of petrol of specific gravity = 0.7*

**Solution.** Given : Volume = 1 litre = $1 \times 1000 \text{ cm}^3 = \frac{1000}{10^6} \text{ m}^3 = 0.001 \text{ m}^3$

Sp. gravity $S = 0.7$

(*i*) *Density* ($\rho$)

Using equation (1.1*A*),

*Density* ($\rho$) $= S \times 1000 \text{ kg/m}^3 = 0.7 \times 1000 =$ **700 kg/m³. Ans.**

(*ii*) *Specific weight* ($w$)

Using equation (1.1), $w = \rho \times g = 700 \times 9.81 \text{ N/m}^3 =$ **6867 N/m³. Ans.**

(*iii*) *Weight (W)*

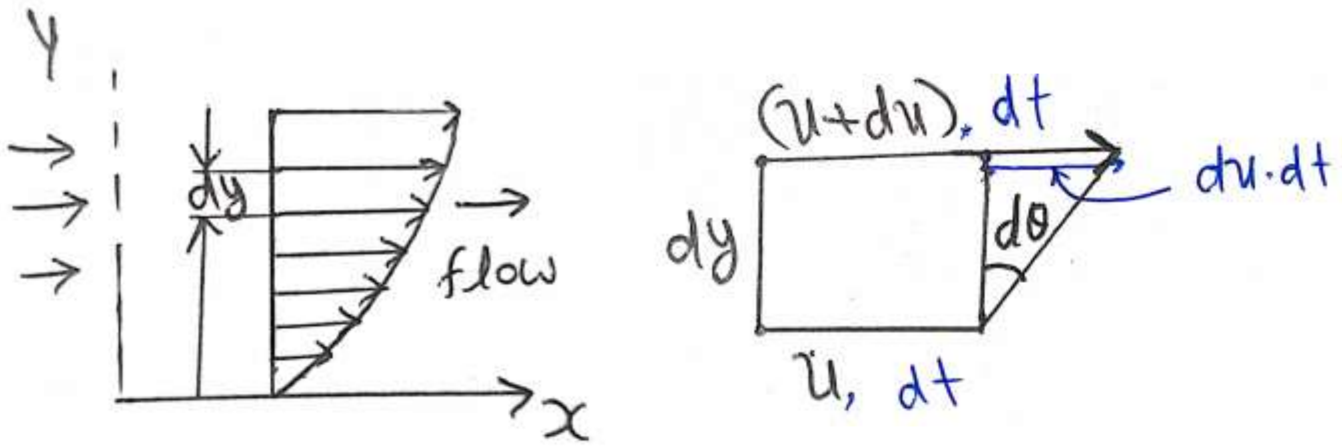
We know that specific weight $= \frac{\text{Weight}}{\text{Volume}}$

or $w = \frac{W}{0.001}$ or $6867 = \frac{W}{0.001}$

$\therefore$ $W = 6867 \times 0.001 =$ **6.867 N. Ans.**

# Q.5 Explain Viscosity.

- "Two adjacent layers of the fluid **resist** the motion of each other such a fundamental property of the fluid is known as **viscosity or dynamic viscosity**" denoted by **μ**.
- Therefore the frictional force between the adjacent layers is known as viscous shear force.




$$\tan d\theta = \frac{du.dt}{dy}$$

if $d\theta$ is very small $d\theta = \dfrac{du.dt}{dy}$

$$\frac{d\theta}{dt} = \frac{du}{dy}$$

Where $\dfrac{d\theta}{dt}$ = Rate of angular(shear) deformation and $\dfrac{du}{dy}$ = Velocity gradient.

# Viscosity………

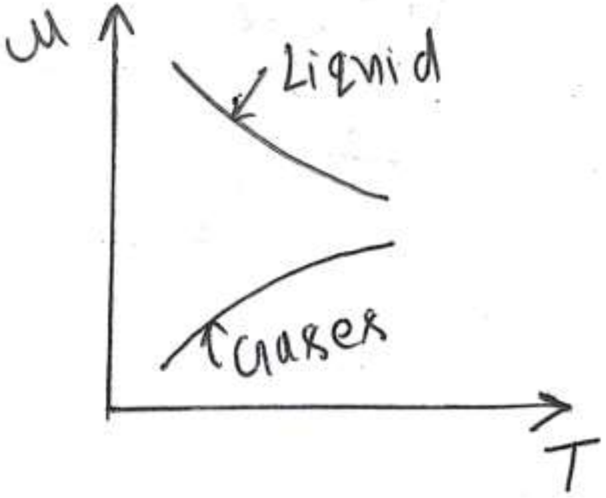
- Basic cause of viscosity is **cohesive forces** between the molecules.

- Because in case of liquid cohesive force is high and in case of gases cohesive force is very less.

- Therefore viscosity of liquid is very high as compared to viscosity of gases.

# Dependency of Viscosity on Temperature

- Viscosity of **liquid** decreases with increase in temperature.[if T↑ then cohesion ↓]




- Viscosity of **gases** increases with increase in temperature.[if T↑ then randomness↑]

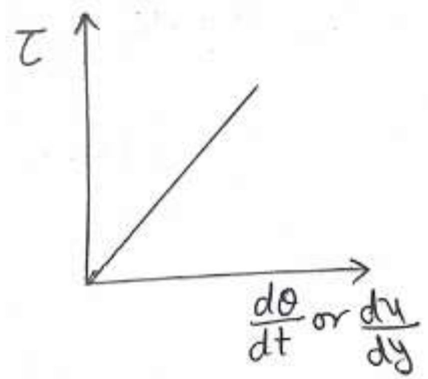
- C = $\sqrt{\frac{3RT}{m}} = \sqrt{\frac{3Pv}{m}}$

# Q .6 State the Newton's law of Viscosity.

❖According to Newton's law of viscosity "Shear stress between the layers of fluid is directly proportional to rate of shear deformation."

$$\tau \ \alpha \ \frac{d\theta}{dt} \quad \text{or} \quad \tau \ \alpha \ \frac{du}{dy} \qquad \left[\text{Because } \frac{d\theta}{dt} = \frac{du}{dy}\right]$$

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




❖Where μ is proportionality constant(**property of fluid**) which is known as viscosity or dynamic viscosity.

❖Unit of viscosity

➢MKS : $\frac{N-s}{m^2} = \frac{kg-m}{s^2} \times \frac{s}{m^2} = \frac{kg}{m-s}$ [F = ma]

➢**CGS :** $\frac{gm}{cm-s} = \frac{10^{-3}kg}{10^{-2}\ m-s} = 0.1 \frac{kg}{m-s} = 0.1 \frac{N-s}{m^2}$

❖ $\frac{gm}{cm-s} = 1 \text{ Poise} = 0.1 \frac{N-s}{m^2}$

# Q.7 Define Kinematic Viscosity.

- "Ratio of dynamic Viscosity and density is called Kinematic Viscosity, denoted by **ν**.

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

- Unit of Kinematic Viscosity
  - MKS : $m^2/s$
  - CGS : $cm^2/s$

$$1\,\frac{cm^2}{s} = 10^{-4}\,\frac{m^2}{s} = 1 \text{ stoke}$$

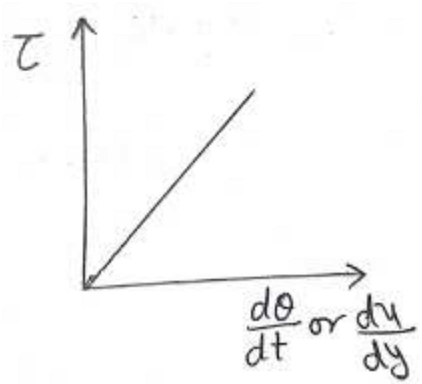
# Q .8 Define Newtonian and Non Newtonian fluids.

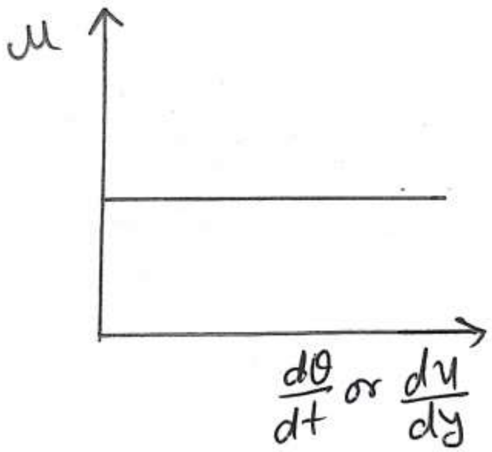
❖ **NEWTONIAN FLUID :** "All the fluids which obey Newton's law of viscosity are known as Newtonian fluids."

❖ There is a linear relation between magnitude of Ʈ and $\frac{d\theta}{dt}$.

❖ Example : Air, water, kerosene, petrol etc.

Ʈ = **μ** $\frac{du}{dy}$ Or Ʈ = **μ** $\frac{d\theta}{dt}$



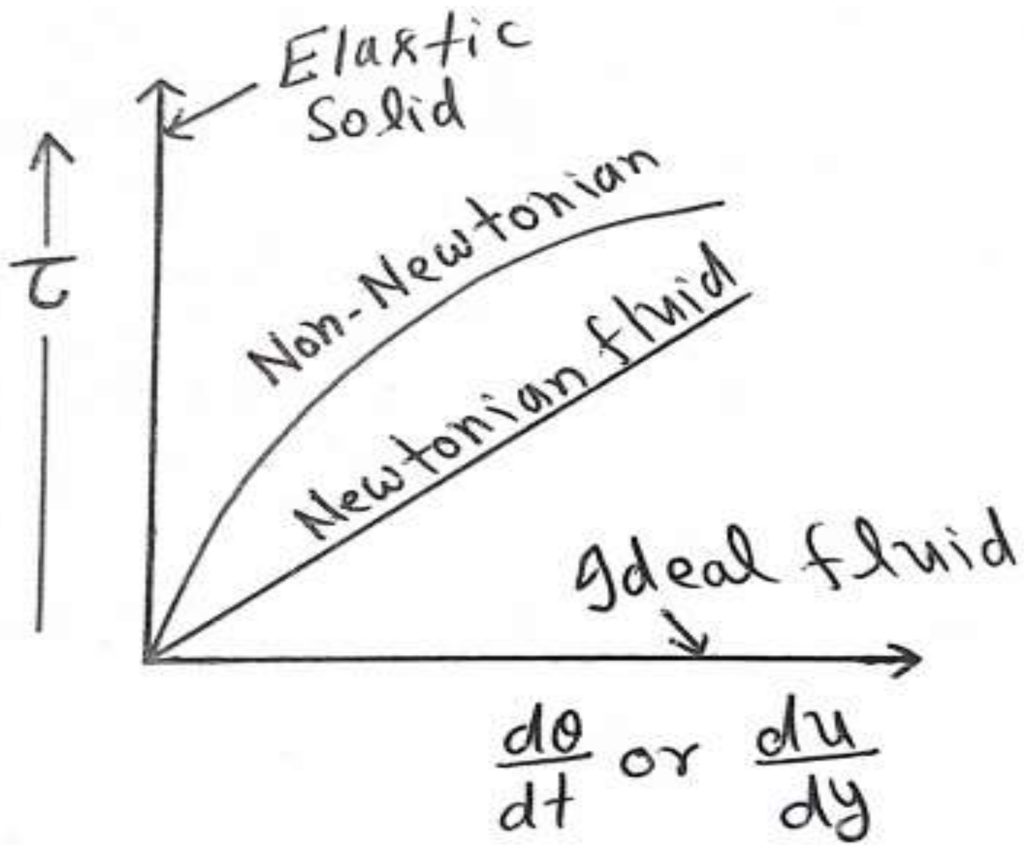

**μ =** Ʈ/ $(\frac{d\theta}{dt})$

**μ is the slope of (Ʈ-** $\frac{d\theta}{dt}$) diagram.

❖ Note: In Newtonian fluid the viscosity does not change for same fluid.

❖ **Non Newtonian fluids:-**The fluids which do not follow Newton’s law viscosity are known as Non-Newtonian Fluid.

❖ There is a non-linear relation between magnitude of Ʈ and $\frac{d\theta}{dt}$.

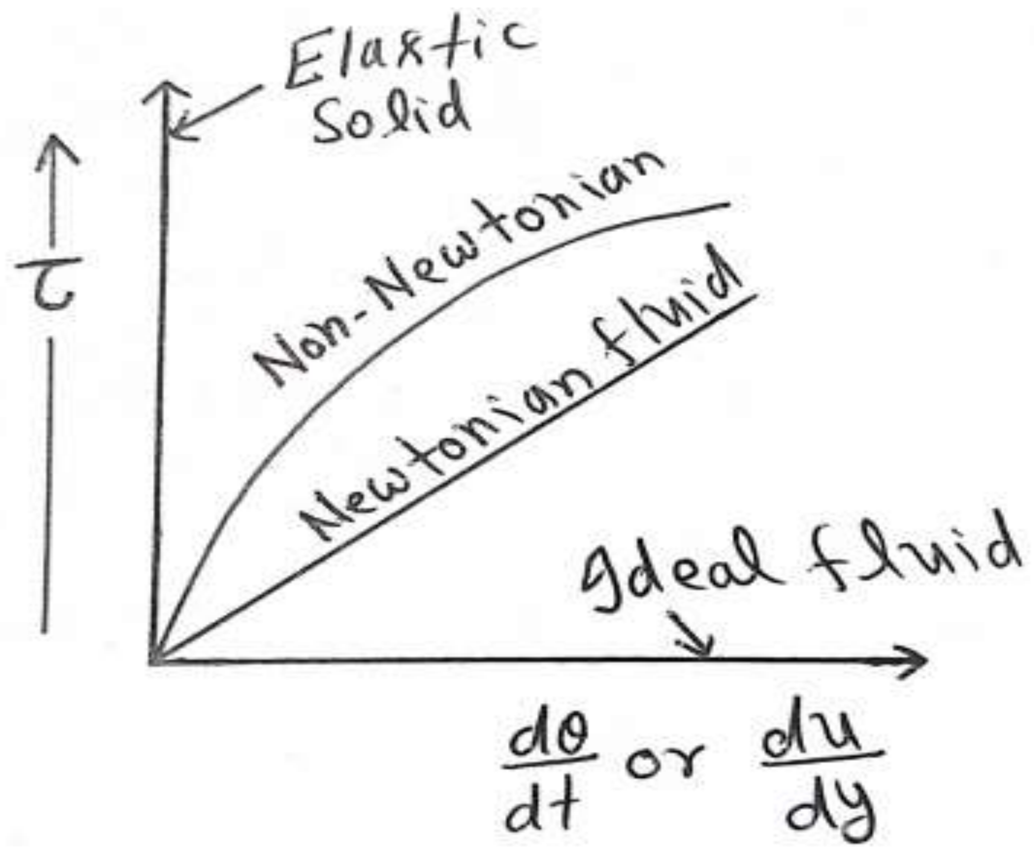


# <u>Q .9</u> Differentiate between Real and Ideal fluids.

❖**<u>IDEAL FLUID:-</u>**Incompressible fluid having zero viscosity is called ideal fluid($\tau = 0$).

❖**Ideal fluid** do not actually exist in nature.

❖It is represented by horizontal line on **(**$\tau$-$\frac{d\theta}{dt}$) diagram .




❖**Real fluid: Fluid** that have viscosity($\mu > 0$) and their motion known as viscous flow.

❖All the fluids in actual are real fluids.

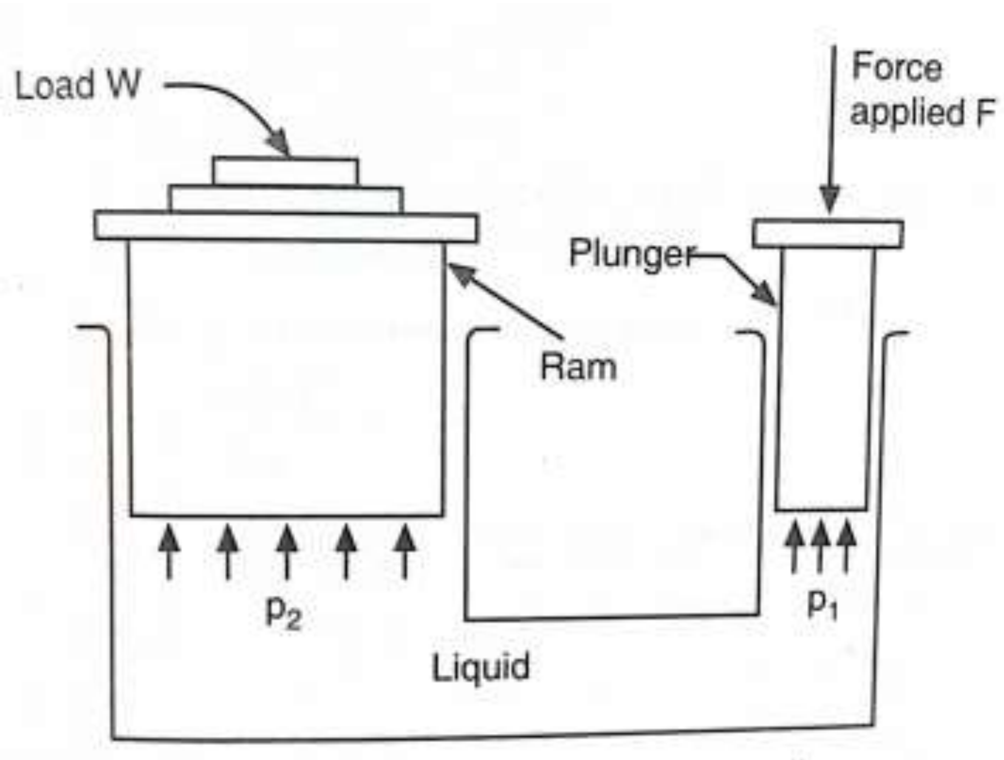
# Pascal's Law and its applications

❖In a fluid at rest the intensity of pressure is same in all directions.

❖In other words, when a certain pressure is applied in a fluid at rest, the pressure is equally transmitted in all the directions.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{F_2}{F_1} = \frac{A_2}{A_1}$$




❖Applications of Pascal's law are

- Hydraulic lift
- Hydraulic Jacks
- Hydraulic brakes
- Hydraulic pumps

# CONTINUITY EQUATION

- This equation is based on the principle of conservation of mass.
- The quantity of fluid per second is constant at all the cross sections through the pipe.

- Flow Rate → Volume flow rate $(\frac{m^3}{s}) = \frac{AL}{s} = A\,V$ [V = velocity]
- Flow Rate → mass flow rate $(\frac{kg}{s}) = \frac{\rho AL}{s} = \rho\,A\,V$

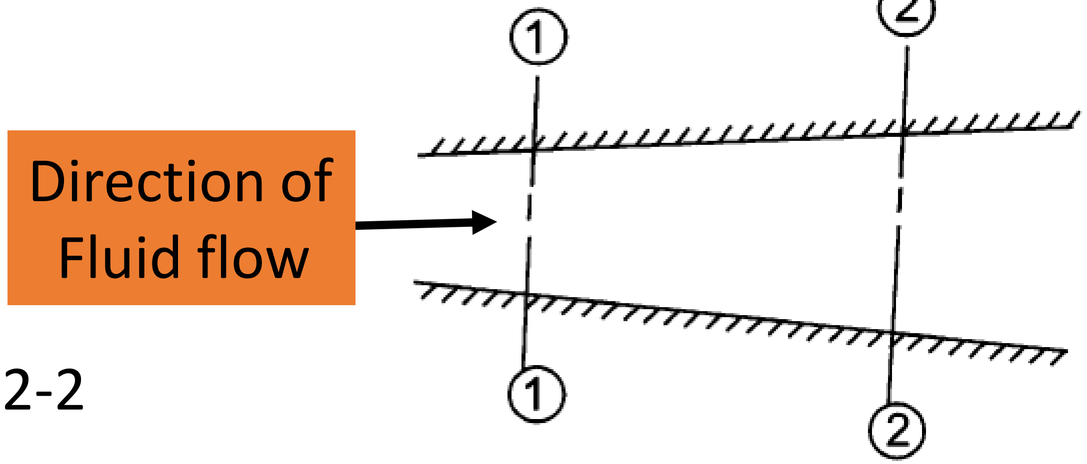
- Consider two cross sections as shown in figure:

Let $V_1$ = Average velocity at cross-section 1-1

$\rho_1$ = density at section 1-1

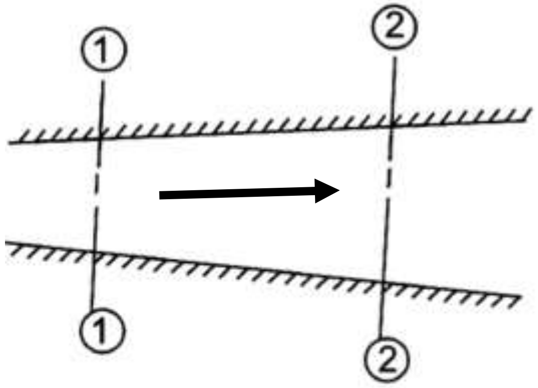
$A_1$ = Area of pipe at section 1-1

and $V_2, \rho_2, A_2$ are corresponding values at section 2-2



- Rate of flow at section at 1-1 = $\rho_1 A_1 V_1$
- Rate of flow at section at 2-2 = $\rho_2 A_2 V_2$
- According to law of conservation of mass:

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




$$\boxed{\rho_1 A_1 V_1 = \rho_2 A_2 V_2 = \text{Constant}}$$

- This **Continuity Equation is** applicable for the **compressible** fluids .
- If the fluid is **In-compressible**, i.e. water then $\rho_1 = \rho_2$ and continuity equation becomes:

$$\boxed{Q = A_1 V_1 = A_2 V_2 = \text{Constant}}$$

**Problem** — *The diameters of a pipe at the sections 1 and 2 are 10 cm and 15 cm respectively. Find the discharge through the pipe if the velocity of water flowing through the pipe at section 1 is 5 m/s. Determine also the velocity at section 2.*

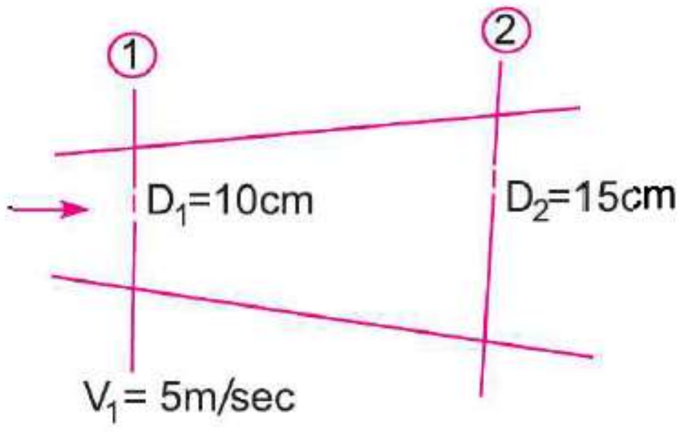
**Solution.** Given :

At section 1,

$$D_1 = 10 \text{ cm} = 0.1 \text{ m}$$

$$A_1 = \frac{\pi}{4}(D_1^2) = \frac{\pi}{4}(.1)^2 = 0.007854 \text{ m}^2$$

$$V_1 = 5 \text{ m/s.}$$




At section 2,

$$D_2 = 15 \text{ cm} = 0.15 \text{ m}$$

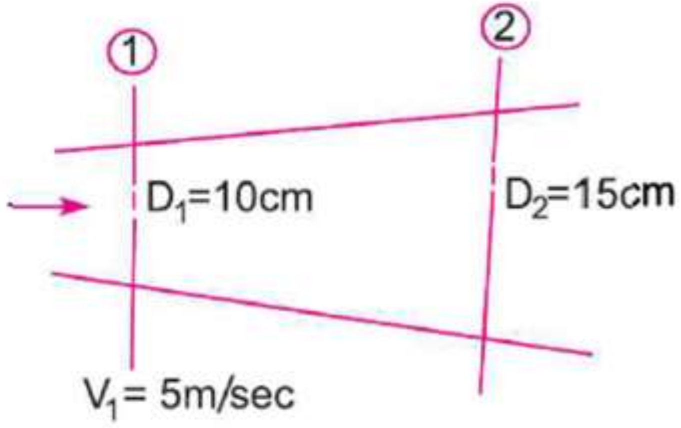
$$A_2 = \frac{\pi}{4}(.15)^2 = 0.01767 \text{ m}^2$$

**$Q$ = ? and $V_2$ = ?**

(*i*) Discharge through pipe is given by equation

or $$Q = A_1 \times V_1$$

$$= 0.007854 \times 5 = \mathbf{0.03927\ m^3/s.\ Ans.}$$




Using continuity equation for In-compressible fluid

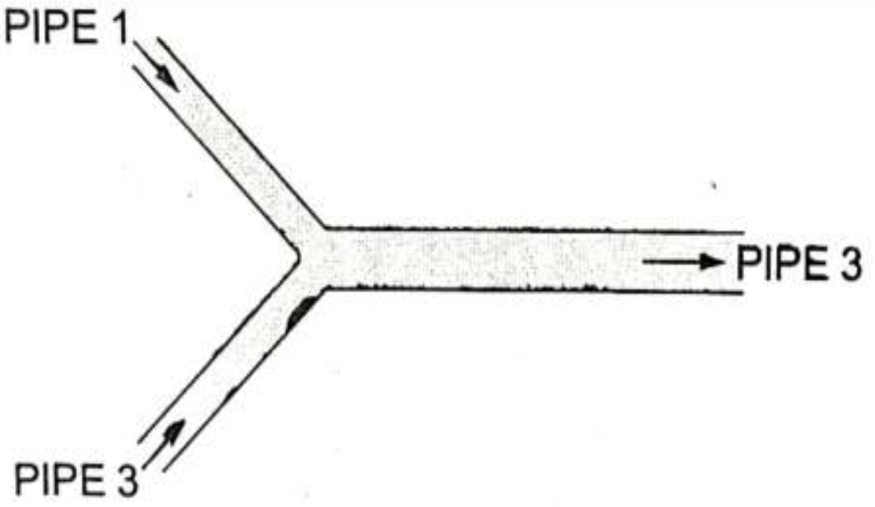
we have, $A_1V_1 = A_2V_2$

(*ii*) $\therefore$ $$V_2 = \frac{A_1V_1}{A_2} = \frac{0.007854}{0.01767} \times 5.0 = \mathbf{2.22\ m/s.\ Ans.}$$

## Problem

Consider steady flow of water in a situation where two pipe lines (pipe 1 and pipe 2) combine into a single pipe line (pipe 3) as shown in figure. The cross-sectional area of all three pipelines are constant. The following data is given

| Pipe number | Area ($m^2$) | Velocity (m/s) |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 2 | 2 |
| 3 | 2.5 | ? |




Assuming the water properties and the velocities to be uniform across the cross-section of the inlets and the outlet, the exit velocity (in m/s) in pipe 3 is

(a) 1 (b) 1.5

(c) 2 (d) 2.5

[2009 : 2 Marks]

## Solution

$$Q_1 + Q_2 = Q_3$$

$$A_1V_1 + A_2V_2 = A_3V_3$$

$$1 + 4 = 2.5 \times V_3$$

$$V_3 = 2 \text{ m/s}$$

# Bernoulli's Equation

- **FLUID DYNAMICS:- Study of motion of fluid flow along with force causing the flow.**

The fluid dynamics is governed by Newton's second law of motion.

$$\mathbf{F = ma}$$

Where

F = Net external force,

m = Mass of the fluid element on which force acts ,

a = total acceleration

❖ **Forces acting on the fluid in Motion: A fluid may subjected be to various forces during motion such as**

1. Gravity force ($F_g$)
2. Pressure force ($F_p$)
1. Viscous force ($F_v$)
2. Turbulence force ($F_t$)
3. Surface tension ($F_s$)
4. Elastic force or compressibility ($F_e$)

According to Newton's second law

$F_g + F_p + F_v + F_t + F_s + F_e = F_i$ Eqn (1)

Where $\mathbf{F_i}$ is inertia force , $\mathbf{F_i = ma}$.

**In most of the fluids flow, surface tension force and the compressibility force are not significant.**

Therefore, $F_s = 0$ and $F_e = 0$

**So Eqn 1 becomes $F_g + F_p + F_v + F_t = F_i$ Eqn (2)**

If flow is laminar then $F_t = 0$

Eqn 2 becomes $F_g + F_p + F_v = F_i$ Eqn (3)

$F_g + F_p + F_v = F_i$ Eqn (3)

**When fluid is non- viscous i.e. ideal or the viscosity of fluid is negligible, then $F_V = 0$**

Hence Eqn 3 becomes

**$F_g + F_p = F_i$ Eqn (4) (Euler's eqn)**

(Eqn (4) is used to deriving Bernoulli's equation

# Assumptions of Bernoulli’s Equation

1. The flow must be steady

2. Incompressible flow

3. Non-viscous or ideal fluid

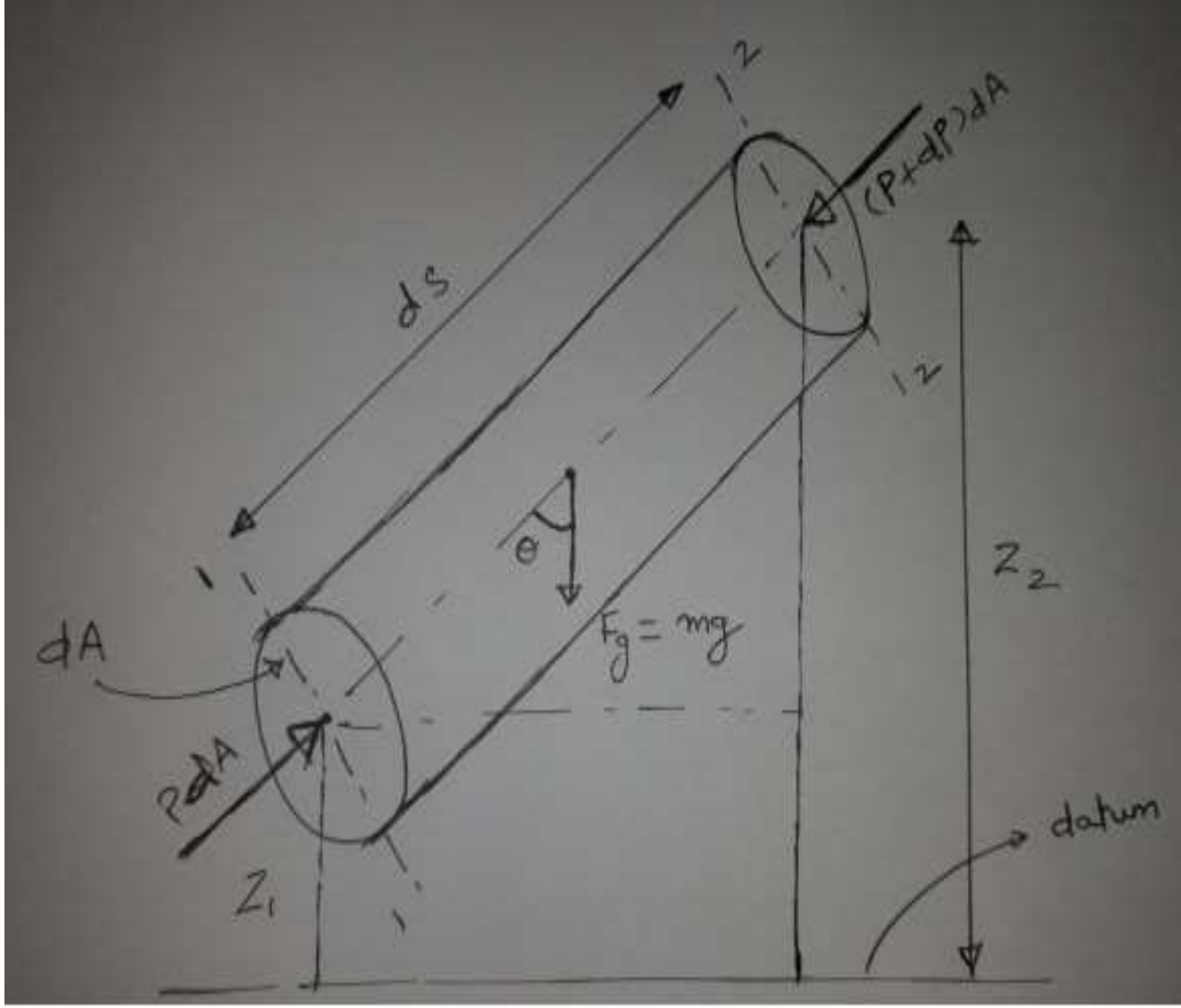
4. Irrotational flow

5. Flow only along the stream line

Consider a fluid element is flowing along a stream line of cross-sectional area **dA** between two arbitrarily chosen sections **1-1** and **2-2**.

Suppose in time interval **dt**, the fluid element moves through a short distance **ds**.

Let $\mathbf{Z_1}$ and $\mathbf{Z_2}$ be the distance of a point on sections **1-1** and **2-2** from datum.




Suppose $\mathbf{P_1}$ and $\mathbf{P_2}$ be the pressure and $\mathbf{V_1}$ and $\mathbf{V_2}$ are the velocities at sections **1-1** and **2-2** respectively.

From Euler's equation (4)

$F_p + F_g = F_i$

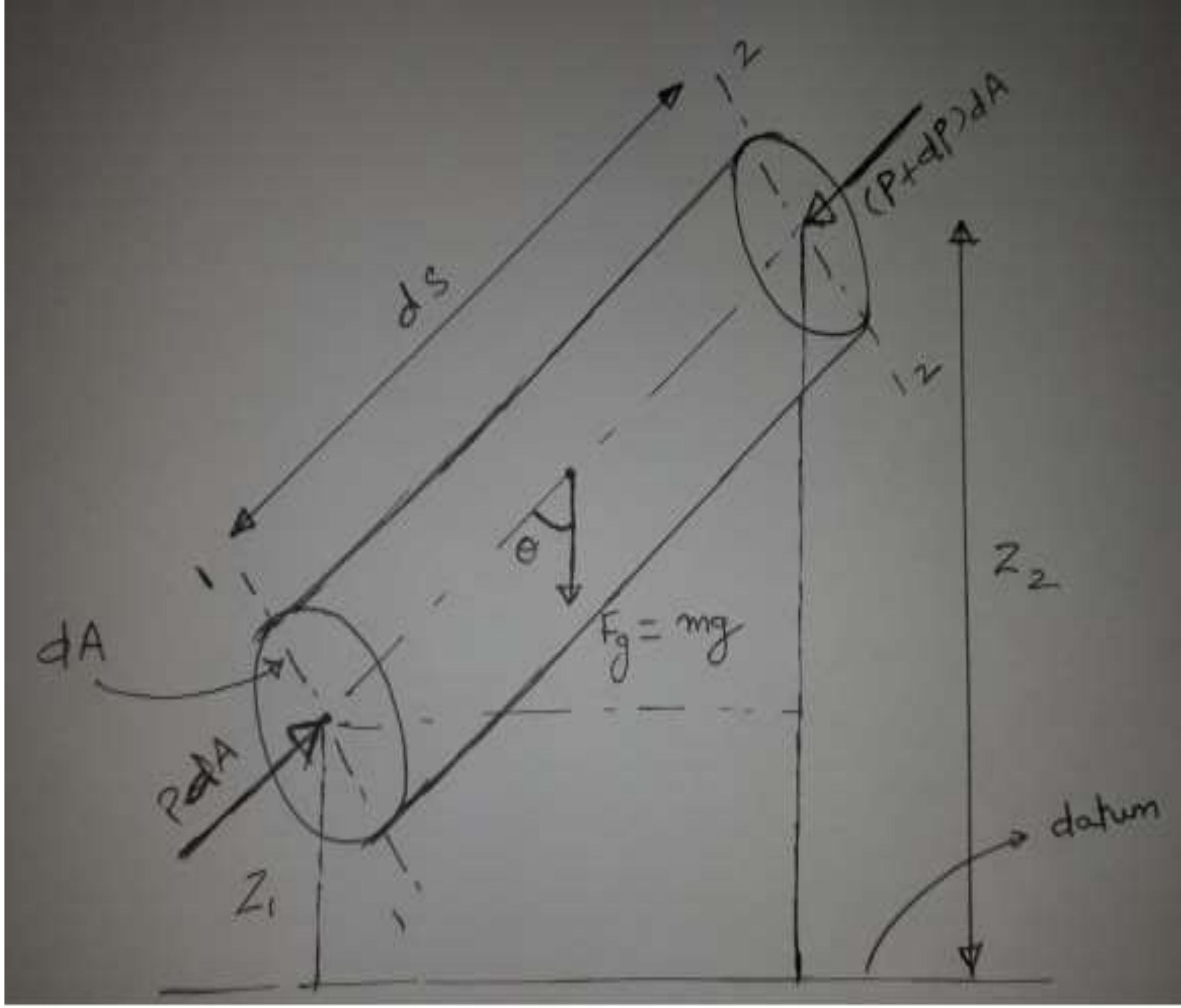
$$PdA - (P + dP)\, dA - mg\, \text{Cos}\theta = m\, a$$

$$\text{Where } a = \underbrace{v.\frac{dv}{ds}}_{\substack{\text{Convective} \\ \text{acceleration}}} + \underbrace{\frac{dv}{dt}}_{\substack{\text{Temporal} \\ \text{acceleration}}}$$

$$\text{for steady flow, } \frac{dv}{dt} = 0$$

therefore,

$$PdA - (P + dP)\, dA - mg\, \text{Cos}\theta = m\, v.\frac{dv}{ds}$$



$$PdA - (P + dP)\, dA - mg \cos\theta = m\, v.\frac{dv}{ds}$$

but $m = \rho.ds.dA$

$$-dP.dA - \rho g dA.ds\cos\theta = (\rho ds.dA).v.\frac{dv}{ds}$$

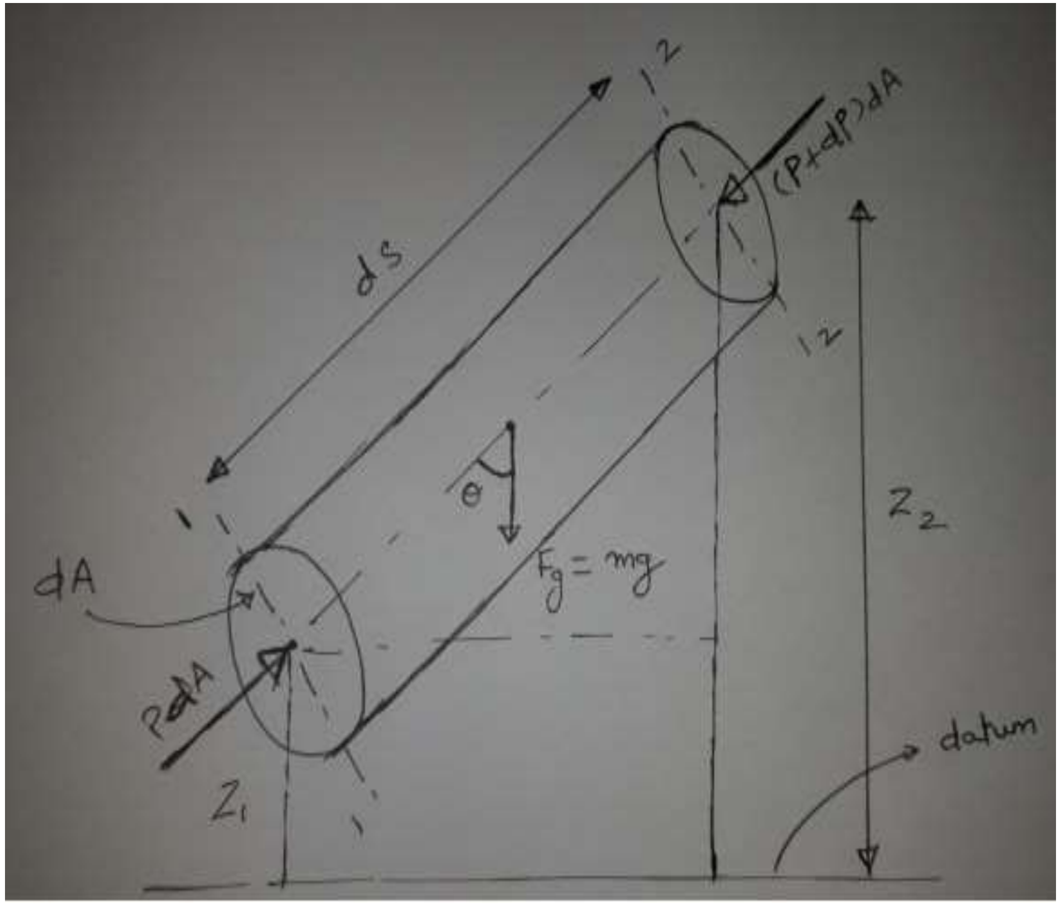
From figure , $Z_2 - Z_1 = dZ = ds\cos\theta$

$$-dP.dA - \rho g dA.dZ = (\rho ds.dA).v.\frac{dv}{ds}$$

$$-dP - \rho g.dZ = \rho.v.dv$$

$$\frac{-dP}{\rho} - g.dz = v.dv$$

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



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

Since flow is incompressible, mass density (ρ) of the fluid will be independent of pressure. Hence

$$\frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(Z_2 - Z_1) = 0$$

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gZ_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gZ_2 \qquad \text{—————— Eqn (5)}$$

$$\frac{P_1}{\omega} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\omega} + \frac{V_2^2}{2g} + Z_2 \qquad \text{—————— Eqn (6)}$$

Where ω = specific weight or weight density = ρg

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gZ_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gZ_2 \qquad \text{———— Eqn (5)}$$

$$\frac{P_1}{\omega} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\omega} + \frac{V_2^2}{2g} + Z_2 \qquad \text{———— Eqn (6)}$$

$$\frac{P}{\omega} + \frac{V^2}{2g} + Z = \text{Constant} \qquad \text{———— Eqn (7)}$$

Equation **(5)**, **(6)** and **(7)** are known as Bernoulli's equation for steady incompressible flow of an ideal (non-viscous) fluid.

The term $\frac{P}{\omega} = \frac{P}{\rho g}$ is known as pressure head or static head.

$\frac{V^2}{2g}$ is known as velocity head or kinetic head.

**Z** is known as potential head or datum head.

# Applications of Bernoulli's Equation

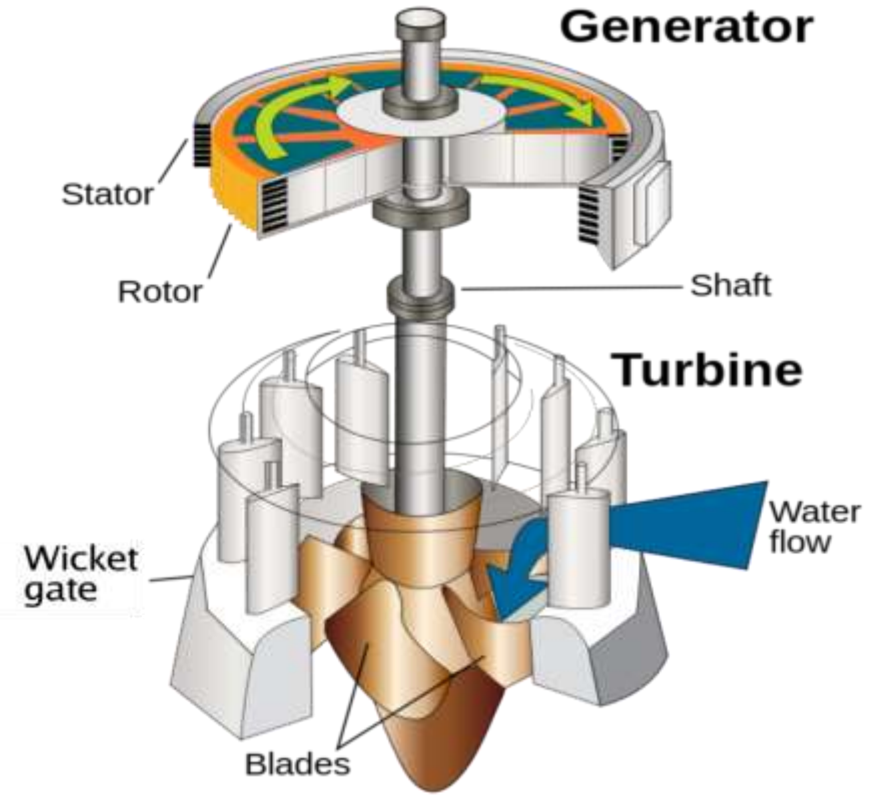
- Venturi Meter
- Orifice Meter
- Pitot Tube

- Hydraulic machines are defined as those machines which convert either *hydraulic energy* into *mechanical energy* or ***mechanical* energy into *hydraulic energy*.**

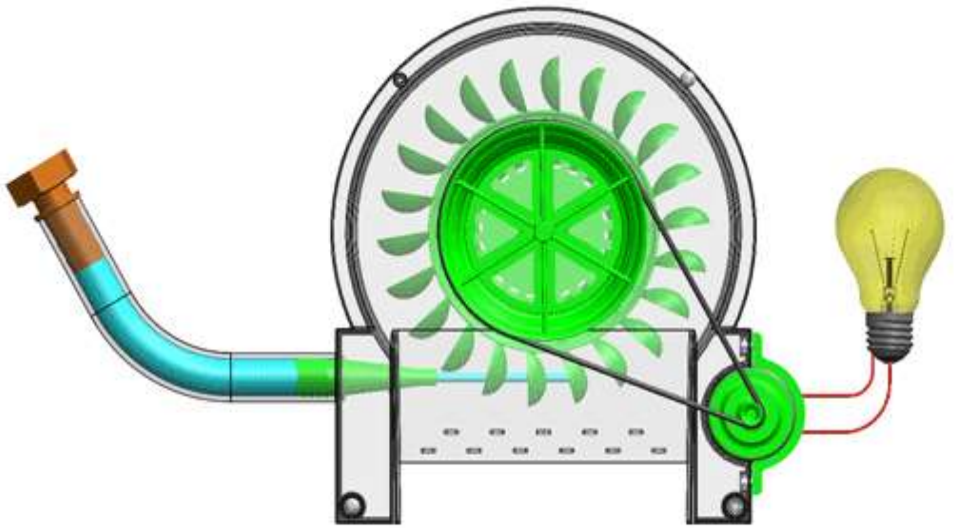
- Hydraulic Energy- Energy possessed by water is called hydraulic energy.

- Mechanical Energy- power produced at shaft of turbine is called mechanical energy.

- Mechanical energy can be further converted into electrical energy with the help of generator.

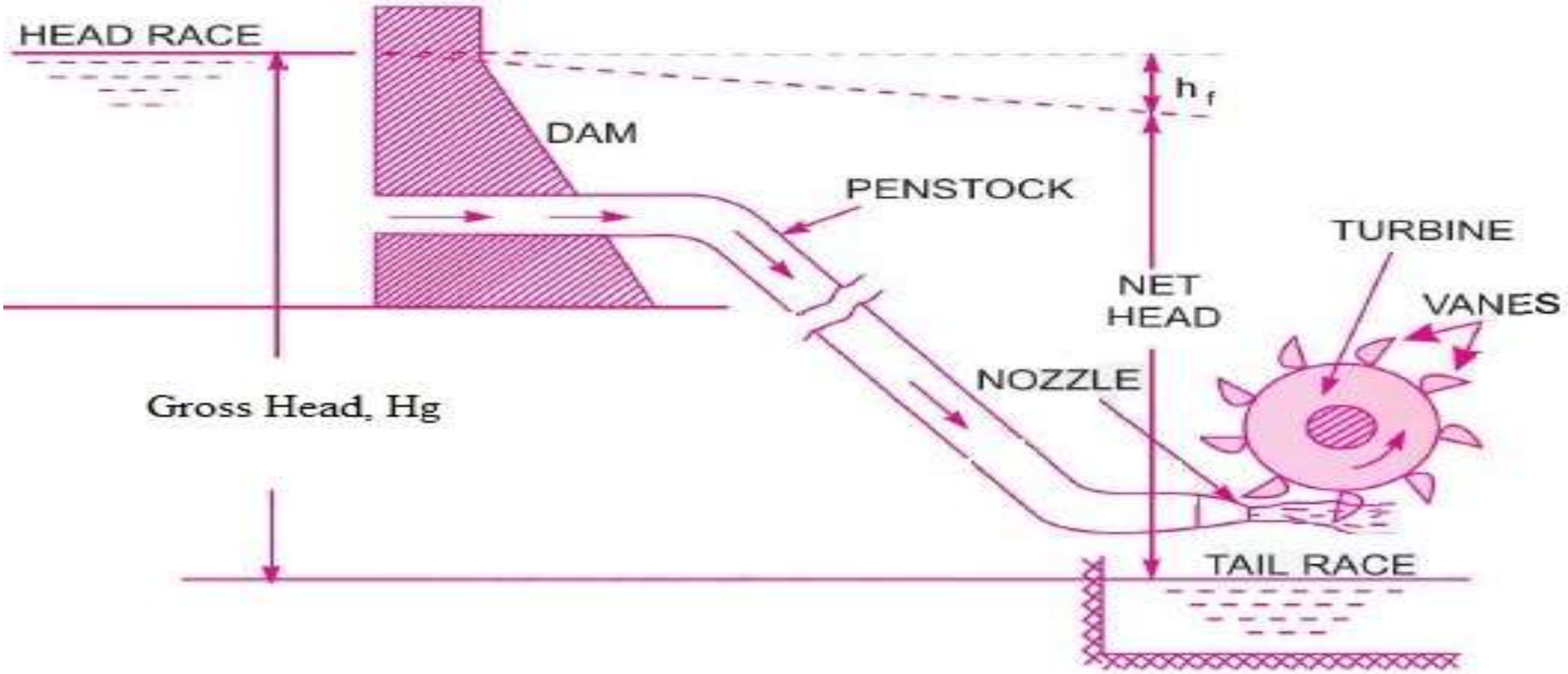


- The **hydraulic machines** which converts the hydraulic energy into mechanical energy, are called as **turbines**.



- The **hydraulic machines** which converts mechanical energy into hydraulic energy , are called as **pump**.

# General Layout of Hydro-electric power plant



# CLASSIFICATION OF TURBINE

The turbines are classified in the following ways:-

1. According to the type of energy available at inlet

   (a) **Impulse turbine** (b) **Reaction turbine**

- If at the inlet of the turbine , **only kinetic energy is available**, the turbine is known as ***impulse turbine*.**

Eg. Pelton Turbine.

- If at the inlet of the turbine, water possesses **kinetic energy** as well as **pressure energy**, the turbine is known as ***reaction turbine*.**

eg. Francis turbine, Kaplan turbine.

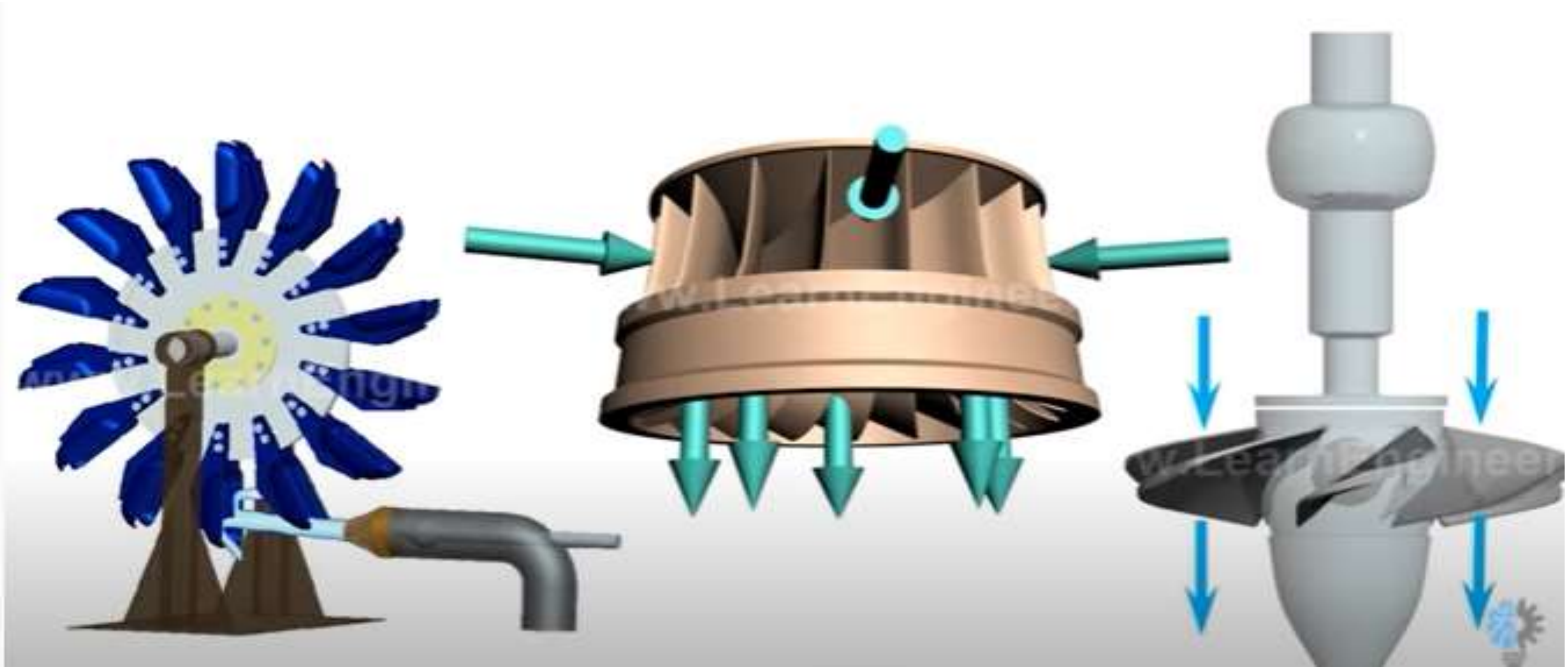
2. According to the *direction of flow* of water through runner:

a) Tangential flow turbine (e.g. Pelton Turbine)

b) Radial flow turbine (e.g. Francis Turbine)

c) Axial flow turbine (e.g. Kaplan and propeller Turbine)

d) Mixed flow turbine (e.g. Modern Francis Turbine)



**Pelton Turbine** **Francis Turbine** **Kaplan Turbine**

3. According to the head available at inlet of turbine

a) High head turbine( $150m < H < 2000m$) e.g.. Pelton turbine

b) Medium Head turbine ( $30 < H < 150m$) e.g. Francis Turbine

c) Low Head turbine ( $H < 30m$) e.g.. Kaplan and propeller turbine

4. According to the specific speed of turbine

a) Low specific speed turbine, ($N_s < 50$) e.g. P.T.

b) Medium specific speed turbine,($50 < N_s < 250$) e.g. F.T.

c) High specific speed turbine. ($N_s > 250$) e.g. K.T.

- Mathematically,

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

where, $N$ = normal speed of turbine in rpm

$P$ = turbine power output in kW

$H$ = net head of turbine in m

5. According to the position of shaft of turbine

a) Horizontal shaft turbine
b) Vertical shaft turbine

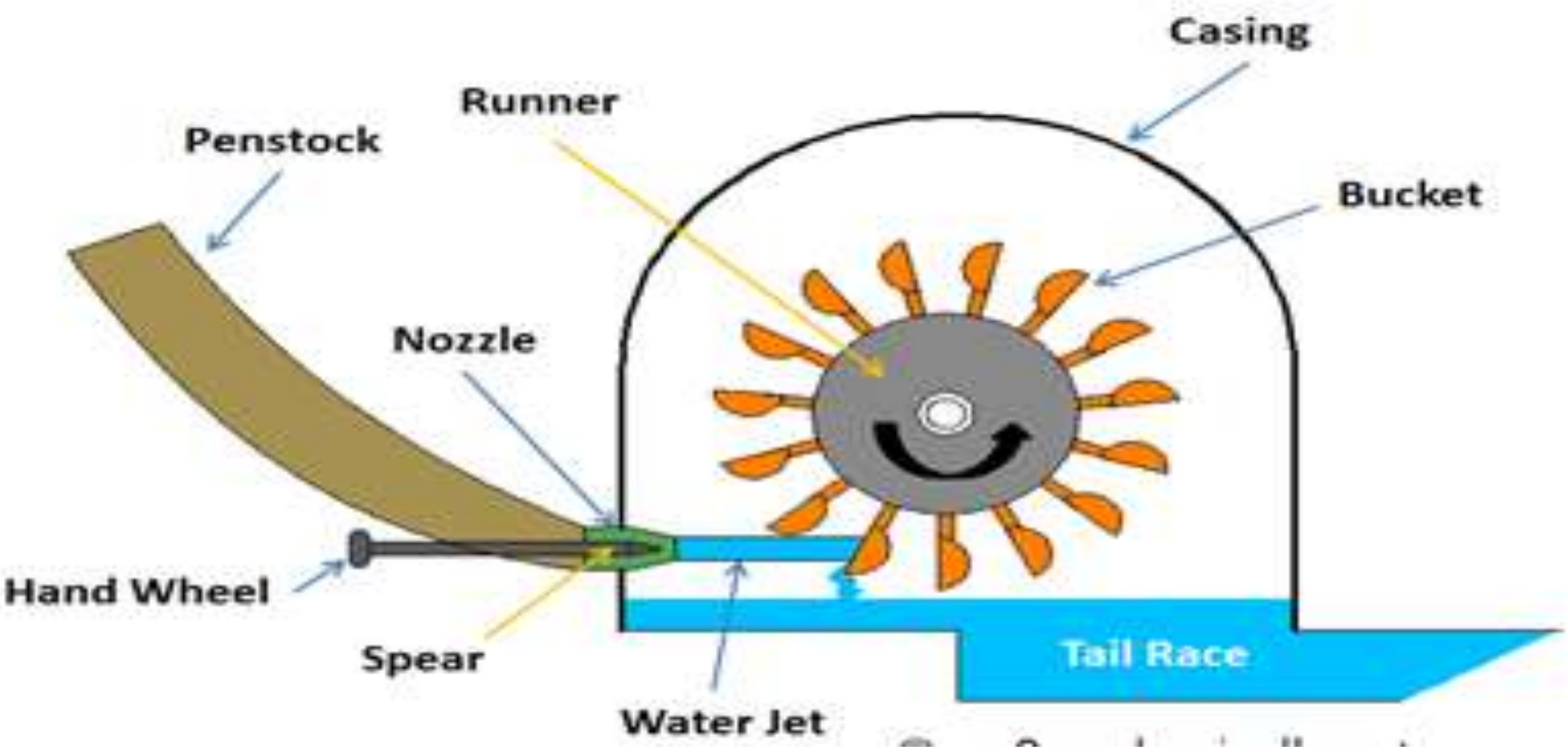
(Pelton turbine has horizontal shaft whereas the rest have vertical shaft)

6. According to name of originator
a) Pelton Turbine(Pelton Wheel)
b) Francis Turbine,
c) Kaplan Turbine.

CONSTRUCTION AND WORKING OF IMPULSE TURBINES

# Main parts of Impulse turbine are :-

1. Nozzle and flow regulating device
2. Runner and bucket
3. casing



- Nozzle with guide mechanism- It is provided to convert the pressure energy into kinetic energy in the form of jet and it also regulates the quantity of water according to the load on turbine.

- Runner- A wheel of the turbine consist of series of buckets/blades/vanes mounted on its periphery.

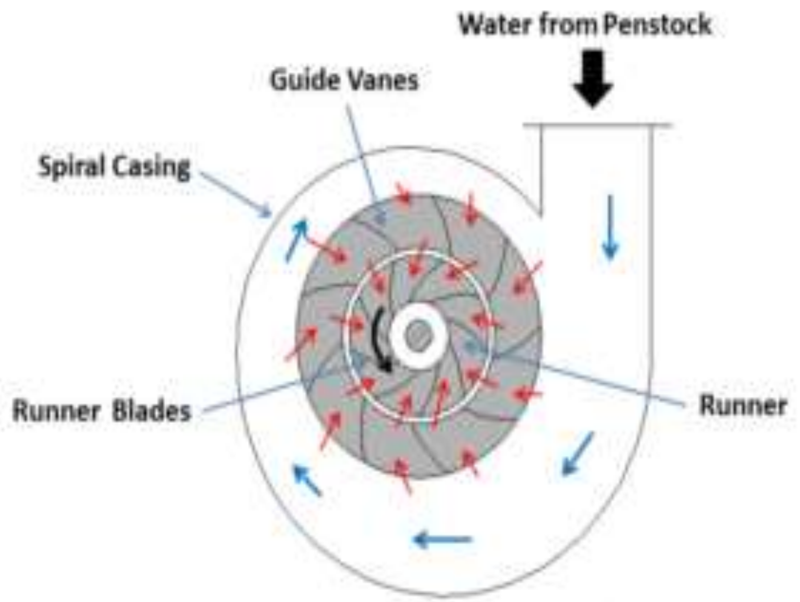
- Casing- It is used to avoid accident and prevents the splashing of water. It does not perform any hydraulic function.

- The pressure throughout the turbine from inlet to outlet is **atmospheric** in case Impulse turbine.

# CONSTRUCTION AND WORKING OF REACTION TURBINES

Main parts of reaction turbine are :-

1. Casing
2. Guide mechanism
3. Runner
4. Draft tube



- **Casing-** In reaction turbine, casing and runner are always full of water. It is of spiral shape.

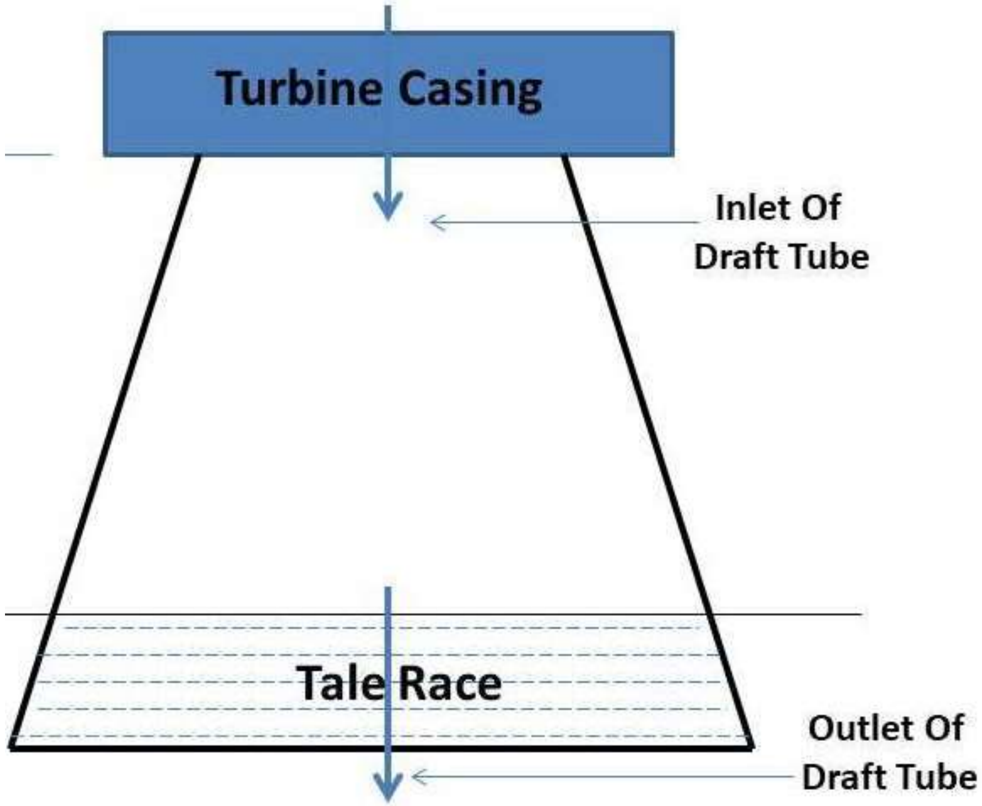
- **Runner-** A wheel of the turbine consist of series of buckets/blades/vanes mounted on its periphery.

- **Guide mechanism-** The guide vanes allow the water to strike the fixed blades on the runner without shock at inlet.

**Draft tube-** Draft Tube is a diverging tube fitted at the exit of runner of turbine and used to utilize the kinetic energy available with water at the exit of runner.

- Pressure head is increased by decreasing the exit velocity.

- Overall efficiency and the output of the turbine can be improved.



# PUMP

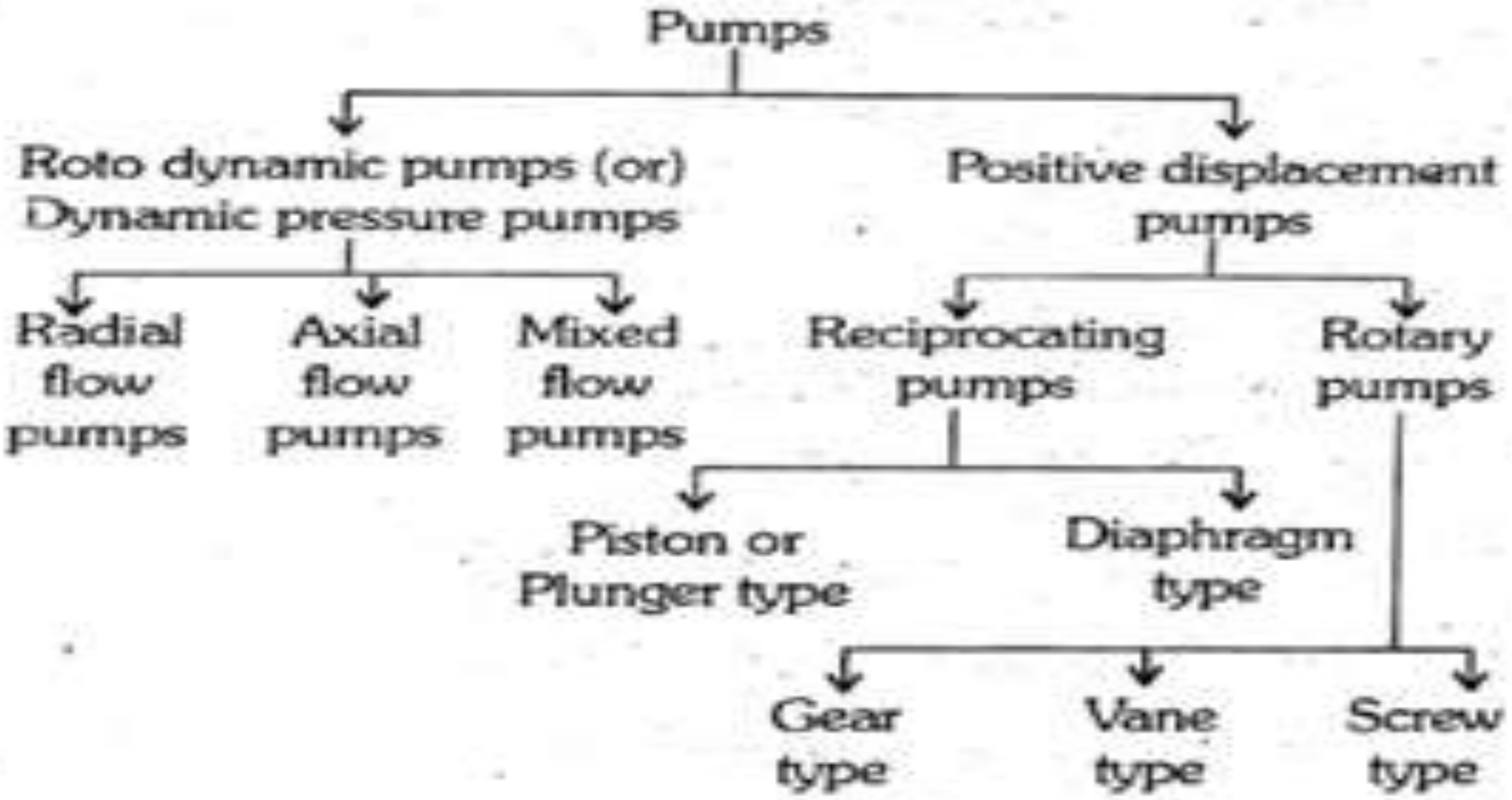
- The hydraulic machine which converts ***Mechanical energy*** *into* ***Hydraulic energy*** is known as pump.

- The hydraulic energy is in the form of ***Pressure Energy***.

- If the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydraulic machine is called ***Centrifugal Pump***.

- The centrifugal pump works on the principle of ***forced vortex flow.***

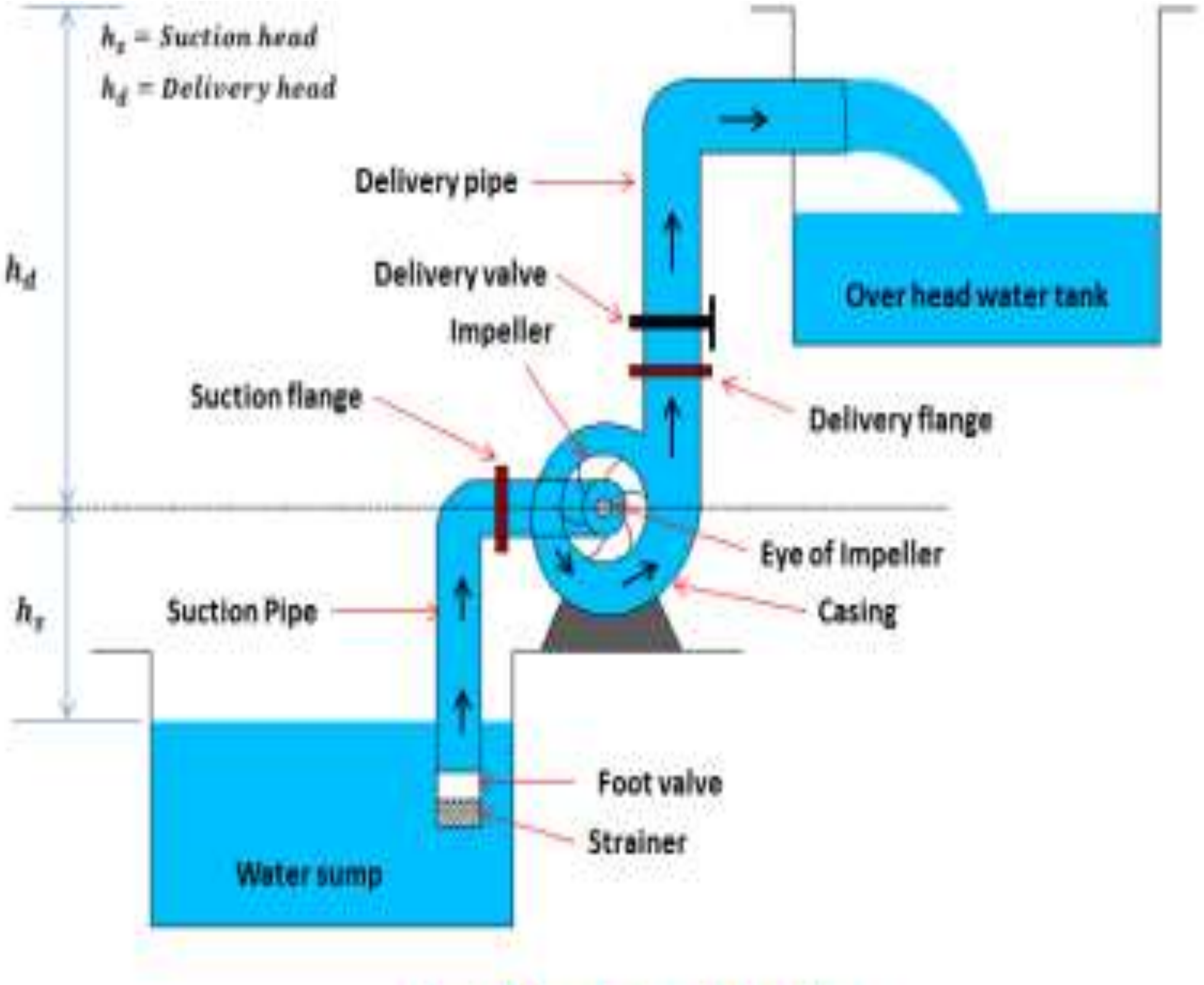
# CLASSIFICATION OF PUMP



# CENTRIFUGAL PUMP

Main parts of a C.P. are :-

1. Impeller
2. Casing
3. Suction pipe with foot valve and a strainer
4. Delivery pipe




Centrifugal Pump Working

- A centrifugal pump is a mechanical device designed to move a fluid by means of the transfer of rotational energy from one or more driven rotors, called impellers.

- Fluid enters the rapidly rotating impeller along its axis and is cast out by centrifugal force along its circumference through the impeller's vane tips.

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

**Impeller:** The rotating part of a centrifugal pump is called impeller. It consists of a series of backward curved vanes. The impeller is mounted on a shaft which is connected to the shaft of an electric motor.

**Casing:** the casing of a centrifugal pump is similar to the casing of a reaction turbine. It is an air tight passage surrounding the impeller and is designed in such a way that the kinetic energy of the water discharged at the outlet of the impeller is converted in to pressure energy before the water leaves the casing and enters the delivery pipe.

**Suction pipe with a foot valve and a strainer:** A pipe whose one end is connected to the inlet of the pump and other end dips in to water in a sump is known as suction pipe.

A foot valve which is a non-return valve or one-way type of valve is fitted at the lower end of the suction pipe. The foot valve opens only in the upward direction.

A strainer is also fitted at the lower end of the suction pipe. Delivery pipe: A pipe whose one end is connected to the outlet of the pump and the other end delivers the water at the required height is known as delivery pipe.

# RECIPROCATING PUMP

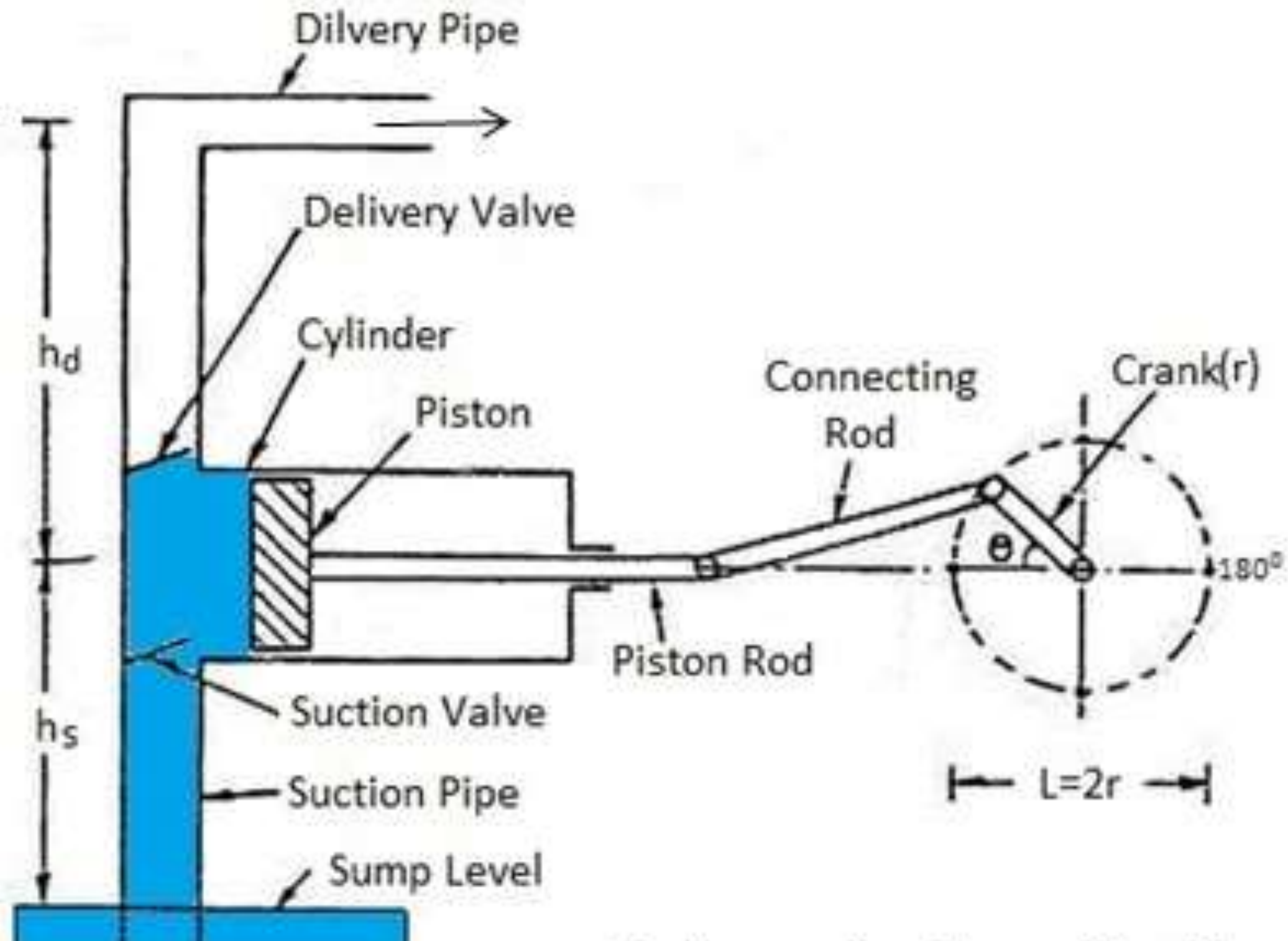
- **Reciprocating Pumps** are positive displacement machines typically **used for** low-flow, *high-pressure* operations.

- **Centrifugal pump** is a roto-dynamic **pump** that uses kinetic energy to transfer fluid from low pressure to high pressure while the **reciprocating pump** uses a piston (suction and discharge stroke) to transfer fluid.

# RECIPROCATING PUMP

The main components of R.P.:

1. Cylinder.
2. Piston and Piston Rod.
3. Crank and Connecting Rod.
4. Suction Pipe.
5. Suction Valve.
6. Delivery Pipe.
7. Delivery Valve.




Reciprocating Pump Working

## Water Sump:

It is the source of water. From the sump, water is to be transported to the delivery pipes by the usage of the piston.

## Strainer:

It acts as a mesh that can screen all the dirt, dust particles, etc. from the sump. If there is no strainer, then the dirt or dust also enters into the cylinder which can jam the region and affects the working of the pump.

## Suction Pipe:

The main function of the suction pipe is to collect the water from the sump and send it to the cylinder via a suction valve. The suction pipe connects the water sump and the cylinder.

## Suction Valve:

It is a non-return valve which means it can take the fluid from the suction pipe and send it to the cylinder but cannot reverse the water back to it. In the sense, the flow is unidirectional.

This valve opens only during the suction of fluid and closes when there is a discharge of fluid to outside.

## Cylinder:

It is a hollow cylinder made of cast iron or steel alloy and it consists of the arrangement of piston and piston rod.

## Piston and Piston rod:

For suction, the piston moves back inside the cylinder and for discharging of fluid, the piston moves in the forward direction.

The Piston rod helps the piston to move in a linear direction i.e. either the forward or the backward directions.

## Crank and Connecting rod:

For rotation, the crank is connected to the power source like engine, motor, etc. whereas the connecting rod acts as an intermediate between the crank and piston for the conversion of rotary motion into linear motion.

## Delivery Pipe:

The function of the delivery pipe is to deliver the water to the desired location from the cylinder.

## Delivery valve:

Similar to the suction valve, a delivery valve is also a Non-return valve. During suction, the delivery valve closes because the suction valve is in opening condition and during Discharge, the suction valve is closed and the delivery valve Is opened to transfer the fluid.

These are the various components of Reciprocating pump. Let’s understand the working principle of it.

# TYPES OF RECIPROCATING PUMP

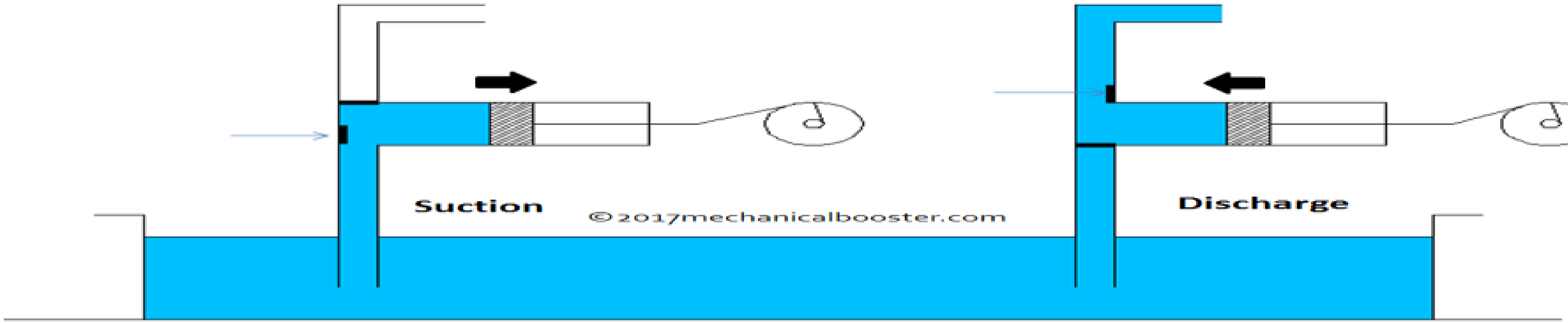
1. According to the water being in contact with one side or both sides of the piston-

A. Single acting pump
B. Double acting pump

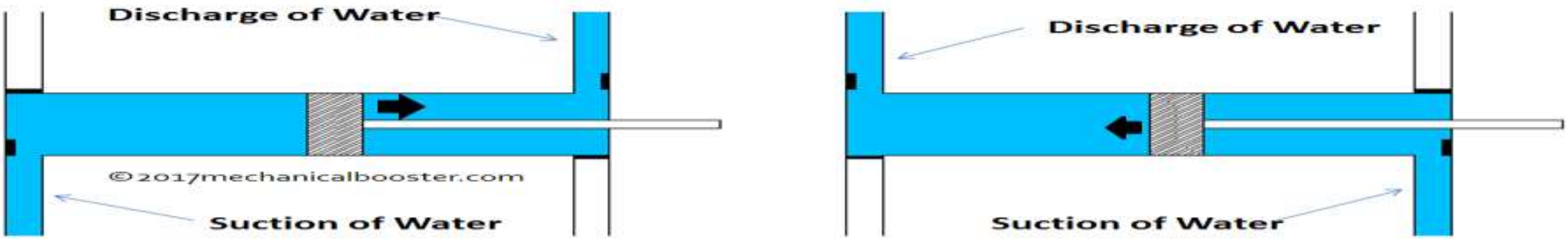
2. According to the number of cylinder provided

A. Single cylinder pump,
B. Double cylinder pump,
C. Triple cylinder pump.

# RECIPROCATING PUMP




Single Acting Reciprocating Pump




Double Acting Reciprocating Pump

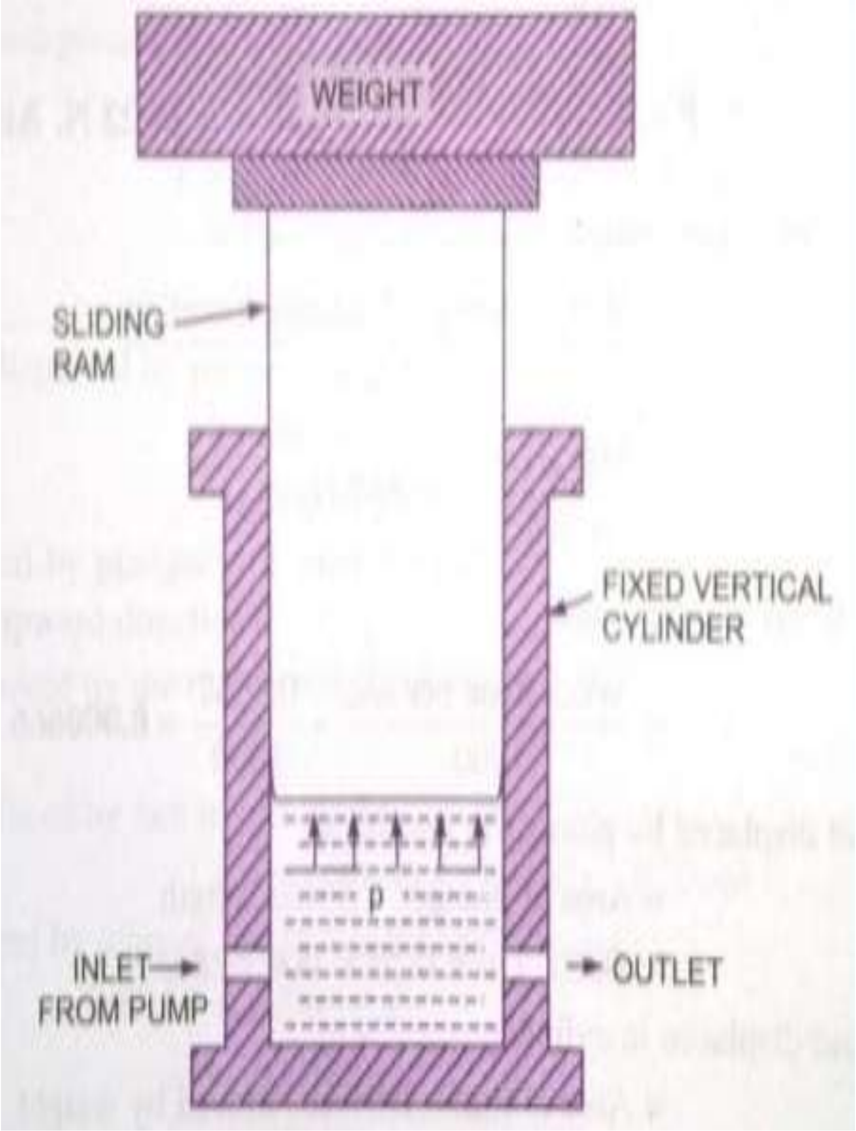
# HYDRAULIC ACCUMULATOR

❖ The hydraulic accumulator is a device used for storing energy of a liquid in the form of pressure energy, which may be supplied for any sudden or intermittent requirement.

❖ In hydraulic lift or the hydraulic crane, a large amount of energy is required when lift or crane is moved upward.

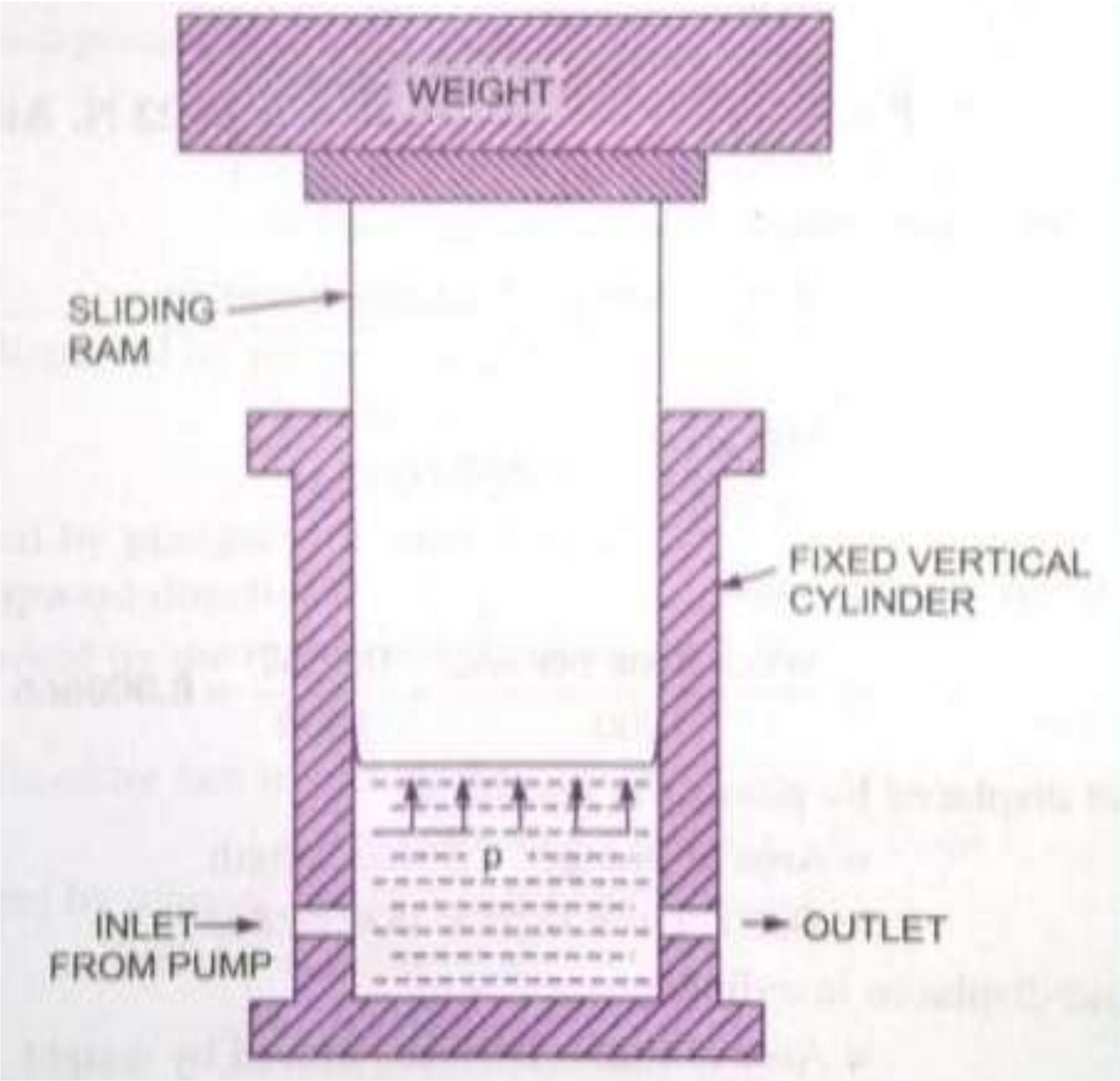
❖ This energy is supplied from hydraulic accumulator.

❖ When the lift is moving in the downward direction, no external energy is required at that time, the energy from the pump is stored in the accumulator.



# CONSTRUCTION

- ❖ Hydraulic accumulator consists of a fixed vertical cylinder containing a sliding ram.
- ❖ The heavy weight is placed on the ram.
- ❖ The inlet of the cylinder is connected to the pump which continuously supply water under pressure to the cylinder.
- ❖ Outlet of the cylinder is connected to the machine which may be a lift or a crane

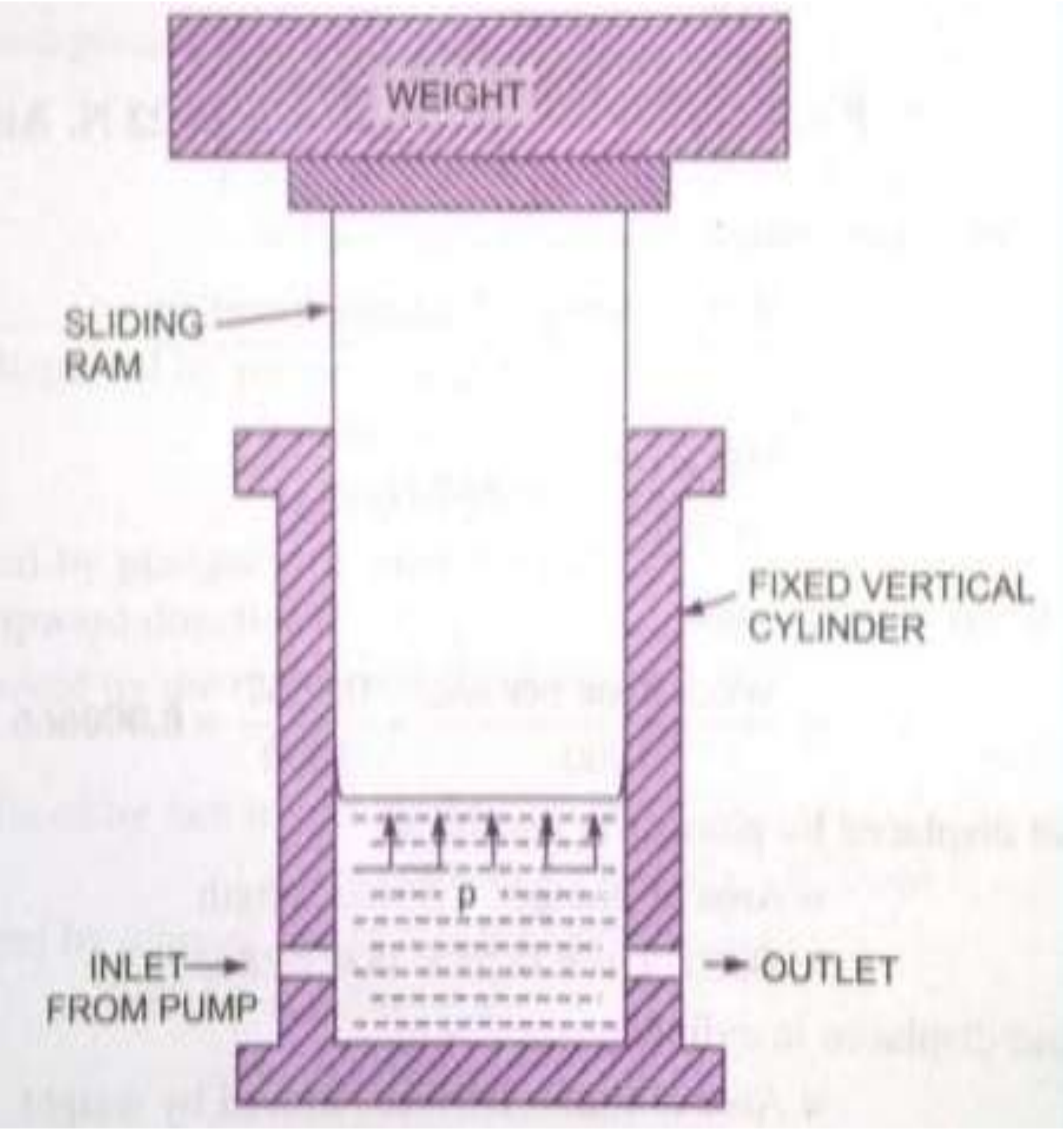


# WORKING

❖The ram is at the lower position in the beginning.

❖The pump supplies water under pressure continuously.

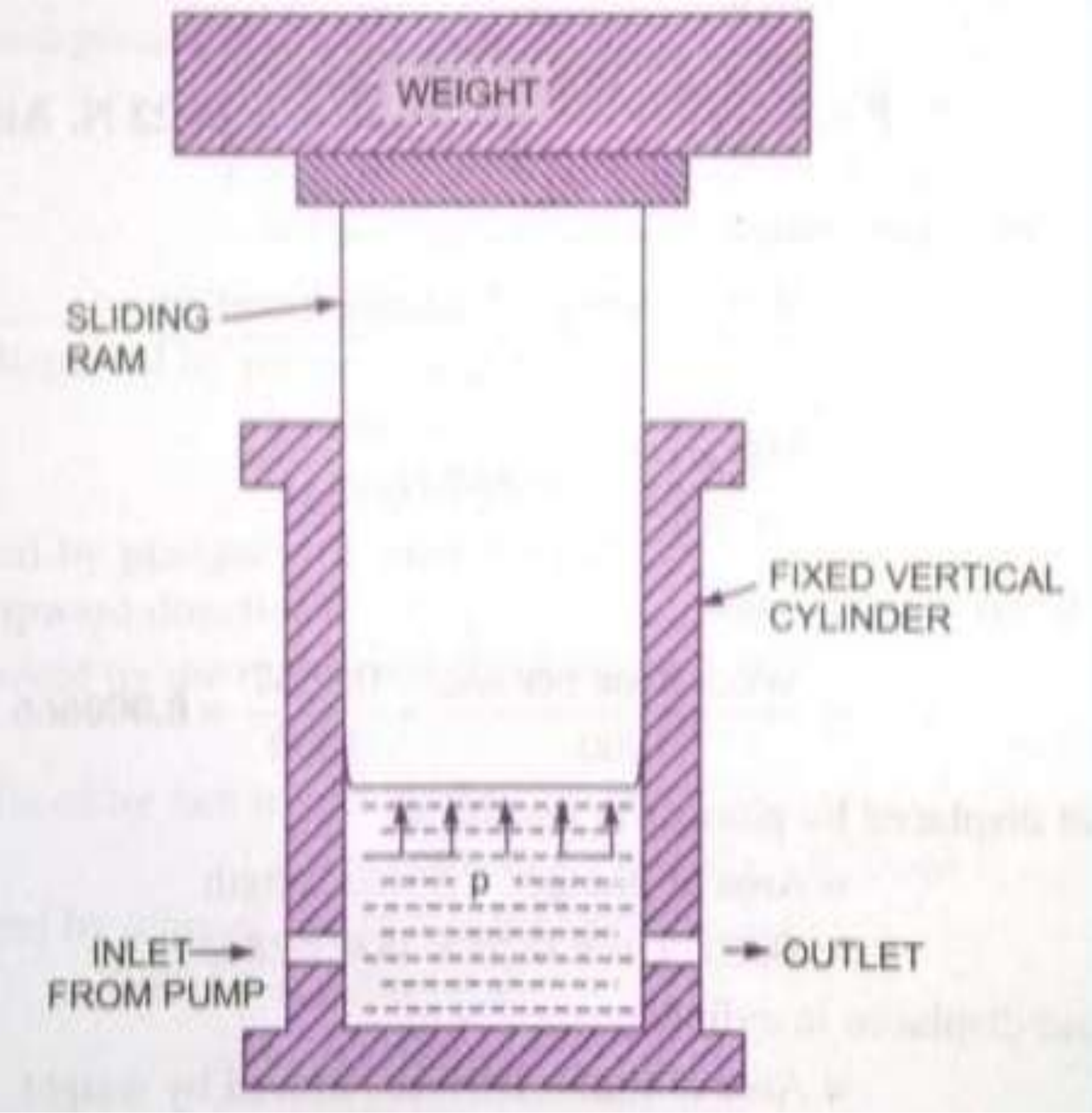
❖If the water under pressure is not required by the machine the water pressure will be stored in the cylinder.



❖This will raise the ram on which the heavy weight is placed.

❖When the ram is at the upper most position the cylinder is full of water and the accumulator as stored the maximum amount of pressure energy.

❖ When the machine requires large amount of energy the hydraulic accumulator will supply this energy and the ram will move in the downward direction.



# CAPACITY OF HYDRAULIC ACCUMULATOR

It is defined as the maximum amount of a hydraulic energy stored in a accumulator.

Let

A=Area of the sliding ram,     L=stroke or lift of the ram

P=intensity of water pressure supplied by the pump,

W=weight placed on the ram,

W=intensity of pressure x area of ram

=(P x A)

The work done in lifting the ram=W x lift of the ram

=W x L

=P x L X A

Therefore the capacity of accumulator =work done in lifting the ram

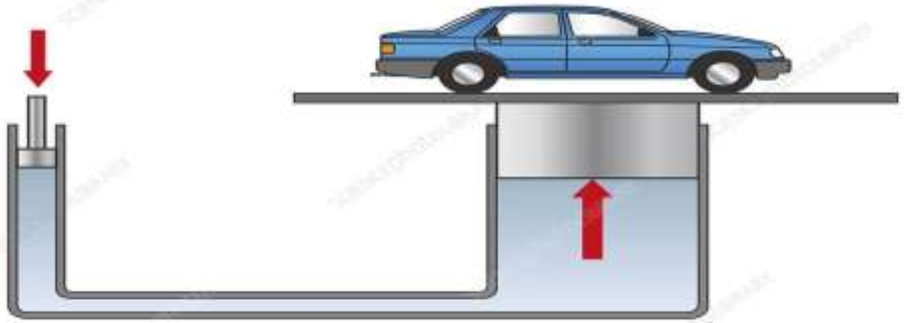
=P x A x L

**Capacity of accumulator = P X Volume of accumulator**

= A x L=volume

# HYDRAULIC LIFT

- ❖ Hydraulic lift is a device used for carrying passenger or goods from one floor to another in multistoried building to raise heavy objects.
- ❖ It works on the principle of Pascal's Law.



# TPPES OF HYDRAULIC LIFT

The Hydraulic Lifts are of two types-

1. Direct acting hydraulic lift

2. Suspended hydraulic lift

# 1. DIRECT ACTING HYDRAULIC LIFT

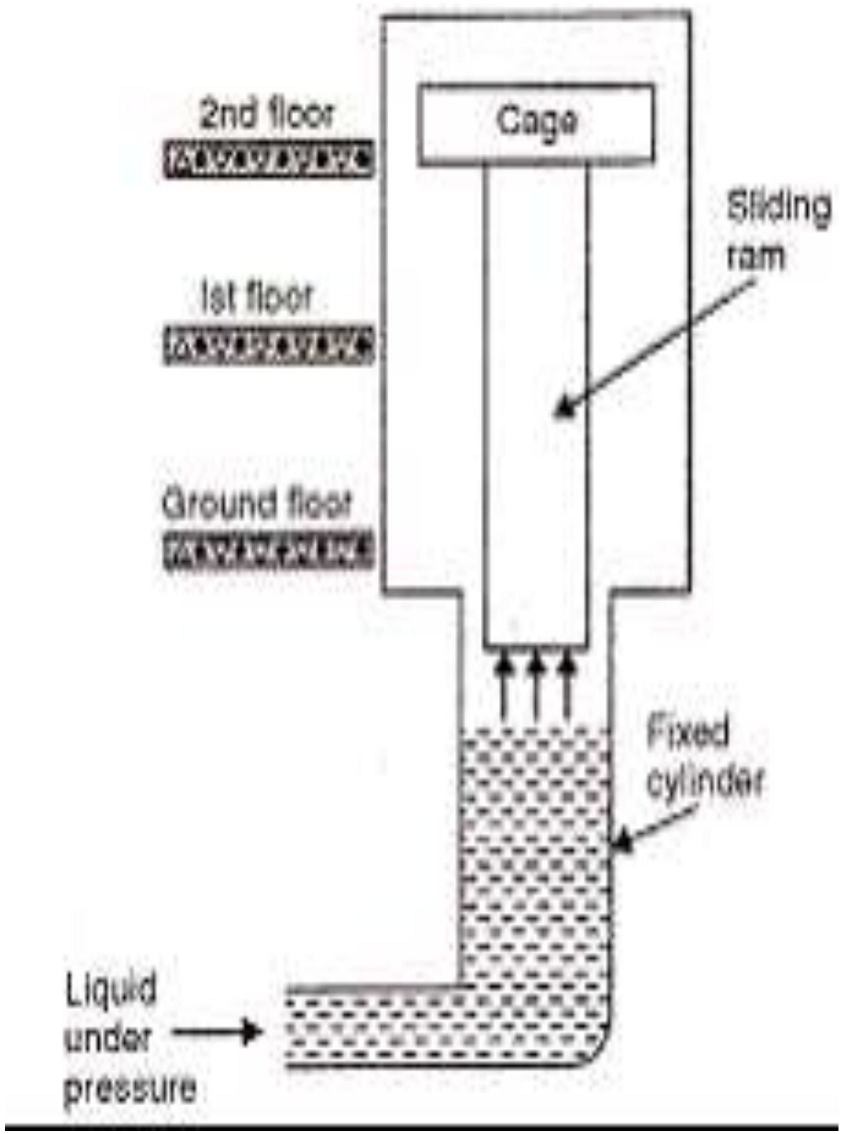
❖ It consists of a ram, sliding in the fixed cylinder.

❖ At the top of the sliding ram a cage is fitted.

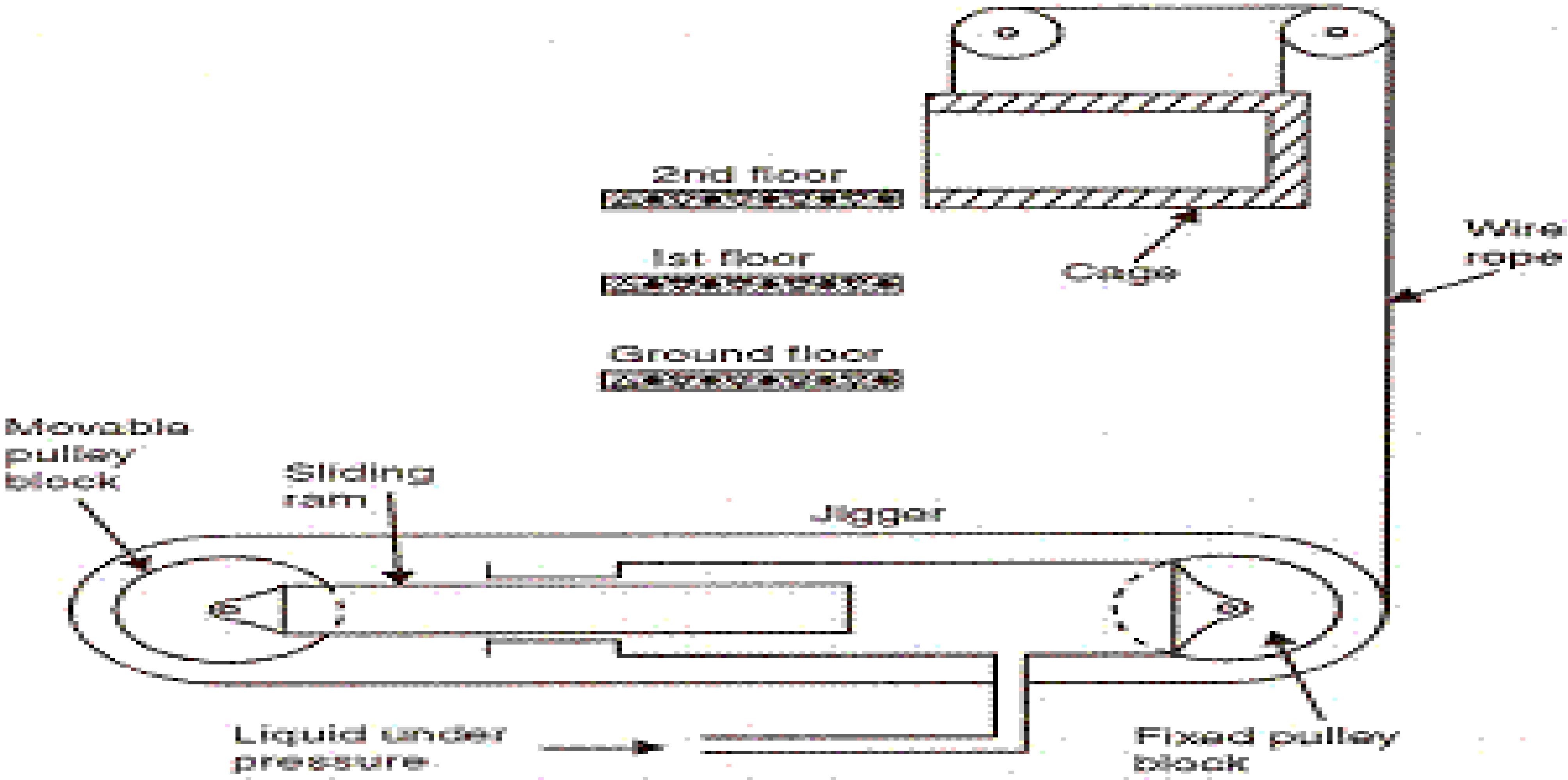
❖ Cage- on which the person may be stand or goods may be placed.

❖ The liquid under pressure flows into fixed cylinder.

❖ This liquid exerts force on the sliding ram, which moves vertically up and thus raises the cage to the required height.



# 2. SUSPENDED HYDRAULIC LIFT



# 2. SUSPENDED HYDRAULIC LIFT

- When water under high pressure is admitted into the fixed cylinder of the jigger, the sliding ram is forced to move towards left.

- As one of the end of the sliding ram is connected to the movable pulley block.

- Hence the movable pulley block moves towards the left , thus increasing the distance between two pulley blocks.

- The wire rope connected to cage is pulled and the cage is lifted.

- For lowering the cage, water from fixed cylinder is taken out.

# 2. SUSPENDED HYDRAULIC LIFT

❖The sliding ram moves towards right and hence movable pulley block also moves towards right.

❖This decrease the distance between two pulley blocks and cage is lowered due to increased length of the rope

# Thank You