GOVERNMENT POLYTECHNIC, DHENKANAL

LECTURE NOTES

ON

ELEMENT OF MECHANICAL ENGINEERING

3rd SEMESTER ELECTRICAL ENGINNERING

PREPARED BY

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Ch-1

THERMODYNAMICS

Defination:-

It is the combination of two word (Thermo + dynamics) which means Thermo → Heat, Dynamics → Motion.

HEAT:-

Heat is the form of energy which is transferred from one medium to another medium as a result of temperature difference between the system & the surrounding.

→ Heat can be transferred in three different ways.
i.e → 1) Conduction 2) Convection 3) Radiation

Conduction:-

→ The transfer of heat through solid is known as Conduction.

Convection:-

→ The transfer of heat through fluid is known as Convection.

Radiation:-

→ The radiation is an electromagnetic wave phenomena in which energy can be transferred through transparent substance or through vaccum.

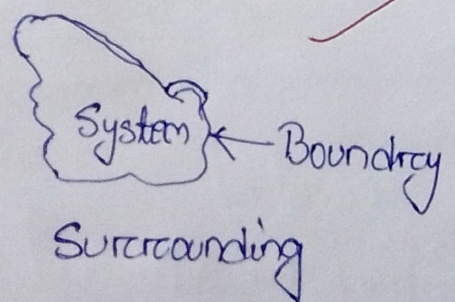
* Heat is usually represented by the symbol Q.
* The unit of heat is expressed in Joule(J) / kilo Joule(kJ).

System:-

→ System is the definite area through which thermodynamic process is taking place.

Surrounding:-

→ Anything Outside to the system is known as surrounding.



Work:-

→ Work is defined as the product of the force and the distance move in the direction of force.

→ Mathematically, workdone (w) = $F \times x$

where F = Force

x = Distance moved / Displacement

→ The unit of workdone is NM (Newton Meter).

FIRST LAW OF THERMODYNAMICS:-

→ This may stated as follows -

(A) "The heat and mechanical work are mutually Convertible."

According to this law, "when a closed system undergoes a thermodynamic cycle, the net heat transfer is equal to the network transfer. In otherwords "The cyclic integral of heat transfer is equal to the cyclic integral of work transfer."

→ Mathematically, $\oint \delta Q = \oint \delta W$

where, $\oint$ = cyclic integral

δQ = Infinite small element of heat

δW = Infinite small element of work

(B) "The energy can neither be created nor be destroyed, it can be transferred from one form to another."

According to this law, "when a system undergoes a change of state, the both heat transfer and work transfer takes place. The net energy transfer is stored within the system and is known as stored energy or total energy of the system.

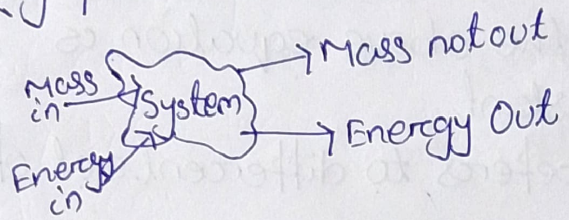
→ Mathematically, $\delta Q - \delta W = dE$

CLASSIFICATION / TYPES OF SYSTEM :-

→ It is three type 1) Closed System
2) Open System
3) Isolated System

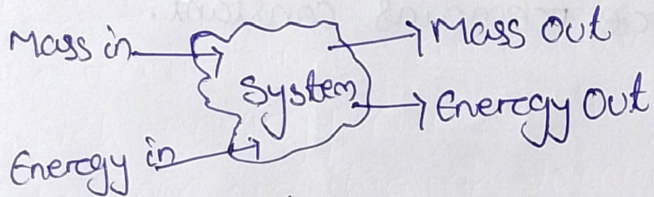
1) Closed System :-

→ Here the mass is fixed and the energy is transfer is taking place.



2) Open System :-

→ Here both mass and energy transfer is taking place or in otherword Both mass and energy can cross the boundary.



3) Isolated System :-

→ Here Both mass and energy cannot cross the boundary or in otherwords both mass & energy are fixed.

Perfect gas :-

→ A perfect gas / Ideal gas may be defined as a state of substance, whose evaporation from its liquid state is complete. and it obeys all the gas laws under all Condition of temperature & Pressure.

LAWS OF PERFECT GAS :-

→ The behaviour of a perfect gas is maintained by the following laws

① Boyle's law

② Charle's law

③ Gay-Lussac law

(1) Boyle's law:-

→ This law was formulated by Robert boyle in 1662 it's states "The absolute pressure of a given mass of a perfect gas varies inversly to it's volume, when the temperature remains constant."

→ Mathematically $P \propto \frac{1}{V}$

$$\boxed{PV = C}$$

→ The more useful form of the above equation is

$$P_1V_1 = P_2V_2 = P_3V_3 = ---- \text{Constant}$$

where the suffixes 1,2,3 refers to different set of condition.

(2) Charle's law:-

→ This law was formulated by French man Jacques A.C Charles in 1787. This law states that "The volume of a given mass of a perfect gas varies directly to its temperature when the absolute pressure remains constant."

→ Mathematically $V \propto T$

$$\boxed{\frac{V}{T} = C}$$

or

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \frac{V_3}{T_3} = ----- \text{Constant}$$

→ where the suffix 1,2,3 refers to different set of condition.

(3) Gay-Lussac law:-

→ This law states "The absolute pressure of a given mass of a perfect gas varies directly to its absolute temp. when the volume remains constant."

→ Mathematically $P \propto T$

$$\boxed{\frac{P}{T} = C} \text{ or}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \frac{P_3}{T_3} = --- \cdot \text{Constant}$$

→ where the suffixes 1,2,3 refers to different set of condition.

General gas equation :-

→ when the boyle's law and charle's law are combine together, they give the general gas equation.

According to boyle's law

$$P \propto \frac{1}{V} \text{ (where } T = \text{Constant)}$$

$$\text{or } V \propto \frac{1}{P} \text{ ------- (1)}$$

According to charle's law

$$V \propto T \text{ (where } P = \text{Constant) ---- (2)}$$

Combining both eq^n (1) and (2)

$$V \propto \frac{1}{P}$$

$$V \propto T$$

$$V \propto \frac{T}{P}$$

or

$$PV = T$$

$$\text{or } PV = CT$$

$$\text{or } \boxed{\frac{PV}{T} = C}$$

Finally eq^n is $\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3} = \text{----- Constant}}$

→ where the suffixes 1,2,3 refers to different set of condition.

Q) A Gas occupies is a volume of 0.1 meter cube at a temperature of 20°C and a pressure of 1.5 bar. find the final temperature of gas if it is compressed at a pressure of 7.5 bar and occupies a volume of $0.04m^3$.

Ans- Given $P_1 = 1.5$ bar

$P_2 = 7.5$ bar

$V_1 = 0.1m^3$

$V_2 = 0.04m^3$

$T_1 = 20°C$

$T_2 = ?$

According to general gas equation

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\Rightarrow \frac{1.5 \times 0.1}{20} = \frac{7.5 \times 0.04}{T_2}$$

$$\Rightarrow T_2(1.5 \times 0.1) = 20 \times 7.5 \times 0.04$$

$$\Rightarrow T_2 = \frac{7.5 \times 0.04 \times 20}{1.5 \times 0.1} \Rightarrow \boxed{T_2 = 40°C}$$

Q) Determine the final temperature of a gas when $2m^3$ of a gas at 6 bar is heated by keeping the temp. constant. The final volume is $6m^3$.

Ans- Given $P_1 = 6$ bar

$V_1 = 2m^3$

$V_2 = 6m^3$

$P_2 = ?$

According to boyle's law

$$P_1V_1 = P_2V_2$$

$$\Rightarrow 6 \times 2 = 6P_2$$

$$\Rightarrow 12 = 6P_2$$

$$\Rightarrow P_2 = \frac{12}{6} = 2 \Rightarrow \boxed{P_2 = 2 \text{ bar}}$$

Q) A certain quantity of air is cooled at a constant pressure from 300K to 280K. if the initial volume of the air is 0.15 m³, find by How much the volume will dismiss.

Ans- Given $T_1 = 300K$
$T_2 = 280K$
$V_1 = 0.15 m^3$
$V_2 = ?$

According to Charle's law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\Rightarrow \frac{0.15}{300} = \frac{V_2}{280}$$

$$\Rightarrow \frac{0.15}{300} \times 280 = V_2 \Rightarrow V_2 = \frac{42}{300} \Rightarrow \boxed{V_2 = 0.14 m^3}$$

Q) A gas at a temperature of 333°C and 20 bar as a volume of 0.06 m³. It is expanded to a volume of 0.54 m³. Determine the final pressure of the gas, if the temp. of the gas after expansion is 30°C.

Ans- Given $T_1 = 333°C$
$T_2 = 30°C$
$V_1 = 0.06$
$V_2 = 0.54$
$P_1 = 20$ bar
$P_2 = ?$

According to general gas equation

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\Rightarrow \frac{20 \times 0.06}{333} = \frac{P_2 \times 0.54}{30}$$

$$\Rightarrow 30(20 \times 0.06) = 0.54 P_2 \times 333$$

$$\Rightarrow 30 \times 1.2 = 179.82 P_2$$

$$\Rightarrow 36 = 179.82 P_2$$

$$\Rightarrow P_2 = \frac{36}{179.82} \Rightarrow \boxed{P_2 = 0.2 \text{ bar}}$$

SPECIFIC HEAT :-

→ The specific heat of a substance is defined as the amount of heat required to raise the temperature of a unit mass of substance through 1°c.

→ It is of two types :- (1) Specific heat of gas at constant Pressure
(2) Specific heat of gas at constant Volume

(1) SPECIFIC HEAT OF GAS AT CONSTANT PRESSURE :-

→ It is defined as the amount of heat required to raise the temp of a unit mass of gas through 1°, when it is heated at constant pressure.

→ It is denoted by "Cp".

→ Let m = mass of the substance (gas)

T_1 = Initial temp of the gas

T_2 = Final temp. of the gas

P_1 = Initial pressure of the gas

P_2 = Final pressure of the gas

∴ Total heat supplied to the gas at constant Pressure $= m \times Cp(T_2 - T_1)$

$= mCp(T_2 - T_1)$

$$Q = mCp(T_2 - T_1)$$

(2) SPECIFIC HEAT OF GAS AT CONSTANT VOLUME :-

→ It is defined as the amount of heat required to raise the temp of a unit mass of gas through 1° when it is heated at constant volume.

→ It is denoted by the symbol "Cv".

→ Let m = mass of the gas

T_1 = Initial temp of the gas

T_2 = Final temp of the gas

V_1 = Initial Volume of the gas

V_2 = Final Volume of the gas

∴ Total heat supplied to the gas at constant ~~temp~~ volume

$$\boxed{Q = mC_v(T_2 - T_1)}$$

(1) 5 kg of air at a temperature of 34°C is heated to a temperature of 65°C. Find the heat supplied to the air when heated at constant pressure. The specific heat for air at constant pressure is 0.712 KJ/kg.k.

Ans- Given $m = 5\,kg$

$T_1 = 34°C \Rightarrow T_1 = 34 + 273K = 307K$

$T_2 = 65°C \Rightarrow T_2 = 65 + 273K = 338K$

$C_P = 0.712\ KJ/kg.K$

$Q = mC_p(T_2 - T_1)$

$= 5 \times 0.712\,(338 - 307)$

$= 3.56 \times 31$

$$\boxed{Q = 110.36\ KJ}$$

(2) A gas occupies a volume of $0.32m^3$ at a temperature of 12°C and a pressure of 1.3 bar. find the final temp of the gas if it is compressed to a pressure of 7.34 bar and occupies a volume of $0.54m^3$.

Ans- Given $T_1 = 12°C$

$V_1 = 0.32m^3$

$V_2 = 0.54m^3$

$P_1 = 1.3\,bar$

$P_2 = 7.34\,bar$

According to general gas equation.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\Rightarrow \frac{1.3 \times 0.32}{12} = \frac{7.34 \times 0.54}{T_2}$$

$$\Rightarrow T_2(1.3 \times 0.32) = 12(7.34 \times 0.54)$$

$\Rightarrow 0.416T_2 = 12 \times 3.963$

$\Rightarrow 0.416T_2 = 47.556$

$\Rightarrow T_2 = \frac{47.556}{0.416}$

$\Rightarrow \boxed{T_2 = 114.31°C}$

③ 2kg air at a temp of 17°C is heated to a temp of 52°C find the total heat supply to air when it is heated at constant volume. The specific heat for air constant volume 0.693 KJ/kg.K.

Ans:- Given $m = 2kg$

$T_1 = 17°C + 273K = 290K$

$T_2 = 52 + 273K = 325K$

$C_v = 0.693\ KJ/kg.K$

$Q = mC_v(T_2 - T_1)$

$= 2 \times 0.693\ (325 - 290)$

$= 1.386 \times 35$

$\boxed{Q = 48.51KJ}$

Imp **Relationship between specific heat:-**

→ Consider a gas enclosed in a container and is being heated at a constant pressure, from the initial state 1 to the final state 2.

→ Let m = mass of the gas

T_1 = Intial temp of the gas

T_2 = Final temp. of the gas

V_1 = Initial volume of the gas

V_2 = Final volume of the gas

P = Constant pressure

C_p = specific heat of gas at constant pressure

C_v = Specific heat of gas at constant volume

We know that the heat supplied to the gas at constant pressure = $Q_{1-2} = mC_p(T_2 - T_1)$

We have already know that,

Workdone = $W_{1-2} = P(V_2 - V_1)$

We also know that, change in internal energy

$du = mC_v(T_2 - T_1)$

We also know that $Q = du + dw$

$\Rightarrow mC_p(T_2 - T_1) = mC_v(T_2 - T_1) + P(V_2 - V_1)$

We know before that $PV = mRT$

where R = Characteristics gas constant

$mC_p(T_2 - T_1) = mC_v(T_2 - T_1) + P(V_2 - V_1)$

$\Rightarrow mC_p(T_2 - T_1) = mC_v(T_2 - T_1) + PV_2 - PV_1$

$\Rightarrow mC_p(T_2 - T_1) = mC_v(T_2 - T_1) + mRT_2 - mRT_1$

$\Rightarrow mC_p(T_2 - T_1) = mC_v(T_2 - T_1) + mR(T_2 - T_1)$

$\Rightarrow mC_p(T_2 - T_1) = m(T_2 - T_1)(C_v + R)$

$\Rightarrow C_p = C_v + R$

$\Rightarrow \boxed{C_p - C_v = R}$

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PROPERTIES OF STEAM

Steam:-

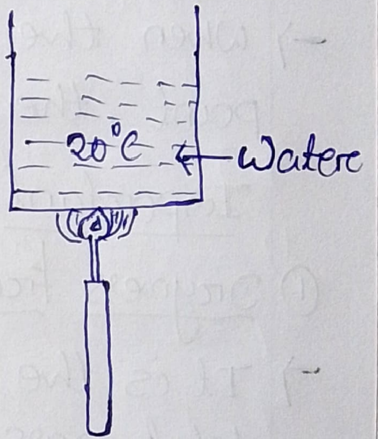
→ It is the vapour or gaseous form of water.
→ It is colourless, odourless, tasteless.

Use:-

→ It is used in powerplant for production of electricity.
→ It is also used for drying purposes.

Formation of steam:-

→ Take 1kg of water at 20°C under atmospheric pressure in a container.
→ Let the water to be heated by an external source.



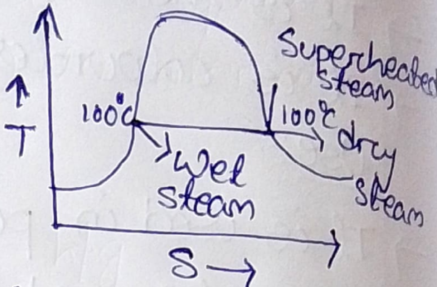
→ The temp. of water raises from 20°C to 100°C by taking heat. The heat used have is known as sensible heat.
→ 100°C water is converted into 100°C steam using latent heat of vapourisation.
→ If we will further supply heat, the temp. of steam will increase and the steam become super heated.

Heat
- ↓ Sensible Heat
  - ↓ Change only temperature
- ↓ Latent Heat
  - ↓ Change only state or phase.

Types of Steam :-

1. **Wet steam :-**

→ The steam which contains moisture particles in it is known as wet steam.



2. **Dry steam :-**

→ When the steam has no moisture content in it, called as dry steam.

3. **Super heated steam :-**

→ When the temp. of the steam is more than its boiling point, then the steam is called as superheated steam.

Important terms (x) :-

1. **Dryness fraction :-**

→ It is the ratio between mass of water vapour to the total mass of water vapour and liquid water.

i.e. $$x = \frac{m_v}{m_v + m_l}$$

where m_v → Mass of water vapour
m_l → Mass of liquid water

Range of x, $0 \le x \le 1$

$x = 0$ → No steam
$x = 1$ → All steam (dry steam)
$0 < x < 1$ → wet steam

2. **Specific Volume :-**

→ It is the ratio between volume of the state to the mass of the steam.

i.e. $$v = \frac{V}{m} = \frac{1}{\rho}$$

v → specific volume
V → volume, m → mass, ρ → density

→ S.I. Unit of Specific Volume (v) = m^3/kg

→ specific volume of wet steam

$$v_x = v_f + x v_{fg}$$

where $v_{fg} = v_g - v_f$

v_f → specific volume of saturated water.

v_g → Specific volume of saturated vapour.

③ Specific Enthalpy:-

→ It is denoted as enthalpy of steam per unit mass.

i.e. $h = \frac{H}{m}$ h → Specific Enthalpy

H → Enthalpy (Amount of Heat content in a system)   m → mass

→ S.I unit of specific enthalpy (h) = J/kg

→ specific enthalpy of wet steam.

$$h_x = h_f + x h_{fg}$$, $h_{fg} = h_g - h_f$

④ Specific Entropy:-

→ It is defined as Entropy of the steam per unit mass.

i.e → $s = \frac{S}{m}$ where s → Specific Entropy

S → Entropy (Degree of disorderness) , m → Mass

→ S.I unit of specific Entropy (s) = J/kg.k

→ Specific entropy of wet steam

$$s_x = s_f + x s_{fg}$$

$s_{fg} = s_g - s_f$

(5) Enthalpy of Vapourisation:-

→ It is the amount of enthalpy or heat required to convert saturated liquid (Water) to saturated vapour (steam).

→ i.e. Enthalpy of Vapourisation $= h_g - h_f = h_{fg}$

STEAM TABLE:-

→ In it different properties of steam like - specific volume, Specific enthalpy and specific entropy are written in tabular form at different temp. and pressure.

→ It is divided into 3 Categories -

1) Saturation temperature table
2) Saturation pressure table
3) Superheated table

Problem-1

steam coming from a boiler is at temperature of 185°c if the dryness fraction of the steam is 0.85. find its enthalpy, volume entropy per kg of steam.

Given

At Saturation temp of 185,

kJ/kg		m³/kg		kJ/k	
h_f	h_g	v_f	v_g	s_f	s_g
190	850	0.5	3.7	1.82	9.42

Solve

$V_x = V_f + xV_{fg}$
$= 0.5 + 0.85(3.7 - 0.5)$
$= 3.22 \, m^3/kg$

$h_x = h_f + xh_{fg}$
$= 190 + 0.85(850 - 190)$
$= 751 \, kJ/g$

$S_x = S_f + xS_{fg} = 1.82 + 0.85(9.42 - 1.82) = 8.28 \, kJ/kg.k$

Problem-2

Steam coming from a boiler has a temperature of 220°C. If the dryness fraction of the steam is 0.9, find its specific volume, specific enthalpy and specific entropy.

Solve: Given data

Temp. of steam $(t) = 220°C$

dryness fraction $(x) = 0.9$

At 220°C $\quad v_x = v_f + x v_{fg}$

$v_f = 0.001190$

$v_g = 0.0862$, $v_{fg} = 0.0862 - 0.001190 = 0.08501$

$$v_x = v_f + x v_{fg}$$
$$= 0.001190 + 0.9 \times 0.08501$$
$$= 0.077699 \text{ m}^3/\text{kg}$$

$$h_x = h_f + x h_{fg}$$
$$= 943.62 + 0.9 \times 1858.5$$
$$= 2616.27 \text{ kJ/kg}$$

$$S_x = S_f + x S_{fg}$$
$$= 2.5178 + 0.9 \times 3.7683$$
$$= 5.90927 \text{ kJ/kg.K}$$

$\therefore$

$v_x = 0.077699 \text{ m}^3/\text{kg}$
$h_x = 2616.27 \text{ kJ/kg}$
$S_x = 5.90927 \text{ kJ/kg.K}$

Problem-3:-

A saturated steam has a pressure of 11 bar. If its specific enthalpy is 2700 kJ/kg. Find its specific volume and specific entropy.

Solu: Given Steam pressure (P) = 11 bar

Specific Enthalpy (h) = 2700 kJ/kg

h_f = 781.34 kJ/kg

h_{fg} = 2000.4 kJ/kg

$$h = h_f + x h_{fg}$$

$$\Rightarrow x = \frac{h - h_f}{h_{fg}}$$

$$\Rightarrow x = \frac{2700 - 781.34}{2000.4} \Rightarrow x \simeq 0.96$$

$$V = V_f + x V_{fg}$$

$$= 0.001133 + 0.96 \times 0.176397$$

$$= 0.17047412 \ m^3/kg$$

$$S = S_f + x S_{fg}$$

$$= 2.1792 + 0.96 \times 4.3744$$

$$= 6.378624 \ kJ/kg.K$$

$\therefore$ $V = 0.17047412 \ m^3/kg$

$S = 6.378624 \ kJ/kg.K$

BOILER

Defination:-

It is a mechanical device used to produce steam from water by heating it using fuel.

Types of Boiler:-

① According to position of axis of boiler shell:-

a) Horizontal boiler → Ex = Lanchashire boiler

b) Vertical boiler → Ex = Cochran boiler

c) Inclined boiler → Ex = Babcock and wilcox boiler

② According to firing Position:-

a) Internally fired boiler Ex → Lanchashire boiler

b) Externally fired boiler Ex → Babcock and wilcox boiler

③ According to type of Substance inside the tube:-

a) Fire tube boiler Ex → Cochran boiler

b) Water tube boiler Ex → Babcock and wilcox boiler

④ According to no of tubes:-

a) Single tube boiler. Ex → Cornish boiler

b) Multi tube boiler Ex → Babcock and wilcox boiler

⑤ According to pressure inside boiler:-

a) High pressure boiler (>80 bar) Ex - Babcock and wilcox boiler

b) Low pressure boiler (<80 bar) Ex - Cochran boiler

⑥ According to its Portability:-

a) Stationary boiler Ex - Lanchashire boiler

b) Portable boiler Ex - Cochran boiler

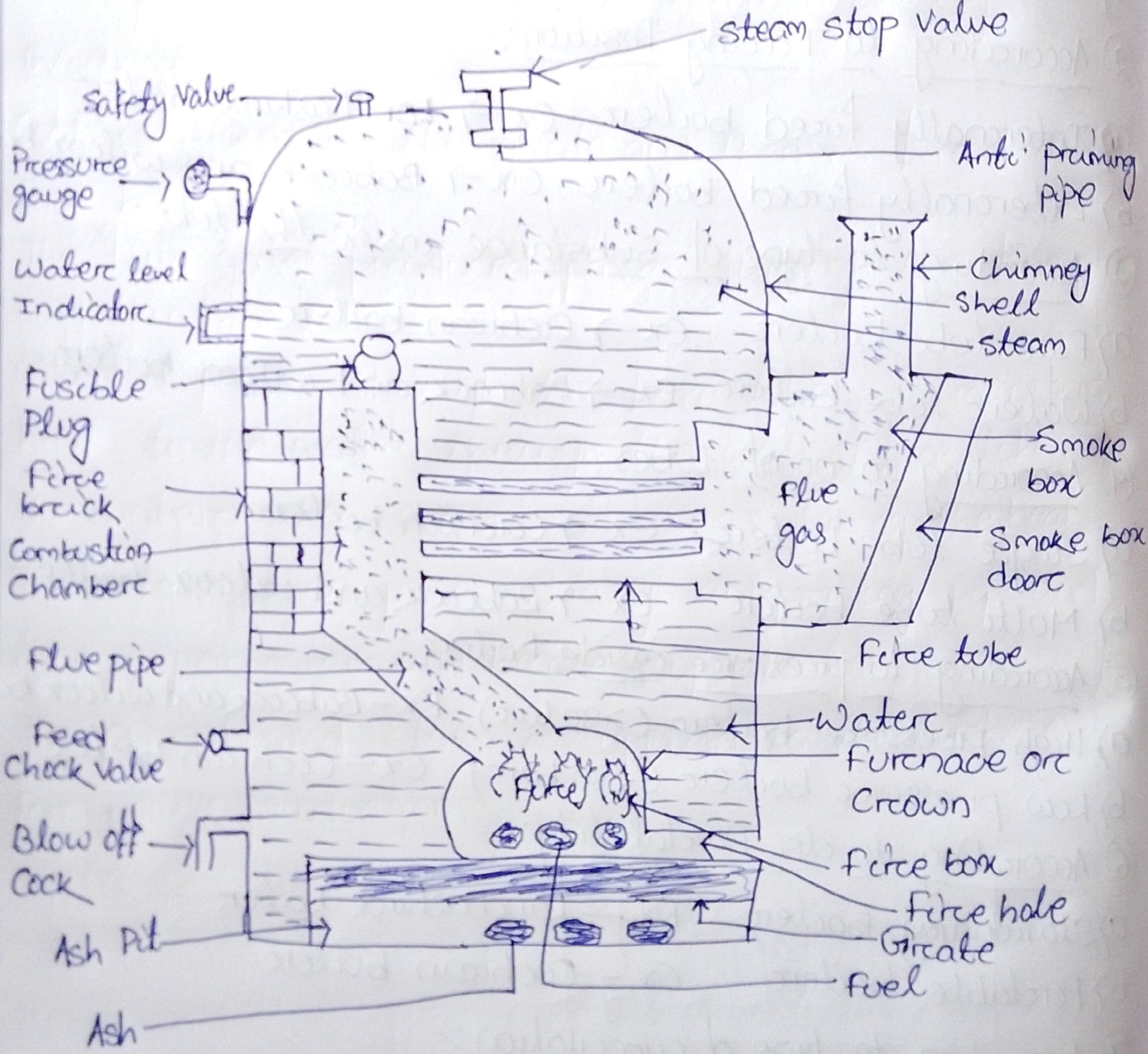
⑦ According to type of circulation:-

a) Natural Circulation (without pump) Ex - Babcock and wilcox

b) Forced Circulation (with pump) Ex - Benson

COCHRAN BOILER :-

→ It is a boiler of
i) Vertical
ii) Fire tube
iii) low pressure
iv) Portable
v) Multi tube
vi) Internally fired
vii) Natural Circulation



Different parts of Cochran boiler

① Safety Valve:-

→ It behaves like safe guard for a boiler.

→ When the pressure inside the boiler exceeds its limit, the safety valves opens and releases excess pressure.

② Pressure gauge:-

→ It measures gauge pressure inside a boiler.

③ Water level Indicator:-

→ It indicates the water level present inside boiler shell.

④ Steam stop valve:-

→ The steam form inside the boiler is supplied to the steam turbine through this valve.

⑤ Man Hole:-

→ It is an opening on the top of a boiler through which a person enters inside the boiler for maintainance and cleaning purposes.

⑥ Fusible Plug:-

→ When the water level inside the boiler drops below a certain level, fusible plug melts down and make a hole through which water enteres and burn out the fire.

⑦ Feed check valve:-

→ When the water level drops below a certain level, water enters into the boiler through feed check valve.

⑧ Blow off cock:-

→ The waste products after cleaning are throughout through the blow off cock.

9) Grate:-

→ It is made up of cost iron on which coal is placed

10) Anti priming Pipe:-

→ It absorbs the water particles present in the steam and makes the steam dry.

11) Chimney:-

→ The flue gases produce inside fire box finally throughout to the atmosphere through chimney.

Working:-

→ Coal is placed on the grate and then is fired in the fire box.

→ The flue gases produced passes through the fire pipe and then fire tube.

→ When it passes through the fire tube, it transfers heat to the water through the wall of fire tube.

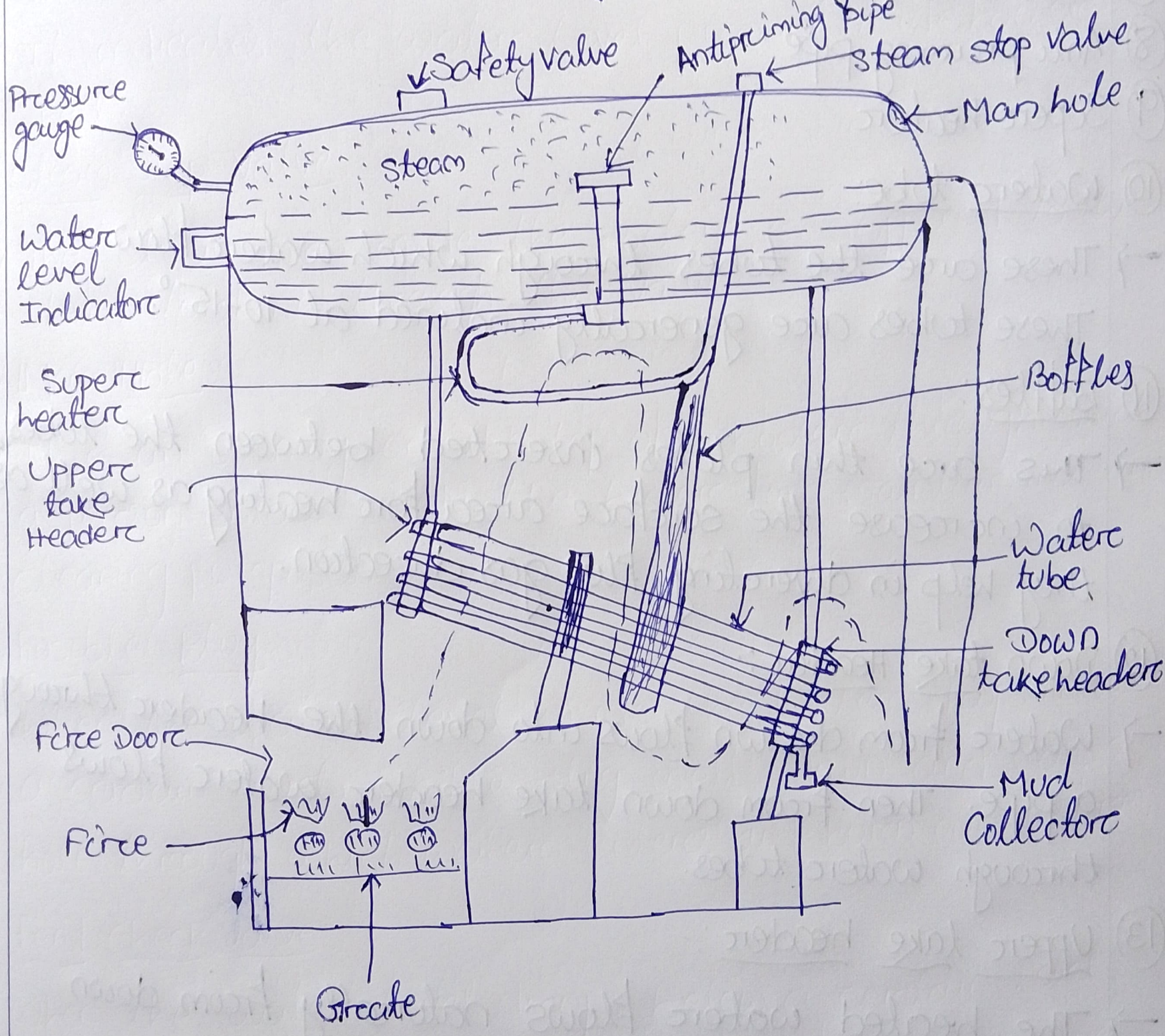
→ The water then converts to steam taking the heat.

→ The steam then passes through antipriming pipe and then superheater and become superheated.

→ The superheated steam is supplied to the turbine for power production.

Babcock And Wilcox Boiler:-

→ It is a boiler of type
a) High Pressure
b) Water tube
c) Inclined
d) Natural Circulation
e) Stationary
f) Multi tube
g) Externally fired



(Babcock and Wilcox Boiler)

Different parts of Babcock and Wilcox Boiler :-

1. Safety valve
2. Man hole
3. steam stop valve
4. Grate
5. Pressure gauge
6. Water level indicator
7. feed check valve
8. Anti priming pipe
9. Super heater
10. Water tube:

→ These are the tubes through which water flow. These tubes are generally inclined at 10-15°.

11. Baffles :-

→ This are thin plates inserted between the tubes to increase the surface area for heating as well as they help in diverting flue gas direction.

12. Down take Header :-

→ Water from drawn flows into down the header through a pipe. Then from down take header water flows through water tubes.

13. Upper take header :-

→ The heated water flows naturally from down take header to upper take header where some water converts to steam and flows into the drum.

HYDROSTATICS

Defination:-

→ Hydrostatic is the branch of science which deals with the behaviour of the fluid at the condition of rest.

FLUID:-

→ Fluid is a substance which has the capacity to flow.

PROPERTIES OF FLUID:-

① **DENSITY (MASS DENSITY):-**

→ It is defined as the ratio of mass of the fluid to it's volume.

→ Mathematically, Density = $\frac{\text{Mass of fluid}}{\text{Volume of fluid}}$

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

→ The unit of density is $\frac{kg}{m^3}$ (S.I. Unit)

→ The C.G.S unit of density is $\frac{gm}{cm^3}$.

→ The value of density of water is $1 gm/cm^3$ or $1000 kg/m^3$.

(2) **SPECIFIC WEIGHT (WEIGHT DENSITY):-**

→ Specific weight / weight density of a fluid is defined as the ratio of the weight of the fluid to it's volume.

→ It is denoted by the symbol 'w'.

→ Mathematically, $w = \frac{\text{weight of the fluid}}{\text{Volume of the fluid}}$

$$w = \frac{\text{mass} \times \text{Acceleration due to gravity}}{\text{Volume of the fluid}}$$

$$w = \frac{m \times g}{V}$$

$$w = \frac{m}{V} \times g \Rightarrow \boxed{w = \rho \times g}$$

- The S.I unit of weight density → N/m^3
- The C.G.S unit of weight density → $dyne/cm^3$
- The value of specific weight of water is $1000 \times 9.81\ N/m^3$.

(3) SPECIFIC VOLUME:-

- It is defined as the ratio of volume of the fluids to it's mass.
- It is the reciprocal of Mass density.
- Mathematically specific volume = $\frac{\text{Volume of the fluid}}{\text{mass of the fluid}}$

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

- S.I unit of the specific volume m^3/kg.
- C.G.S unit of the specific volume cm^3/gm.

Specific gravity:-

- Specific gravity is defined as the ratio of weight density of a fluid to the weight density of a standard fluid.
- For liquid, the standard fluid is taken as water and for gas, the standard fluid is taken as air.
- It is denoted by the symbol "S".
- Mathematically,

$$S(\text{liquid}) = \frac{\text{Weight density of liquid}}{\text{Weight density of water}}$$

$$S(\text{gas}) = \frac{\text{Weight density of gas}}{\text{Weight density of air}}$$

- Weight density of ~~fluid~~ liquid = S × weight density of water.
- Weight density of gas = S × weight density of air
- It is a dimension less quantity.
- It has no unit.

Q) Calculate the specific weight, density and specific gravity of 1 liter of liquid which weights 7N.

Ans- Given Volume (V) = 1 liter

Weight (W) = 7N

$$\text{Volume} = 1 \text{ lit} = 1000 cm^3 = \frac{1}{1000} m^3$$

(1) $$\text{Specific weight} = \frac{\text{Weight}(W)}{\text{Volume}(V)}$$

$$= \frac{7}{\frac{1}{1000}} \Rightarrow 7 \times 1000 = 7000 \ N/m^3$$

(2) $$\text{Density} (\rho) = \frac{\text{Weight}}{\text{gravity}} = \frac{W}{g} \Rightarrow \frac{7000}{9.81} = 713.5 \ kg/m^3$$

(3) $$\text{Specific gravity} = \frac{\text{Weight density of liquid}}{\text{Weight density of water}}$$

$$= \frac{\rho \times g}{1000 \times 9.81}$$

$$= \frac{713.5 \times 9.81}{1000 \times 9.81}$$

$$= 0.71$$

Q) Calculate the density, specific weight, and weight of 2 liter of petrol of specific gravity 0.7.

Ans Given volume (V) = 2 litre = 2×1000 = 2000

Specific gravity ~~of Petrol~~ = 0.7

$$S(liq) = \frac{\text{Weight density of liquid}}{\text{Weight density of water}}$$

$$\Rightarrow 0.7 = \frac{\text{Weight density of Petrol}}{\text{Weight density of water}}$$

$\Rightarrow 0.7 = \frac{\text{weight density of Petrol}}{9.81 \times 1000}$

$\Rightarrow$ weight density of Petrol $= 0.7 \times 9.81 \times 1000$

$= 6867 \ N/m^3$

1) Density = We know that $w = \rho g$

$\Rightarrow 6867 = \rho \times 9.81$

$\Rightarrow \rho = \frac{6867}{9.81}$

$\Rightarrow \rho = 700 \ kg/m^3$

2) specific weight or weight density of petrol is $6867 \ N/m^3$

3) ~~weight of the petrol~~ specific weight = $\frac{\text{weight of the fluid}}{\text{Volume of the fluid}}$

$\Rightarrow$ weight of the petrol $= \frac{6867}{2000} = 3.43 \ N$

Pressure at a point, Pressure measuring instruments:-

→ Pressure at a point is defined as the ratio of applied force to the unit area.

→ Mathematically, Pressure (P) $= \frac{\text{Force}}{\text{Unit Area}} = \frac{F}{A}$

→ The unit of pressure is N/m^2 or N/mm^2.

→ In S.I unit N/m^2 is known as Pascal and is represented by Pa.

Measurement of Pressure:-

→ The pressure of a fluid is measured by the following devices ① Manometer

② Mechanical Gauge

(1) Manometer :-

→ Manometers are defined as the devices which is used for measuring the pressure at a point in a fluid by balancing the column of fluid by the same or another column of the fluid.

→ This is classified into 2 type :- (1) Simple Manometer
(2) Differential Manometer

(2) Mechanical Gauge :-

→ Mechanical Gauge are defined as the devices which is used for measuring the pressure by balancing the fluid Column by the spring or deadweight.

→ It is divided into 4 type :-
1) Diaphragam Pressure Gauge
2) Bourdon tube pressure gauge
3) Deadweight pressure gauge
4) Bellos pressure gauge.

Simple Manometer :-

→ A simple manometer consist of a glass tube having one end connected to a point where pressure is to be measured and another end remains open to the atmosphere.

→ It is up three types :-
(1) Piezometer
(2) U-tube manometer
(3) Single Column manometer

Density of Mercury = 13.6 kg/m^3

(1) PIEZOMETER:-

→ It is the simplest form of manometer which is used for measuring of gauge pressure (The pressure which present above the atmospheric pressure is known as gauge pressure).

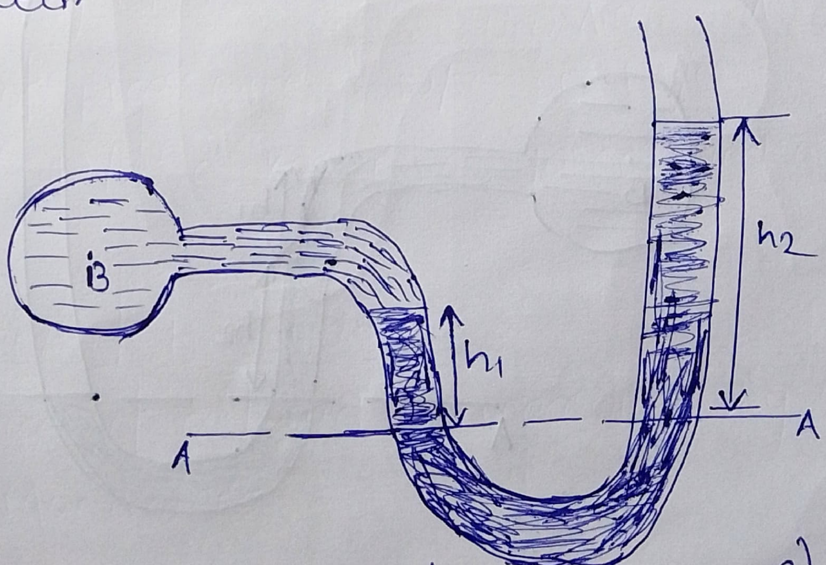
→ One end of the manometer is connected to a point where pressure is to be measure and another end remains upon to the atmosphere.

→ The raise of liquid gives the pressure head at that point if the point 'A' the height of the liquid (water) is 'h' in the piezometer tube, then the pressure at a point $\boxed{A = \rho \times g \times h \frac{N}{m^2}}$

(2) U-TUBE MANOMETER:-

→ It consist of a glass tube which is bend in 'U' shape, one end of which is connected to a point where pressure is to be a measure and another end remains open to the atmosphere.

→ The tube generally contains mercury or any other liquid whose specific gravity is greater than the specific gravity of the liquid whose pressure is to be measured.



(For measurement of gauge Pressure)

→ Let B is the point at which pressure is to be measured

→ A·A → Datum line or reference line.

→ h_1 → Height of the light liquid above the datum line.

→ h_2 → Height of the Heavy liquid above the datum line.

→ S_1 → Specific gravity of light liquid.

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

→ S_2 → Specific gravity of heavy liquid.

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

→ As the pressure is same for both the horizontal surface so the pressure above the horizontal datum line (AA) in the left column and in the right column is same.

→ Pressure above the datum line in the left column $= P_B + \rho_1 g h_1$

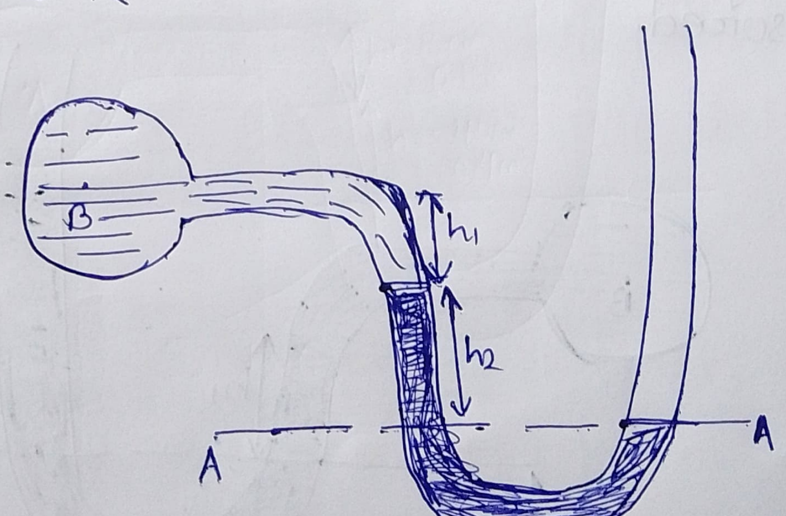
→ Pressure above the datum line in the right column $= \rho_2 g h_2$

For equilibrium $P_B + \rho_1 g h_1 = \rho_2 g h_2$

Finally we got, $\boxed{P_B = \rho_2 g h_2 - \rho_1 g h_1}$

Vacuum Pressure:-

→ The pressure present below the atmospheric pressure is known as vacuum pressure.



→ Pressure above the datum line in the left column

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

Pressure above the datum line in the right column $= 0$

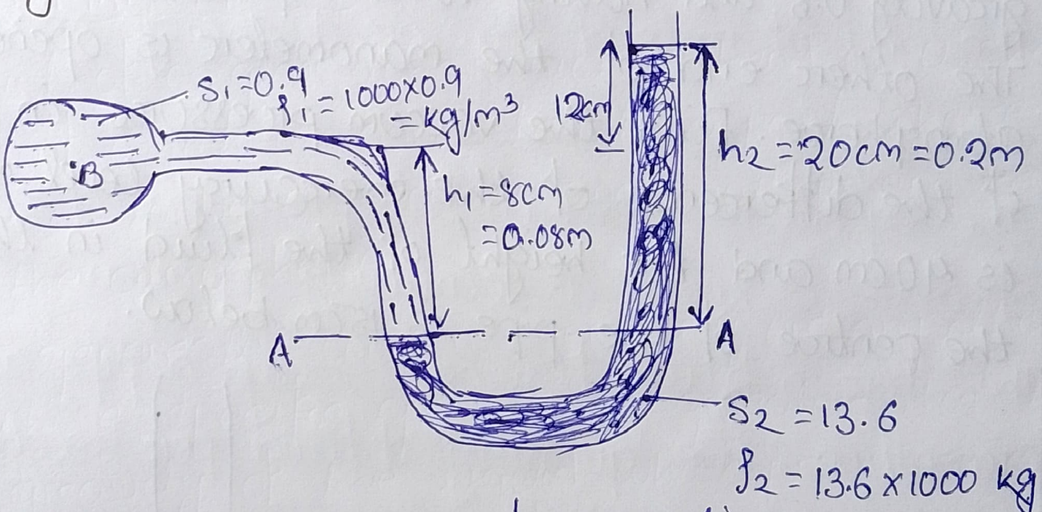
For equilibrium $P_B + \rho_1 g h_1 + \rho_2 g h_2 = 0$

$\Rightarrow P_B = -\rho_1 g h_1 - \rho_2 g h_2$

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

Q) The right limb of a simple U-tube manometer containing mercury is open to the atmosphere while the left limb is connected to a pipe in which a fluid of specific gravity 0.9 is flowing. The centre of the pipe is 12cm below the level of mercury in the right limb. Find the pressure of the fluid in the pipe if the difference of mercury level in the 2 limb is 20cm.

Ans-



Given A.A → Datum line or reference line

h_1 → Height of light liquid above the datum line $= 0.08m$

h_2 → Height of the heavy liquid above the datum line $= 0.2m$

g → specific gravity $= 9.81$

S_1 → Specific gravity of light liquid $= 0.9$

S_2 → Specific gravity of heavy liquid $= 13.6$

ρ_1 → density of light liquid $= 1000 \times 0.9$ kg/m³

ρ_2 → density of Heavy liquid $= 13.6 \times 1000$ kg/m³

So $\rho_1 = 1000 \times 0.9$
$= 900\ kg/m^3$

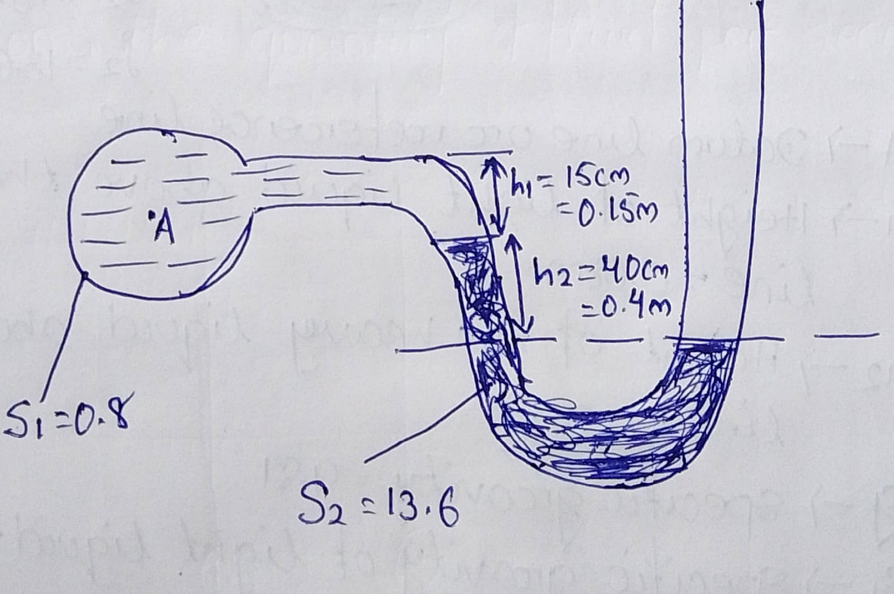
$\rho_2 = 13.6 \times 1000$
$= 13600\ kg/m^3$

$P_B = \rho_2 g h_2 - \rho_1 g h_1$
$= 13600 \times 9.81 \times 0.2 - 900 \times 9.81 \times 0.08$
$= 26683.2 - 706.32$
$= 25976.88$

$\therefore$ $P_B = 25976.88$

Q) A Simple U-tube manometer containing mercury is connected to a pipe in which a fluid of specific gravity 0.8 and having vaccum pressure is flowing. The other end of the manometer is opened to the atmosphere. Find the vaccum pressure in the pipe if the difference of the mercury level is two limb is 40 cm and the height of the fluid in the left from the centre of the pipe is 15 cm below.

Ans-



Where $S_1 = 0.8$

$S_2 = 13.6$

$h_1 = 0.15m$

$h_2 = 0.4m$

$\rho_1 = S_1 \times 1000$

$= 0.8 \times 1000$

$= \frac{8}{10} \times 1000 = 800 \ kg/m^3$

$\rho_2 = S_2 \times 1000$

$= 13.6 \times 1000$

$= 13600 \ kg/m^3$

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

$= -(800 \times 9.81 \times 0.15 + 13600 \times 9.81 \times 0.4)$

$= -(1177.2 + 53366.4)$

$= -54543.6$

$\therefore \boxed{P_A = -54543.6}$

HYDROKINETICS

Defination:-

Hydrokinetics or Hydrokinematics is the branch of science which deals with the behaviour and properties of the fluid in motion.

Rate of Discharge (Q):-

→ It is defined as the quantity of fluid flowing per second through a section of pipe or a channel.

→ Consider a liquid flowing through a pipe

If A = Crossectional area of the pipe

V = Velocity of the fluid across the section then

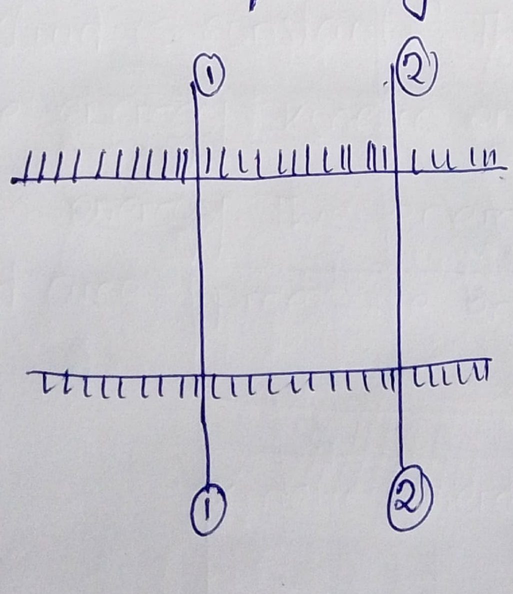
$$\boxed{Q = AV}$$

→ The unit of rate of flow or discharge $= m^2 \times \frac{m}{s} = \frac{m^3}{sec}$

imp **Continuity Equation:-**

→ The equation based on the principle of conservation of mass is known as continuity equation.

→ Thus for a fluid flowing through a pipe at all the crossection, the quantity of fluid per second is constant.



Consider the crosection of the pipe such as (1-1) and (2-2)

Let V_1 = Average velocity at section (1-1)

ρ_1 = Density at section (1-1)

A_1 = Crosectional Area at section (1-1)

V_2 = Average velocity at section (2-2)

ρ_2 = Density at section (2-2)

A_2 = Crosectional Area at section (2-2)

According to the law of conservation of mass

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

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

→ This eqn is valid for compressible as well as incompressible fluid.

* If the density of the fluid is constant that is called incompressible fluid.
* If the density of the fluid is not constant that is called compressible fluid.

→ For incompressible fluid density = Constant

$$\Rightarrow \cancel{\rho_1} A_1 V_1 = \cancel{\rho_2} A_2 V_2$$

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

Q) The diameter of a pipe at section 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 the velocity at section-2.

Ans - Given $D_1 = 10\ cm = 0.1\ m$

$D_2 = 15\ cm = 0.15\ m$

$A_1 = \frac{\pi}{4} \times (D_1)^2 = \frac{\pi}{4} \times (0.1)^2 = 7.85 \times 10^{-3}\ m^2$

$A_2 = \frac{\pi}{4} \times (D_2)^2 = \frac{\pi}{4} \times (0.15)^2 = 0.01767\ m^2$

$V_1 = 5\ m/sec$

As we know from continuity equation

$A_1 V_1 = A_2 V_2$

$\Rightarrow V_2 = \frac{A_1 V_1}{A_2} = \frac{7.85 \times 10^{-3} \times 5}{0.01767} = 2.22\ m^3/sec$

Bernoulli's theorem:-

It states that " In a steady, Ideal flow of incompressible fluid, the total energy at any point of the fluid is constant." The total energy consist of pressure energy, kinetic energy and potential energy or datum energy. This energy per unit weight of the fluid are

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

Kinetic energy $= \frac{V^2}{2g}$

Datum energy (Potential energy) $= Z$

→ So Mathematically
Bernoulli's equation is written as

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

* Steady flow:-

→ It is defined that types of fluid flow in which the fluid characteristics like velocity, pressure and density at a point don't change with time.

* Ideal Flow:-

→ The flow posses by the Ideal fluid is known as Ideal flow.

* Ideal Fluid

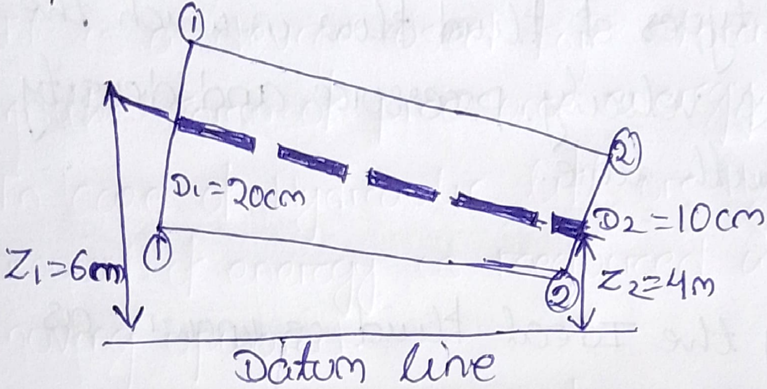
→ A fluid which is incompressible and having no viscosity is known as Ideal fluid.

* Viscosity:-

→ Viscosity is defined as the property of fluid which offers resistance to one layer of fluid over another adjacent layer of fluid.

Q) The water is flowing through a pipe having diameter 20cm and 10cm at section-1 and 2 respectively. The rate of flow through the pipe is 35 litre/s. The section 1 is 6m above the datum and section 2 is 4m above the datum. If the pressure at section-1 is 39.24 N/cm², find the intensity of pressure at section-2.

Ans-



Given $D_1 = 20cm = \frac{20}{100} = 0.2m$

$D_2 = 10cm = \frac{10}{100} = 0.1m$

$Q = 35 \text{ lit/sec} = \frac{35}{1000} = 0.035 \text{ m}^3/\text{sec}$

$Z_1 = 6m$

$Z_2 = 4m$

$P_1 = 39.24 \text{ N/cm}^2$

$= 39.24 \times 10^4 \text{ N/m}^2$

$A_1 = \frac{\pi}{4} \times (D_1)^2$

$= \frac{\pi}{4} \times (0.2)^2 = 0.0314 m^2$

$A_2 = \frac{\pi}{4} \times (D_2)^2$

$= \frac{\pi}{4} \times (0.1)^2 = 7.85 \times 10^{-3} m^2$

$Q = A_1V_1 = A_2V_2$

$V_1 = \frac{Q}{A_1} = \frac{0.035}{0.0314} = 1.114 \text{ m/s}$

$V_2 = \frac{Q}{A_2} = \frac{0.035}{7.85 \times 10^{-3}} = 4.46 \text{ m/s}$

Now applying Bernoullis equation at section 1 and 2

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

$$\Rightarrow \frac{39.24 \times 10^4}{1000 \times 9.81} + \frac{(1.114)^2}{2 \times 9.81} + 6 = \frac{P_2}{1000 \times 9.81} + \frac{(4.46)^2}{2 \times 9.81} + 4$$

$$\Rightarrow 46.063 = \frac{P_2}{9810} + 5.013$$

$$\Rightarrow \frac{P_2}{9810} = 46.063 - 5.013$$

$$\Rightarrow \frac{P_2}{9810} = 41.05$$

$$\Rightarrow P_2 = 41.05 \times 9810$$

$$\Rightarrow P_2 = 402700.5 \ N/m^2$$

$$\Rightarrow P_2 = 402700.5 \times 10^{-4}$$

$$= 40.27 \ N/cm^2$$

HYDRAULIC DEVICE AND PNEUMATIC

Defination:-

→ A PNeumatic system is a system that usages Compressed air to transmit the power.

HYDRAULIC DEVICE:-

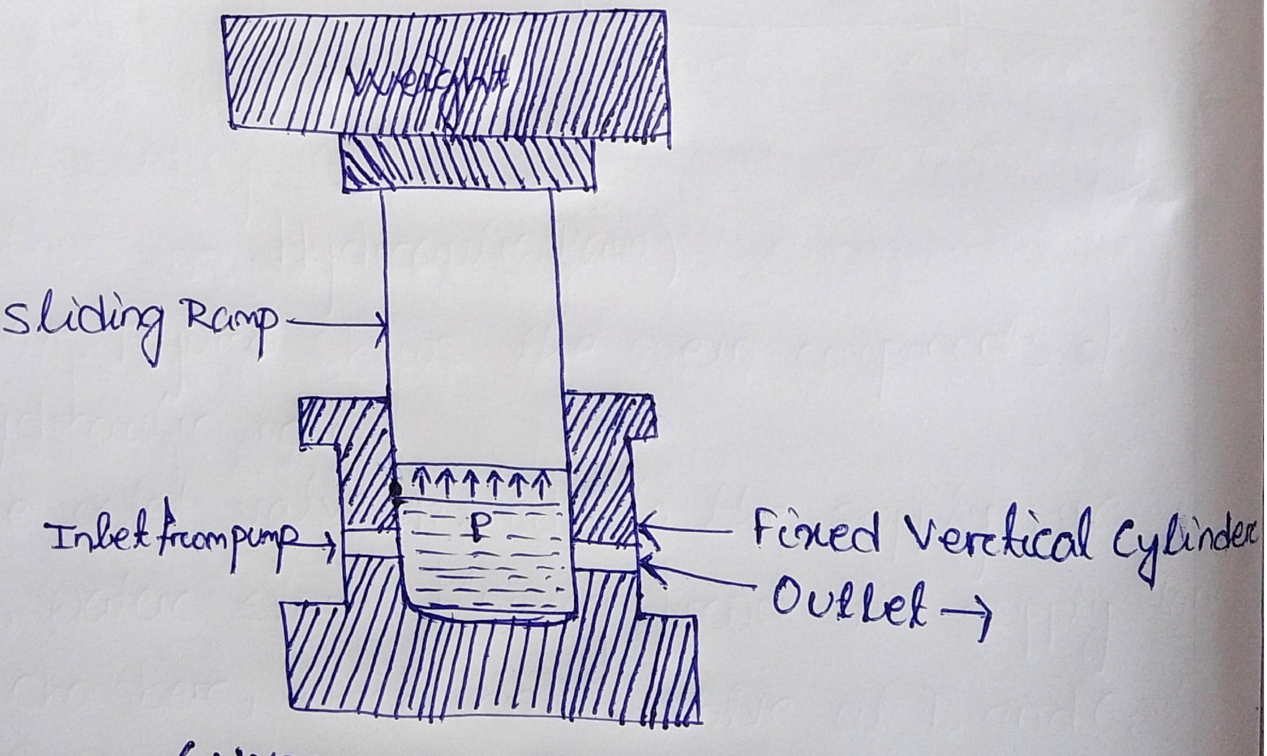
1) HYDRAULIC ACCUMULATOR:-

→ It is a device used for storing the energy of a liquid in the form of pressure energy.

→ In case of Hydraulic lift or Hydraulic crain. A large amount of energy is required when lift or crain is moving upward.

→ This energy is supplied from the Hydraulic Accumulator.

→ When the lift is moving in the downward direction. No external energy is required and at that time the energy from the pump is stored in the Accumulator.



(HYDRAULIC ACCUMULATOR)

→ The above figure shows a Hydraulic Accumulator which consist of fixed vertical cylinder containing a sliding ram.

→ A heavy weight is placed on the ram and the inlet of cylinder is connected to the pump, which continuously supply water under pressure to the cylinder.

→ The outlet of the cylinder is connected to the machine which may be lift or crain.

→ The ram is at the lower most position at the begining.

→ The pump supply is water under pressure continuously.

→ If the water under pressure is not required by the machine (Lift or Crain).

→ The water under pressure will be stored in the cylinder.

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

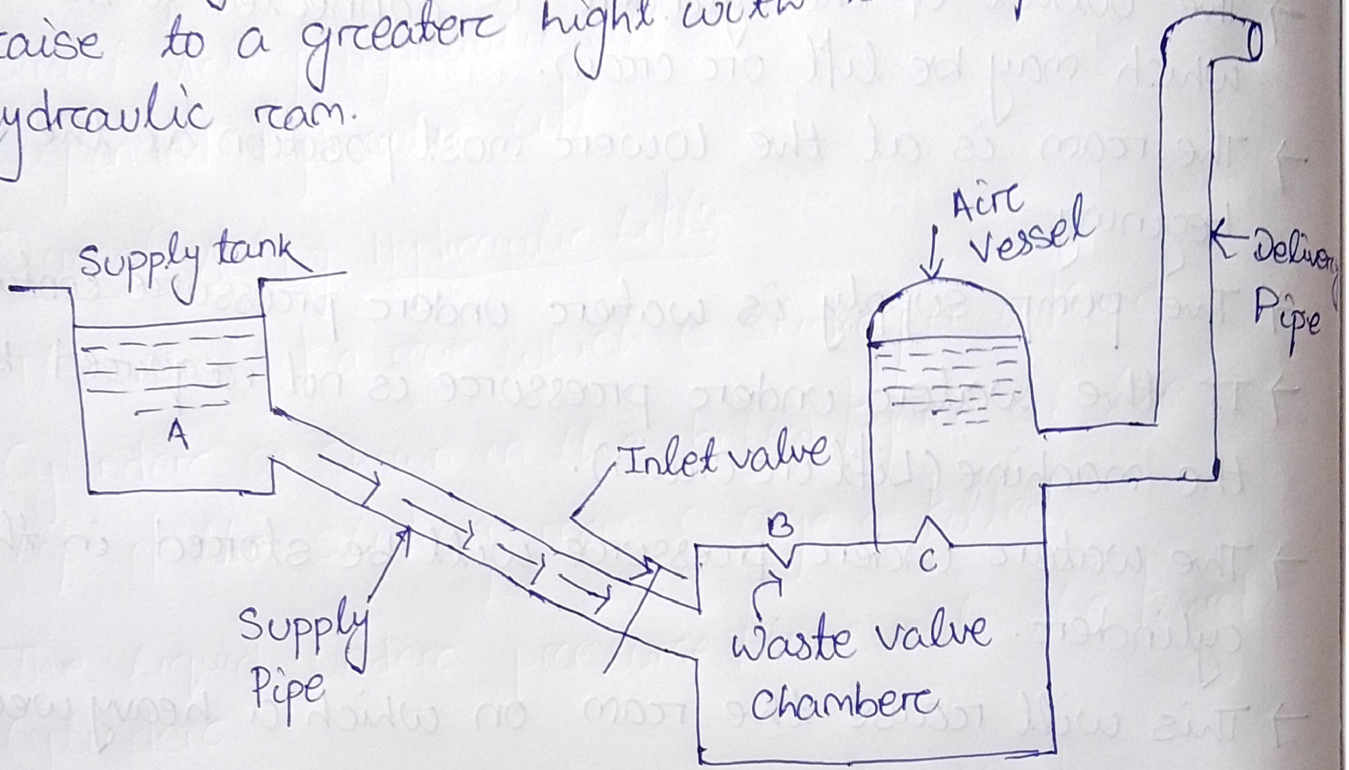
→ When the ram is at the uppermost position, the cylinder is full of water and the accumulator has to stored the maximum amount of pressure energy.

→ When the machine (Lift or Crain) required a large amount of energy, the Hydraulic Accumulator will supply this energy and ram will move in the downward direction.

HYDRAULIC RAM:-

→ The hydraulic ram is a pump which raises the water without any external power for its operation.

→ When large quantity of water is available at a small height a small quantity of a water can be raise to a greater hight with the help of hydraulic ram.



(Figure of Hydraulic Ram)

→ The above figure shows the mein components of the hydraulic ram.

→ When the inlet valve fitted to the supply pipe is open, water starts flowing from the supply tank to the chamber, which has 2 valve at B and C.

→ The valve B is called waste valve and the valve C is called the delivery valve.

→ The valve C is fitted to an air vesel. As the water is coming into the chamber from the supply tank the level of water raise in the chamber and the waste valve be starts moving upward.

→ A stage comes, when the waste valve B Suddernly closes.

→ This suddern closer of waste valve creates high pressure inside the chamber.

→ This high pressure force opens the delivery valve C

→ The water from the chamber enters the air vessel and compresses the air inside the air vessel.

This compressed air exerts force on the water in the air vessel at small quantity of water is raised to a greater height.

Hydraulic Lift:-

→ The Hydraulic lift is a device used for carrying passenger or goods from one floor to another floor in a building.

→ The Hydraulic are of two types

1) Direct Acting Hydraulic lift

2) Suspended Hydraulic lift

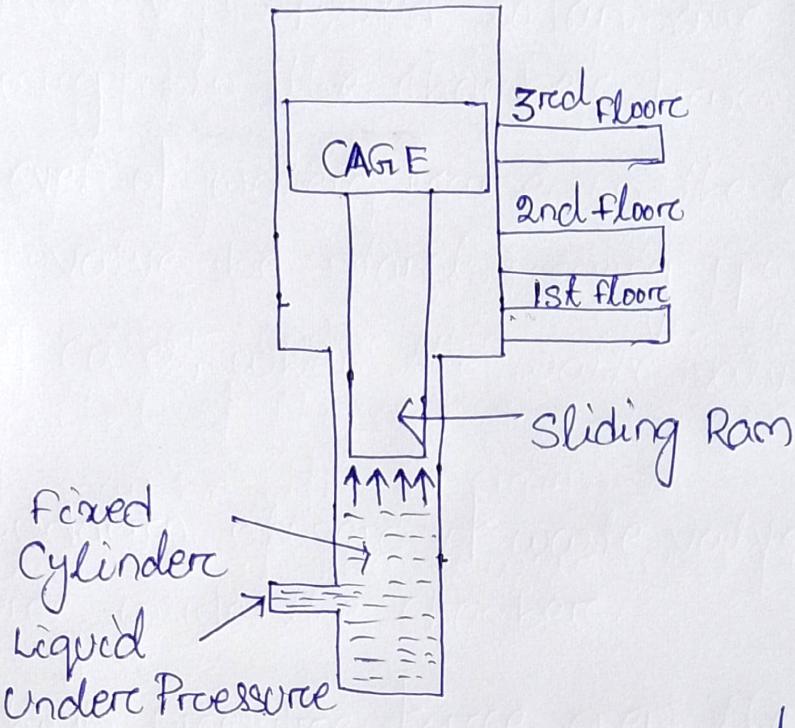
1) Direct Acting Hydraulic Lift:-

→ It consist of a ram which is sliding in a fixed Cylinder as shown in the below figure at the top of the sliding ram a cage is fitted.

→ The liquid under pressure flows into the fixed cylinder.

→ This liquid under pressure exerts the force on the sliding ramp, which moves vertically of and thus raises the cage to the required height.

→ The cage is moving in the downward direction by removing the liquid from the fixed cylinder.



(Direct Acting Hydraulic Lift)