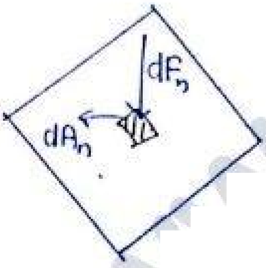
Fluid static

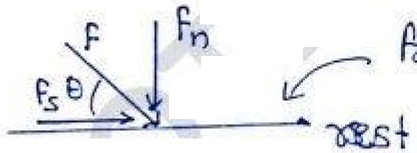
Pressure Measurement:-

Pressure :- Normal force per unit area exerted by the fluid known as pressure.

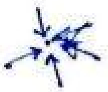
pressure is compressive in nature as per the pascal when the fluid is at rest the pressure has no direction i.e. infinite direction. so pressure is scalar in nature.

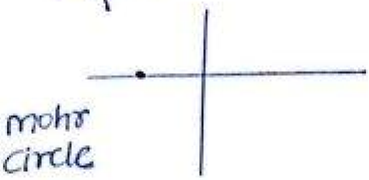


$$P = \frac{dF_n}{dA} \quad N/m^2 = Pa$$



$P = (-\sigma)$ $\tau = 0$





$\tau = 0$

$F_n = F\sin\theta$

$F_s = F\cos\theta$

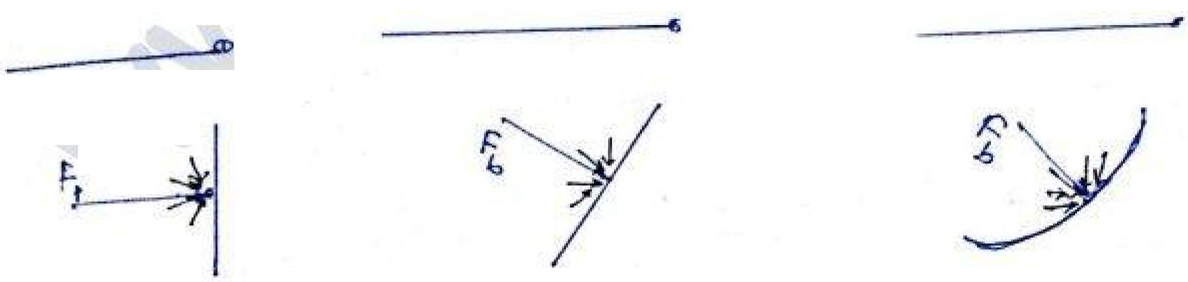
{ it is not necessary that there will be no shear stress but shear stress must be 0

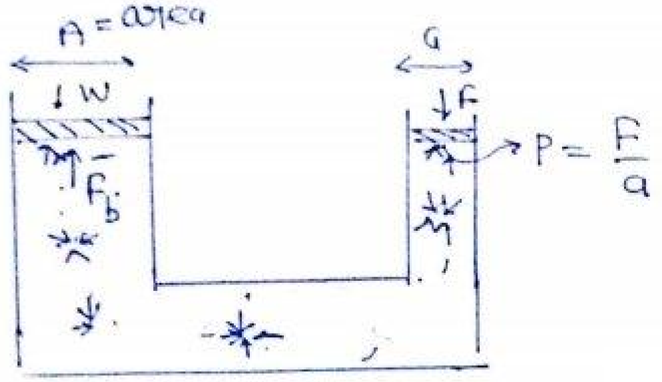
free surface $\tau = 0$

$F_s = 0$, $\cos\theta = 0$

$\theta = 90^\circ$

+ Always act $\perp^{r}$





$F_p = P \times A$

$F_p = W$

$P \times A = W$

$\frac{F}{a} \times A = W \Rightarrow \frac{W}{F} = \frac{A}{a}$

$A > a$

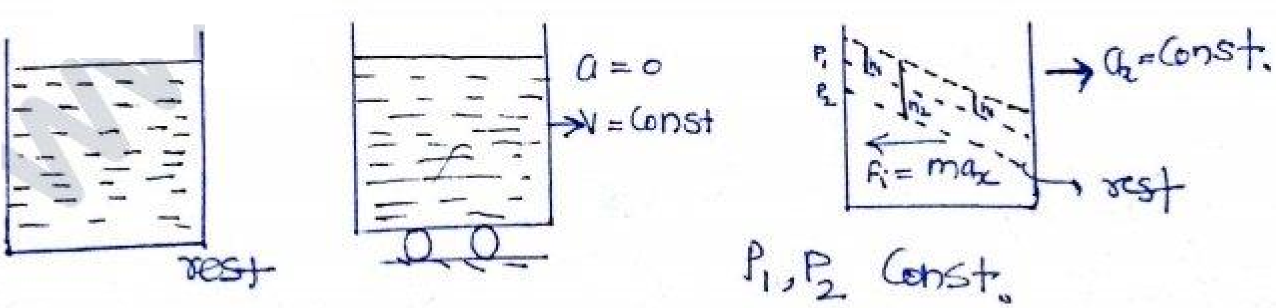
$\boxed{W > F}$

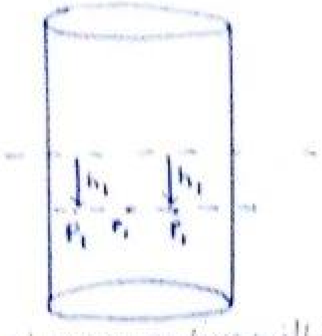
Validity of Pascal's law:-

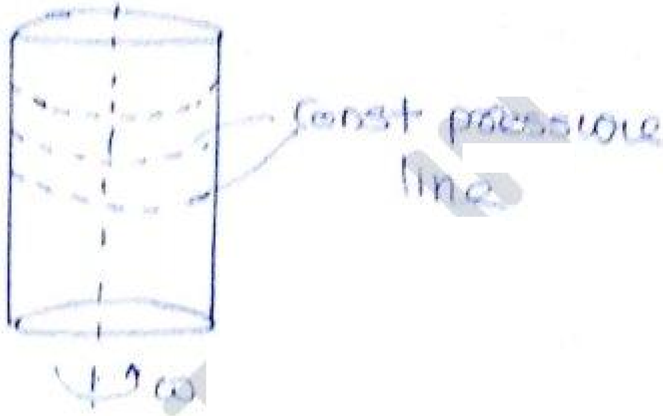
(i) It is valid for compressible, incompressible, viscous, non viscous fluid but the fluid must be at rest.

(ii) If the fluid in a container, container is moving with constant velocity, uniform acc^n and constant angular velocity.

iii) Fluid is ideal.







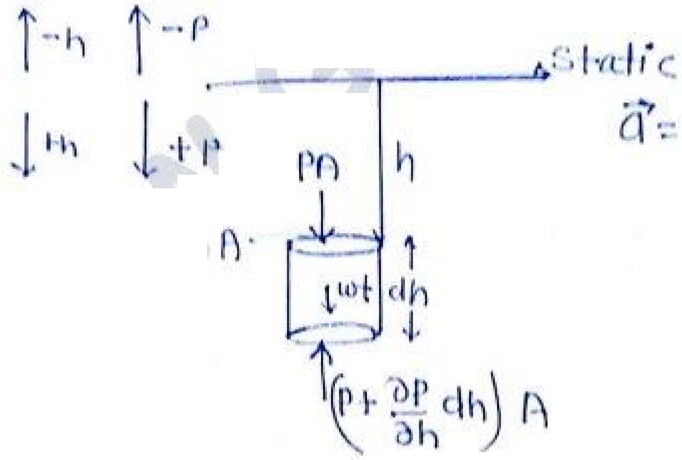
Pressure at every radius will be same

$P \neq f(r)$

$P = f(z)$

Hydrostatic Load:-

our convention



$\vec{a} = 0$

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$

$\quad\quad\downarrow\quad\quad\downarrow\quad\quad\downarrow$

$\quad\quad 0 \quad\quad 0 \quad\quad 0$

$$\Sigma F_{net} = m a_z \rightarrow 0$$

$$PA + wt - \left(P + \frac{\partial P}{\partial h} dh\right) A = 0$$

$$PA + \rho\omega \times A dh - PA - \left(\frac{\partial P}{\partial h}\right) A dh$$

*
$$\boxed{\frac{\partial P}{\partial h} = \omega = \rho g}$$

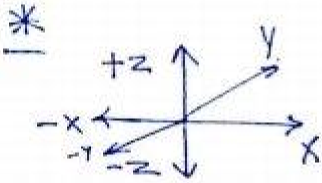
in-compressible fluid

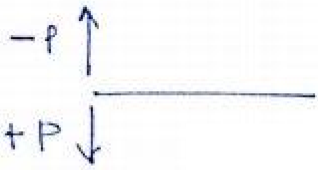
$\rho \neq f(P)$

$$\boxed{dP = \rho g\, dh}$$

$$dP \propto dh$$

*





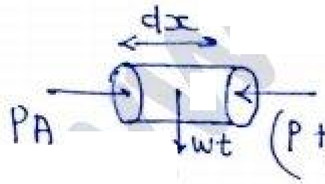
$$dP \propto (-)dz$$

$\downarrow$ +ve $\qquad$ $\downarrow$ -(-ve)

$$dP = -\omega\, dz$$

$$\boxed{\frac{dP}{dz} = -\omega = -\rho g}$$

*



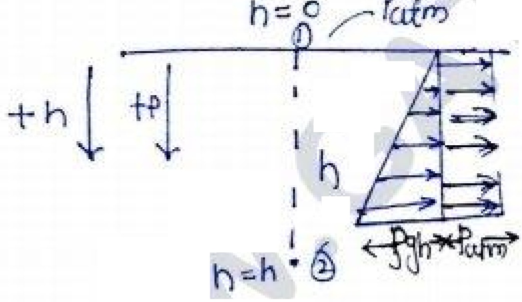
$$(P + (\frac{\partial P}{\partial x})dx)A$$

$$PA - \left(P + \left(\frac{\partial P}{\partial x}\right)dx\right)A = 0$$

$$\frac{\partial P}{\partial x} = 0$$

Pressure remains constant at Detum.

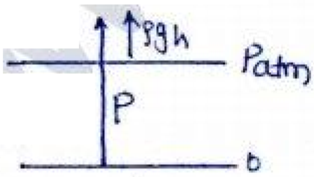
*



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

incompressible flow

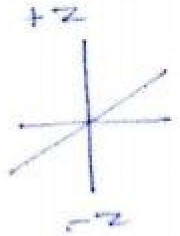
$$\frac{1}{\rho}\int_{P_{atm}}^{P} dP = g\int_{0}^{h} dh$$

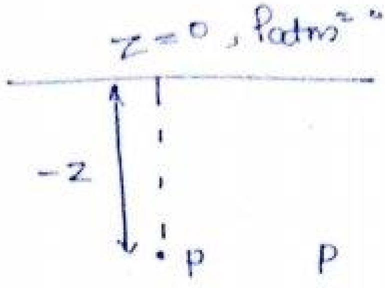


$$\boxed{P = P_{atm} + \rho g h}$$ Absolute

$$\boxed{P = \rho g h}$$ Gauge. $(P_{atm} = 0)$

*





$$\frac{dp}{dz} = -\omega \Rightarrow \int_0^p dp = -\rho g \int_0^{-z} dz$$

~~$P = \rho g h$~~ ~~$P = \rho g h$ Gauge~~

$P = \rho g z$ Gauge pressure

Gas (in Compressible fluid)

$$dP = \rho g \, dh$$

ideal Gas

$P = \rho R T$ (T → const.)

$\rho = \frac{P}{RT}$

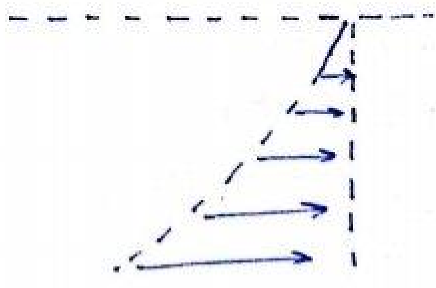
$$dP = \frac{P}{RT} g \, dh$$

$$\int_{P_{atm}}^{P} \frac{dP}{P} = \int_0^{+h} \frac{g}{RT} \, dh$$

$$\ln\left(\frac{P}{P_{atm}}\right) = +\frac{gh}{RT}$$

**

$$\boxed{P = P_{atm} \, e^{gh/RT}}$$



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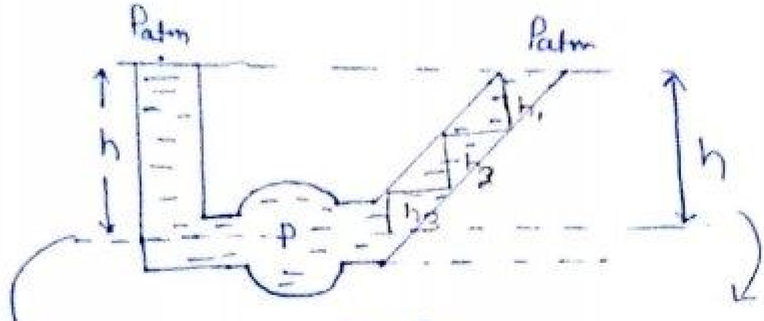


$h_1 + h_2 + h_3 = h$

$P > P_{atm}$

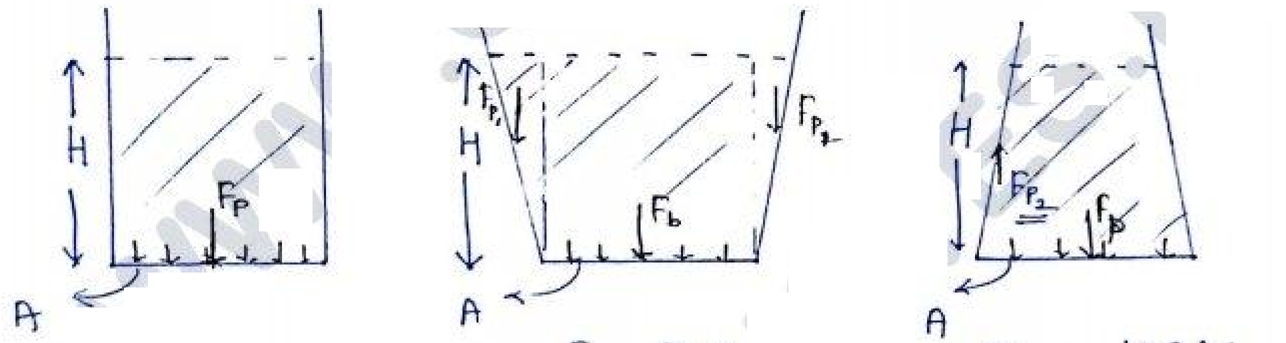
$P_{atm} + \rho g h = P$

$P_{atm} + \rho g (h_1 + h_2 + h_3) = P$

$P_{atm} + \rho g h = P$

Pressure remain same on detum.

Hydrostatic Paradox:-



$Wt = w \times Vol.$

$Wt = wAH (\downarrow)$

$F_b = PA = \rho g H A (\downarrow)$

$F_b = P \times A$

$= wHA$

$Wt > F_b$

$\overset{\downarrow}{F_{p_1}} + \overset{\downarrow}{F_b} = Wt$

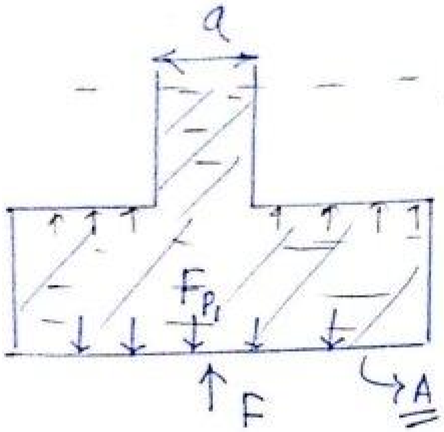
$F_p = wAH$

$Wt < F_p$

$Wt = \overset{\downarrow}{F_p} - \overset{\uparrow}{F_{p_2}}$

* Hydrostatic force depands on the depth of container and surface area only for the given fluid.

Q.3

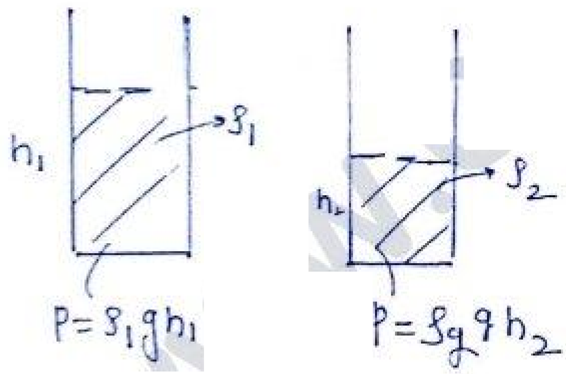


$F_{P_2} = \rho g H(A - a)$

$F_{P_1} = F$

$F = \rho g H A$ Ans

Conversion of one liquid coloumn to another:-



$P = P$

$\rho_1 g h_1 = \rho_2 g h_2$

$\rho_1 h_1 = \rho_2 h_2$

$$h_2 = \frac{\rho_1}{\rho_2} h_1$$

$\rho_1 g h_1 = \rho_2 g h_2$

$w_1 h_1 = w_2 h_2$

$$h_2 = \frac{w_1}{w_2} h_1$$

$\frac{\rho_1 h_1}{\rho_w} = \frac{\rho_2 h_2}{\rho_w}$

$S_1 h_1 = S_2 h_2$

$$h_2 = \frac{S_1 h_1}{S_2}$$

if $S_2 = 1$ (water.)

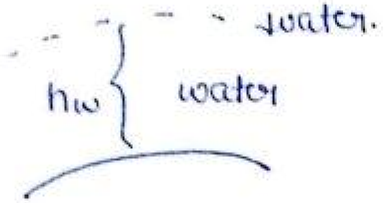
$h_2 = S_1 h_1$

Atmospheric Pressure:

The pressure exerted by the environmental mass on earth surface is known as atmospheric pressure.

$P_{atm} = 101.325\ kPa$

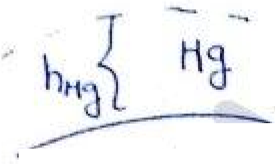
$P_{atm} = 101.325\ kPa$



$w_w h_w = P_{atm}$

$9810 \times h_w = 101.325 \times 10^3\ Pa.$

$h_w = 10.3\ m$ of water



$w_{Hg} h_{Hg} = 101.325 \times 10^3$

$$h_{Hg} = \frac{101.325 \times 10^3}{13.6 \times 9810}$$

$h_{Hg} = 760\ mm$ of Hg

$h_{Hg} = 76\ cm$ of Hg.

Units of Pressure:-

$P = \frac{F}{A}$ N/m^2 (S.I.)

$P_{atm} = 101.325 \times 10^3\ Pa$

$N/m^2 = Pa$

$10^3\ N/m^2 = kPa$, $10^6\ N/m^2 = MPa$

$P_{atm} = 101.325 \times 10^3 \, Pa = 101325 \times 10^5 \, Pa$

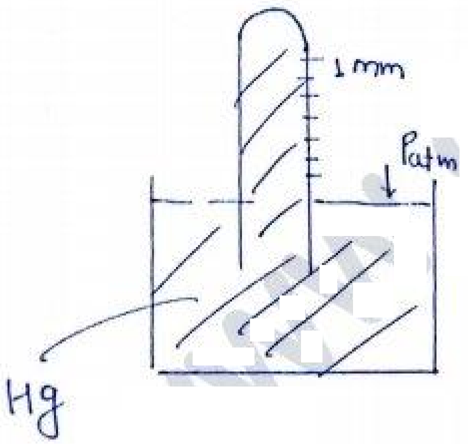
$\simeq 1 \times 10^5 \, Pa \simeq 1 \times 10^5 \, Pa$

$10^5 \, Pa = kgf/cm^2$ $10^5 \, Pa = 1 \, bar$

$1 \, atm = 1 \, bar$

$1 \, bar = kgf/cm^2$

Barometer. (By Torricelli)



$1 \, Torr = 1 \, mm \text{ of } Hg$

$1 \, Torr = 10^{-3} m \text{ of } Hg$

$= 10^{-3} \times 13.6 \times 9810$

$1 \, Torr = 133.33 \, Pa.$

F.P.S. (foot Pounds sec.)

$Psi = \frac{Lbf}{(inch)^2}$ → Pounds Force

Psi → Pounds force per sq. inch

$Lbf = 0.453 \, kgf$

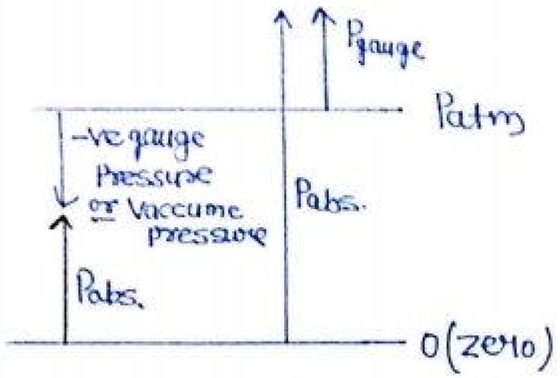
$Lbf = 0.453 \times 9.81 \, N$

$inch = 2.54 \, cm$

$1 \, atm = 14.7 \, Psi$

Absolute Pressure, Gauge Pressure, -ve gauge Pressure

Vaccume pressure.



eq -30 KPa

30 KPa Vaccume

30 KPa (-Ve gauge pressure)

There may be positive gauge pressure or negative gauge pressure but there can not be negative absolute pressure.

Gauges are callibrated as per their local envt.

Pressure measure from atmospheric pressure is gauge pressure and pressure ~~pre~~ measured from zero pressure is absolute pressure.

Classification of pressure measurment device.

① on the basis of liq. Column deflection (Manometers)

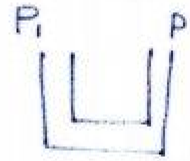
(i) simple manometers

(a) Piezometers

(b) U-tube manometer

(c) single column manometers

(ii) Differential Manometers



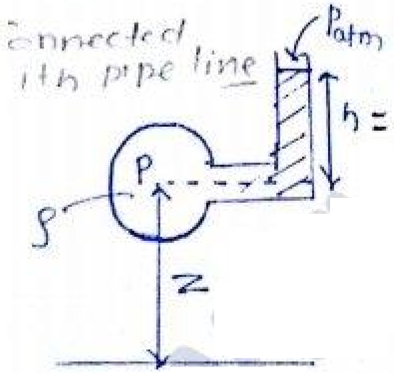
(a) U-tube differential manometer

(b) Inverted tube manometer.

② on the basis of Elastic properties.
(Mechanical Gauge)
⇓
Bourdum tube Gauge

Piezometers:- It is the simple manometer it one end open to atmosphere and another end is connected where pressure is to measure.

Disadvantages: (i) Can not measure Gases pressure
(ii) Can not measure vaccume pressure
(iii) Gives large deflection at high pressure for lighter liquids so moderate pressure should be measure.



$P - \rho g h = P_{atm}$

$P = P_{atm} + \rho g h$ → Abs.

$P_{atm} = 0$

$P = \rho g h$ Gauge

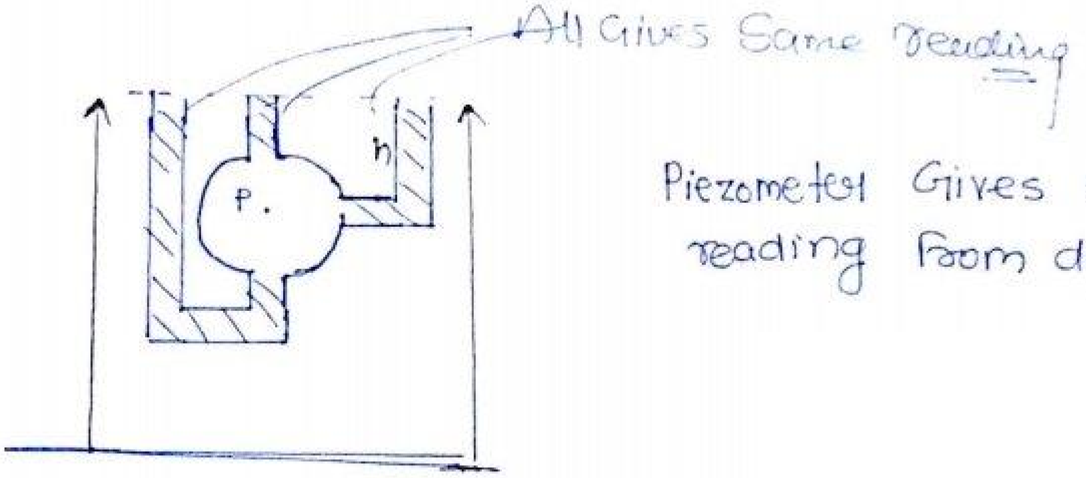
$P = \omega h$

$h = \frac{P}{\omega}$

✻ Piezometric head $= \frac{P}{\omega} + Z$

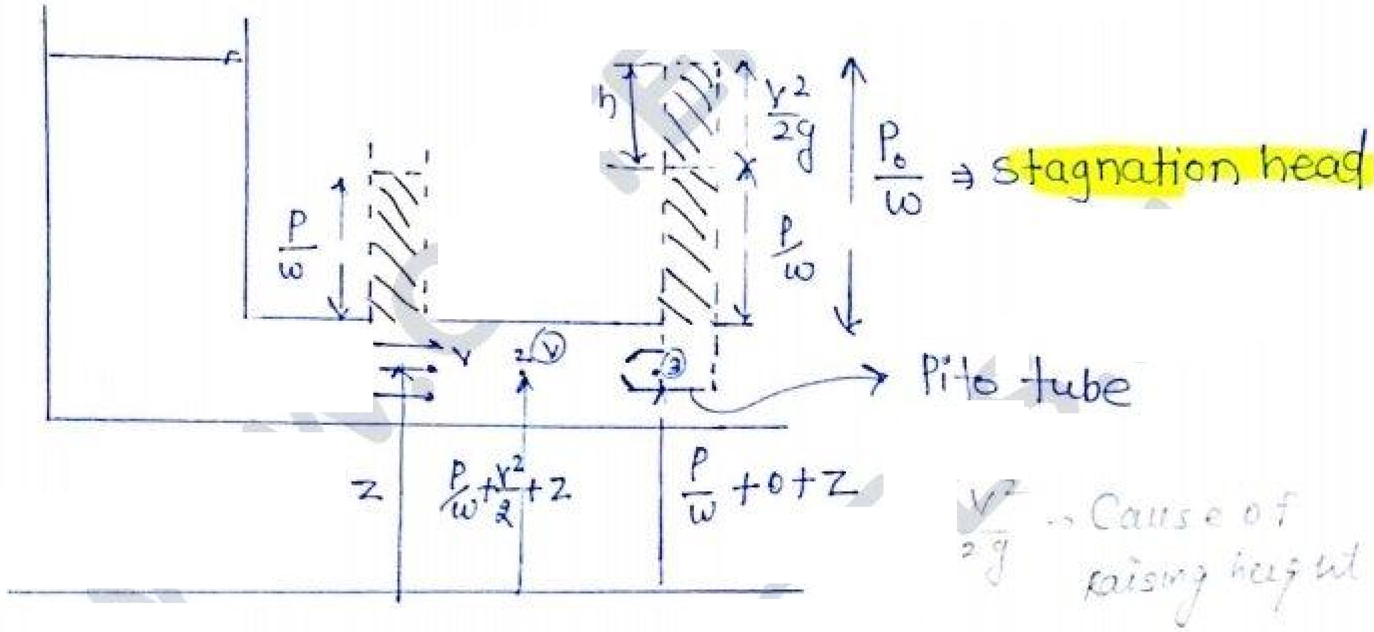
$\frac{P}{\omega}$ → static head

Z → datum head



Piezometer Gives same reading from detum

||*



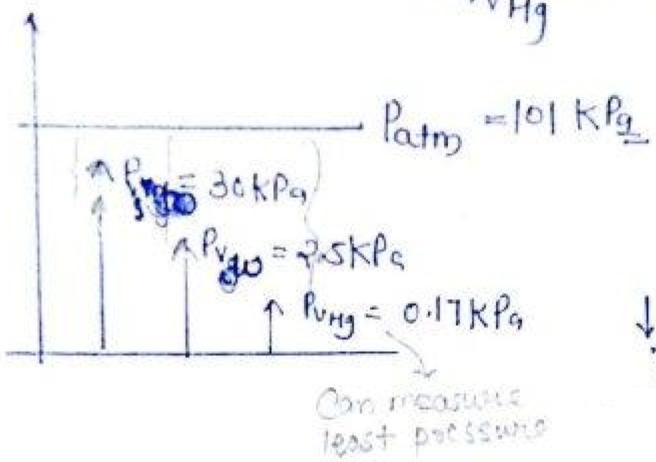
$$h = \frac{V^2}{2g} \Rightarrow V = \sqrt{2gh}$$

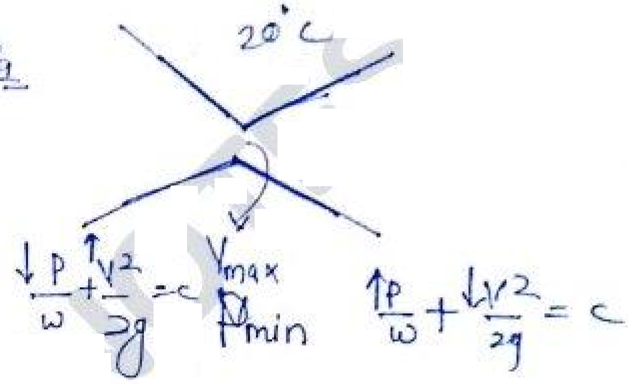
Vapour Pressure: → Pressure excerted (partial pressure) by the saturated vapour in the close container on the liquid surface at given temprature is known as saturated vapour pressure.

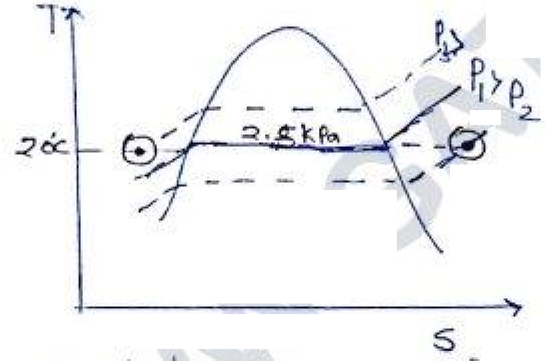
at 20°C $P_{V_{water}} = 2.5$ KPa

100°C $P_{V_w} = 100$ kPa $\simeq$ 1 atm at 20°C Gasoline $P_{V_g} = 30\,kPa$

Hg $P_{V_{Hg}} = 0.17\,kPa$







→ at 20° above P-Vapour sat liquid

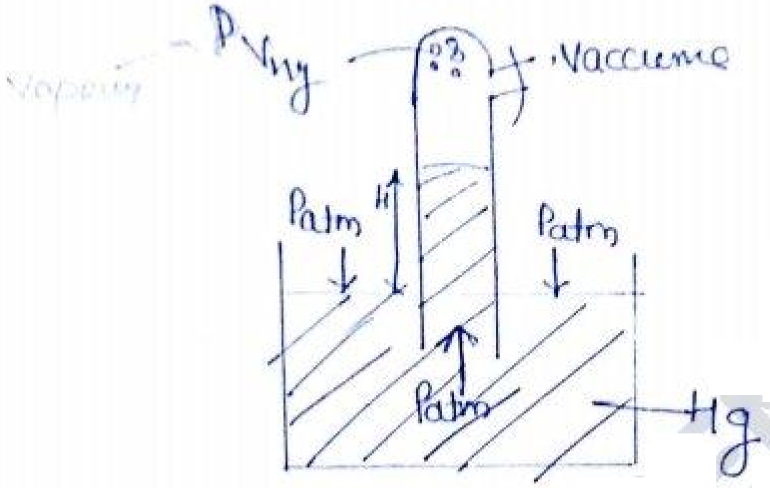
→ at 20° below P-Vapour saturated steam.

* at const. temp if P below P_{vapour} then fluid (hg, water) evaporate & bubble formes

Cavitation:– In the fluid if the abs pressure of fluid becomes less than corrosponding temp. vapour pressure the bubbles are formed and if these bubbles carries in a region of high pressure the bubbles gets collapse the pitting, cavitation phinomena takes place it errod the surface.

eg. at succession side of pump, exit of reaction turbine etc.

Barometer:- it is an instrument which measure local atmospheric pressure



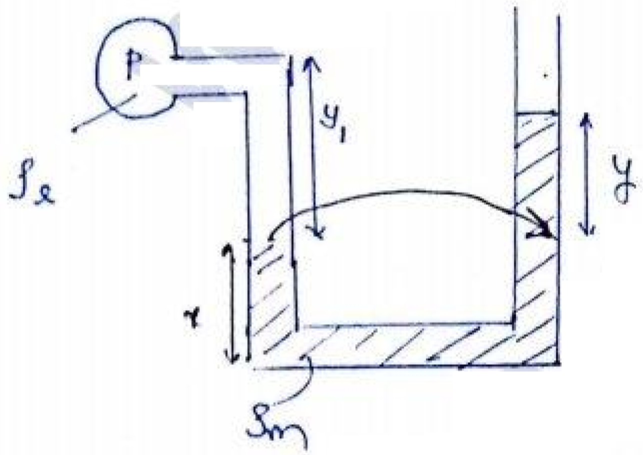
$$P_{V_{Hg}} + \omega_{Hg} H = P_{atm}$$

$P_{V_{Hg}} \to 0$

$$\boxed{P_{atm} = \omega_{Hg} H}$$

* Mercury (Hg) used in barometer because of high density and low vapour pressure.

U-Tube manometer:→



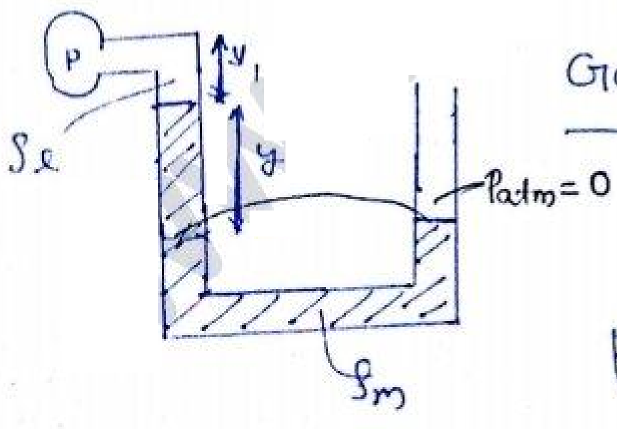
$$P + \rho_e g y_1 + \rho_m g x - \rho_m g x - \rho_m g y = P_{atm}$$

$$P = P_{atm} + \rho_m g y - \rho_e g y_1$$

↳ Absolute

$P_{atm} = 0$

$$\text{Gauge} \Rightarrow P = \rho_m g y - \rho_e g y_1$$

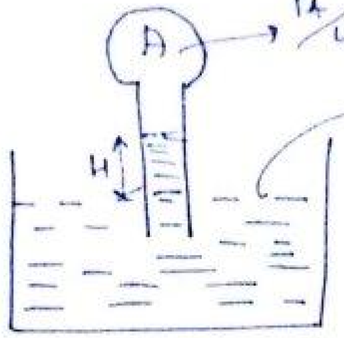


$$0 - \rho_m g y - \rho_e g y_1 = P$$

$$P = -\rho_m g y - \rho_e g y_1 \quad \text{Gauge}$$

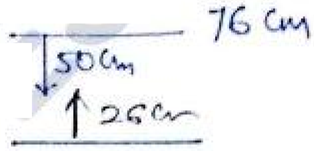
Q.~~3~~

Q.12



P_A/w = 50 Cm of Hg Vaccume (−50 Hg)

P_{atm}/w = 76 Cm of Hg



$$\frac{P_A}{w} + H = 76$$

Abs. pressure — $26 + H = 76$

$H = 50$ Cm of Hg Ans

or

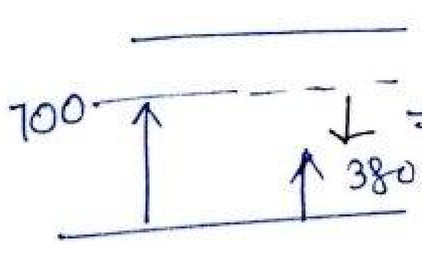
Consider Patm = 0

$0 - H = -50$ ⇒ Gauge

$H = 50$ cm

Q.13 P_{atm} = 762 mm of Hg

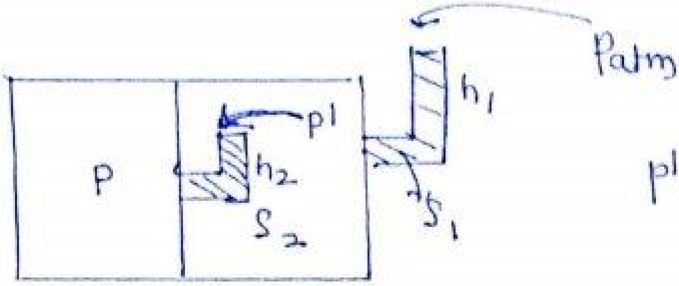
700 mm local envt. reading.



$(P)_{Vacc} = 700 - 380 = 320$ mm Hg Vaccume

Q.14

*

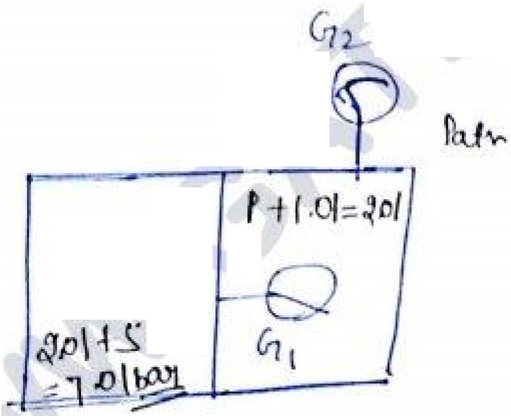


$p' = P_{atm} + \rho_1 g h_1$

$p = p' + \rho_2 g h_2$

$p = P_{atm} + \rho_1 g h_1 + \rho_2 g h_2$

Q. 19



$P_{G_1} = 5$ bar

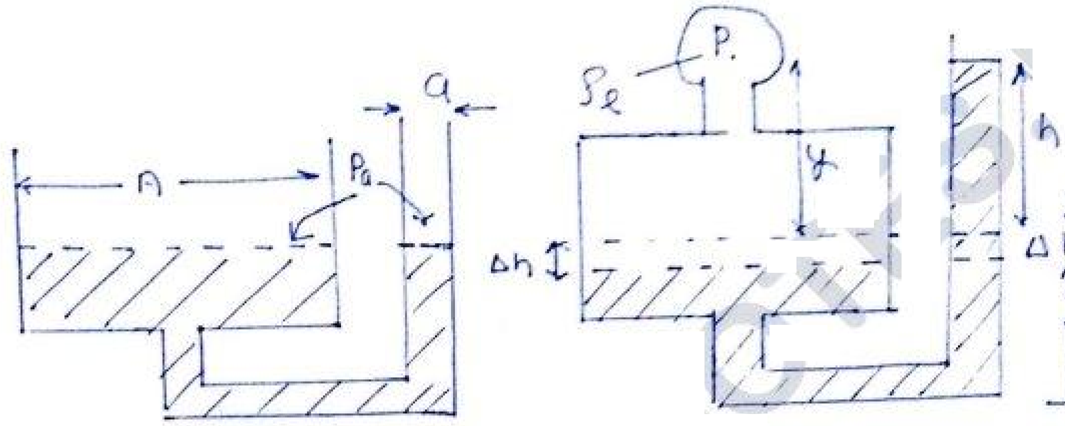
$P_{G_2} = 1$ bar

$P_{atm} = 1.01$ bar.

$p = 1.01 + 1 + 5$

$p = 7.01$ bar

Single Column manometer:-



$$A\Delta h = ah$$

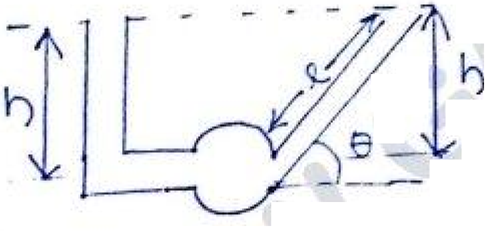
$$P + \rho_l g y + \rho_l g \Delta h - \rho_m g \Delta h - \rho_m g h = P_{atm}$$

Q14 $A = 500\,a$ error $= (h + \Delta h) - h$

$A \Delta h = a h$

$$\%\text{error} = \frac{\Delta h}{h} \times 100 = \frac{a}{A} \times 100 = \frac{100}{500} = \underline{0.2\%}$$

Sensitivity of manometer:→

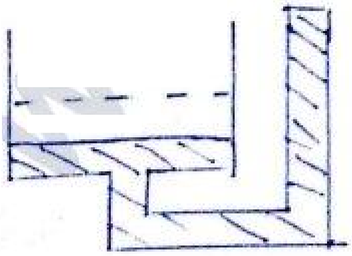


$l \sin\theta = h$

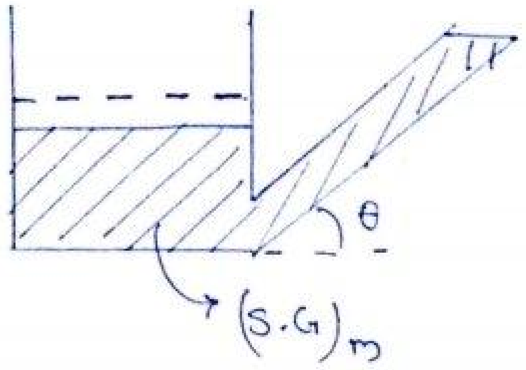
sensitivity $\left(S \propto \frac{l}{h}\right)$

$$S \propto \frac{1}{\sin\theta}$$

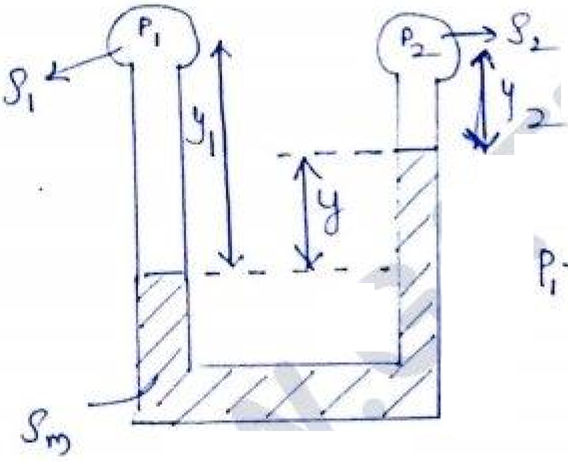
$\theta \downarrow \rightarrow \sin\theta \downarrow \rightarrow \underline{S \uparrow}$



$S \propto \frac{1}{(a/A)}$, $S \propto \frac{1}{(S.G)_m}$



For Differential manometer

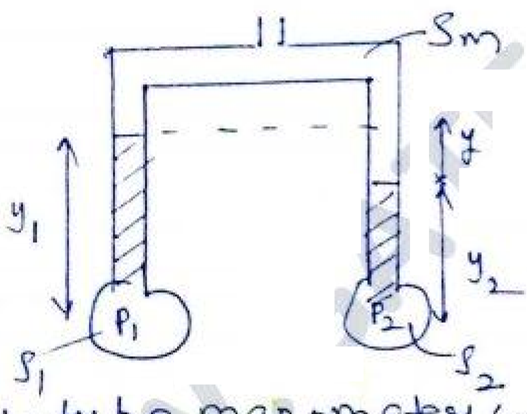


$$P_1 + \rho_1 g y_1 - \rho_m g y - \rho_2 g y_2 = P_2$$

$$P_1 - P_2 = \rho_m g y - \rho_1 g y_1 + \rho_2 g y_2$$

Inverted tube manometer

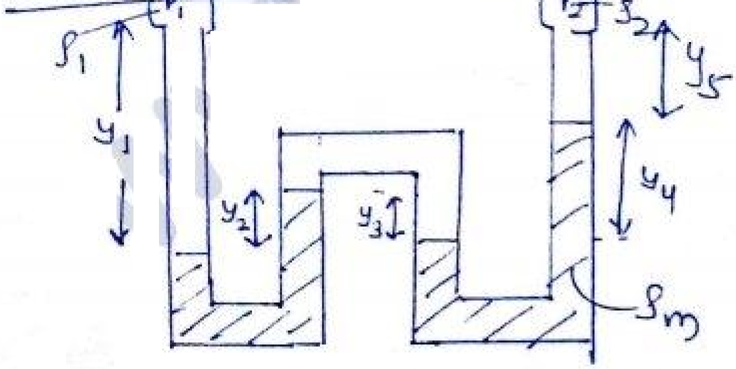
used ~~for~~ to measure low pressure diff.



$$P_1 - \rho_1 g y_1 + \rho_m g y + \rho_2 g y_2 = P_2$$

$$P_1 - P_2 = -\rho_m g y + \rho_1 g y_1 - \rho_2 g y_2$$

Multi U-tube manometer :- for high pressure diff



$$P_1 - P_2 = -\rho_1 g y_1 + \rho_m g y_2 - \rho_m' g y_3 + \rho_m g y_4 + \rho_2 g y_5$$