Pressure

$P = F/A = \frac{N}{m^2}$

$F = mg$

$F = \rho V g$

$P = F/A = \frac{\rho V g}{A}$

$P = \rho \left(\frac{V}{A}\right) g$

$P = \frac{\rho (A \cdot h) g}{A}$

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

1 atm = 760 mm of Hg

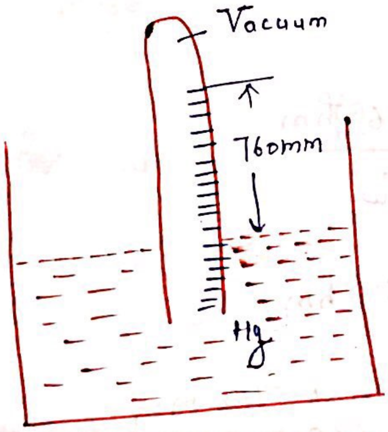
= 760 Torr

= 1 Bar

= 1×10^5 Pascal (N/m^2)

= 15 Psi

1 Pascal = 1 N/m^2



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

if $P_1 = P_2$

$\rho_{mercury} * g\, h_{mercury} = \rho_{water}\, g \cdot h_{water}$

$$\boxed{\rho_m h_m = \rho_w h_w}$$

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Q:

If in the barometer, mercury is replaced with water the liquid is going to raise upto ---- ?

$\rho_m = 13600 \ kg/m^3$

$\rho_m = 13.6 \times 10^3 \ kg/m^3$

$\rho_m = 13.6 \times 1000 \ kg/m^3$

$\rho_m = 13.6 \ \rho_w$ $\quad\quad$ $\rho_w = 1000 \ kg/m^3$

$$\therefore h_w = \frac{\rho_m h_m}{\rho_w}$$

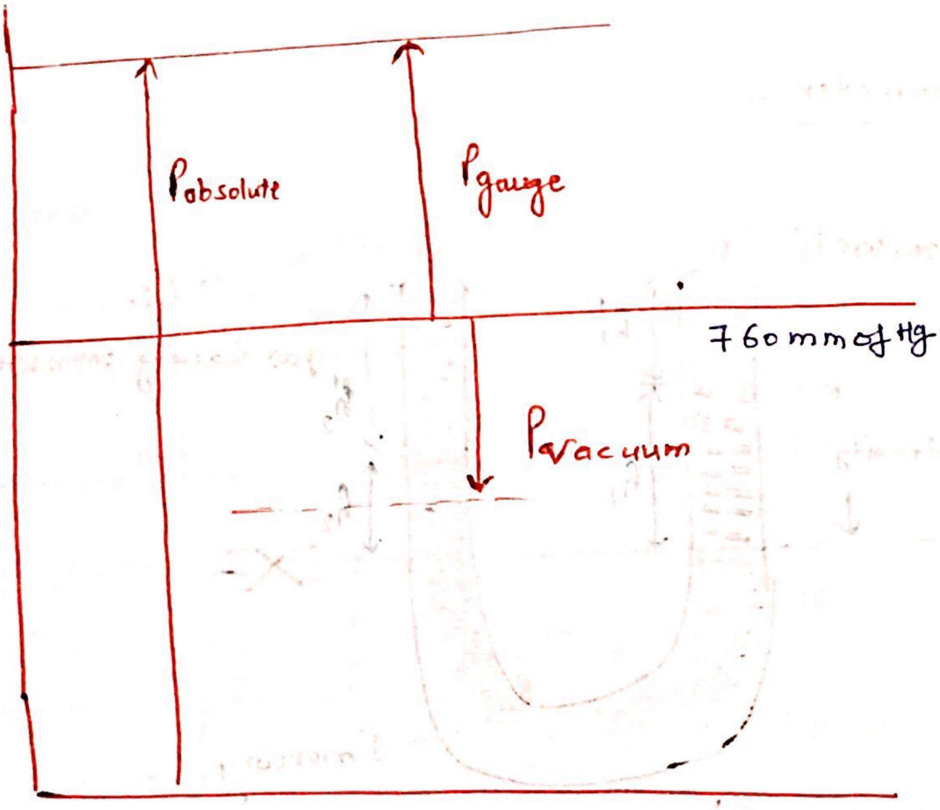
$$= \frac{(13.6 \rho_w) h_m}{\rho_w}$$

$$= 13.6 \ h_m$$

$= 13.6 * 760 \ mm$

$= 10336 \ mm$

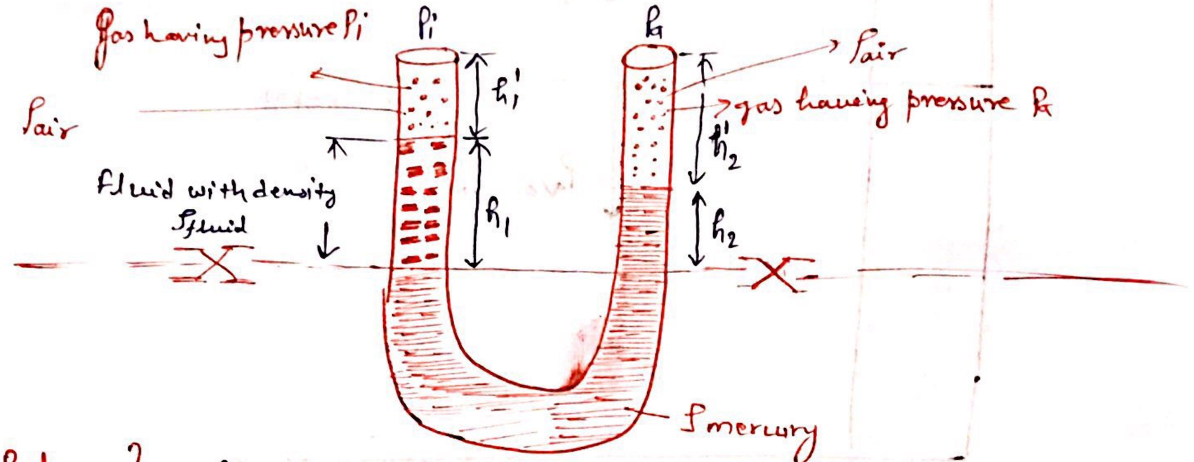
$= 10.336 \ meter$



$$P_{absolute} = P_{atm} + P_{gauge}$$

$$P_{absolute} = P_{atm} - P_{vacuum}$$

U-tube manometer –



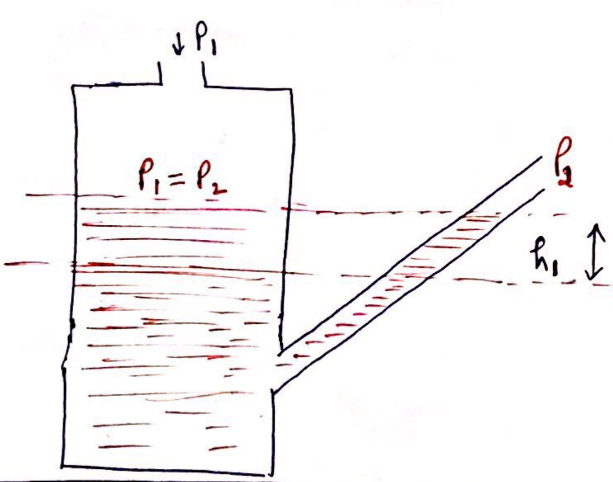
Balance at X–X $\Bigg\} \Rightarrow$ $P_i + \underline{\rho_{air}\, g\, h_1'} + \rho_{fluid}\, g\, h_1 = P_a + \underline{\rho_{air}\, g\, h_2'} + \rho_{mercury}\, g\, h_2$

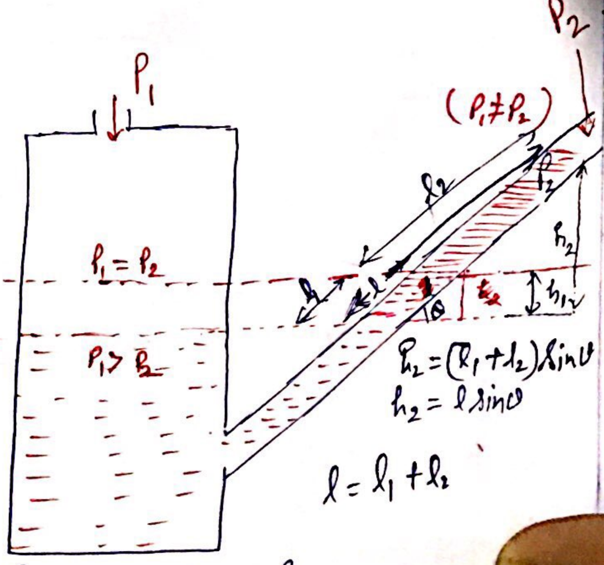
or $\quad P_i + \rho_{fluid}\, g\, h_1 = P_a + \rho_{mercury}\, g\, h_2$

$\Rightarrow \quad P_i + \rho_f\, g\, h_1 = P_a + \rho_m\, g\, h_2$

* We have neglected the $\rho_{air}\, g\, h_1'$ and $\rho_{air}\, g\, h_2'$. Because air density is very low.

Inclined manometer –





$h_2 = (l_1 + l_2)\sin\theta$

$h_2 = l\sin\theta$

$l = l_1 + l_2$

Volume $V_1 = V_2$

$A_1 * h_1 = A_2 * l_2$

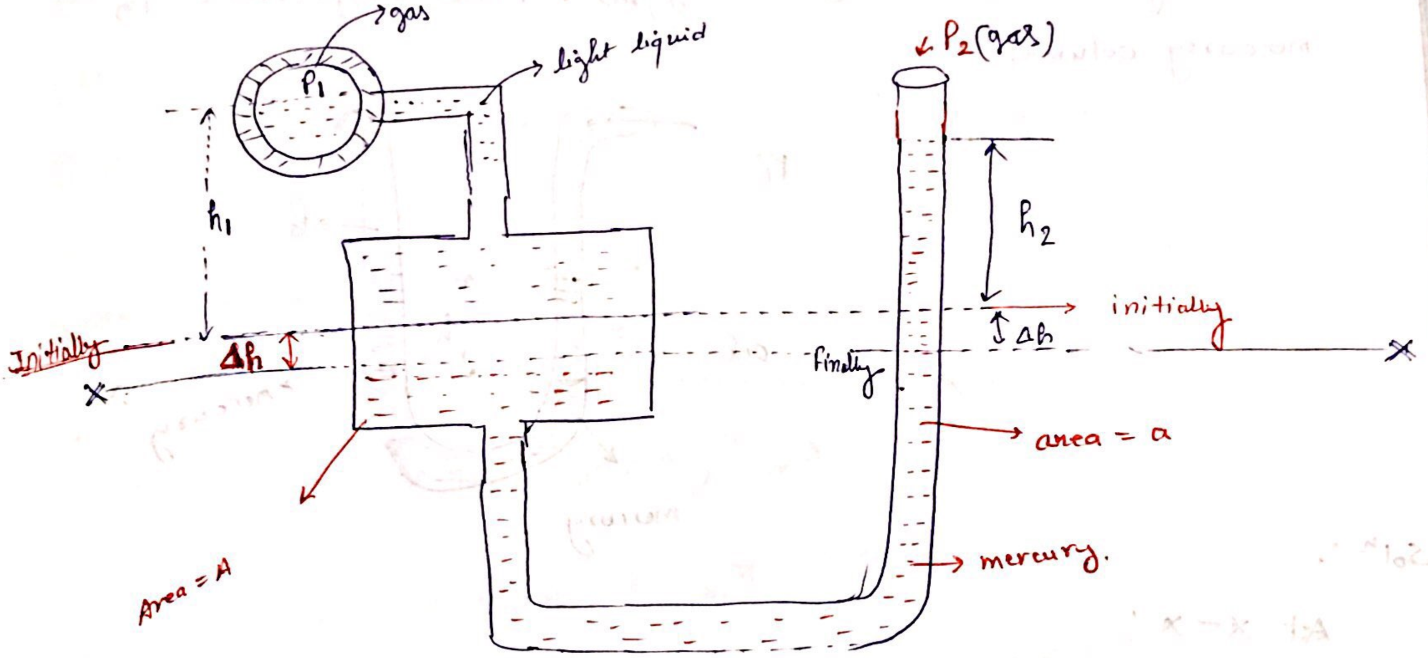
$P_1 = \rho g\, h_2 + P_2$

$P_1 = \rho g\, (l\sin\theta) + P_2$

$P_1 - P_2 = \rho\, g\, l\sin\theta$

$\boxed{\Delta P = \rho \cdot g\, l \sin\theta}$

Well type manometer -



$$A \cdot \Delta h = a \cdot h_2 \quad —①$$

[A = area of left well
a = area of right limb.]

$$\boxed{\Delta h = \frac{a h_2}{A}}$$

Balance equation at X-X line ⇒

$$P_1 + (h_1 + \Delta h) \cdot r_1 = P_2 + (h_2 + \Delta h) \cdot r_2$$

$$\begin{bmatrix} r_1 = \rho_1 g \\ r_2 = \rho_2 g \end{bmatrix}$$

$\boxed{\text{where } r = \text{specific weight} : r = \rho g}$

$$\text{Specific weight} = \frac{\text{Weight of fluid}}{\text{Volume of fluid}} = \frac{m \cdot g}{V} = \left[\frac{m}{V}\right] g \qquad (N/m^3)$$

$$\boxed{r = \rho g} \qquad [N/m^3]$$

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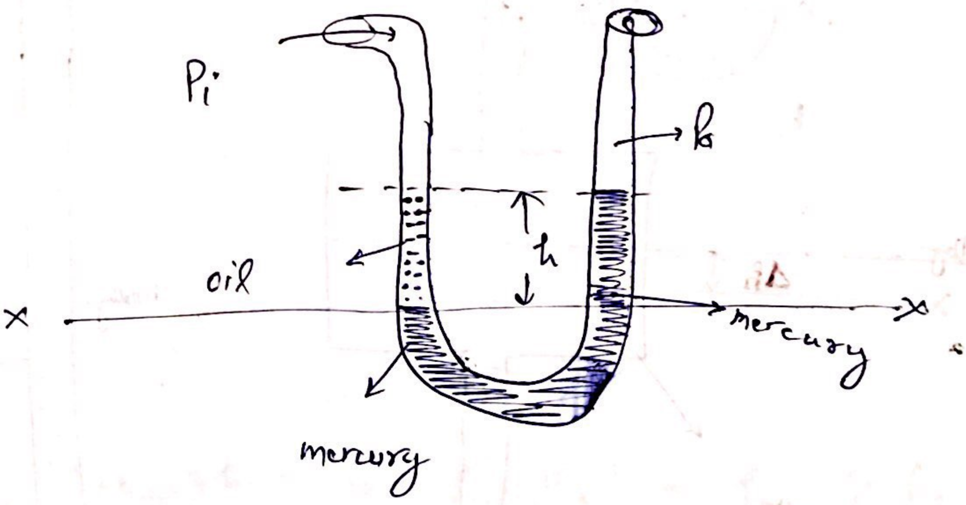
Q: An U-tube monometer is used to measure differential pressure of 100 KPa of oil with density 800 kg/m3. find defference in mercury column.



Solⁿ:

At x-x:

$$P_1 + \rho_{oil} g h = P_2 + \rho_{mercury} g h$$

$$P_1 - P_2 = g h(\rho_m - \rho_{oil})$$

$$\Delta P = 9.8 * h[13600 - 800]$$

$$100 \times 10^3 = 9.8 \times h * 12800$$

$$h = 0.797 m$$

$$\boxed{h = 80 cm}$$

Q. U tube monometer open at both ends and with 10 mm diameter of glass tube with mercury filled. if 20 $(cm)^3$ [20 CC] of water is added to one of the limbs then find the difference in mercury level.

water volume = 20 cc

$V_w = 20 \ cm^3$

$V_w = 20 \times (10^{-2})^3 \ m^3$

$V_w = 20 \times 10^{-6} \ m^3$

$V_w = \pi r^2 h$

$20 \times 10^{-6} = \pi * (5 \times 10^{-3})^2 \ h$

$\boxed{\therefore h_{water} = 25 \ cm}$

$\rho_{water} \ g \ h_{water} = \rho_{mercury} \ g \ h_{mercury}$

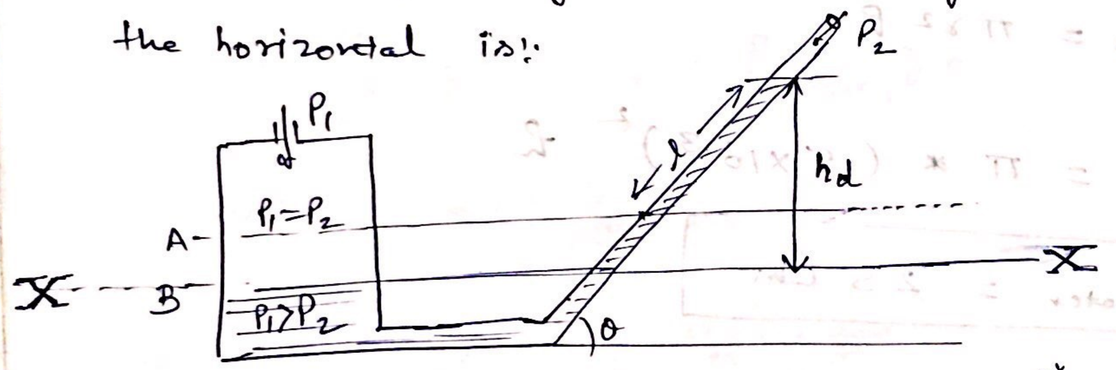
$\rho_w \cdot \cancel{g} \cdot 25 = \rho_m \ \cancel{g} \ h_{mercury}$

$\rho_w \cdot 25 = [13.6 \ \rho_w] \ \rho_{mercury}$

$h_{mercury} = \frac{25.0}{13.6} = 1.8 \ cm$

$\boxed{\text{height for mercury} = 1.8 \ cm}$

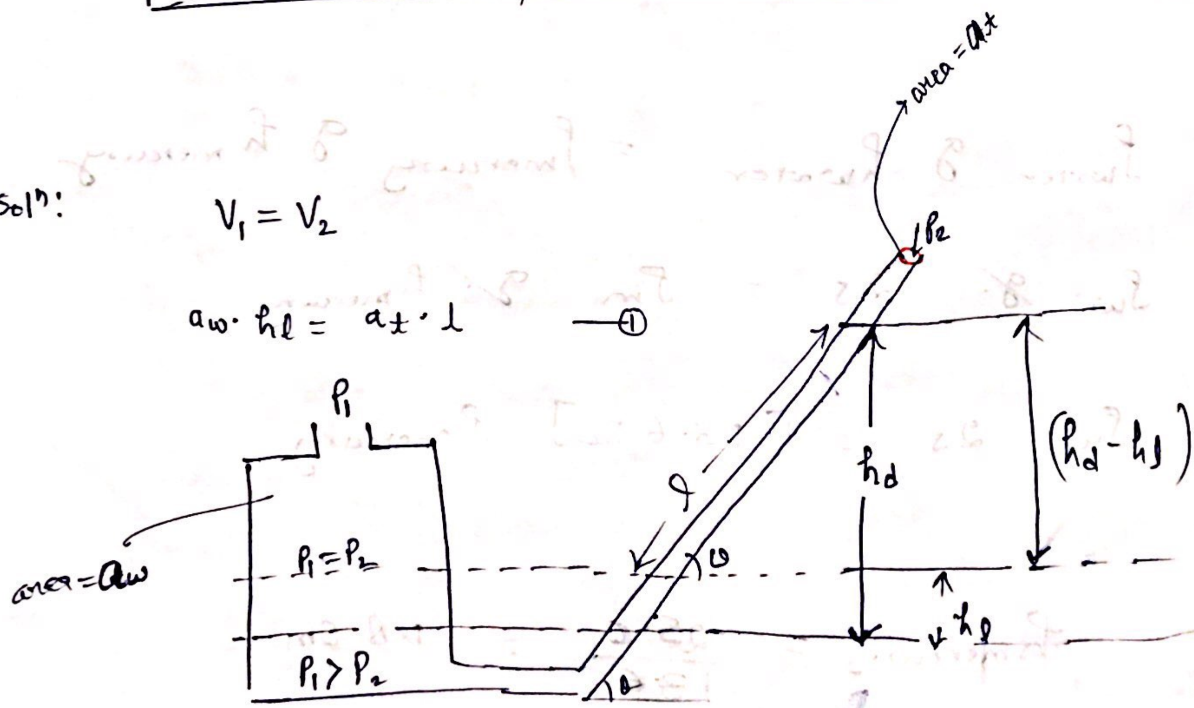
Q: A well of cross section area 'a_w' is connected to an inclined tube of cross section area 'a_t' to form a differential pressure gauge as shown in figure below. When $P_1 = P_2$ the common liquid level is denoted by A, when $P_1 > P_2$, the liquid level in the well is depressed to B, and the level in the tube rises by l along its length such that difference in the tube and well levels is h_d. The angle of inclination θ of the tube with the the horizontal is:



Soln:

$$V_1 = V_2$$

$$a_w \cdot h_l = a_t \cdot l \quad \text{—①}$$

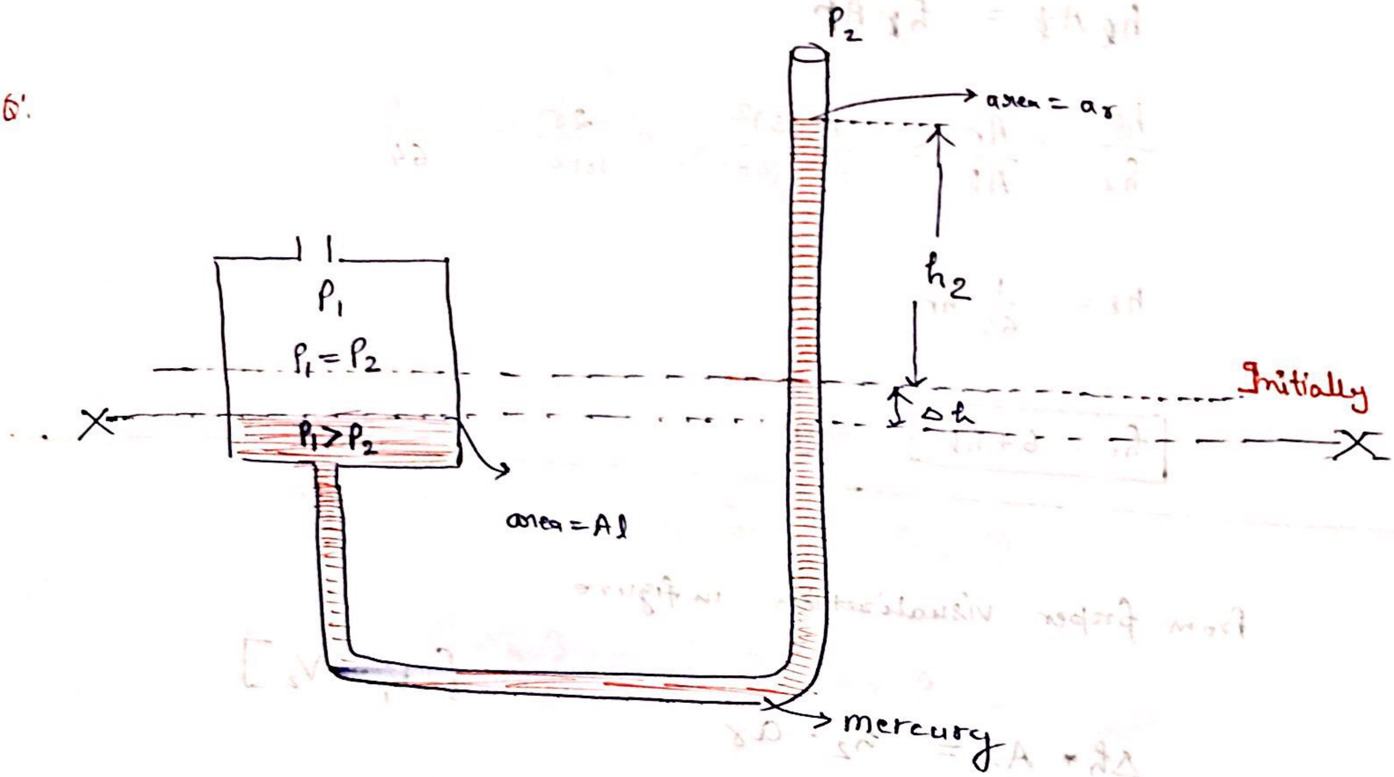


$$\sin\theta = \frac{h_d - h_l}{l}$$

$$\theta = \sin^{-1}\left[\frac{h_d}{l} - \frac{h_l}{l}\right]$$

$$\theta = \sin^{-1}\left[\frac{h_d}{l} - \frac{a_t}{a_w}\right] \qquad \left[\because \frac{h_l}{l} = \frac{a_t}{a_w}\right]$$

Q.



mercury manometer is shown above. Pressure is applied on left limb and mercury movement is taken in right limb. The diameter of left and right limbs respectively are 80mm and 10mm. Find the rise of mercury in the right limb for applied pressure of 85 KN/m².

Soln.

At balance : X − X :

$$P_1 = P_2 + (h_2 + \Delta h)\rho_m g$$

$$P_1 - P_2 = (h_2 + \Delta h)\rho_m g$$

$$\Delta P = (h_2 + \Delta h)\rho_m g \quad \text{---} (1)$$

$$85\times10^3 = (h_2+\Delta h) * 13.6\times1000 \times 9.8$$

$$\therefore \boxed{h_2 + \Delta h = 0.637 \text{ meter}}$$

$$[V_1]_{\text{Left limb}} = [V_2]_{\text{Right limb}}$$

$$h_l A_l = h_r A_r$$

$$\frac{h_l}{h_r} = \frac{A_r}{A_l} = \frac{\pi(5)^2}{\pi(40)^2} = \frac{25}{1600} = \frac{1}{64}$$

$$h_l = \frac{1}{64} h_r$$

$$\boxed{h_r = 64 h_l} \quad \text{---} (1)$$

---

from proper visualization in figure

$$\Delta h * A_l = h_2 \cdot a_r \qquad [V_1 = V_2]$$

$$\frac{\Delta h}{h_2} = \frac{a_r}{A_l} = \frac{\pi(5)^2}{\pi(40)^2} = \frac{1}{64}$$

$$h_2 = 64\,\Delta h \quad \text{---} (2)$$

from eq^n (1) and (2)

$$h_2 + \frac{h_2}{64} = 0.637$$

$$h_2\left[\frac{65}{64}\right] = 0.637$$

$$h_2 = \frac{64}{65} \times 0.637 = 0.6272 \text{ meter}$$

$$\boxed{h_2 = 0.6272 \text{ meter}}$$

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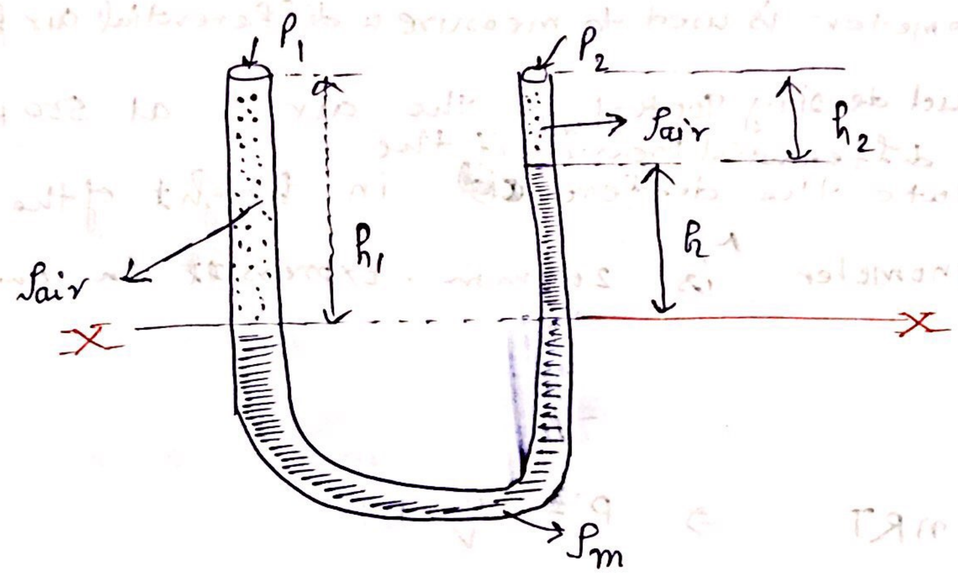
Note



Balance equation ⇒

$$P_1 + h_1 \rho_{air} g = P_2 + h_2 \rho_{air} g + h \rho_m g$$

$$P_1 - P_2 = h \rho_m g + h_2 \rho_{air} - h_1 \rho_{air} g$$

$$P_1 - P_2 = h \rho_m g + [h_2 - h_1] \rho_{air} g$$

$$= h \rho_m g - [h_1 - h_2] \rho_{air} g$$

$$P_1 - P_2 = h \rho_m g - h \rho_{air} g$$

$$\boxed{P_1 - P_2 = h [\rho_m - \rho_{air}] g}$$

Q: U tube manometer is used to measure a differential air pressure with a fluid density 900 kg/m3. The air is at 500 KPa and 25°C. Calculate the ~~difference~~ differential pressure if the difference in height of the fluid in the manometer is 200mm. Express ~~it~~ it in units of KPa.

Sol^n:

$$PV = nRT \Rightarrow P = \frac{n}{V} RT$$

$$n = \text{mol of gas} = \frac{\text{mass of gas}}{\text{molar mass}} \quad \frac{(\text{gram})}{(\text{gram/mol})}$$

$$P = \frac{n}{V} RT = \frac{\text{mass}}{V * \text{Molar mass}} R \cdot T = \left(\frac{\text{mass}}{V}\right) * \frac{1}{\text{molar mass}} RT$$

$$P = \rho * \frac{1}{\text{molar mass}} R \cdot T$$

$$P = \rho * \frac{R}{\text{molar mass}} T$$

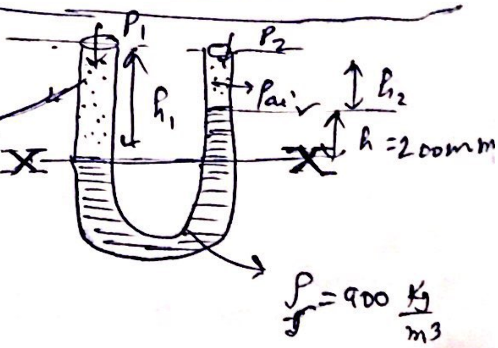
$$\boxed{P = \rho R^* T}$$ where $R^* = \frac{R}{\text{molar mass}} = \frac{8.314 \ J\ mol^{-1} K^{-1}}{28.97 \ \text{gram/mol}}$

Consider molar mass of dry air = 28.97 gram/mol $\therefore R^* = \frac{8.314}{28.97 \times 10^{-3}} \ J\ Kg^{-1} K^{-1}$

$$\boxed{R^* = 287 \ J\ Kg^{-1} K^{-1}}$$

$PV = nRT \Rightarrow P = \rho R^* T$

$\therefore \rho = P/R^* T = \frac{500 \times 10^3}{287 * 298} = 5.85 \ kg/m^3$



Balance eq^n at X-X

$$P_1 + h_1 \rho_{air} g = P_2 + h_2 \rho_{air} g + h \rho_f g$$

$$P_1 - P_2 = h \rho_f g + (h_2 - h_1) \rho_{air} g$$

$$= h \rho_f g - h \rho_{air} g = h [\rho_f - \rho_{air}] g = 0.2 * [900 - 5.85] * 9.8$$

$$= 1.75 \ KPa$$

Pressure sensor –

High pressure sensor –

1. Bourdon tube

[760 mm of Hg to 700 MPa]
[15 psi to 105000 psi]

2 - Bellows

3 – Diaphragm

4 - Capsule

Bourdon tube > Bellows > Diaphragm > Capsule

Low pressure sensor –

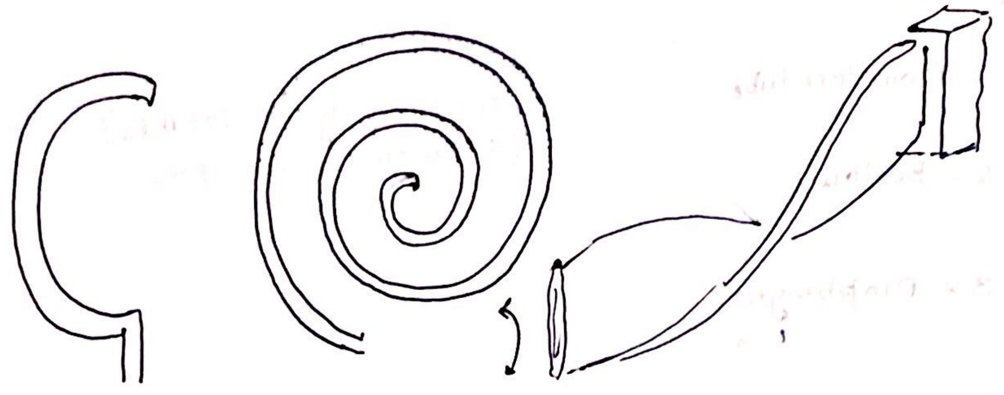
1 - Pirani gauge

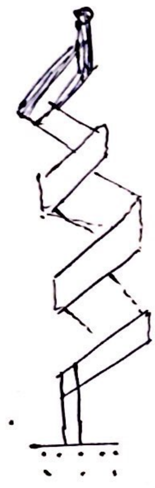
2 - Mcleod gauge

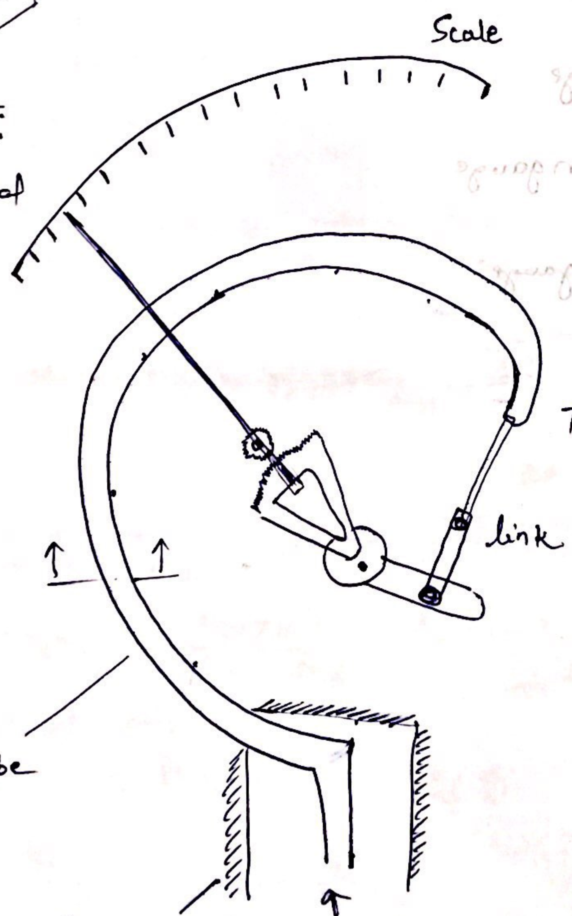
3 - Ionization gauge

4 - Knudsen gauge

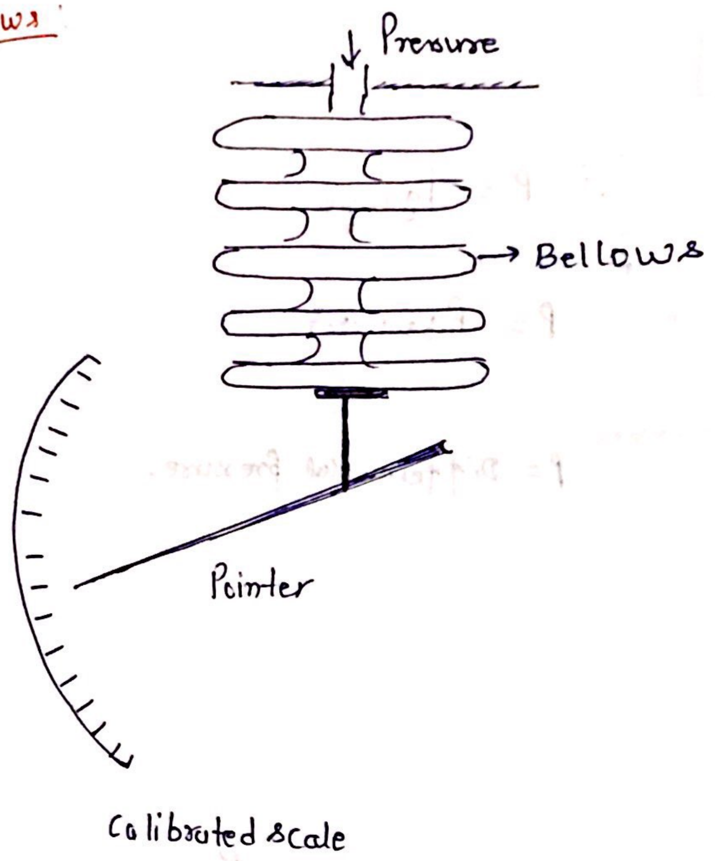
Bourdontube :-

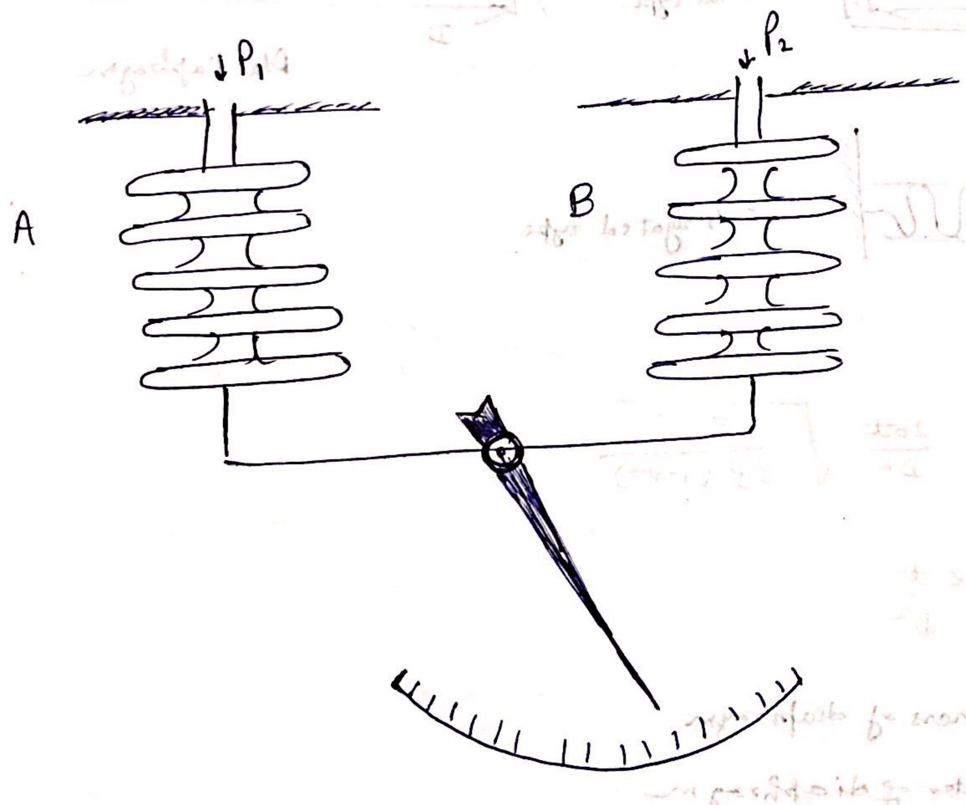






Bellows :





When P_1 is applied to bellows A and P_2 is applied to bellows B, then differential pressure will be $P = P_1 - P_2$, which can be measured from above diagram.

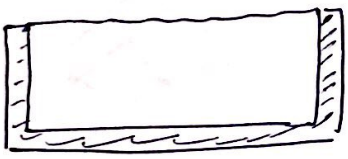
$$\boxed{P = P_1 - P_2}$$

1) $P = P_1 - P_{atm}$ $\therefore$ $P = P_{gauge}$

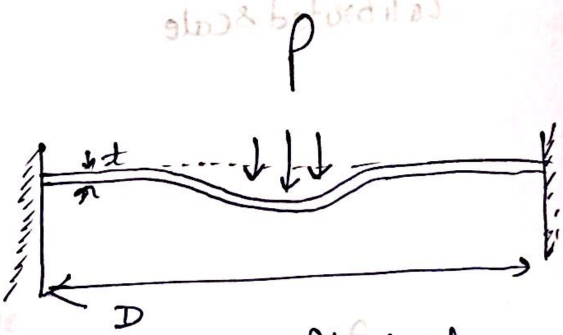
2) $P = P_1 - 0$ $P = P_{absolute}$

3 $P = P_1 - P_2$ $P =$ Differential pressure.

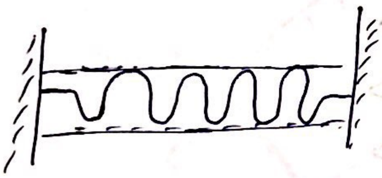
Diaphragm -



flat type



Flat diaphragm



Corrugated type

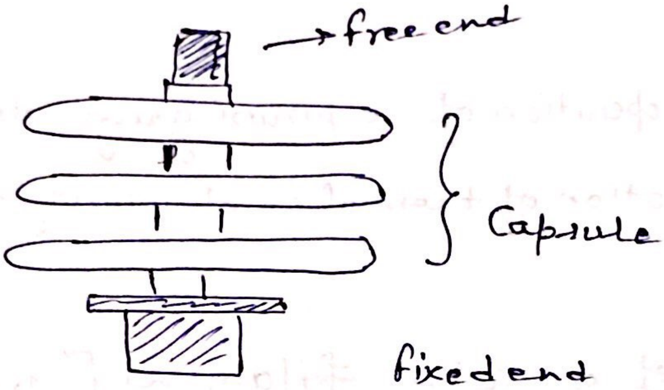
* $$\omega_n = \frac{20t}{D^2}\sqrt{\frac{E}{3\rho\,(1-\nu^2)}}$$

$$\omega_n \propto \frac{t}{D^2}$$

t = thickness of diaphragm

D = diameter of diaphragm

Capsule :



Measure of low pressure

1. **Pirani gauge** – The operation of a pirani gauge depends upon the variation of thermal conductivity of gas with pressure.

* Pirani gauge consists of a metal filament [usually platinum]. Suspended in a tube which is connected to the system whose vacuum pressure is to be measured. Filament [platinum] is connected to an electrical circuit from which [after calibration] a pressure reading may be taken.

* A platinum filament gets heated when electric current flows through it. This wire, is suspended in a gas, will lose heat to the gas as its molecules collide with the wire and remove heat.

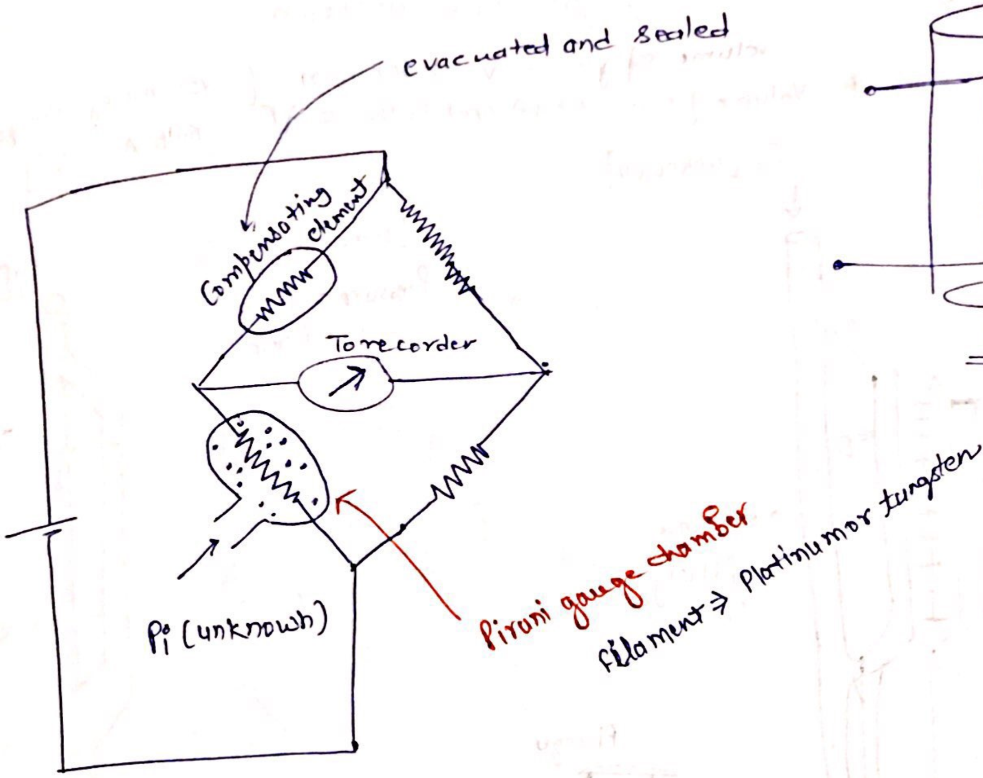
* As the gas pressure is reduced [By the vacuum pumps] the number of molecules present will fall proportionately and the conductivity of surrounding media will fall and the wire will lose heat more slowly. Measuring the heat loss is an indirect indication of pressure.

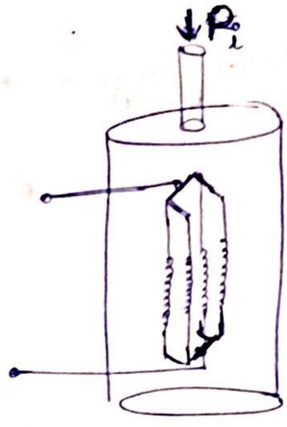
* There are three possible schemes that can be done ⇒

(i) Keep the bridge voltage constant and measure the change in resistance as a function of pressure.

(ii) keep the current constant and measure the change in resistance as a function of pressure.

(iii) keep the temperature of the sensor wire constant





Pirani gauge chamber

* It is in the form of four coiled tungsten wires connected in parallel and supported inside a glass tube to which gas is admitted.

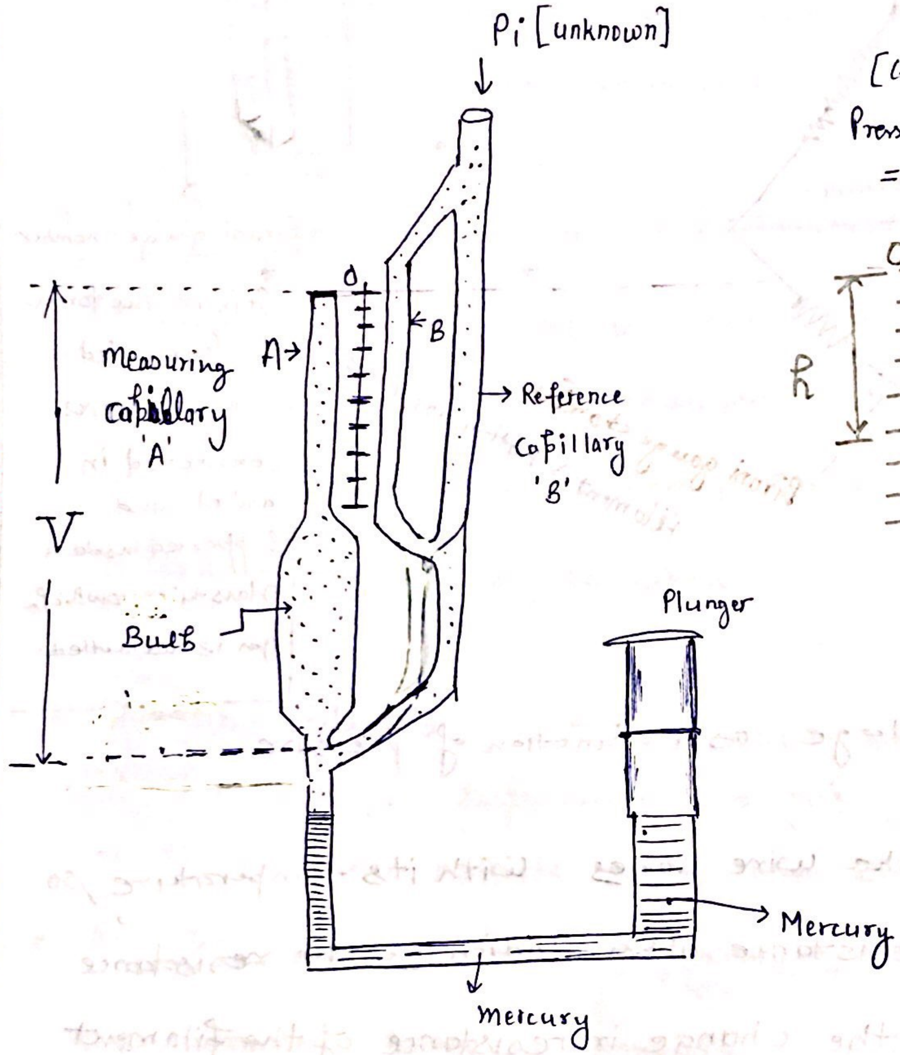
and measure the voltage as a function of pressure.

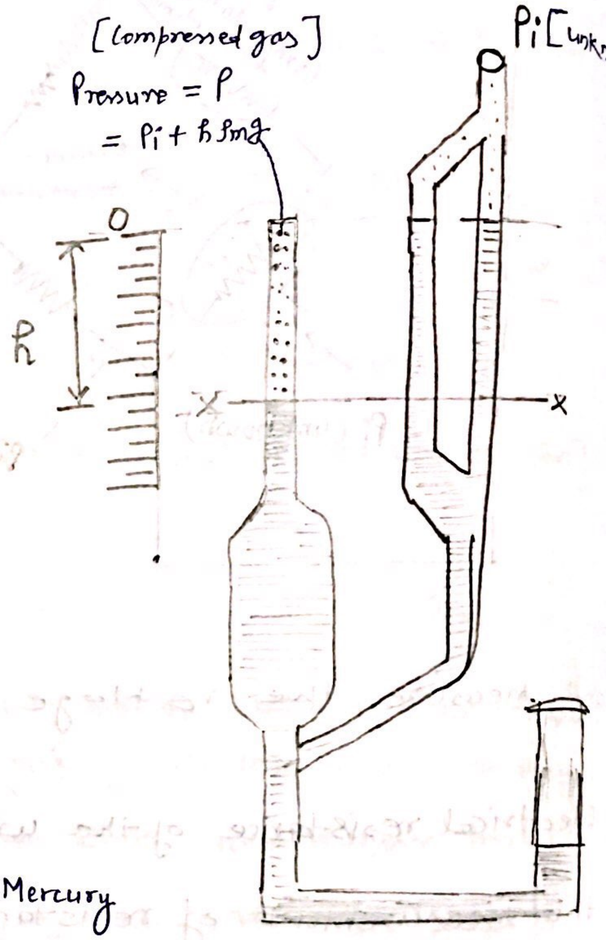
* Electrical resistance of the wire varies with its temperature, so the measurement of resistance also indicates the ~~resistance~~ temperature of wire. Now the change in resistance of the filament is determined using the bridge.
* The change in resistance of the pirani gauge filament becomes a measure of the applied pressure when calibrated.

Note ⇒ Use of compensating element ⇒ Some heat is lost from heater [filament] by radiation, conduction and along leads. But these effects do not depend upon pressure or presence of gas. The compensation for this effect may be carried out by introducing a similar pirani element in an opposite arm of bridge. This second element is evacuated and sealed which ... ambient temperature.

2. Mc leod gauge - * Pressure of gas = $P_i \Rightarrow$ unknown

* Volume of capillary A and bulb = V





* Let P_i is the unknown pressure and volume of the capillary A and bulb is V. (known).

first plunger is push out (pulled) so that known volume of gas will enter in the capillary [Column A and B]

* Now plunger is pushed in, therefore mercury hight starts increasing Pressing of plunger continues until mercury level in capillary B is at zero mark.

* Some amount of gas is left in capillary A as shown in figure. Let the hight of the gas is h. Let the pressure of compressed air is P

$$P = P_i + h\rho_m g \quad \text{—— (1)}$$

Boyle's law

$$P_1V_1 = P_2V_2 \quad \text{—— (2)}$$

area of capillary $A = A_t$

$\therefore V_2 = A_t h$

$$P_iV = (P_i + h\rho_m g) * A_t * h$$

$$P_iV = P_i A_t h + h^2 A_t \rho_m g$$

$$P_i[V - A_t h] = h^2 A_t \rho_m g$$

$$\boxed{P_i = \frac{h^2 A_t \rho_m g}{V - A_t h}}$$

Specific weight

$\gamma = \rho_m g$

$$\boxed{P_i = \frac{h^2 A_t \gamma}{V - A_t \cdot h}}$$

Q- A Mcleod gauge has volume of bulb, capillary and tube down to its opening equal to 90 cm3. Diameter of capillary = 1mm. Calculate the pressure indicated by a reading of 3cm.

Sol^n

$V = 90\ cm^3 = 90 \times 10^{-6} m^3$

diameter = 1 mm = 1×10^{-3} meter

$h = 3 \times 10^{-3}$ meter

$A_t = \frac{\pi d^2}{4} = \frac{\pi}{4} \times (1 \times 10^{-3})^2 = \frac{\pi}{4} \times 10^{-6}$ m^2

$$P_i = \frac{h^2 A_t}{V - A_t h} = \frac{[3 \times 10^{-2}]^2 * \frac{\pi}{4} \times 10^{-6}}{90 \times 10^{-6} - \frac{\pi}{4} \times 10^{-6} * 3 \times 10^{-2}}$$

$$= \frac{7.065 \times 10^{-10}}{[90 - 0.02355] \times 10^{-6}}$$

$$= \frac{7.065 \times 10^{-4}}{89.97645}$$

$$= 0.0785 \times 10^{-4}\ m$$

$$= 7.85 \times 10^{-6}\ \text{meter}$$

$$\boxed{P_i = 7.85 \times 10^{-3}\ mm}$$

Q A Mcleod gauge is available which has a volume V_B of $150\,cm^3$ and capillary diameter of 1·5 mm. Calculate the gauge reading (h) for a pressure of 40 μm of mercury.

Sol

$$P_i = \frac{h^2 A_t \rho_m g}{V - A_t h} \qquad (P_i \text{ in } N/m^2)$$

$$P_i = \frac{h^2 A_t}{V - A_t h} \qquad (P_i \text{ in mm})$$

Data given :-

$V_B = V = 150 \times 10^{-6}\ m^3$

$A_t = \frac{\pi d^2}{4} = \frac{3.14}{4} * (1.5 \times 10^{-3})^2 = \frac{3.14}{4} \times (0.0015)^2$

$A_t = 1.767 \times 10^{-6}\ m^2$

$P_i = 40 \times 10^{-6}\ m$ of Hg

$h^2 A_t = P_i (V - A_t h)$

$A_t h^2 = P_i V - P_i A_t h = 0$

$$\boxed{(A_t) h^2 + (P_i A_t) h - P_i V = 0}$$

$a x^2 + b x + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$h = \frac{-P_i A_t \pm \sqrt{[P_i A_t]^2 + 4 A_t P_i V}}{2 * A_t}$$

$$h = \frac{-40 \times 10^{-6} * (1.767 \times 10^{-6}) \pm \sqrt{[40 \times 10^{-6} \times 1.767 \times 10^{-6}]^2 + \{4 (1.767 \times 10^{-6}) * 40 \times 10^{-6} * 150 \times 10^{-6}}}{2 * 1.767 \times 10^{-6}}$$

$h = 58.135$ mm Hg

Q: A Mcleod gauge has a volume of the bulb equal to 100 cm^3 and a capillary of diameter 1mm. Calculate the pressure indicated by a reading of 3 cms. What error would occur if the capillary volume is assumed to be negligible compared to the volume of the bulb.

Sol:

$V = 100\ cm^3 = 100 \times 10^{-6}\ m^2$

$r = \frac{1}{2}\ mm$

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

$P_i = ?$

$$A_t = \frac{\pi d^2}{4} = \frac{3.14}{4} * (1 \times 10^{-3})^2 = 0.785 \times 10^{-6}$$

$$P_i = \frac{h^2 A_t}{V - A_t h}\ m \text{ of } Hg$$

$$= \frac{[3 \times 10^{-2}]^2 \times 0.785 \times 10^{-6}}{100 \times 10^{-6} - 0.785 \times 10^{-6} \times 3 \times 10^{-3}} = \frac{9 \times 0.785 \times 10^{-10}}{[100 - 0.002355] \times 10^{-6}}$$

$$P_i = \frac{7.065 \times 10^{-10}}{99.997645 \times 10^{-6}}$$

$= 0.07065 \times 10^{-4}$

$= 7.06516 \times 10^{-6}$

$= 7.06516\ \mu m$

$$\boxed{P_i = 7.06516\ \mu m}$$

If capillary volume (At) is neglected then:

$$P_i = \frac{h^2 At}{V} \qquad [V >> At \cdot h]$$

$$P_i = \frac{(3\times10^{-2})^2 * 0.785\times10^{-6}}{100\times10^{-6}}$$

$$P_i = \frac{7.065\times10^{-10}}{100\times10^{-6}}$$

$$P_i = 7.065\times10^{-6}$$

$$\boxed{P_i = 7.065\ \mu m}$$

Error = MV − TV

$= [7.06516 - 7.065]\ \mu m$

$= 7.06516 - 7.065\ \mu m$

$= 0.0016\ \mu m = 1.6\times10^{-9} = 1.6\ nm$

$$\boxed{\text{Error} = 1.6 nm}$$

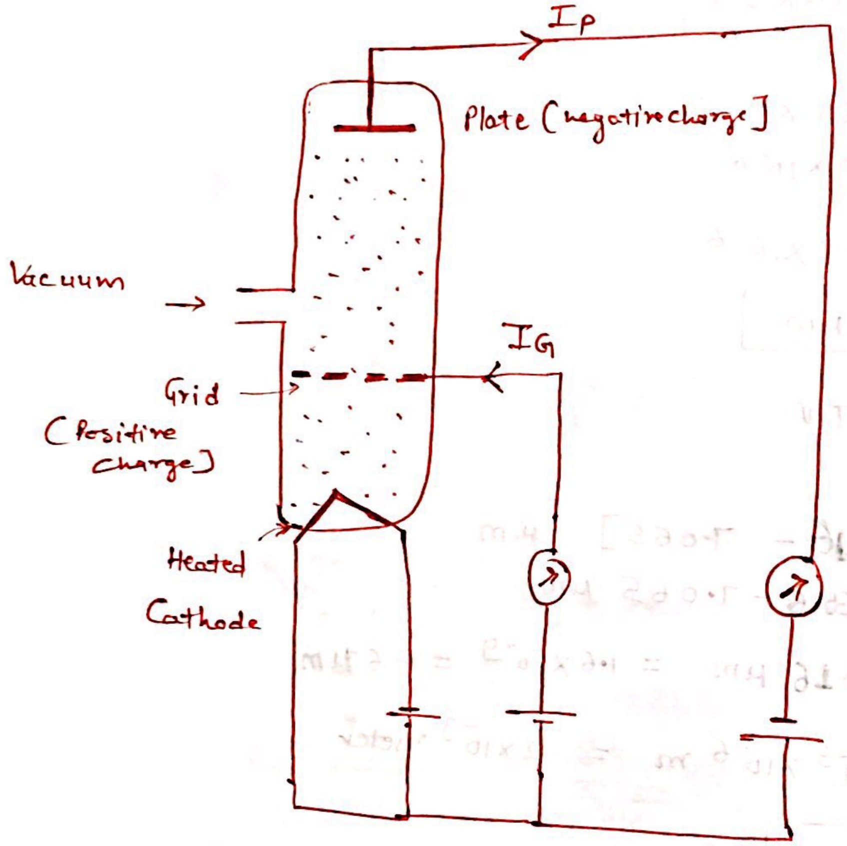
$$\%\ \text{Error} = \frac{MV - TV}{TV}$$

$$\%\ \text{Error} = \frac{1.6\times10^{-9}}{7.06516\times10^{-6}} \times 100$$

$$\boxed{\%\ \text{Error} = 0.022265\ \%}$$

3- Ionization gauge-

* Ionization is the process of removing an electron from an atom producing a free electron and positively charged ion. Ionization may be produced by collisoion of a high speed electron with the atom.



* Electrons are emitted from heated Cathode using a filament and are accelerated towards the grid which is positively charged. Some of the electrons are captured by the grid producing grid current I_G.

* Electrons having high kinetic energy pass through grid and cause ionization of gas atoms.

* Positive ions so produced are attracted to plate (which is at negative potential) and current I_p is produced in the plate circuit.

* Pressure of gas $\boxed{P = \frac{1}{S} \frac{I_p}{I_G}}$

S = sensitivity of the gauge

$$\boxed{S = \frac{I_p}{P I_G}}$$

I_p = Plate Current

I_G = Grid Current

4- Knudsen gauge -

* P_i (unknown pressure) is admitted to chamber containg fixed plates heated to absolute temperature T_f, whose temperature must be measured, and a spring-restrained movable vane whose temperature T_v also must be known.

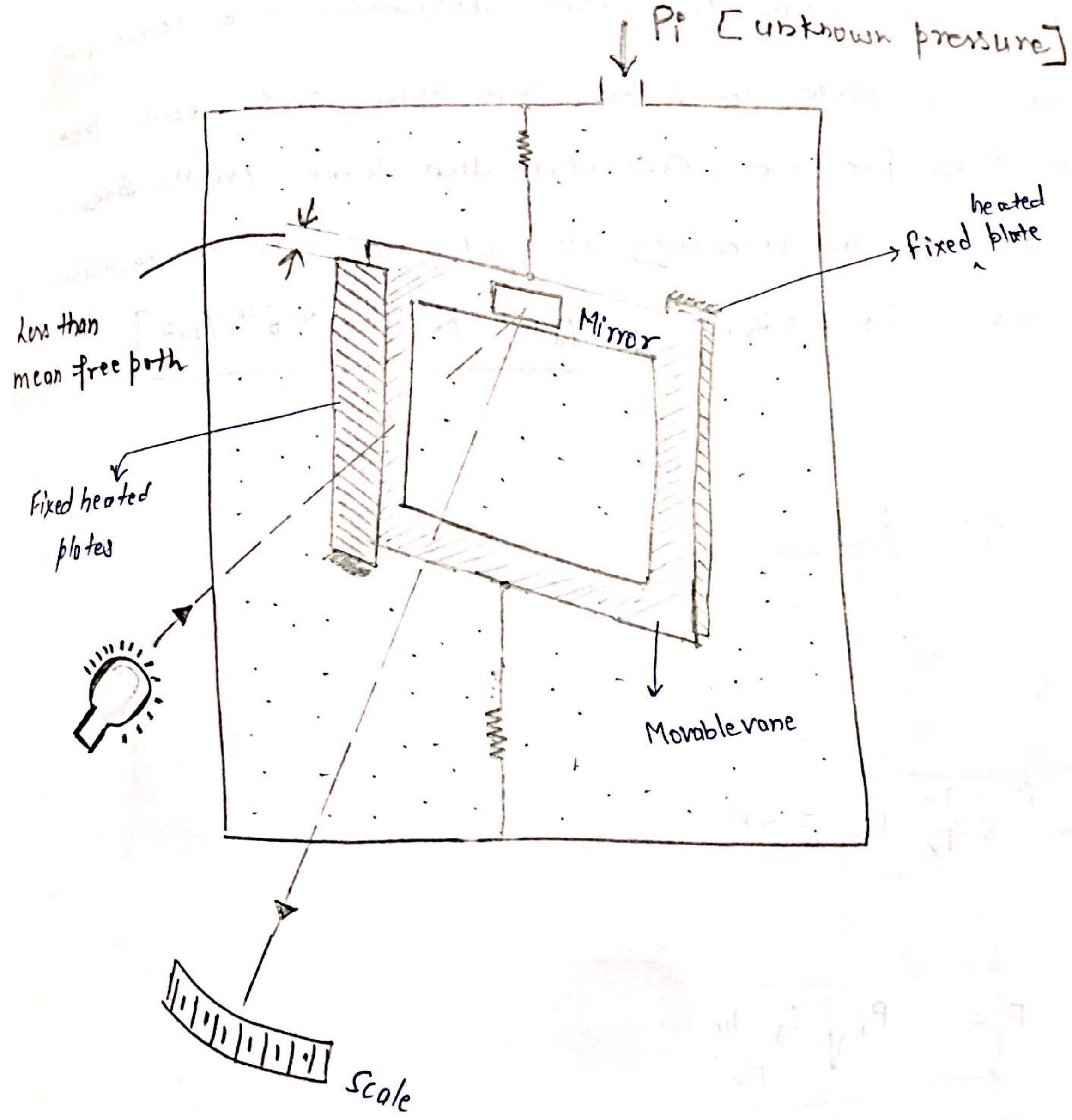
* The space between the fixed and movable plates must be less than the mean free path of the gas whose pressure is being measured.

* Kinetic theory of gases shows that gas molecules rebound [increase in strength] from the heated plates with greater momentum than from the cooler movable vane, thus giving a net force on the movable vane which is measured by deflection of spring suspension.

* Analysis shows that the force is directly proportional to pressure for a given T_f and T_v, following a law of the form:

$$\boxed{P_i = \frac{KF}{\sqrt{\frac{T_f}{T_v} - 1}}}$$

where F is force and K is constant



* Note:- Knudsen gauge is relatively insensitive to gas composition and thus give promise of devlopment into a standard for pressures too low for the Mcleod gauge.

Q: A knudsen gauge is to be designed to operate at a maximum pressure of 2 μm of Hg. For this application the spacing of the vane and plate is to be less than 0.3 mean free path at this pressure. Calculate the force on the vanes when the gas temperatures is 27°c and the temperature difference is 40K. Let [K = 4×10^{-4} /m2]

Soln:

$$P_i = \frac{KF}{\sqrt{\frac{T_f}{T_v} - 1}}$$

$$P_i \sqrt{\frac{T_f}{T_v} - 1} = KF$$

$$F = \frac{P_i \sqrt{\frac{T_f - T_v}{T_v}}}{K}$$

$$= \frac{P_i}{K} \sqrt{\frac{T_f - T_v}{T_v}}$$

$$= \frac{13600 \times 9.81 \times 2 \times 10^{-6}}{4 \times 10^{-4}} * \sqrt{\frac{40k}{300k}}$$

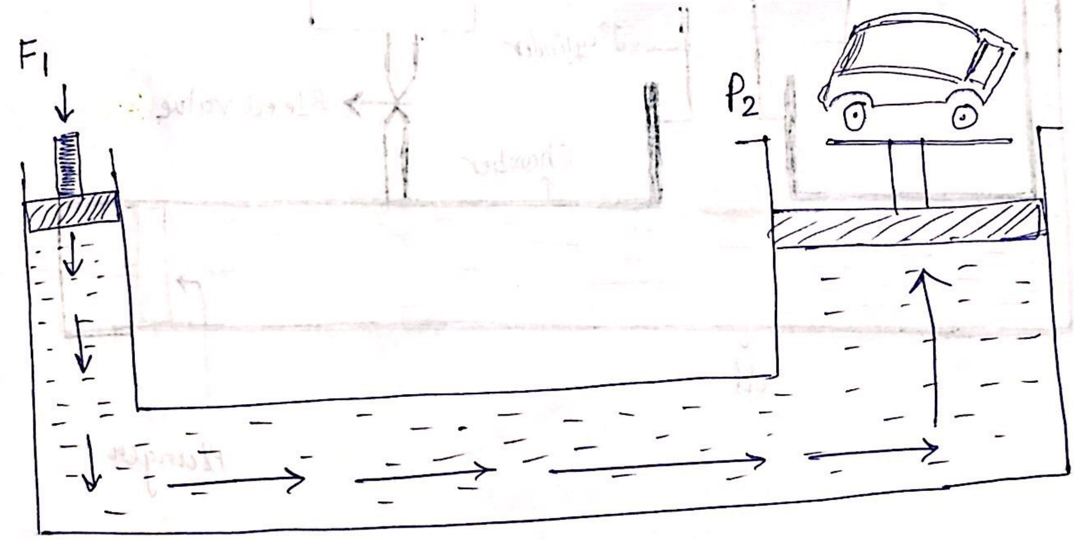
$$= 667.08 \sqrt{0.1333}$$

$$= 667.08 * 0.365$$

$$\boxed{F = 243.58 \text{ Newton}}$$

Pascal's principle – Pascal's law states that when there is an increase in pressure at any point point in a confined & incompressible fluid, there is an equal increase in pressure at every other point in the container.

Hydraulic systems use an incompressible fluid such as oil or water to transmit forces from one location to another location within the fluid



$$P_1 = \frac{F_1}{A_1} \quad \text{——} (1)$$

$$F_2 = P_2 \cdot A_2$$

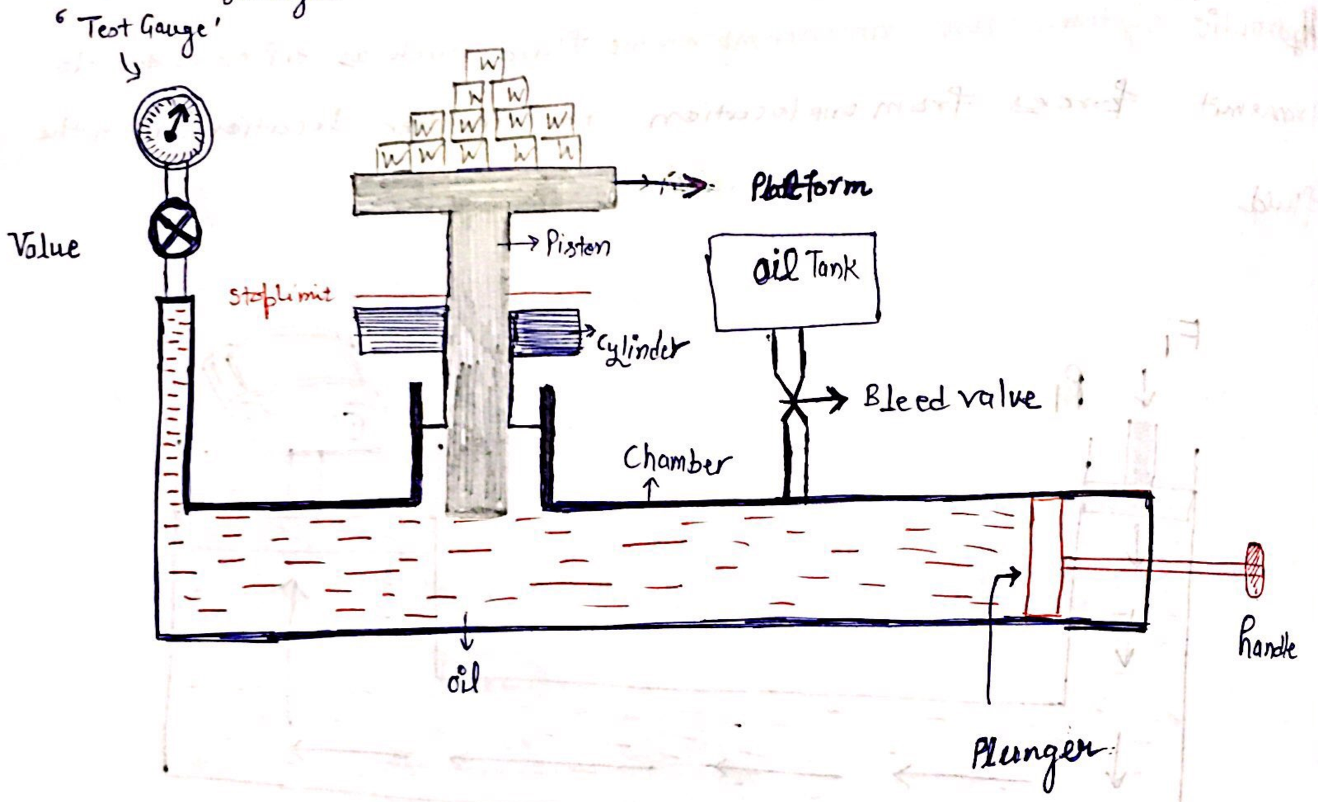
$$F_2 = P_1 A_2$$

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

$$\boxed{F_2 = \frac{A_2}{A_1} \cdot F_1} = \frac{KA'}{A} F_1 = K * F_1$$

Dead weight gauge

* It is basically a pressure producing and pressure measuring device. It is used to calibrate pressure gauge. Calibration of pressure means introducing an accurately known sample of pressure to the gauge under test and then observe the response of the gauge.



* initially valve of test gauge is closed. Pluger is pullled out word direction until piston reaches at 'stop Limit point'.

* Now plunger is pushed therefore piston goes upward direction because of force of oil on piston.

* When piston starts floating then stop the pushing of plunger.

At this point ⇒

$$\boxed{\text{fluid pressure} = \frac{\text{Dead weight supported by piston}}{\text{Area of Piston}}}$$

* Now the valve of the 'Test Gauge' is opened so that oil reaches to the test gauge. Note down the reading of test gauge.

* Now compare the reading of test gauge and fluid pressure [which is calculated from equation (1)]. If both readings are same it means our test gauge is giving correct reading other wise test gauge is giving wrong reading and you will have to replace it.

Q: Dead weight tester is shown below:

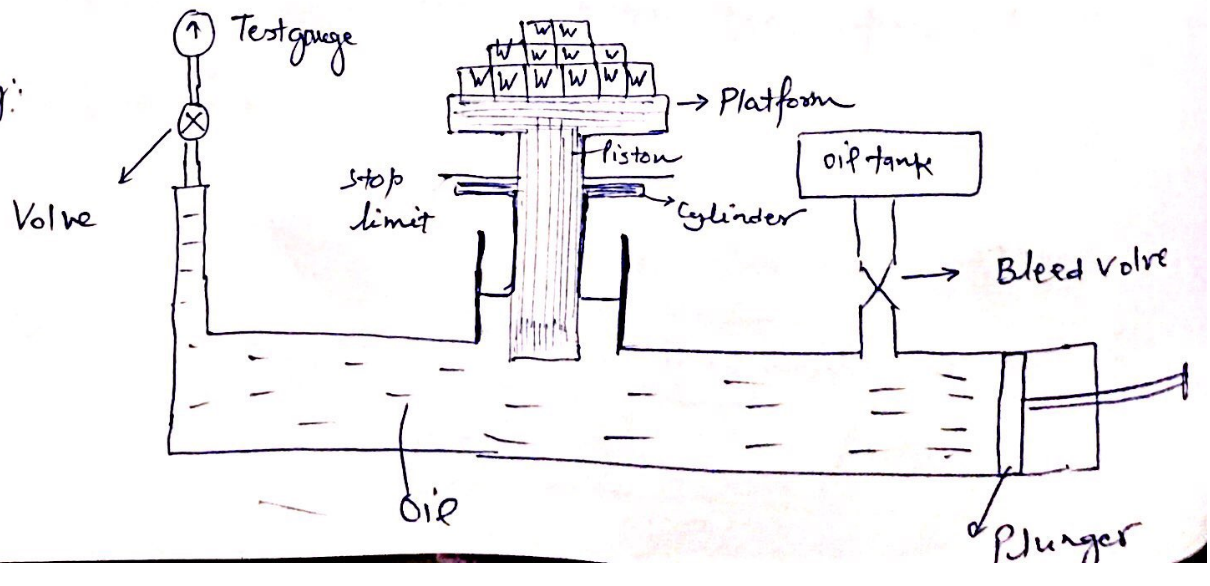
a) By what factor must the actual weight of steel weights be multiplied to correct the air buoyancy.

$$\begin{bmatrix} \rho_{air} = 1.23 \text{ kg/m}^3 \\ \rho_{steel} = 7800 \text{ kg/m}^3 \end{bmatrix}$$

b) What correction must be applied to the platform weight to account for oil buoyancy if the piston is immersed 125 mm and has a diameter of 5mm. $[\rho_{oil} = 840 \text{ kg/m}^3]$

c) If, in part (b), air rather than oil, is the pressure medium, what would the correction be when the gauge pressure is 700 KPa gauge and temperature is 20°C? Make an estimate, assuming constant air temperature and pressure varying linearly from the high pressure end of the piston to atmospheric (1 atm) at the top end.

Fig:



Soln- (a) $\rho_{air} = 1.23\ kg/m^3$

$\rho_{steel} = 7800 kg/m^3$

For a weight of Volume V :

The effective weight $W_e = V \cdot [\rho_{steel} - \rho_{air}]\ g$

$= V [7800 - 1.23] g$

$W_e = (7800 - 1.23)\ V \cdot g$ ——— (1)

By using multiplication factor K, effective weight is given by:-

$W_e = \rho_{steel} \cdot g \cdot V \cdot K$

$= 7800\ K \cdot V \cdot g$ ——— (2)

(1) = (2)

$7800\ K V g = (7800 - 1.23)\ V \cdot g$

$$K = \frac{7800 - 1.23}{7800} = 0.9984$$

[b]

Oil buoyancy correction:-

$F_{buoyancy} = \left[\frac{\pi D^2}{4} * L\right] * \rho_{oil} \cdot g$ $[F = \rho V g]$

$= \left[\frac{\pi}{4} * (5\times10^{-3})^2 * 125\times10^{-3}\right] * 840 \times 9.8$

$= 0.020\ N$ or $20\times10^{-3}\ N$

[C] If air is used in part (b) at 700kPa at 20°C

So first we have to calculate density of air at 20°C.

$$P_{absolute} = P_{atm} + P_{gauge}$$

$$= 1\times10^5 \frac{N}{m^2} + (700\times10^3)\frac{N}{m^2}$$ [1 atm = 1×10^5

$$= 100\times10^3 \frac{N}{m^2} + 700\times10^3 N/m^2$$ [1 Pa = $1\frac{N}{m^2}$

$$= 800\times10^3 \frac{N}{m^2}$$

$$= 800\times10^3 \text{ Pascal}$$

$$PV = nRT$$

$$P = \rho R^* T$$

$$\rho_{air} = \frac{P}{R^* T} = \frac{800\times10^3}{287 * (20+273)}$$

$$\rho_{air} = 9.5 \text{ kg/m}^3$$

$$F_{buoyancy} = \left[\frac{\pi D^2}{4} * L\right] * \rho_{air} * g \qquad (F = V\rho g)$$

$$= \left\{\frac{\pi}{4}(5\times10^{-3})^2 * 125\times10^{-3}\right\} * 9.5 * 9.8$$

$$= 2.28\times10^{-4} \text{ N}$$