Manometry

2

1. Pascal's Law

- The intensity of fluid at any point in a stationary fluid is same in all directions.

$$p_x = p_y = p_z$$

- Pressure varies **only with depth** in stationary fluids, whereas if fluids is in motion pressure may vary in horizontal direction also.
- Fluid pressure is measured in Force/Area and it is expressed in Pascal (N/m^2) or bar.

$$1 \text{ bar} = 10^5 \text{ N/m}^2$$

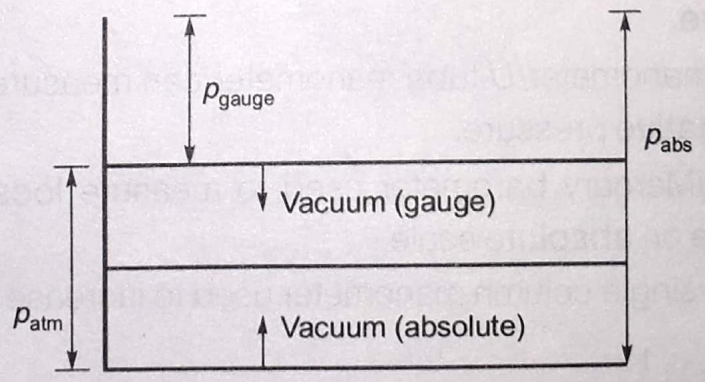
$$1 \text{ MPa} = 10 \text{ bar}$$

- Barometer shows **atmospheric** pressure.
- 1 kgf = 9.81 Newton.
- Pressure is a scalar quantity.

2. Absolute Pressure

Absolute pressure measured with reference to absolute zero. Absolute pressure cannot be negative

Asbolute pressure = gauge pressure + local atmospheric pressure



- $$p_{gauge} = \rho g h$$

Here, ρ = Density of fluid, g = Acceleration due to gravity

h = Height

- **Gauge** pressure can be positive, negative or zero.
- Atmospheric pressure varies with **altitude**, **temperature** and **local** conditions.
- At **mean sea level** atmospheric pressure is 1.01×10^5 Pascal or 1 bar or 10.3 m. of height of water or 76 cm height of **mercury**.

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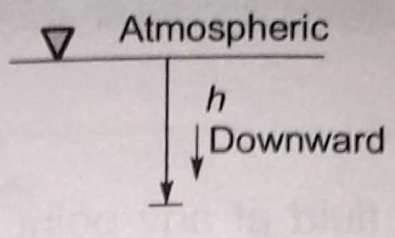
3. Hydrostatic Law

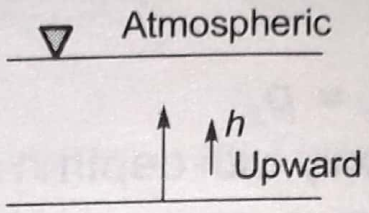
- For h measured downward

$$\frac{dp}{dh} = w$$



- For upward h

$$\frac{dp}{dh} = -w$$



Remember:

☑ Hydrostatic pressure shows linear variation with depth below the free surface.

4. Conversion of one Fluid Column to Another Fluid Column

$$\sigma_1 h_1 = \sigma_2 h_2$$
$$S_1 h_2 = S_2 h_2$$

where, ρ = Density of fluid, S = Relative density

Remember:

☑ Piezometer is suitable for **small** and **positive** pressure measurement.

☑ The manometric liquid should have **high density** and **low vapour pressure**.

☑ Simple manometer/U-tube manometer can measure both **positive** and **negative** pressure.

☑ Aneroid/Mercury barometer used to measure **local** atmospheric pressure on **absolute** scale.

☑ Inclined single column manometer used to increase sensitivity by a factor of $\frac{1}{\sin\theta}$

☑ Inverted column U-tube manometer used for measuring liquid pressure only. [$S_{manometric} < S_{liquid}$]

☑ Density of mercury = 13600 kg/m^3

☑ Density of air = 1.24 kg/m^3

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* Pressure Measuring devices :-

(i) Manometers → (a) Simple
→ (b) Differential

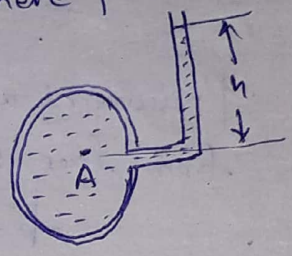
(ii) Mechanical Gauges → (a) Diaphragm pr. gauge
→ (b) Bourdon tube "
→ (c) Dead weight "
→ (d) Bellows "

→ Manometers :-

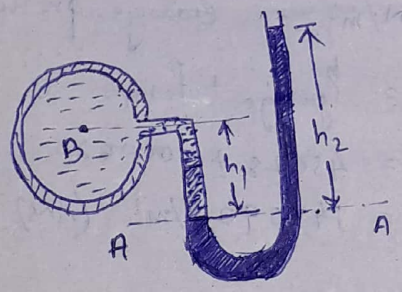
(a) Simple Manometers → (1) Piezometer
→ (2) U-tube manometer
→ (3) Single column Manometer.

(1) Piezometer - One end open to atmosphere and other end is connected to the point where pressure is to be measured

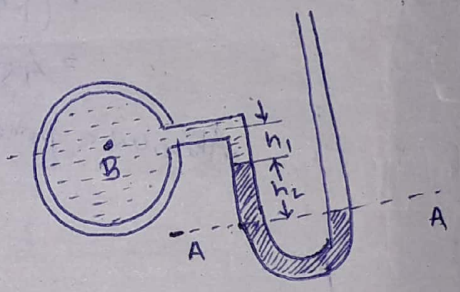
$P_A = \rho g h \ N/m^2$



(2) U-tube manomer -



(a) For gauge pressure



(b) for vacuum pressure

Pressure above A-A in left side column $= p_B + \rho_1 g h_1$

Pressure above A-A in Right side column $= \rho_2 g h_2$

$\therefore \ p_B + \rho_1 g h_1 = \rho_2 g h_2$

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

$p_B + \rho_1 g h_1 + \rho_2 g h_2 = 0$

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

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

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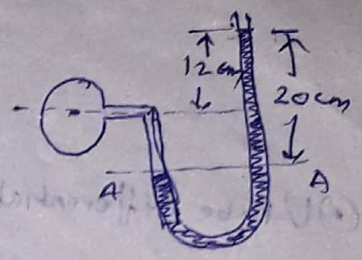
Sol^n: $S_1 = 0.9$

$\rho_1 = S_1 \times 1000 = 900\ kg/m^3$

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

$h_2 = 20\ cm = 0.2\ m$

$h_1 = 20 - 12 = 8 = 0.08\ m$



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

$\Rightarrow p = g(\rho_2 h_2 - \rho_1 h_1)$

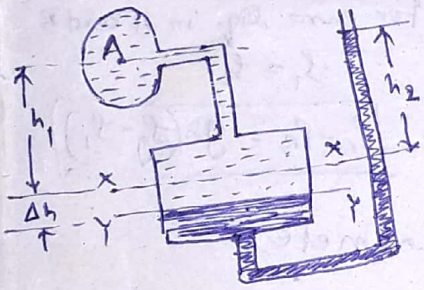
$= 9.81\ (13.6 \times 10^3 \times 0.2 - 900 \times 0.08)$

$= 25977\ N/m^2$

$= 2.597\ N/cm^2$ (Ans)

(2) Single column manometer → Vertical / Inclined

(a) Vertical Single column Manometer



$A \times \Delta h = a \times h_2$

$\Rightarrow \Delta h = \frac{a \times h_2}{A}$

Pressure in left limb above Y-Y,

$= \rho_1 g(h_1 + \Delta h) + p_A$

Pressure in right limb above Y-Y,

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

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

$\Rightarrow p_A = \rho_2 g(h_2 + \Delta h) - \rho_1 g(h_1 + \Delta h)$

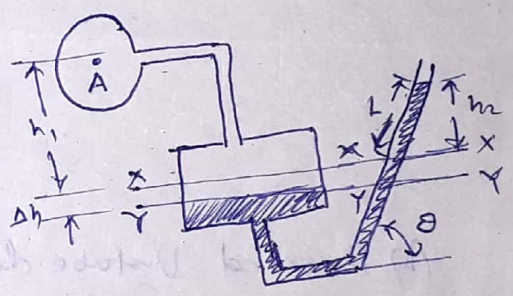
$= \Delta h(\rho_2 g - \rho_1 g) + \rho_2 g h_2 - \rho_1 g h_1$

$= \frac{a h_2}{A}(\rho_2 g - \rho_1 g) + \rho_2 g h_2 - \rho_1 g h_1$

if $\frac{a}{A}$ very small, then

$\boxed{p_A = \rho_2 g h_2 - \rho_1 g h_1}$

(b) Inclined Single column Manometer.



$A \times \Delta h = a \times L$

$\because h_2 = L \sin\theta \Rightarrow L = \frac{h_2}{\sin\theta}$

$p_A + \rho_1 g(h_1 + \Delta h)$

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

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

if Δh is very small

$\therefore \boxed{p_A = \rho_2 g L \sin\theta - \rho_1 g h_1}$

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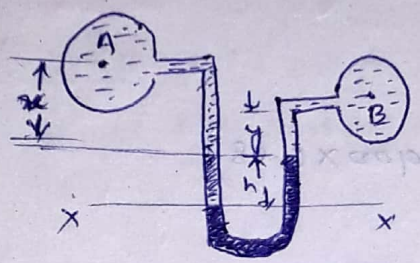
(3) Differential Manometers → U-tube
→ Inverted U-tube

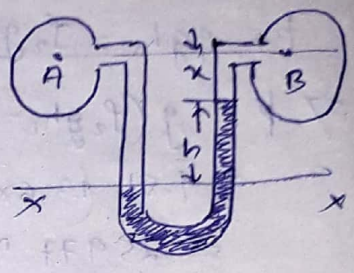
(a) U-tube differential manometer



$$\rho_1 g(h+x) + p_A = \rho_g gh + \rho_2 gy + p_B$$

$$\Rightarrow p_A - p_B = \rho_g gh + \rho_2 gy - \rho_1 g(h+x)$$

$$\Rightarrow \boxed{p_A - p_B = hg(\rho_g - \rho_1) + \rho_2 gy - \rho_1 gx}$$



$$p_A + \rho_1 g(h+x) = p_B + \rho_2 gx + \rho_g gh$$

$$\Rightarrow p_A - p_B = \rho_g gh + \rho_2 gx - \rho_1 g(h+x)$$

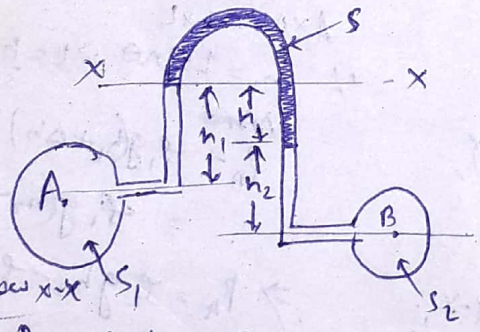
$$\Rightarrow p_A - p_B = hg(\rho_g - \rho_1) + \rho_2 gx - \rho_1 gx$$

For same liq. in A and B

$$\rho_1 = \rho_2$$

$$\therefore \boxed{p_A - p_B = gh(\rho_g - \rho_1)}$$

(b) Inverted U-tube differential manometer



Pressure below x-x

$$p_A - \rho_1 gh_1 = p_B - \rho_2 gh_2 - \rho_s gh$$

$$\Rightarrow p_A - p_B = \rho_1 gh_1 - \rho_2 gh_2 - \rho_s gh$$

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b) Given data: $V = 5\,m^3$
$W = 20\,KN$

$\therefore$ Specific weight $= \frac{20}{5} = 4\,KN/m^3 = 4000\,N/m^3$

Mass density $= \frac{\text{weight density}}{\text{Acc. due to gravity}}$

$\rho = \frac{w}{g} = \frac{4000}{9.81} = 407.74\,Kg/m^3$

Specific gravity $= S = \frac{\rho}{\rho_{water}} = \frac{407.74}{1000}$

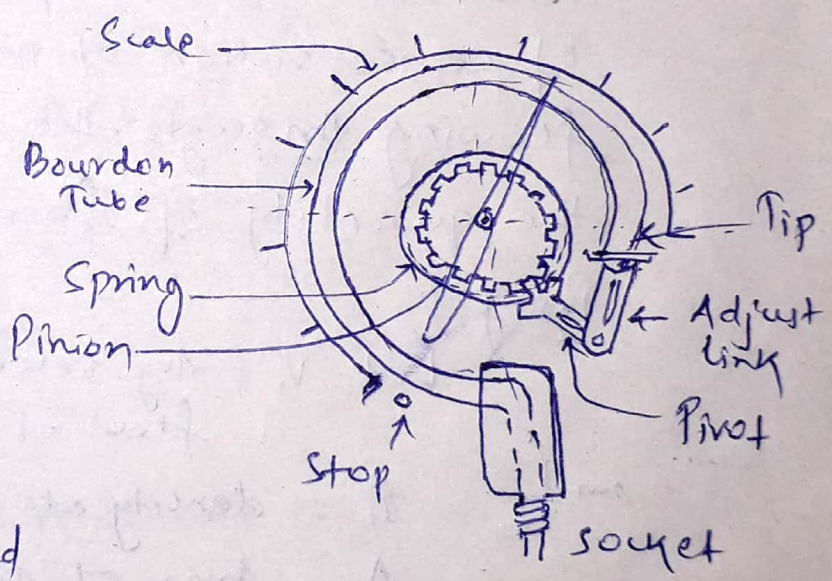
$= 0.407$

(c) Working of Bourdon Tube Pressure Gauge :- (7)

It is a mechanical gauge used for measuring high range of differential pressure measurement, in the range of 700 Mpa. It is an elastic type pressure transducer.

→ The Bourdon tube of C-shape generally like elliptical shape or arc length of about 27 degrees

→ It works on a simple principle that a bent tube will change its shape when exposed to variations of internal and external pressure. As pressure is applied, tube straightens and returns to its original form when the pressure is released.



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→ The tip of tube moves with the internal pressure change and is easily converted with a pointer onto a scale. A connector link is used to transfer the tip movement to geared movement sector. The pointer is rotated through a toothed pinion by the adjustment link.

→ This type of gauge may require vertical mounting for correct results.

→ This type of gauge has an advantage of pressure measurement which can be used for positive and negative pressure ranges.

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