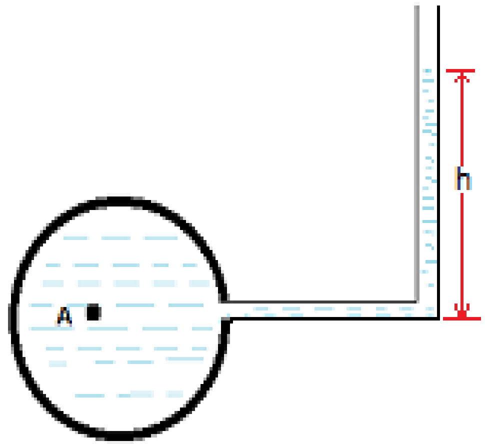
Section B

MANOMETER

Manometer



- Devices used for measuring the pressure at a point by balancing the column of fluid or another column.

Types :

1) Simple Manometer
2) Differential Manometer

Manometers use vertical or inclined liquid columns to measure pressure.

Simple Manometer

- A simple manometer consists of a glass tube having one of its ends connected to the point, where pressure is to be measured and other end is open to the atmosphere.

TYPES OF SIMPLE MANOMETER

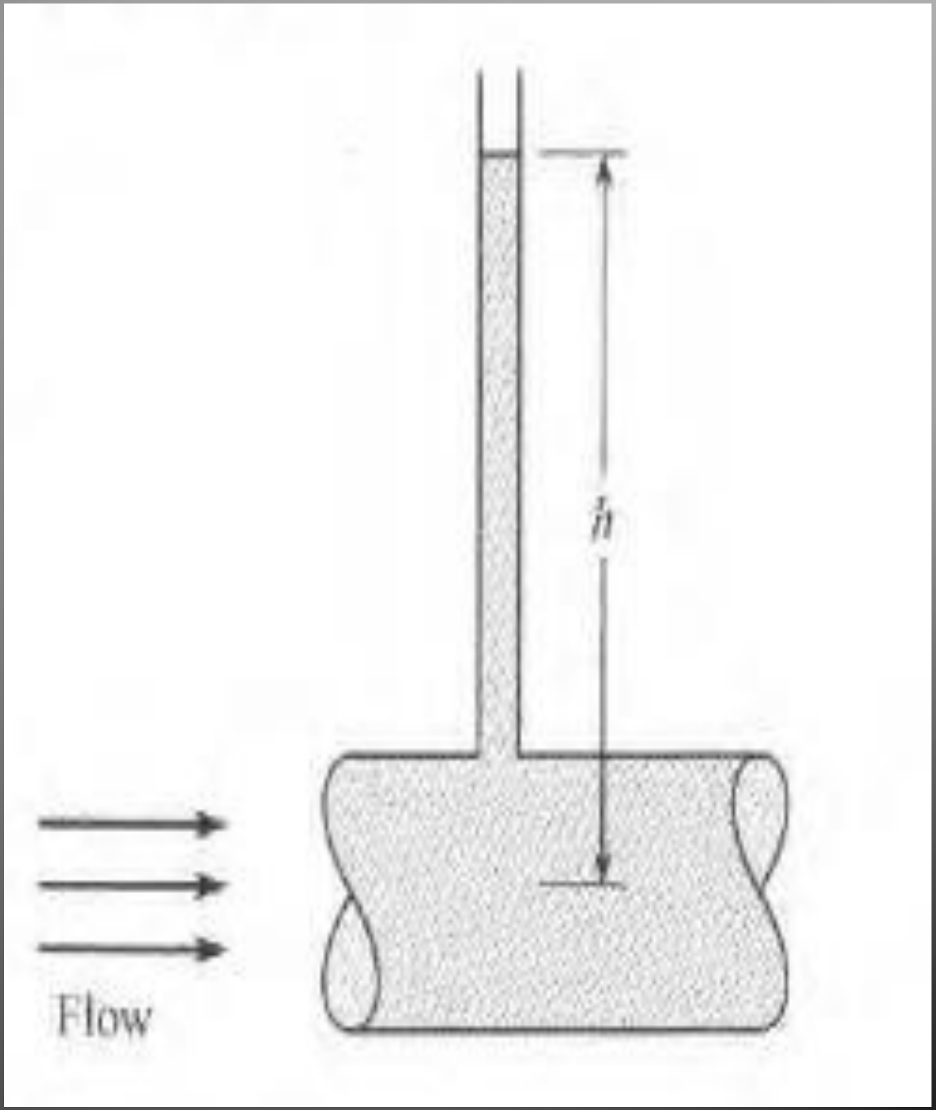
- PIEZOMETER
- U-TUBE
- SINGLE COLOUMN

PIEZOMETER MANOMETER

- Piezometer is a vertical tube, usually transparent, in which a liquid rises in response to a positive gage pressure.
- $p = \rho g h \ N/m^2$

  Or

  $p = \gamma h$



ADVANTAGES

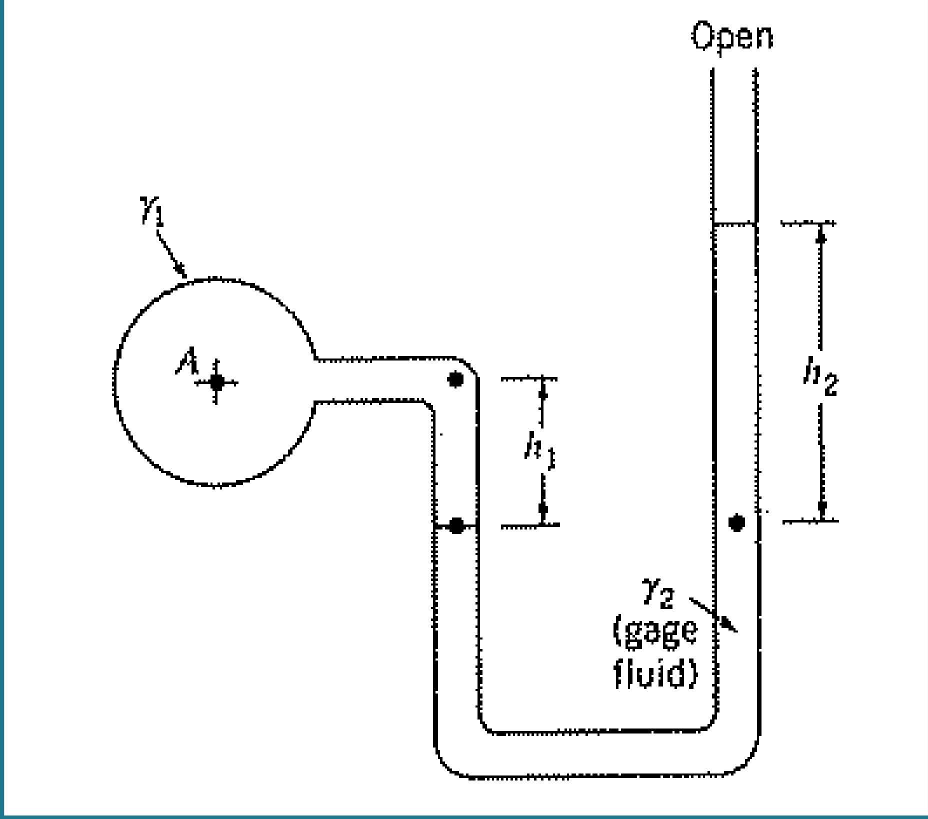
- Simplicity.
- Direct Measurement (No Need For Calibration).
- Accuracy.

DISADVANTAGES

- It cannot easily be used for measuring pressure in a gas, so the fluid in the container in which the pressure is to be measured must be a liquid.
- Piezometer is limited to low pressures because the column height becomes too large at high pressures.

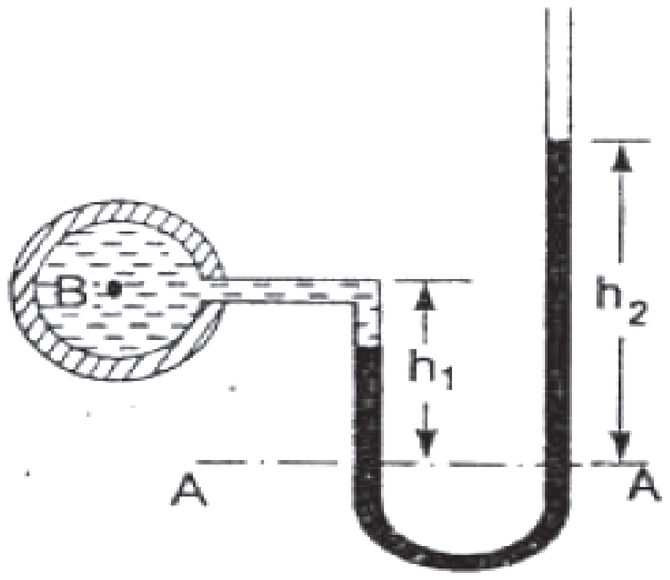
U-TUBE MANOMETER

- It consists of glass tube bent in U-Shape, one end of which is connected to a point at which pressure is to be measured and other end remains open to the atmosphere.
- The tube contains liquid whose sp. gr is greater than the sp. gr of the liquid whose pressure is to be measured. It generally contains Mercury.



For Gauge Pressure

- h_1 = Height of light liquid above the datum line.
- h_2 = Height of heavy liquid above the datum line.
- S_1 = Sp. gr of light liquid.
- ρ_1 = Density of light liquid = $1000 \times S_1$.
- S_2 = Sp. gr of heavy liquid.
- ρ_2 = Density of heavy liquid = $1000 \times S_2$.



(a) For gauge pressure

Pressure above A-A in the left column $= p + \rho_1 \times g \times h_1$

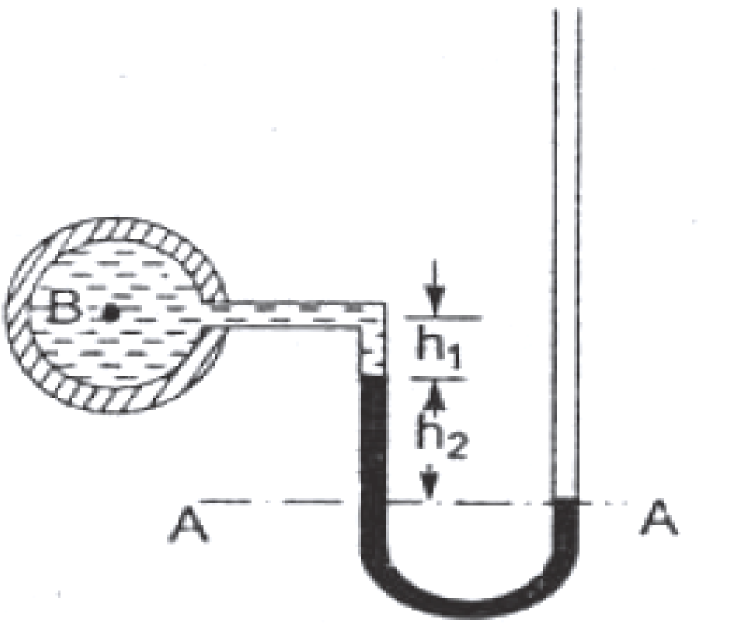
Pressure above A-A in the right column $= \rho_2 \times g \times h_2$

Hence equating the two pressures $p + \rho_1 g h_1 = \rho_2 g h_2$

$\therefore \quad p = (\rho_2 g h_2 - \rho_1 \times g \times h_1)$.

For Vacuum Pressure

For measuring Vacuum pressure ,the level of heavy liquid in the manometer will be as shown in Figure (b).



(b) For vacuum pressure

Pressure above A-A in the left column $= \rho_2 g h_2 + \rho_1 g h_1 + p$

Pressure head in the right column above A-A = 0

$\therefore \quad \rho_2 g h_2 + \rho_1 g h_1 + p = 0$

$\therefore \quad p = -(\rho_2 g h_2 + \rho_1 g h_1).$

Single Column Manometer

- Modified form of a U-tube Manometer in which a reservior,having a large cross sectional area(about 100 times)as compared to the area of the tube is connected to one of the limbs of the manometer .
- For any variation in pressure, the change in the liquid level in the reservoir will be very small, which may be neglected and hence pressure is given by the height of liquid in the other limb.

Types of Single Column Manometer

- Vertical Single Column Manometer.
- Inclined Single Column Manometer. Single Column Manometer

Vertical Single Column Manometer.

Let Δh = Fall of heavy liquid in reservoir

h_2 = Rise of heavy liquid in right limb

h_1 = Height of centre of pipe above X-X

p_A = Pressure at A, which is to be measured

A = Cross-sectional area of the reservoir

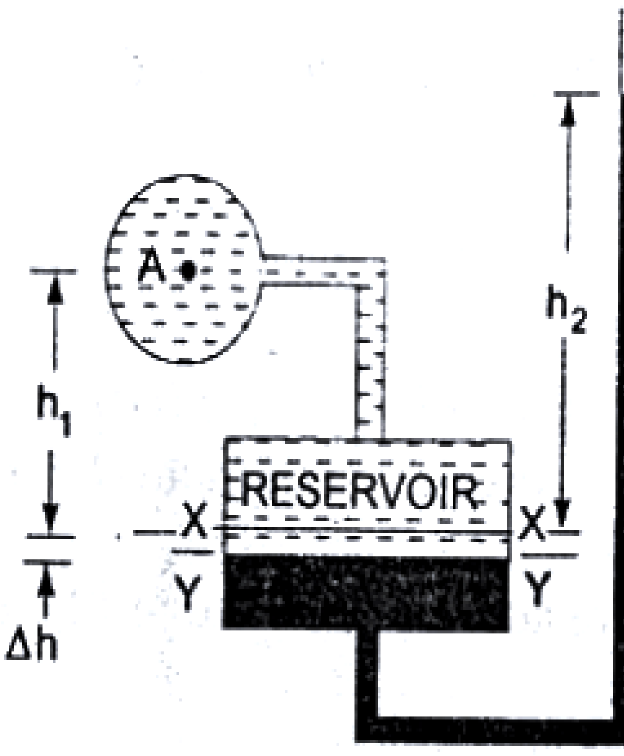
a = Cross-sectional area of the right limb

S_1 = Sp. gr. of liquid in pipe

S_2 = Sp. gr. of heavy liquid in reservoir and right limb

ρ_1 = Density of liquid in pipe

ρ_2 = Density of liquid in reservoir



Vertical single column manometer.

Fall of heavy liquid in reservoir will cause a rise of heavy liquid level in the right limb.

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

$$\therefore \quad \Delta h = \frac{a \times h_2}{A} \quad \text{...(i)}$$

Now consider the datum line *Y-Y* as shown in Fig. 2.15. Then pressure in the right limb above *Y-Y*.

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

Pressure in the left limb above $Y\text{-}Y = \rho_1 \times g \times (\Delta h + h_1) + p_A$

Equating these pressures, we have

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

or

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

$$= \Delta h[\rho_2 g - \rho_1 g] + h_2\rho_2 g - h_1\rho_1 g$$

But from equation (*i*), $\Delta h = \frac{a \times h_2}{A}$

$$\therefore \quad p_A = \frac{a \times h_2}{A}[\rho_2 g - \rho_1 g] + h_2\rho_2 g - h_1\rho_1 g \quad \text{...(2.9)}$$

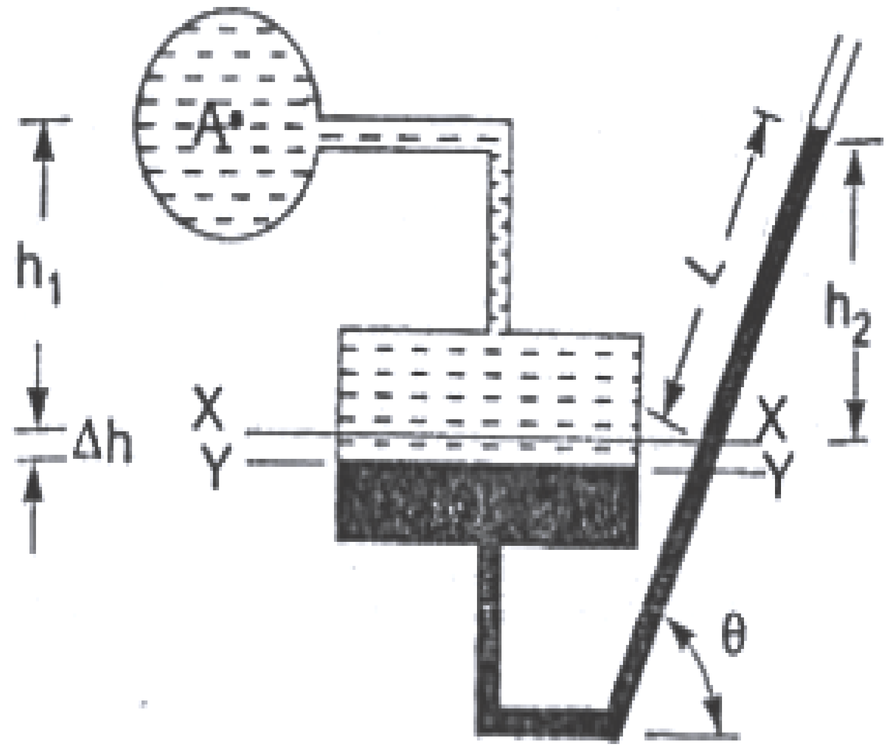
As the area A is very large as compared to a, hence ratio $\frac{a}{A}$ becomes very small and can be neglected.

Then $p_A = h_2\rho_2 g - h_1\rho_1 g$ ...(2.10)

From equation (2.10), it is clear that as h_1 is known and hence by knowing h_2 or rise of heavy liquid in the right limb, the pressure at A can be calculated.

Inclined Single Column Manometer

- It is more sensitive ,due to inclination the distance moved by the heavy liquid in the right limb will be more.
- L=Length of heavy liquid moved in right limb from X-X.
- θ = Inclination of right limb with horizontal.
- h_2 = Vertical rise of heavy liquid in right limb from X-X=L × sin θ.



From equation (2.10), the pressure at A is

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

Substituting the value of h_2, we get

$$p_A = \sin \theta \times \rho_2 g - h_1 \rho_1 g.$$

Differential Manometers

- Differential manometers are the devices used for measuring the difference of pressures between two points in a pipe or in two different pipes.

- A differential manometer consists of a U-tube , containing a heavy liquid , whose two ends are connected to the points , whose difference of pressure is to be measured.

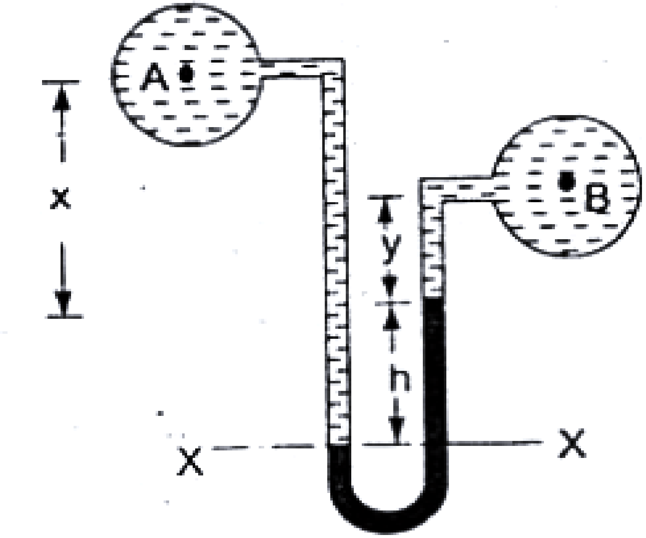
Types

- U-tube Differential Manometer

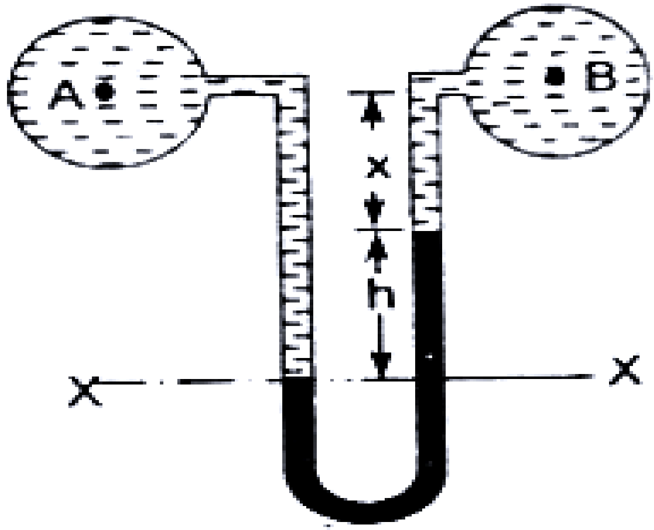
- Inverted U-tube differential Manometer

U-tube Differential Manometer

- It is widely used to measure the difference in pressure between two containers or two points in a given system.



(a)Two pipes at different levels



(b) A and B are at the same level

h = Difference of mercury level in the U-tube.

y = Distance of the centre of B, from the mercury level in the right limb.

x = Distance of the centre of A, from the mercury level in the right limb.

ρ_1 = Density of liquid at A.

ρ_2 = Density of liquid at B.

ρ_g = Density of heavy liquid or mercury.

Taking datum line at X-X.

Pressure above X-X in the left limb $= \rho_1 g(h + x) + p_A$

where p_A = pressure at A.

Pressure above X-X in the right limb $= \rho_g \times g \times h + \rho_2 \times g \times y + p_B$

where p_B = Pressure at B.

Equating the two pressure, we have

$$\rho_1 g(h + x) + p_A = \rho_g \times g \times h + \rho_2 g y + p_B$$

$$\therefore \quad p_A - p_B = \rho_g \times g \times h + \rho_2 g y - \rho_1 g(h + x)$$

$$= h \times g(\rho_g - \rho_1) + \rho_2 g y - \rho_1 g x \quad \text{...(2.12)}$$

$\therefore$ Difference of pressure at A and $B = h \times g(\rho_g - \rho_1) + \rho_2 g y - \rho_1 g x$

A and B are at the same level and contains the same liquid of density ρ_1. Then

Pressure above X-X in right limb $= \rho_g \times g \times h + \rho_1 \times g \times x + p_B$

Pressure above X-X in left limb $= \rho_1 \times g \times (h + x) + p_A$

Equating the two pressure

$$\rho_g \times g \times h + \rho_1 g x + p_B = \rho_1 \times g \times (h + x) + p_A$$

$$\therefore \quad p_A - p_B = \rho_g \times g \times h + \rho_1 g x - \rho_1 g(h + x)$$

$$= g \times h(\rho_g - \rho_1). \quad \text{...(2.13)}$$

Inverted U-tube differential Manometer

- It consists of an inverted U-tube, containing a light liquid. The two ends of the tube are connected to the points whose difference of pressure is to be measured.

- It is used for measuring differences of low pressures.

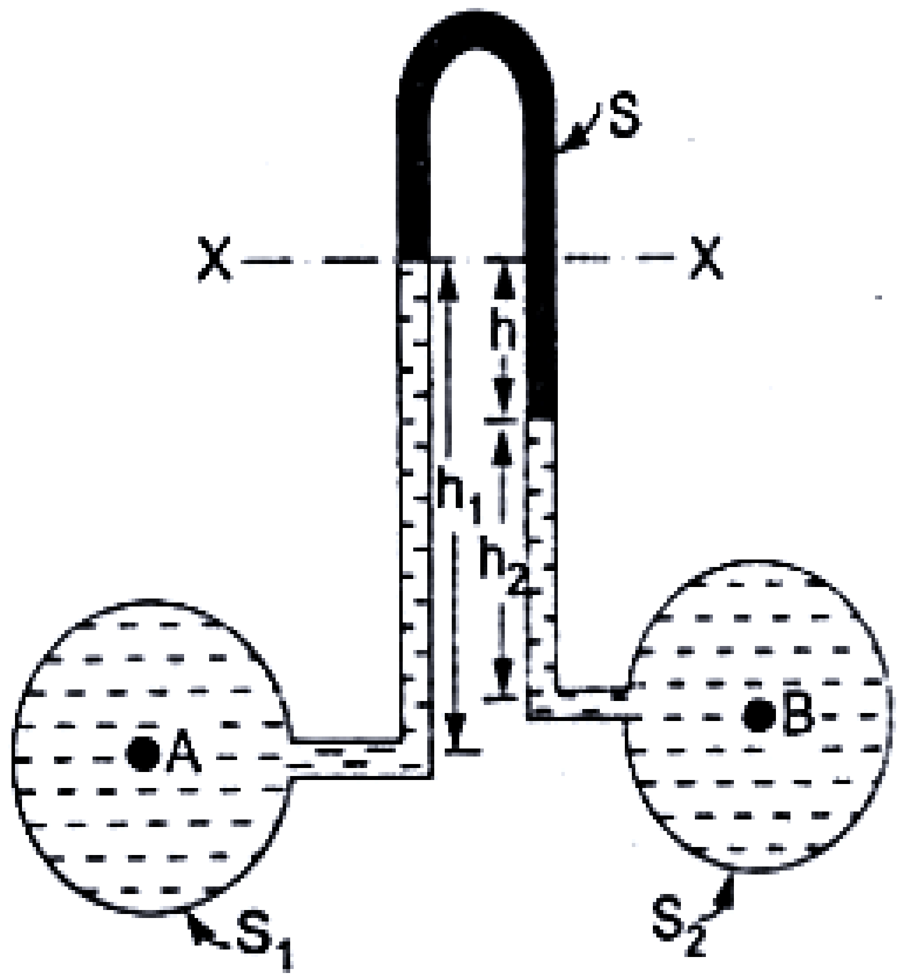


Fig. 2.21

h_1 = Height of liquid in left limb below the datum line X-X
h_2 = Height of liquid in right limb
h = Difference of light liquid
ρ_1 = Density of liquid at A
ρ_2 = Density of liquid at B
ρ_s = Density of light liquid
p_A = Pressure at A
p_B = Pressure at B.

Taking X-X as datum line. Then pressure in the left limb below X-X

$$= p_A - \rho_1 \times g \times h_1.$$

Pressure in the right limb below X-X

$$= p_B - \rho_2 \times g \times h_2 - \rho_s \times g \times h$$

Equating the two pressure

$$p_A - \rho_1 \times g \times h_1 = p_B - \rho_2 \times g \times h_2 - \rho_s \times g \times h$$

or

$$p_A - p_B = \rho_1 \times g \times h_1 - \rho_2 \times g \times h_2 - \rho_s \times g \times h.$$