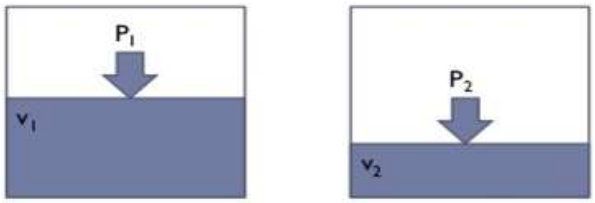
Unit – I

Pressure and Pressure Measurement

Session – III

❑ Compressibility

- All fluids may be compressed by the application of external force, and when the external force is removed the compressed volumes of fluids expand to their original volumes.
- Compressibility is defined as it is the measure of change in volume when the substance is subjected to external pressure.



$P_2 > P_1$

$v_2 < v_1$

Change in volume (Decrease in volume)

$dv = v_1 - v_2$

- Also defined as the ratio of volumetric strain to compressive stress (increase in pressure).
- Compressibility of a fluid is quantitatively expressed as inverse of the bulk modulus of elasticity K of the fluid, which is defined as:

$$K = \frac{\text{Compressive stress (Increase in Pressure)}}{\text{Volumetric Strain}}$$

$$K = \frac{dp}{-\left(\frac{dv}{v}\right)}$$

- Since a increase in pressure always causes a decrease in volume, dv is always negative, and the minus sign is included in the equation to give a positive value of K.
- The SI unit of Bulk modulus of elasticity is N/m^2 or Pa.

❑ Surface Tension and Capillarity

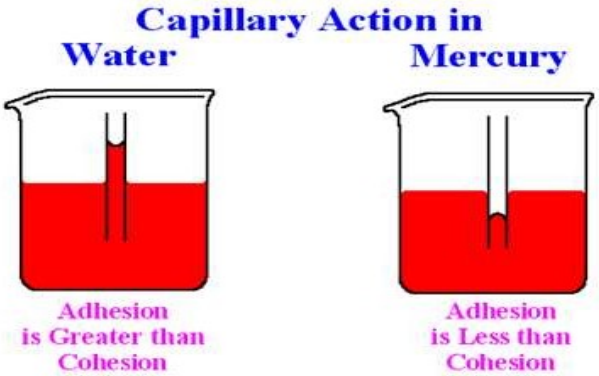
A. Surface Tension

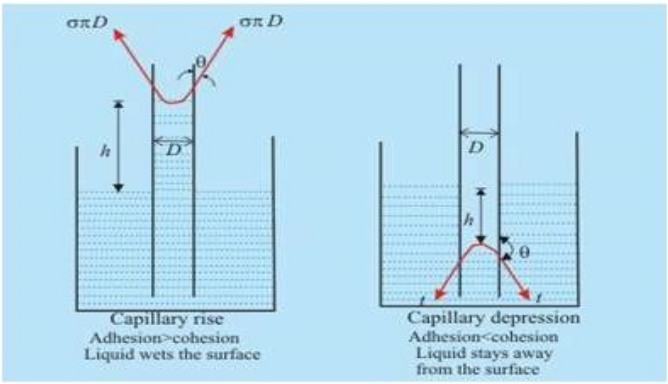
- Surface tension is due to cohesion between liquid particles at the surface
- Cohesion means inter-molecular attraction between molecules of the same liquid. That means it is a tendency of the liquid to remain as one assemblage of particles.
- The property of cohesion enables a liquid to resist tensile stress.

- The property of the liquid surface film to exert a tension is called the surface tension.
- Surface tension is also defined as it is the force required to maintain the unit length in equilibrium.
- It is denoted by σ (Greek 'sigma').
- In SI units surface tension is expressed in N/m.

B. Capillarity

- Capillarity is defined as a phenomenon of rise or fall of a liquid surface in a small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid.
- The rise of liquid surface is known as capillary rise, while the fall of the liquid surface is known as capillary depression.





- It is expressed in terms of 'cm' or 'mm' of liquid.
- Its value depends upon the specific weight of the liquid, diameter of the tube and surface tension of the liquid.

$$h = \frac{4\,\sigma\,cos\theta}{\rho g d}$$

❑ Adhesion and Cohesion

The tendency of two or more different molecules to bond with each other is known as Adhesion, whereas the force of attraction between the same molecules is known as Cohesion.

Problems :

1. **If a certain liquid has viscosity 4.9×10^{-3} N-sec/m² and kinematic viscosity 3.49×10^{-2} stokes, what is its specific gravity ?**

Solⁿ :

Dy. Viscosity, $\mu_l = 4.9 \times 10^{-3}$ N-sec/m²

Kinematic Viscosity, $\nu_l = 3.49 \times 10^{-2}$ strokes $= 3.49 \times 10^{-2} \times 10^{-4}$ m²/sec

Kinematic Viscosity, $\nu_l = 3.49 \times 10^{-6}$ m²/sec

We know, $\text{Kinematic Viscosity} = \dfrac{\text{Dy. Viscosity}}{\text{Mass density}}$

i.e. $\nu_l = \dfrac{\mu_l}{\rho_l}$

There fore, $\rho_l = \dfrac{\mu_l}{\nu_l} = \dfrac{4.9 \times 10^{-3}}{3.49 \times 10^{-6}} = 1404.01\ \text{Kg/m}^3$

We know, $\text{Specific gravity of liquid} = \dfrac{\text{Mass density of liquid}}{\text{Mass density of water}}$

i.e. $s_l = \dfrac{\rho_l}{\rho_w} = \dfrac{1404.01}{1000} = 1.404$

2. **The volume of liquid is 2.5 m^3. It is reduced by 0.0025 m^3 by increasing the pressure from 10 kpa to 210 kpa. Estimate the bulk modulus of elasticity of the liquid.**

Soln :

Original Volume, $V = 2.5\ m^3$

Change in Volume, $-dv = 0.0025 m^3$ (−sign indicates reduction in volume)

Volumetric Strain, $-\frac{dv}{(v)} = \left(\frac{0.0025}{2.5}\right)$

Increase in Pressure, $dp = 210 - 10 = 200$ kpa $= 200 \times 10^3$ pa

$$dp = 200 \times 10^3\ N/m^2$$

$$\text{Bulk Modulus, } K = \frac{dp}{-\left(\frac{dv}{v}\right)} = \frac{200 \times 10^3}{\left(\frac{0.0025}{2.5}\right)}$$

$$K = 2 \times 10^8\ N/m^2$$

3. **The pressure of a liquid is increased from 500 Pa to 1300 Pa producing a decrease in volume of 0.16 percent. Find the bulk modulus of elasticity of the liquid.**

Soln :

Original Volume , $V = 100$ percent

Decrease in Volume , $-dv = 0.16$ percent

$$Volumetric\ strain, -\frac{dv}{v} = \frac{0.16}{100}$$

Increase in Preassure, $dp = 1300 - 500 = 800$ Pa $= 800\ N/m^2$

$$Bulk\ Modulus, K = \frac{dp}{-\left(\frac{dv}{v}\right)} = \frac{800}{\left(\frac{0.16}{100}\right)} = 5\ x\ 10^5\ N/m^2$$