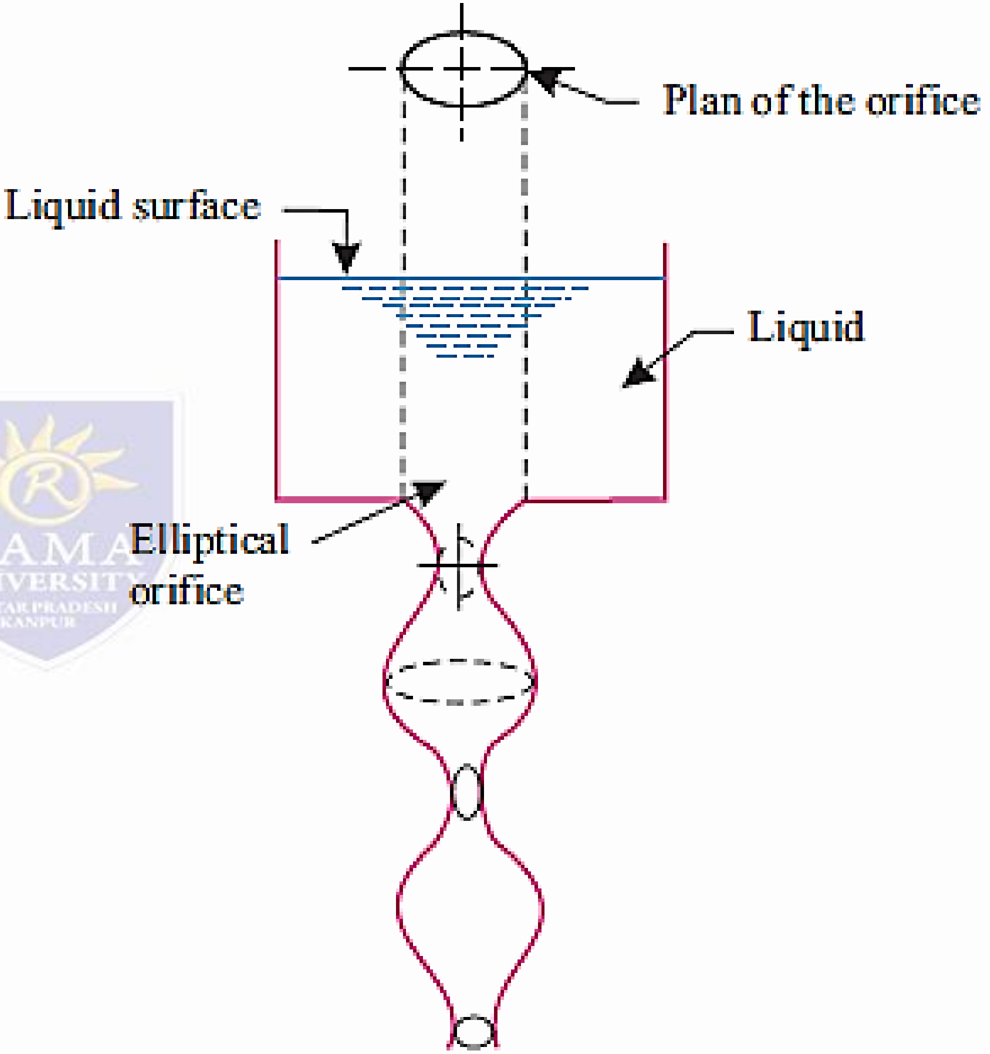
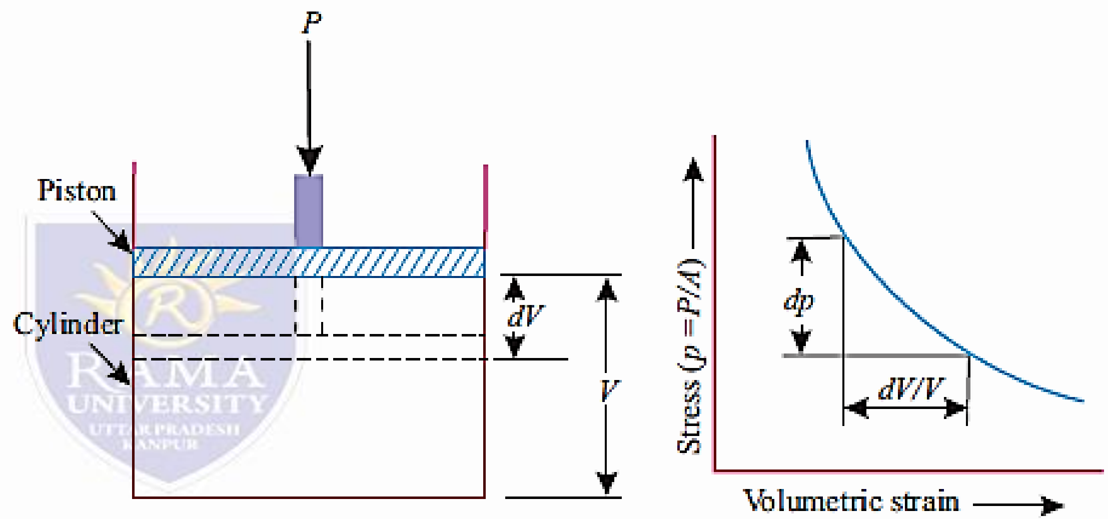
# Fluid Properties

- Capillary inversion :
- Due to surface tension the liquid passing out of an elliptical orifice tends to assume a circular or minimum perimeter cross-sections. Here transformation of surface energy into
- kinetic energy takes place; the flow pattern
- varies as the Weber number changes and the
- motion continues giving rise to a series of
- standing waves. This phenomenon is known as
- capillary inversion of jet for orifices of noncircular
- cross-section. As shown in the Fig. 1.25
- the jet issuing from a small elliptical orifice can
- be observed to undergo two inversion cycles in
- a given length.
- The phenomenon of capillary inversion of
- jets is significant for industries involving the
- production and size control of liquid droplets
- like:
- — paint,
- — molten shot, and
- — agricultural insecticides, etc.



- The property by virtue of which fluids undergo a change in volume under the action of external pressure is known as compressibility.
- It decreases with the increases in pressure of fluid as the volume modulus increases with the increase of pressure.
- The compressibility in Fluid Mechanics is considered mainly when the velocity of flow is high enough reaching 20 percent of speed of sound in the medium.
- Elasticity of fluids is measured in terms of bulk modulus of elasticity (K) which is defined as the ratio of compressive stress to volumetric strain. Compressibility is the reciprocal of bulk modulus of elasticity.

$$\text{Volumetric strain} = -\frac{dV}{V}$$




$$\therefore \qquad \text{Bulk modulus, } K = \frac{dp\,(\text{increase of pressure})}{-dV/V\,(\text{volumetric strain})}$$

$$i.e., \qquad K = \frac{dp}{-dV/V}$$

$$\left(\text{Compressibility} = \frac{1}{K}\right)$$

- When the pressure of liquid is increased from 3.5 MN/m2 to MN/m2 its volume is found to decrease by 0.08 percent. What is the bulk modulus of elasticity of the liquid?

**Solution.** Initial pressure $= 3.5 \text{ MN/m}^2$

Final pressure $= 6.5 \text{ MN/m}^2$

$\therefore$ Increase in pressure, $dp = 6.5 - 3.5 = 3.0 \text{ MN/m}^2$

Decrease in volume $= 0.08$ percent $\therefore -\frac{dV}{V} = \frac{0.08}{100}$

Bulk modulus ($K$) is given by:

$$K = \frac{dp}{-\frac{dV}{V}} = \frac{3 \times 10^6}{\frac{0.08}{100}} = 3.75 \times 10^9 \text{ N/m}^2 \text{ or } 3.75 \text{ GN/m}^2$$

Hence, $K = \mathbf{3.75 \text{ GN/m}^2}$ **(Ans.)**

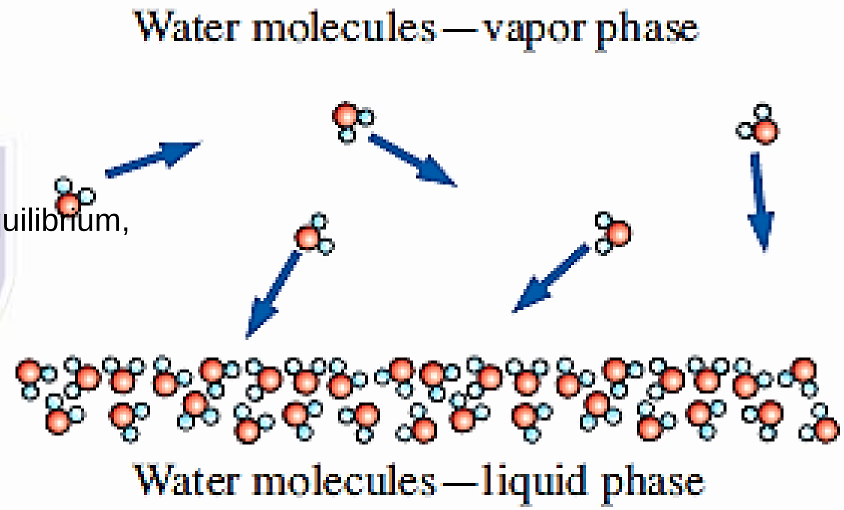
- When a pressure of 20.7 MN/m2 is applied to 100 litres of a liquid its volume decreases by 1 litre. Find the bulk modulus of the liquid and identify this liquid.

# Fluid Properties –Vapour Pressure

- The **vapor pressure** *Pv* of a pure substance is defined as *the pressure exerted by its vapor in phase equilibrium with its liquid at a given temperature*
- *The vapor pressure (saturation pressure) of a pure substance (e.g., water) is the pressure exerted by its vapor molecules when the system is in phase equilibrium with its liquid molecules at a given temperature*
- *We must be careful not to confuse vapor pressure with partial pressure*
- Partial pressure is defined as the pressure of a gas or vapor in a mixture with other gases.
- The partial pressure of water vapor constitutes
- a small fraction (usually under 3 percent) of the atmospheric pressure since
- air is mostly nitrogen and oxygen.

- The partial pressure of a vapor must be
- less than or equal to the vapor pressure if there is no liquid present.

- However,
- when both vapor and liquid are present and the system is in phase equilibrium,
- the partial pressure of the vapor must equal the vapor pressure, and
- the system is said to be saturated.



# Fluid Properties –Capillary numerical

- clean tube of diameter 2.5 mm is immersed in a liquid with a coefficient of surface tension = 0.4 N/m. The angle of contact of the liquid with the glass can be assumed to be 135°. The density of the liquid = 13600 kg/m3. What would be the level of the liquid in the tube relative to the free surface of the liquid inside the tube.
- Solution. Given: d = 2.5 mm ; σ = 4 N/m, θ = 135°; ρ = 13600 kg/m3
- Level of the liquid in the tube, h: The liquid in the tube rises (or falls) due to capillarity. The capillary rise (or fall),

$$h = \frac{4\sigma\cos\theta}{wd}$$

$$= \frac{4 \times 0.4 \times \cos 135°}{(9.81 \times 13600) \times 2.5 \times 10^{-3}}$$

$$= -3.39 \times 10^{-3}\text{m or} -3.39\text{ mm}$$

- Negative sign indicates that there is a capillary depression (fall) of 3.39 mm. (Ans.)
- Assuming that the interstices in a clay are of size equal to one tenth the mean diameter of the grain, estimate the height to which water will rise in a clay soil of average grain diameter of 0.048 mm. Assume surface tension at air-water interface as 0.074 N/m.

**Solution.** *Given:* Diameter of the pores, $d = \frac{1}{10} \times 0.048 = 0.0048$ mm; $\sigma = 0.074$ N/m

Assuming $\theta = 0°$

$$h = \frac{4\sigma}{wd} = \frac{4 \times 0.074}{(9.81 \times 1000) \times 0.0048 \times 10^{-3}} = \textbf{6.286 m (Ans.)}$$

- Calculate the work done in blowing a soap bubble of diameter 100 mm. Assume the surface tension of soap solution = 0.038 N/m.
- Solution. Given: d = 100 mm or 0.1 m; σ = 0.038 N/m.
- The soap bubble has two interfaces.
- ∴ Work done = Surface tension × total surface area
- Plan of the orifice Liquid surface Liquid Elliptical orifice Fig. Capillary inversion of a liquid jet

$$= 0.038 \times 4\pi \times \left(\frac{0.1}{2}\right)^2 \times 2$$

$$= \mathbf{0.002388\ Nm\ (Ans.)}$$

- Determine the minimum size of glass tubing that can be used to measure water level, if the capillary rise in the tube is not to exceed 0.3 mm. Take surface tension of water in contact with air as 0.0735 N/m.

**Solution.** *Given* :Capillary rise, $h = 0.3\text{ mm} = 0.3 \times 10^{-3}\text{ m}$

Surface tension, $\sigma = 0.0735\text{ N/m}$

Specific weight of water, $w = 9810\text{ N/m}^3$.

**Size of glass tubing, *d*:**

$$\text{Capillary rise, } h = \frac{4\sigma\cos\theta}{wd} = \frac{4\sigma}{wd}$$

(Assuming $\theta = 0$ for water)

$$0.3 \times 10^{-3} = \frac{4 \times 0.0735}{9810 \times d}$$

$$\therefore \quad d = \frac{4 \times 0.0735}{0.3 \times 10^{-3} \times 9810} = 0.1\text{ m} = \mathbf{100\ mm\ (Ans.)}$$