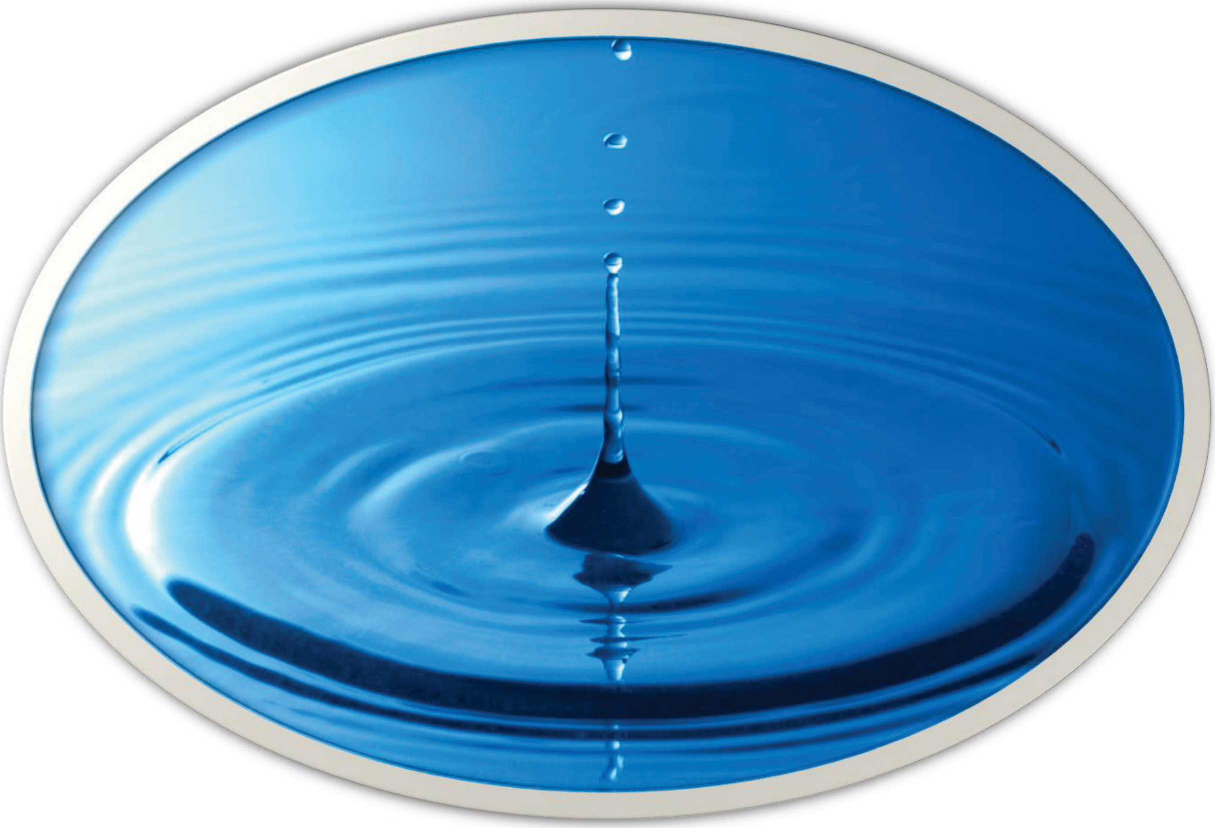
Mechanical Properties of Fluids



For Quick Revision and Smart Practice

NEET FAST FORWARD

An Innovation of **NEET Experts** with **30+ years** of Blissful Teaching Experience and Inspiration of **Lakh+ successful MEDICO professionals**

India's First e - Magazine with Live Testing

Mechanical Properties of Fluids

Hydrostatics

1. **Fluid:** Liquids and gases are collectively called fluids for they have some common properties.
2. **Properties (or characteristics) of a fluid:**
   (a) It can flow since it cannot sustain a tangential force, i.e., shearing stress.
   (b) It has no shape of its own.
   (c) It exhibits the phenomenon of viscosity.
   (d) It exerts pressure on surfaces with which it is in contact.
3. **Pressure:** It is the ratio of the force exerted normally on a surface to the area of the surface. $P = \frac{F}{A}$,

   $F \rightarrow$ constant normal force over an area A.

   Pressure at a point in a fluid is $P = \frac{dF}{dA}$

   The SI unit of pressure is $N.m^{-2}$, called the **pascal** (pa)

   $1\ Pa = 1\ N.\ m^{-2}$

   The dimensional formula for pressure is $[M^1L^{-1}T^{-2}]$

   (a) **Atmospheric pressure (P)**: It is the pressure of the atmosphere at sea level. It is usually expressed in atmosphere (atm). It is the weight of air acting per unit area of a surface.

   $$1\ atm = 1.01 \times 10^5\ Pa$$

   (b) **Hydrostatic pressure** (P_g): It is the pressure exerted at a point by a column of fluid over it. It is also called the gauge pressure. It is the weight of stationary liquid acting per unit area of a surface.

   $$P_g = \rho g h$$

   $\rho \rightarrow$ density of the fluid, $h \rightarrow$ height of the fluid column

   (c) **Absolute (or total) pressure** (P_a): It is the sum of the atmospheric and gauge pressures.

   $$P_a = P + P_g$$

- Pressure is a scalar quantity (why?)
- The pressure at any point in a fluid is the same in all directions. That is, the orientation of the sensor at the point is immaterial.
- A barometer is used to measure atmospheric pressure
- A manometer is used to measure gauge pressure, since it is proportional to the difference in the levels of the manometer liquid.
- Absolute pressure in inflated tyres or the human circulatory system is more than the atmospheric pressure. So, P_g is +ve, sometimes called the **overpressure.**
- $P_a < P$ in your lung when you suck in a straw to pull liquid up the straw. So, P_g is – ve.
- Lying on a bed of nails is much more comfortable than sitting on a bed of nails (why?)
- **Fluid thrust** is the force exerted normally on a surface with which it is in contact.
- The torr is a unit of pressure.
  1 torr = 1 mm of Hg = 133.3 Pa
- In meteorology the bar is a common unit for pressure 1 bar = 10^5 Pa

4. **Pascal's principle:** Pressure applied to an enclosed incompressible static fluid is transmitted undiminished to all parts of the fluid (including the walls of the enclosure)

$$P = \frac{F}{A} = \frac{f}{a} \Rightarrow F = \left(\frac{A}{a}\right)f$$

- The pressure at a point in a fluid in static equilibrium depends on the depth of that point but not on any horizontal dimension of the fluid or its container.
- Pressure exerted is same in all directions in a body at rest (It again reminds us that like other types of stress), pressure is not a vector quantity it is a scalar quantity. No direction can be assigned to it. The force against any area within a fluid at rest and under pressure is normal to the area, regardless of the orientation of the area.

5. **Buoyant force:** It is the vertical resultant upward force exerted by the liquid on an object immersed partially or wholly in a fluid. Its magnitude is given by Archimedes' principle.
6. **Archimedes principle:** A body immersed wholly or partially in a fluid is buoyed up by a force (the buoyant force) equal to the weight of the fluid it displaces.

   $F_b = \rho_f V_f g$

   where, $\rho_f \rightarrow$ density of the fluid

   $V_f \rightarrow$ volume of the displaced fluid (or of the submerged portion of the body)
7. **Floatation:** Two forces acting on a floating body are

   (i) The weight $W (= \rho V g)$ of the body, vertically down and (ii) the buoyant force $F_b (= \rho_f V_f g)$ vertically up. Depending upon their resultant a body can float, just float or just sink, and sink to the bottom.

   (a) If $W < F_b$, i.e., $\rho < \rho_f$, the body floats with a part above the fluid surface.

   (b) If $W = F_b$, i.e., $\rho = \rho_f$, the body just floats or just sinks, i.e. it remains wherever it is within the body of the fluid.

   (c) If $W > F_b$, i.e. $\rho > \rho_f$, the body sinks to the bottom. A body with $\rho > \rho_f$ can also float.

> - The centre of gravity of the displaced fluid is called the centre of **buoyancy**
> - The line through the centre of gravity and the centre of buoyancy is called the **central line**.
>   It is vertical when the body is in static equilibrium. It gets tilted when the body is tilted with respect to the vertical.
> - When a floating body is tilted, the central line also gets tilted and the centre of buoyancy gets shifted. The line of action of the buoyant force through the new centre of buoyancy intersects the central line at a point called the **metacentre.**
> - For a body to be in stable equilibrium the metacentre M should always be at a higher level than that of the centre of gravity of the body. If it is below the centre of gravity it gets capsized. The body, is in **unstable equilibrium**.

8. **Density**

   (a) Density of a rock (or any solid material)

   $$\rho = \left(\frac{w}{w - w_w}\right)\rho_w$$

   where $w \rightarrow$ weight in air, $w_w \rightarrow$ weight in water, $\rho_w \rightarrow$ density of water (or liquid)

   (b) Density of a mixture of two solids or fluids

   $$\rho = \frac{(m_1 + m_2)\rho_1\rho_2}{m_1\rho_2 + m_2\rho_1}$$

   when, $\rho_1 \rightarrow$ density of a substance of mass m_1

   $\rho_2 \rightarrow$ density of a substance of mass m_2

   (i) If the two are of different volumes, say V_1 and V_2 respectively,

   $$\rho = \frac{V_1\rho_1 + V_2\rho_2}{V_1 + V_2}$$

   (ii) If they are of the same volume $(V_1 = V_2)$,

$$\rho = \frac{\rho_1 + \rho_2}{2}$$

(iii) If they are of the same mass $(m_1 = m_2)$,

$$\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$$

(c) **Relative density:** It is the density of a substance relative to that of water.

$$\rho_r = \frac{\text{Density of a substance}}{\text{Density of water}}$$

It is unit less and dimensionless.

(i) Relative density of a solid: $\rho_r = \frac{W'}{W - W'}$

$W \to$ weight in air; $W' \to$ weight in water

(ii) Relative density of a liquid:

$$\rho_r = \frac{W - W_l}{W - W'}$$

$W \to$ weight of a solid in air; $W_l \to$ in a liquid; $W' \to$ in water

9. A floating ice cube in a liquid :

(a) **Cube of ice only:**

Let $M \to$ mass of ice cube.

Volume of water formed, when ice melts, is $V_w = M/\rho_w$

Volume of the liquid displaced by floating ice cube is $V_l = M/\rho_l$

(i) If $\rho_l > \rho_W$, then $V_l < V_W$. So, the level of the liquid together with water formed is more than the level of the liquid with the floating ice cube. In other words, the level rises.

(ii) If $\rho_l < \rho_W$, then $V_l > V_W$. So, the level falls.

(iii) If the liquid is water, the level does not change.

(b) **An ice cube with a cavity in water:**

When the cube is floating, volume of water it displaces is $V_w = \frac{M + m}{\rho_w}$

$M \to$ mass of ice, $m \to$ mass of the cavity substance

Volume of water formed, when ice cube melts, is $V'_w = \frac{M}{\rho_w}$

(i) If the cavity contains air, m = 0. So, $V_w = V'_w$. The level of water remains the same, when ice cube melts.

(ii) If the cavity is filled with a floating object, such as cork, the volume of water displaced by it is

$$V''_W = \frac{m}{\rho_W}$$

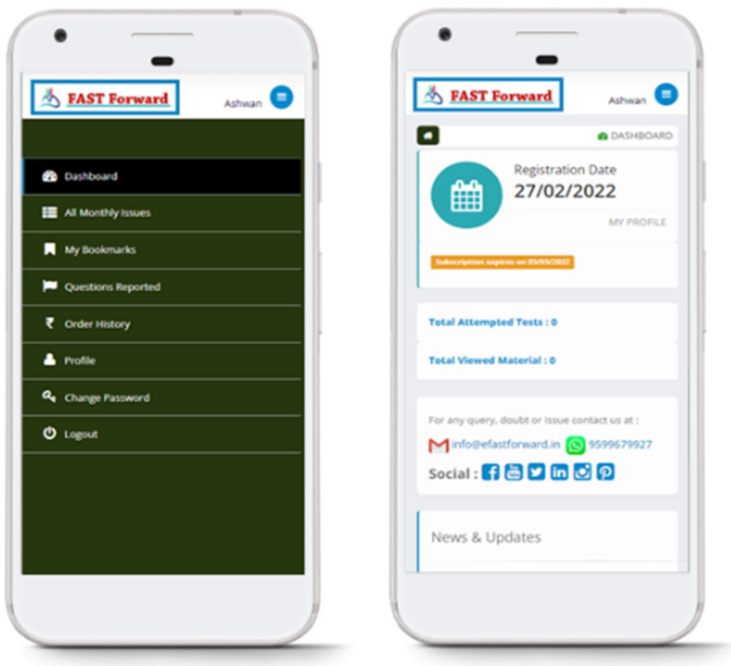
It is obvious that the volume of water formed and the volume of water displaced by the cork equals the volume of water displaced by the floating ice cube. So, the level of water remains the same, when ice melts.

(iii) If the cavity is filled with a heavy object, such as iron, the volume of water displaced is

$$V''_W = \frac{m'}{\rho_{iron}}$$

$$V'_W + V''_W = \left(\frac{M}{\rho_w} + \frac{m}{\rho_{iron}}\right) < \frac{M}{\rho_w} + \frac{m}{\rho_w}$$

Since, $\rho_{iron} > \rho_w$. So, the volume of water formed and that displaced by iron is less than the volume displaced by the floating ice cube. Thus, the level of water falls, when the ice cube melts.


FAST Forward
Ashwan
Dashboard
All Monthly Issues
My Bookmarks
Questions Reported
Order History
Profile
Change Password
Logout
FAST Forward
Ashwan
DASHBOARD
Registration Date
27/02/2022
MY PROFILE
Total Attempted Tests : 0
Total Viewed Material : 0
For any query, doubt or issue contact us at :
info@efastforward.in
9599679927
Social :
News & Updates