Pressure

Dr.Jinchu.I

Pressure

Pressure (P) is defined as the perpendicular or normal force acting per unit area of a substance.

$$Pressure = \frac{Force}{Area}$$

$$P = \frac{F}{A}$$

- SI unit of pressure is N/m^2 or pascal (Pa).

One pascal is the pressure exerted by a force of 1 N on an area of 1 m^2.

- Pascal is a very small unit of pressure. Other commonly used units for pressure are
- $bar = 10^5 Pa$ and $millibar = 100\ Pa$.

Pressure inside a Fluid (Hydrostatic pressure)

- Hydrostatic pressure is the pressure that is exerted by a fluid at equilibrium at a given point within the fluid, due to the force of gravity or weight of the fluid.

$$hydrostatic\ pressure = \frac{Force\ inside\ the\ fluid}{area}$$

$$P = \frac{F_{fluid}}{A}$$

Due to the high mobility of the molecules of the fluid, the force acting at one position propagates immediately and isotropically with the same magnitude through the entire volume of the fluid.

Within a fluid at rest, the normal force exerted on a small surface has the same magnitude everywhere and is independent of the orientation of the surface. This fact is called Pascal's law.

This is the basic principle behind hydraulic machines like a crane, break, lift, etc.

Atmospheric Pressure (P_{atm})

- The pressure of the atmosphere at any point is equal to the weight of a column of air of unit cross-sectional area extending from that point to the top of the atmosphere.
- The atmospheric pressure decreases with an increase in altitude. The higher we climb up a mountain, the lesser will be the air above us and therefore, the lower will be the atmospheric pressure become. Mountaineers get bleed through their nose or ear due to this pressure difference.
- As you move deep into the water, it pushes you up. The pressure inside the water increases with depth.
- Atmospheric pressure can be measured with a mercury barometer in which pressure is measured in terms of the height of the mercury (Hg) column.

At sea level, atmospheric pressure corresponds to 76 cm of Hg which is equivalent to 1.013×10^5 Pa.

One atmosphere (atm) is a standard unit of pressure equal to the mean atmospheric pressure at sea level.

$$1 atm = 1.013 \times 10^5\, Pa = 76\ cm\ of\ Hg$$

Gauge Pressure and Absolute Pressure

- To find the pressure at a depth,

consider a fluid at rest in a container. Point 1 is at height h above point 2. The pressures at points 1 and 2 are P1 and P2 respectively. Consider a cylindrical element of fluid having base area A and height h. As the fluid is at rest the resultant horizontal forces should be zero and the resultant vertical forces should balance the weight of the element.

The forces (Remember, F=PA, since pressure P=F/A)

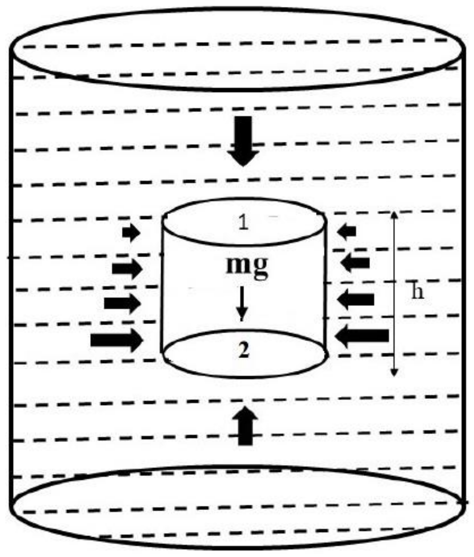
acting in the vertical direction are due to the fluid pressure

at the top (P_1A) acting downward, at the bottom (P_2A)

acting upward. If mg is the weight of the fluid in the cylinder, then

$(P_2 - P_1)A = mg$

Now, if ρ is the mass density of the fluid



Pressure inside a fluid at rest in a container

$$Density\ (\rho) = \frac{Mass}{Volume} = \frac{m}{V}$$

Therefore, the mass of fluid,

$$m = \rho V = \rho h A$$

So, the above equation can rewrite as,

$$(P_2 - P1)A = \rho h A g$$

$$(P_2 - P1) = \rho g h$$

Pressure difference (P_2 - P_1) depends on the vertical distance h between the points (1 and 2), the density of the fluid ρ, and acceleration due to gravity g. If point 1 is shifted to the top of the fluid which is open to the atmosphere, P_1 may be replaced by atmospheric pressure (P_{atm}) and we replace P_2 by P.
Then the above equation turns to

$$(P - P_{atm}) = \rho g h$$
$$P = P_{atm} + \rho g h$$

Thus, the pressure P, at depth below the surface of a liquid open to the atmosphere is greater than atmospheric pressure by an amount $\rho g h$. This P is called absolute pressure at that point. Absolute pressure at a point is pressure measured with respect to zero pressure or absolute vacuum.

The excess of pressure,($P - P_{atm}$) at depth, h is called a gauge pressure at that point.
Gauge pressure at a point is the pressure measured relative to the atmospheric pressure.