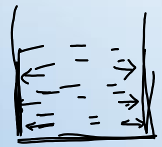
GYANMANJARI INSTITUTE OF TECHNOLOGY

Subject: **Fluid Mechanics and Hydraulic machine**

Chapter : **2. Pressure and Head**

Mechanical Engineering Department

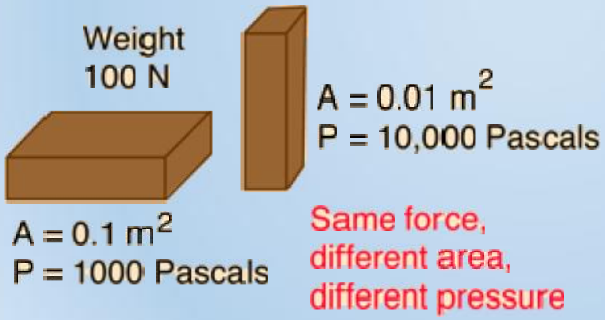
Pressure



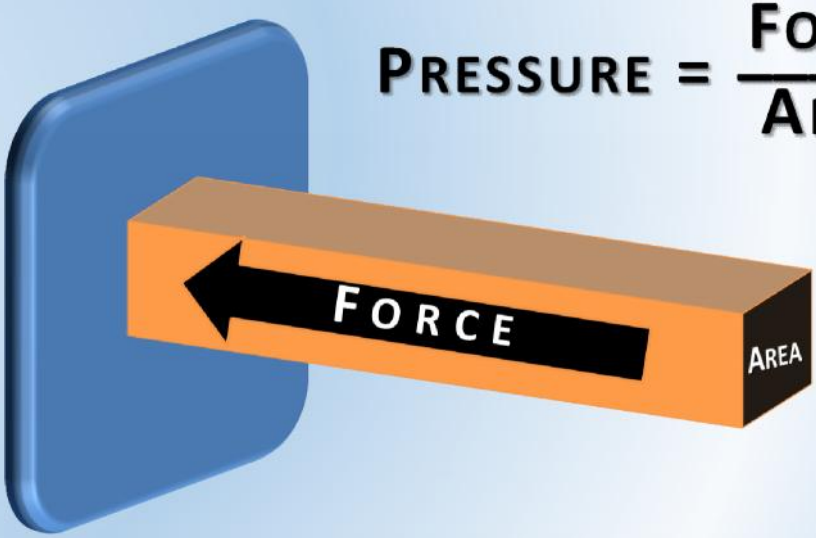
$$\text{Pressure} = \frac{\text{Force}}{\text{area}} = \frac{N}{m^2}$$

Pressure is the force applied perpendicular to the surface of an object per unit area over which that force is distributed. Gauge pressure is the pressure relative to the ambient pressure. Various units are used to express pressure

$$\textit{Pressure} = \frac{\textit{Force}}{\textit{Area}} = \frac{F}{A}$$



$$\text{PRESSURE} = \frac{\text{FORCE}}{\text{AREA}}$$



Units of Pressure

SI

$1 \frac{N}{m^2}$

$1\ N/mm^2$

MKS $\rightarrow \frac{kgf}{m^2}$ OR $\frac{kgF}{cm^2}$

$1 \underline{\text{Pascal}} = 1\ N/m^2$

$1 \underline{\text{bar}} = 100\ kPa$

$= 100 \times 10^3\ Pa$

$= 10^5\ Pa$

$= 10^5\ N/m^2$

$1 \frac{N}{m^2} = 1 \frac{N}{(10^3)^2 mm^2}$

$1 \frac{N}{m^2} = \frac{1}{10^6} \frac{N}{mm^2}$

$1 \frac{N}{m^2} = 10^{-6}\ N/mm^2$

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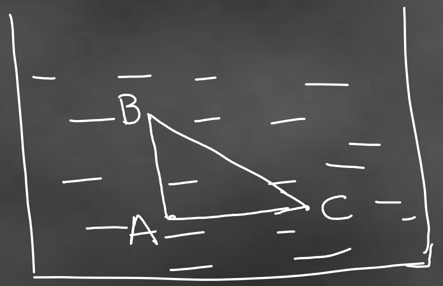
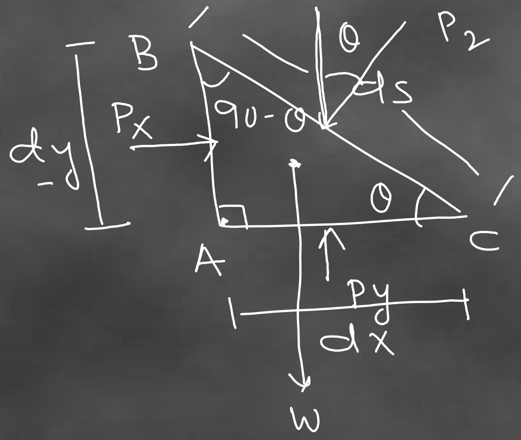
* **Pascal's law** :- "Intensity of pressure at any point in liquid at Rest is same in all Direction"

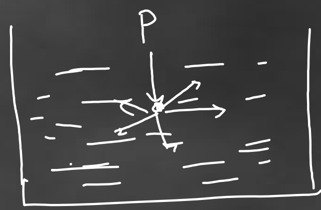
Static





$dz = 1$

Rest



area of AB = $dy \times 1$

area of AC = $dx \times 1$

area of BC = $ds \times 1$

Volume of element = $\left(\frac{1}{2} \times dx \times dy\right) \times 1$

$\rho = m/V$

$m = \rho \times V$

$W = mg = \rho V g = \rho \frac{1}{2} dx\, dy \times 1 \times g$

$= \frac{1}{2} \rho\, dx\, dy\, g$

P_x = Pressure acting in x AB

F_x = Force acting in x AB

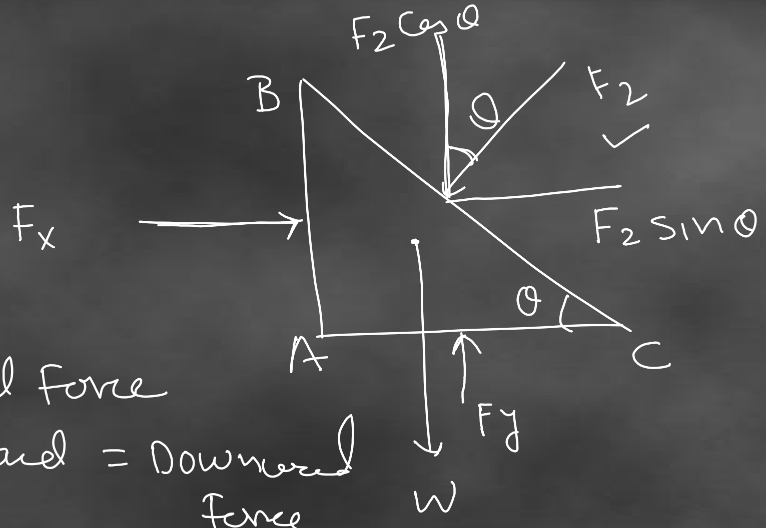
$P_y,\ F_y \Rightarrow$ AC

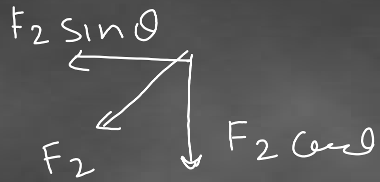
$P_2 \quad F_2 \Rightarrow$ BC

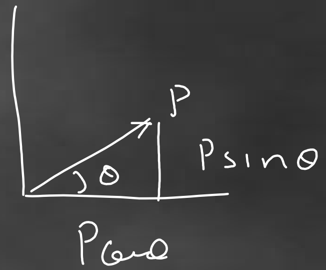
$F_x = P_x \times dy \times 1 \rightarrow$ AB

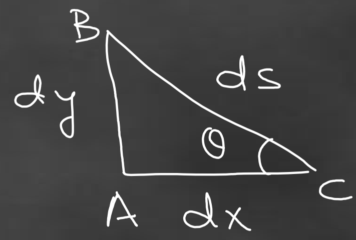
$F_y = P_y \times dx \times 1 \rightarrow$ AC

$F_2 = P_2 \times ds \times 1 \rightarrow$ BC









Vertical force

upward = Downward force

$$F_y = W + F_2 \cos\theta$$

$$P_y \times dx = \frac{1}{2} \rho\, dx\, dy \times g + P_2\, ds \cos\theta$$

$$P_y\, dx - P_2\, ds \cos\theta = \frac{1}{2} \rho g\, dx\, dy \quad \text{— (II)}$$

$$P_y\, dx - P_2\, dx = \cancel{\frac{1}{2} \rho g\, dx\, dy} \rightarrow 0 \quad \text{— (II)}$$

$$P_y\, dx - P_2\, dx = 0$$

$$P_y\, \cancel{dx} = P_2\, \cancel{dx}$$

$$\boxed{P_y = P_2}$$

Horizontal force

$$F_x = F_2 \sin\theta$$

$$F_x - F_2 \sin\theta = 0$$

$$P_x\, dy - P_2\, ds \sin\theta = 0 \quad \left\{ \begin{array}{l} dy = AB = ds \sin\theta \\ dx = AC = ds \cos\theta \end{array} \right.$$

$$P_x\, dy = P_2\, ds \sin\theta \quad \text{— (I)}$$

$$P_x\, \cancel{dy} = P_2\, \cancel{dy} \quad \text{— (I)}$$

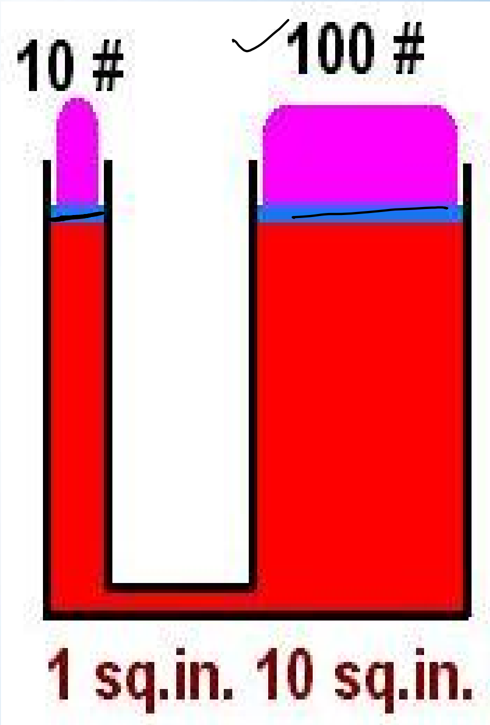
$$\boxed{P_x = P_2}$$

$$\boxed{P_x = P_y = P_2}$$

Using Pascal's Law

$P_{Ram} = P_{plunger}$

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

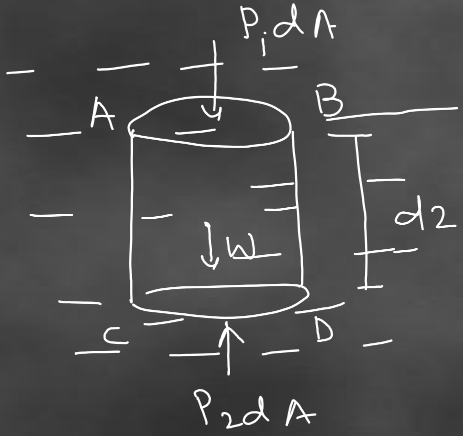


Pascal's Law - gives us the mechanics to do a great deal of work with hydraulics. The drawing on the left shows that we can lift a large amount of weight with a small amount of effort. We can lift 100 pounds by applying just 10 pounds of force to the piston measuring 1 square inch

Hydrostatic law

Variation of pressure in fluid at rest

$$\boxed{\frac{\partial p}{\partial z} = -\rho g}$$



$$W = mg$$
$$= \rho V g$$
$$= \rho (dA \times dz)\, g$$

$$\boxed{P_2 - P_1 = \rho g dz}$$

$$✓\ \Delta P = \rho g h$$

$$P_1 dA + W = P_2 dA$$

$$P_1 dA - P_2 dA + W = 0$$

$$(P_1 - P_2)\, dA + \underline{W} = 0$$

$$(P_1 - P_2)\, \cancel{d}A + \rho \cancel{d}A\, dz \times g = 0$$

$$P_1 - P_2 = -\rho g dz$$

$$P_2 - P_1 = \rho g dz$$

$$\frac{P_2 - P_1}{dz} = \rho g \Rightarrow \boxed{\frac{\partial p}{\partial z} = \rho g}$$

atmosphere Pressure :→

15°C sealevel → 760 mm of hg

10.33 m of water

101.3 KN/m^2

→ 1.033 kgF/cm^2

1 atm

1.1325 bar

20 PSI

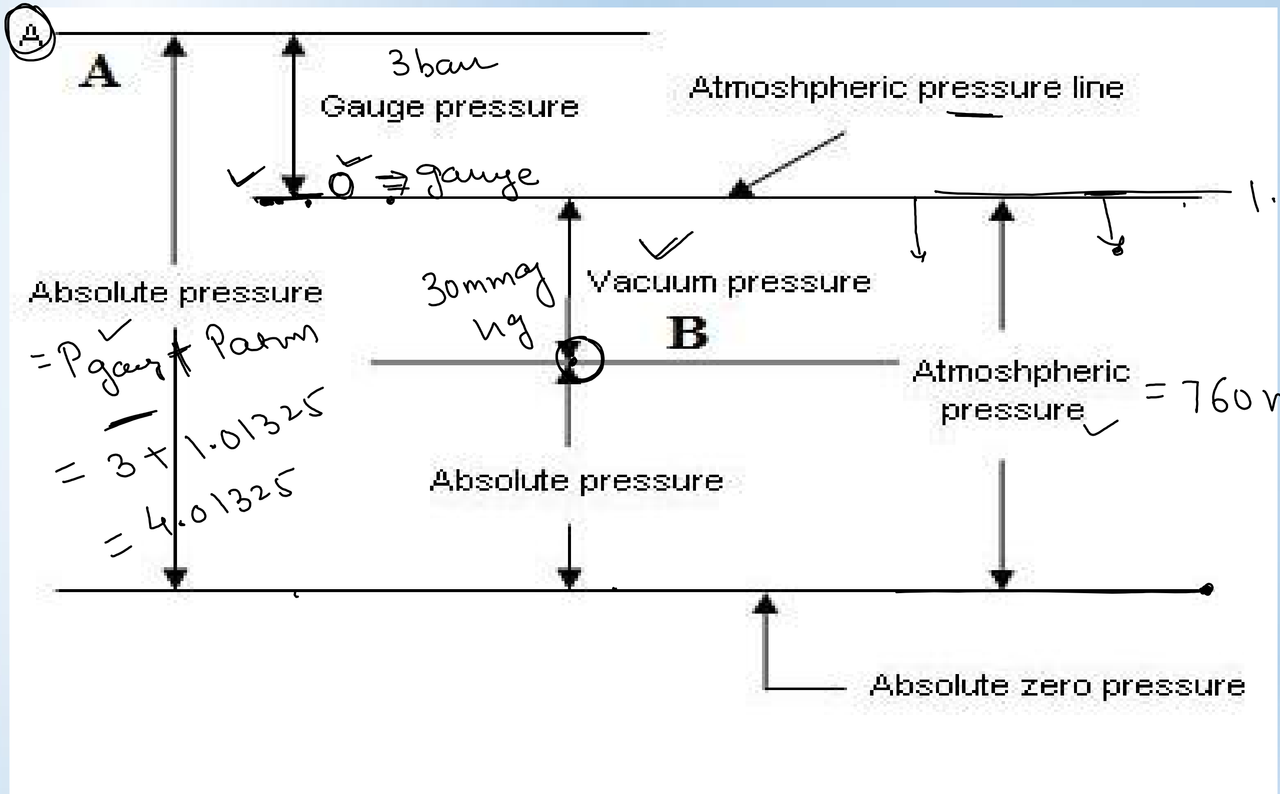
gauge → 0 → atmospher

→ 1.033

Pressure and head

$P_{B\,ab} = 760 - 30$

$= P_{atm} - P_{gauge}$



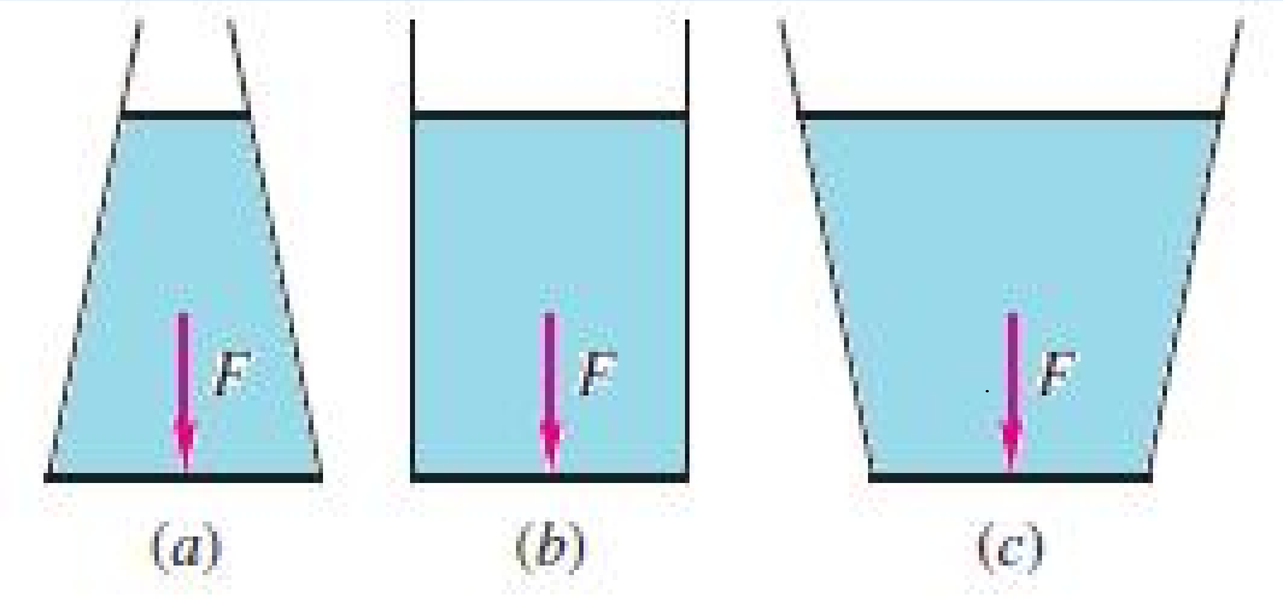
Pressure head

$h = p / \rho g$

$$\boxed{\begin{aligned} P_{ab} &= P_{atm} + P_{gauge} \\ P_{ab} &= P_{atm} - P_{gauge} \end{aligned}}$$

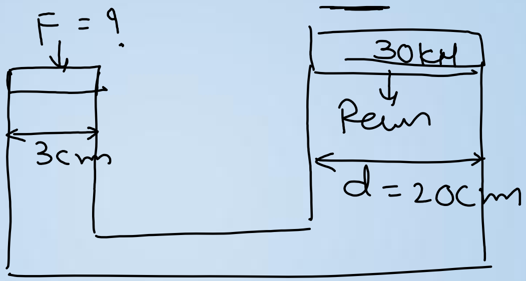
Hydrostatic Paradox

The pressure of any particle in a fluid does not depend on weight of the fluid in any vessel.



Example 1

- A hydraulic press has a ram of 20 cm diameter and a plunger of 3 cm diameter . It is used for lifting a weight of 30 kN. Find the force required at the plunger.



$A_P = \pi/4\, d^2 = \pi/4 \times (3 \times 10^{-2})^2$

$A_R = \pi/4\, D^2 = \pi/4 \times (20 \times 10^{-2})^2$

$A_P = 7.065 \times 10^{-4}\ m^2$

$A_R = 0.0314\ m^2$

Pressure on Plunger = Pressure on Ram

$$\frac{F_P}{A_P} = \frac{F_R}{A_R}$$

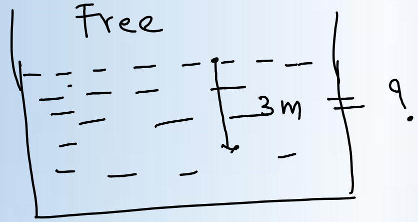
$$F_P = F_R \times \frac{A_P}{A_R} = W \times \frac{A_P}{A_R} = \frac{30 \times 7.065 \times 10^{-4}}{0.0314}$$

$$\boxed{= 675\ N}$$

Example 2

- What are the gauge pressure and absolute pressure at a point 3 m below the free surface of a liquid having a density of 1530 kg/m3 if the atmospheric pressure is equivalent to 750 mm of mercury? The specific gravity of mercury is 13.6 and density of water = 1000 kg/m3.

✓ $P_2 - P_1 = \rho g h$



$P_{gauge} = 1530 \times 9.81 \times 3$ $\quad \frac{kg}{m^3} \times \frac{m}{s^2} \times m \quad \frac{N}{m^2}$

$= 45027.9\ N/m^2$

$SP = \frac{\rho_F}{\rho_W} \Rightarrow 13.6 = \frac{\rho_{hg}}{\rho_W}$

P_{atm} $\quad P_2 - P_1 = \rho g h = 13600 \times 9.81 \times 750 \times 10^{-3}$

$= 100062\ N/m^2$

$\rho_{hg} = 13.6 \times 1000$

$= 13600$

$P_{abs} = P_{atm} + P_{gauge} = 100062 + 450279 = 145089\ N/m^2$